Scyld ClusterWare Documentation

Release 6.10.14

Penguin Computing

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CONTENTS

CHAPTER

ONE

RELEASE NOTES

1.1 Release Notes: Scyld ClusterWare Release v6.10.14-61014g0000

1.1.1 About This Release

Scyld ClusterWare Release v6.10.14-61014g0000 is the latest update to Scyld ClusterWare 6.

Scyld ClusterWare v6.10.14 expects to execute in a Red Hat RHEL6 Update 10 or CentOS 6.10 base distribution environment, each having been updated to the latest RHEL/CentOS 6 errata (https://rhn.redhat.com/errata/rhel-server-6-errata.html) as of the Scyld ClusterWare v6.10.14 release date. Any compatibility issues between Scyld ClusterWare v6.10.14 and RHEL6 are documented on the Penguin Computing Support Portal at https://www.penguincomputing.com/support.

Visit https://docs.redhat.com/docs/en-US/Red_Hat_Enterprise_Linux to view the Red Hat Enterprise Linux 6 6.10 *Release Notes* and other useful documents.

For the most up-to-date product documentation and other helpful information, visit the Penguin Computing Support Portal.

Important: Recommend using `/usr/sbin/install-scyld` script

Penguin Computing *highly* recommends using the `/usr/sbin/install-scyld` script to guide the initial installation of Scyld ClusterWare (including updating the RHEL/CentOS base distribution software) and using the `/usr/sbin/update-scyld` script (which is equivalent to `install-scyld -u`) to update base distribution and ClusterWare software.

Before continuing, make sure you are reading the most recent Scyld ClusterWare *Release Notes*, which can be found on the Penguin Computing Support Portal at https://www.penguincomputing.com/support/documentation. The most recent version will accurately reflect the current state of the Scyld ClusterWare yum repository of rpms that you are about to install. You may consult the *Installation Guide* for its more generic and expansive details about the installation process. The *Release Notes* document more specifically describes how to upgrade an earlier version of Scyld ClusterWare 6 to 6.10 (see *Upgrading An Earlier Release of Scyld ClusterWare 6 to 6.10*), or how to install Scyld ClusterWare v6.10.14 as a fresh install (see *First Installation of Scyld ClusterWare 6 On A Server*).

Important for clusters using 3rd-party drivers or applications

Before installing or updating Scyld ClusterWare, if your cluster uses any 3rd-party drivers (e.g., Ethernet, InfiniBand, GPU, parallel storage) and if an install or update includes a new kernel, then verify that those 3rd-party drivers can be rebuilt or relinked to the new kernel. If an install or update involves upgrading to a new RHEL/CentOS base distribution, then verify that your cluster's 3rd-party applications are all supported by that new base distribution.

Important for clusters using Panasas storage

If the cluster uses Panasas storage, then you must ensure that the appropriate Panasas kernel module is installed. See the *Notable Feature Enhancements And Bug Fixes* section for the specific Scyld ClusterWare version you intend to use to determine the name of that kernel's matching Panasas rpm.

If that Panasas rpm is not already installed, then login to your Panasas account at https://my.panasas.com/portal, click on the *Downloads* tab, then click on *DirectFLOW Client*, then click on *Search DirectFLOW Release*, then do a *Keywords* search naming the specific rpm to download. Install that rpm after you install the associated ClusterWare kernel. If you do not find the appropriate Panasas rpm, then do not install or upgrade to the desired ClusterWare kernel.

1.1.2 First Installation of Scyld ClusterWare 6 On A Server

When installing Scyld ClusterWare 6 on a system that does not yet contain Scyld ClusterWare, you should perform the following steps:

1. The directory `/etc/yum.repos.d/` must contain active repo config files bearing a suffix of `.repo`. If there is no ClusterWare repo file, then you should download `clusterware.repo` that gives your cluster access to the customer-facing Scyld ClusterWare yum repos.

   To download a yum repo file that is customized to your cluster:

   (a) Login to the Penguin Computing Support Portal at https://www.penguincomputing.com/support.

   (b) Click on the tab labeled *Assets*, and then select a specific *Asset Name* in the list.

   (c) In the *Asset Detail* section, click on *YUM Repo File*, which downloads an asset-specific `clusterware.repo` file, and move that file to the `/etc/yum.repos.d/` directory.

   (d) Set the permissions: `chmod 644 /etc/yum.repos.d/clusterware.repo`

   (e) The `clusterware.repo` file contains three sections, labeled *cw-core*, *cw-updates*, and *cw-next*. Generally, the *cw-next* repo should not be enabled unless so directed by Penguin Computing Support.

2. Examine `/etc/yum.repos.d/clusterware.repo` to ensure that it specifies the desired yum repository release version. Employ *$releasever* or 6 to use rpms from the latest Scyld ClusterWare release, which currently is 6.10. Alternatively, a more specific major-minor pair, e.g., 6.2, limits the rpms to just that version, even as ClusterWare releases march forward to newer versions.

3. If updating using a RHEL6 yum repo, then your RHEL6 yum configuration file should also look in the RHEL6 Server Optional repo to find rpms such as `compat-dapl-devel` and `sharutils`. The regular CentOS6 yum repo contains these rpms.

4. Install a useful Scyld ClusterWare script that simplifies installing (and later updating) software, then execute that script:

```
yum install install-scyld
install-scyld
```

5. *If the cluster uses Panasas storage*, then you should have already downloaded the Panasas rpm that matches the Scyld ClusterWare 6 kernel you have just installed. Now install the Panasas rpm using `rpm -i`.

6. Configure the network for Scyld ClusterWare: edit `/etc/beowulf/config` to specify the cluster interface, the maximum number of compute nodes, and the beginning IP address of the first compute node. See the *Installation Guide* for more details.

7. Compute nodes must support the PXE network boot protocol. Each node's BIOS must be configured to prioritize PXE network booting ahead of booting from the local harddrive.

8. If the private cluster network switch uses Spanning Tree Protocol (STP), then either reconfigure the switch to disable STP, or if that is not feasible because of network topology, then enable *Rapid STP* or *portfast* on the compute node and edge ports. See *Issues with Spanning Tree Protocol and portfast* for details.
9. Reboot the master node.
10. After rebooting the new kernel, and after installing any new kernel modules, you should rebuild the master node's list of modules and dependencies using `depmod`. See *Issues with kernel modules* for details.

1.1.3 Upgrading An Earlier Release of Scyld ClusterWare 6 to 6.10

If you wish to upgrade a RHEL5/CentOS5 or earlier base distribution to RHEL6/CentOS6, then we recommend you accomplish this with a full install of Release 6, rather than attempt to *update* from an earlier major release to Release 6. Visit https://docs.redhat.com/docs/en-US/Red_Hat_Enterprise_Linux for the Red Hat Enterprise Linux 6 *Installation Guide* for details. If you already have installed Scyld ClusterWare 5 (or earlier) on the physical hardware that you intend to convert to RHEL6/CentOS6, then we recommend that you backup your master node prior to the new installation of RHEL6/CentOS6, as some of the Scyld ClusterWare configuration files may be a useful reference for Release 6, especially files in `/etc/beowulf/`.

When upgrading from an earlier Scyld ClusterWare 6 version to a newer Scyld ClusterWare 6, you should perform the following steps:

1. Examine `/etc/yum.repos.d/clusterware.repo` to ensure that it specifies the desired yum repository release version. Employ *$releasever* or 6 to use rpms from the latest Scyld ClusterWare release, which currently is 6.10. Alternatively, a more specific major-minor pair, e.g., 6.2, limits the rpms to just that version, even as ClusterWare releases march forward to newer versions.
2. Consider whether or not to stop the cluster prior to updating software. Most updates can be made to a running cluster, although some updates (e.g., those affecting daemons that execute on the master node) require a subsequent restart of the ClusterWare service. Other updates require rebooting the master node, in particular when updating to a new kernel, and this obviously restarts the cluster nodes, too. The safest approach is to stop the cluster before updating the master node, and restart the cluster after the update completes.

```
service beowulf stop
```

3. Update the software on the master node using the `install-scyld` script that guides you through the process, step by step. If this script doesn't exist on your system, then install it.

```
yum install install-scyld    # if not already installed
install-scyld -u
```

4. The script first determines if it needs to update itself. If that self-update occurs, then the script exits and you should re-execute it.
5. *If the cluster uses Panasas storage*, then you should have already downloaded the Panasas rpm that matches the Scyld ClusterWare v6.10.14 kernel you have just installed. Now install the Panasas rpm using `rpm -i`.
6. Compare `/etc/beowulf/config`, which remains untouched by the Scyld ClusterWare update, with the new `config.rpmnew` (if that file exists), examine the differences:

```
cd /etc/beowulf
diff config config.rpmnew
```

and carefully merge the `config.rpmnew` differences into `/etc/beowulf/config`. See *Resolve *.rpmnew and *.rpmsave configuration file differences* for details.

Similarly, the preexisting `/etc/beowulf/fstab` may have been saved as `fstab.rpmsave` if it was locally modified. If so, merge those local changes back into `/etc/beowulf/fstab`.

7. If a new kernel has been installed, then reboot the master node. Otherwise, simply reboot the ClusterWare service:

```
service beowulf restart
```

8. After rebooting a new kernel, and after installing any new kernel modules, you should rebuild the master node's list of modules and dependencies using `depmod`. See *Issues with kernel modules* for details.

1.1.4 Post-Installation Configuration Issues

Following a successful update or install of Scyld ClusterWare, you may need to make one or more configuration changes, depending upon the local requirements of your cluster. Larger cluster configurations have additional issues to consider; see *Post-Installation Configuration Issues For Large Clusters*.

Resolve **.rpmnew* and **.rpmsave* configuration file differences

As with every Scyld ClusterWare upgrade, after the upgrade you should locate any Scyld ClusterWare `*.rpmsave` and `*.rpmnew` files and perform merges, as appropriate, to carry forward the local changes. Sometimes an upgrade will save the locally modified version as `*.rpmsave` and overwrite the basic file with a new version. Other times the upgrade will keep the locally modified version untouched, installing the new version as `*.rpmnew`.

For example,

```
cd /etc/beowulf
find . -name \*rpmnew
find . -name \*rpmsave
```

and examine each such file to understand how it differs from the configuration file that existed prior to the update. You may need to merge new lines from the newer `*.rpmnew` file into the existing file, or perhaps replace existing lines with new modifications. For instance, this is commonly done with `/etc/beowulf/config` and `config.rpmnew`. Or you may need to merge older local modifications in `*.rpmsave` into the newly installed pristine version of the file. For instance, this is occasionally done with `/etc/beowulf/fstab.rpmsave`.

Generally speaking, be careful when making changes to `/etc/beowulf/config`, as mistakes may leave your cluster in a non-working state. In particular, take care when modifying the keyword entries for *interface*, *nodes*, *iprange*, and *nodeassign*. The *kernelimage* and *node* entries are automatically managed by ClusterWare services and should not be merged.

The remaining differences are candidates for careful merging. Pay special attention to merge additions to the *bootmodule*, *modarg*, *server*, *libraries*, and *prestage* keyword entries. New *nodename* entries for *infiniband* or *ipmi* are offsets to each node's IP address on the private cluster network, and these offsets may need to be altered to be compatible with your local network subnet. Also, be sure to merge differences in `config.rpmnew` comments, as those are important documentation information for future reference.

Contact Penguin Computing Customer Support if you are unsure about how to resolve particular differences, especially with `/etc/beowulf/config`.

Disable SELinux and NetworkManager

Scyld ClusterWare execution currently requires that SELinux and NetworkManager services be disabled. The `install-scyld` script assists in performing this disabling. Cluster administrators are strongly encouraged to always use that script to install or update ClusterWare.

Edit /etc/beowulf/conf.d/sysctl.conf as needed

The /etc/beowulf/sysctl.conf.rebuild.sh script simplifies the building of the /etc/beowulf/conf.d/sysctl.conf file, which gets pushed to each compute node's /etc/sysctl.conf at node boot time to configure the node's sysctl command behavior. Prior to Scyld ClusterWare v6.9.8, /etc/beowulf/conf.d/sysctl.conf was automatically built (if it did not currently exist) at node boot time by copying just the master node's /etc/sysctl.conf. In ClusterWare v6.9.8 and beyond, sysctl.conf.rebuild.sh instead performs the rebuild by aggregating all the *.conf files that reside in the various sysctl configuration directories. See man sysctl.conf for a list of those directories.

The script executes automatically (if /etc/beowulf/conf.d/sysctl.conf does not currently exist) when installing or updating the ClusterWare *nodescripts* package. The Cluster Administrator can also manually execute the script at any time to rebuild the file from the latest contents of the master node's various sysctl *.conf files.

After the script executes, the newly built /etc/beowulf/conf.d/sysctl.conf will subsequently be seen on node *$NODE* when *$NODE* reboots, or by executing:

```
bpcp /etc/beowulf/conf.d/sysctl.conf $NODE:/etc/sysctl.conf
bpsh $NODE sysctl -q -e -p /etc/sysctl.conf
```

NOTE: Because the script rebuilds /etc/beowulf/conf.d/sysctl.conf from the master node's sysctl *.conf files, the newly rebuilt file may contain some configuration lines that are appropriate for the master node but not for compute nodes, or there may be lines that should be added that are desired for compute nodes but are unwanted in a master node's sysctl *.conf file. Therefore, the Cluster Administrator should review the contents of /etc/beowulf/conf.d/sysctl.conf after it gets rebuilt to ensure that it contains the desired configuration lines for compute nodes. Once the file is built - whether it is subsequently modified or not - then the file is never modified by ClusterWare until and unless the Cluster Administrator manually executes sysctl.conf.rebuild.sh. If the Cluster Administrator manually deletes /etc/beowulf/conf.d/sysctl.conf, then the file gets automatically rebuilt the first time any node reboots.

Disable library prelinking

Scyld ClusterWare migration between cluster nodes requires stable dynamic libraries. Edit /etc/sysconfig/prelink and ensure that *PRELINKING=no* is set. This will permanently block subsequent (usually daily) prelink operations. In addition, to immediately undo prelinking:

```
prelink --undo -all
```

See the *Administrator's Guide* for more details.

Optionally reduce size of /usr/lib/locale/locale-archive

Glibc applications silently open the file /usr/lib/locale/locale-archive, which means it gets downloaded by each compute node early in a node's startup sequence. The default RHEL6 locale-archive is about 100 MBytes in size, thus consuming significant network bandwidth and potentially causing serialization delays if numerous compute nodes attempt to concurrently boot, and consuming significant RAM filesystem space on each node. It is likely that a cluster's users and applications do not require all the international locale data that is present in the default file. With care, the cluster administrator may choose to rebuild locale-archive with a greatly reduced set of locales and thus create a significantly smaller file. See the *Administrator's Guide* for details.

Optionally configure and enable compute node CPU speed/power management

Modern motherboards and processors support a degree of administrator management of CPU frequency within a range defined by the motherboard's BIOS. Scyld ClusterWare provides the /etc/beowulf/init.d/30cpuspeed script and its associated /etc/beowulf/conf.d/cpuspeed.conf configuration file to implement this management for compute nodes. The local cluster administrator is encouraged to review the *Administrator's Guide*'s *Configuring CPU speed/power for Compute Nodes* for details.

Optionally install a different TORQUE package

TORQUE is available in several versions: torque-4-scyld (which is the current default) and torque-4-nocpuset-scyld provide version 4, torque-5-scyld and torque-5-nocpuset-scyld provide version 5, and torque-6-scyld and torque-6-nocpuset-scyld provide version 6.

The nocpuset packages specifically disable the default *cpuset* functionality that optionally allows an application to constrain the movement of software threads between CPUs within a node in order to achieve optimal performance. See http://docs.adaptivecomputing.com/torque/4-1-4/help.htm#topics/3-nodes/linuxCpusetSupport.htm for details.

One, and only one, TORQUE must be installed at any one time. Since each TORQUE package specifies a list of package dependencies that should not be removed when uninstalling the existing TORQUE package, care must be taken to retain those dependencies when switching from one version of TORQUE to another. For example, to switch from torque-4-scyld to torque-4-nocpuset-scyld:

```
rpm -e --nodeps torque-4-scyld
yum install torque-4-nocpuset-scyld
```

Optionally enable job manager

The default Scyld ClusterWare installation includes two job managers: TORQUE and Slurm. TORQUE is available in several versions. See *Optionally install a different TORQUE package*. Both Slurm and one, and only one, of these TORQUE versions must be installed on the master node, although only Slurm or one of the TORQUE versions may be enabled and executing at any one time.

To enable TORQUE: after all compute nodes are up and running, then disable Slurm (if it is currently enabled), then enable and configure TORQUE, then reboot all the compute nodes:

```
service slurm-scyld cluster-stop
chkconfig slurm-scyld off
beochkconfig 98slurm off
chkconfig torque on
beochkconfig 98torque on
service torque reconfigure
service torque start
bpctl -S all -R
```

and then after the compute nodes have rebooted, restart TORQUE cluster-wide:

```
service torque cluster-restart
```

To enable Slurm: after all compute nodes are up and running, you disable TORQUE (if it is currently enabled), then enable and configure Slurm, then reboot all the compute nodes:

```
service torque cluster-stop
chkconfig torque off
beochkconfig 98torque off
chkconfig slurm-scyld on
beochkconfig 98slurm on
```

Next, configure Slurm by generating /etc/slurm/slurm.conf and /etc/slurm/slurmdbd.conf from Scyld-provided templates:

```
service slurm-scyld reconfigure
```

Finally, start Slurm on the master node and reboot all compute nodes:

```
service slurm-scyld start
bpctl -S all -R
```

and then after the compute nodes have rebooted, restart Slurm cluster-wide:

```
service slurm-scyld cluster-restart
```

Finally, start Slurm (and Munge and mysql) on the master node and reboot all compute nodes:

```
service slurm-scyld start
bpctl -S all -R
```

and then after the compute nodes have rebooted, restart Slurm cluster-wide:

```
service slurm-scyld cluster-restart
```

See the *Administrator's Guide* for more details about TORQUE configuration, and the *User's Guide* for details about how to use TORQUE.

Each Slurm user must setup the PATH and LD_LIBRARY_PATH environment variables to properly access the Slurm commands. This is done automatically for users who login when the *slurm* service is running and the *pbs_server* is not running, via the `/etc/profile.d/scyld.slurm.sh` script. Alternatively, each Slurm user can manually execute `module load slurm` or can add that command line to (for example) the user's `.bash_profile`.

See the *Administrator's Guide* for more details about TORQUE and Slurm configuration.

Optionally enable TORQUE scheduler

Scyld ClusterWare installs by default both the TORQUE resource manager and the associated Maui job scheduler. The Maui installation can coexist with an optionally licensed Moab job scheduler installation, although after the initial installation of either of these job schedulers, the cluster administrator needs to make a one-time choice of which job scheduler to employ.

If Moab is not installed, and if TORQUE is enabled as the operative job manager (see *Optionally enable job manager*), then simply activate Maui by moving into place two global profile files that execute `module load maui` and then start the maui service:

```
cp /opt/scyld/maui/scyld.maui.{csh,sh} /etc/profile.d
chkconfig maui on
service maui start
```

If Moab was previously installed, is currently active, and is the preferred job scheduler, then the cluster administrator can ignore the Maui installation (and any subsequent Maui updates) because Maui installs in a deactivated state and will not affect Moab.

If Maui is active and the cluster administrator subsequently installs Moab, or chooses to use an already installed Moab as the default scheduler, then deactivate Maui so as to not affect Moab:

```
rm /etc/profile.d/scyld.maui.*
chkconfig maui off
service maui stop
```

and then activate Moab as appropriate for the cluster.

Optionally enable Ganglia monitoring tool

To enable the Ganglia cluster monitoring tool,

```
chkconfig beostat on
chkconfig xinetd on
chkconfig httpd on
chkconfig gmetad on
```

then either reboot the master node, which automatically restarts these system services; or without rebooting, manually restart *xinetd* then start the remaining services that are not already running:

```
service xinetd restart
service httpd start
service gmetad start
```

See the *Administrator's Guide* for more details.

Optionally enable beoweb service

The beoweb service facilitates remote job submission and cluster monitoring (e.g., used by POD Tools). Beoweb version 2.0+ requires that the scyld-lmx license manager service be executing and able to access a valid license file at `/opt/scyld/scyld-lmx/scyld.lic`. If this file does not exist, then send your master node's MAC address to Penguin Computing Support to obtain a free license file.

When the license file is in place, start the scyld-lmx license manager, and enable and start beoweb:

```
/etc/init.d/scyld-lmx start
chkconfig beoweb on
service beoweb start
```

See the *Administrator's Guide* for more details.

Optionally enable NFS locking

If you wish to use cluster-wide NFS locking, then you must enable locking on the master node and on the compute nodes. First ensure that NFS locking is enabled and running on the master:

```
chkconfig nfslock on
service nfslock start
```

Then for each NFS mount point for which you need the locking functionality, you must edit `/etc/beowulf/fstab` (or the appropriate node-specific `/etc/beowulf/fstab.`*N* file(s)) to remove the default option *nolock* for that mountpoint. See the *Administrator's Guide* for more details.

Optionally adjust the size limit for locked memory

OpenIB, MVAPICH, and MVAPICH2 require an override to the limit of how much memory can be locked.

Scyld ClusterWare adds a *memlock* override entry to `/etc/security/limits.conf` during a Scyld ClusterWare upgrade (if the override entry does not already exist in that file), regardless of whether or not Infiniband is present in the cluster. The new override line,

```
*    -    memlock    unlimited
```

raises the limit to *unlimited*. If Infiniband is not present, then this new override line is unnecessary and may be deleted. If Infiniband is present, we recommend leaving the new *unlimited* line in place. If you choose to experiment with a smaller discrete value, then understand that Scyld ClusterWare MVAPICH requires a minimum of 16,384 KBytes, which means changing *unlimited* to *16384*. If your new discrete value is too small, then MVAPICH reports a “CQ Creation” or “QP Creation” error.

Optionally increase the max number of processes per user

RHEL6 defaults to a maximum of 1024 processes per user, as specified in `/etc/security/limits.d/90-nproc.conf`, which contrasts with the RHEL5 default of 16,384. If this RHEL6 value is too low, then override the *nproc* entry in that file, as appropriate for your cluster workload needs. Use a discrete value, not *unlimited*.

Optionally enable SSHD on compute nodes

If you wish to allow users to execute MVAPICH2 applications, or to use `/usr/bin/ssh` or `/usr/bin/scp` from the master to a compute node, or from one compute node to another compute node, then you must enable `sshd` on compute nodes by enabling the script:

```
beochkconfig 81sshd on
```

The cluster is preconfigured to allow user *root* ssh access to compute nodes. The cluster administrator may wish to configure the cluster to allow ssh access for non-root users. See the *Administrator’s Guide* for details.

Optionally allow IP Forwarding

By default, the master node does not allow IP Forwarding from compute nodes on the private cluster network to external IP addresses on the public network. If IP Forwarding is desired, then edit `/etc/beowulf/config` to enable the directive *ipforward yes*, and ensure that the file `/etc/sysconfig/iptables` eliminates or comments-out the default entry:

```
-A FORWARD -j REJECT --reject-with icmp-host-prohibited
```

Optionally increase the nf_conntrack table size

Certain workloads may trigger a syslog message *nf_conntrack: table full, dropping packet*. At cluster startup, Scyld ClusterWare insures a NAT table max size of at least 524,288. However, this max value may still be inadequate for local workloads, and the *table full, dropping packet* syslog messages may still occur. Use:

```
sysctl -n net.nf_conntrack_max
```

to view the current max size, then keep manually increasing the max until the syslog messages stop occurring, e.g., use:

```
sysctl -w net.nf_conntrack_max=Nmax
```

to try new *Nmax* values. Make this value persist across master node reboots by adding:

```
net.nf_conntrack_max=Nmax
```

to `/etc/sysctl.conf`.

Optionally configure vm.zone_reclaim_mode on compute nodes

Because Scyld ClusterWare compute nodes are predominantly used for High Performance Computing, versus (for example) used as file servers, we suggest that the /etc/beowulf/conf.d/sysctl.conf file contain the line:

```
vm.zone_reclaim_mode=1
```

for optimal NUMA performance. Scyld ClusterWare‘s node_up script adds this line if it doesn’t already exist, but will not alter an existing *vm.zone_reclaim_mode* declaration in that file. If the file /etc/beowulf/conf.d/sysctl.conf does not exist, then node_up creates it by replicating the master node’s /etc/sysctl.conf, which may contain a *vm.zone_reclaim_mode=N* declaration that is perhaps not *=1* and thus not optimal for compute nodes, even if the value is optimal for the master node. In this case, the cluster administrator should consider manually editing /etc/beowulf/conf.d/sysctl.conf to change the line to *vm.zone_reclaim_mode=1*.

Optionally configure automount on compute nodes

If you wish to run automount from compute nodes, you must first set up all the necessary configuration files in /etc/beowulf/conf.d/autofs/ before enabling the /etc/beowulf/init.d/50autofs script. These config files are similar to those normally found on a server in /etc/, such as /etc/auto.master, as the 50autofs script copies the files in /etc/beowulf/conf.d/autofs/ to each compute node’s /etc/.

A default /etc/beowulf/conf.d/autofs/auto.master must exist. All automount config files that are listed in that master.conf, such as /etc/auto.misc, /etc/auto.net, etc., should also reside in /etc/beowulf/conf.d/autofs/.

Node-specific config files (auto.master and related auto.*) may reside in /etc/beowulf/conf.d/autofs/$NODE/. Those files override the default top level /etc/beowulf/conf.d/auto.master, etc., for the specific $NODE.

The 50autofs script parses the config files as mentioned above. It creates mount point directories, installs the autofs4 kernel module, and starts automount on each booting compute node. The script exits with a warning if there are missing config files.

NOTE: This script does *not* validate the correctness of potential future automount mount requests (i.e., those described in the various auto.* config files). The cluster administrator should set up the config files, then enable 50autofs and reboot one or a limited number of nodes and ensure that each potential automount will function properly prior to rebooting all compute nodes. Common failures include naming an unknown server or attempting to mount a directory that has not been properly exported by the server. Mount failures will be syslogged in /var/log/messages.

Optionally reconfigure node names

You may declare site-specific alternative node names for cluster nodes by adding entries to /etc/beowulf/config. The syntax for a node name entry is:

```
nodename format-string [IPv4offset] [netgroup]
```

For example,

```
nodename node%N
```

allows the user to refer to node 4 using the traditional *.4* name, or alternatively using names like *node4* or *node004*. See man beowulf-config and the *Administrator’s Guide* for details.

1.1.5 Post-Installation Configuration Issues For Large Clusters

Larger clusters have additional issues that may require post-installation adjustments.

Optionally increase the number of nfsd threads

The default count of 8 `nfsd` NFS daemons may be insufficient for large clusters. One symptom of an insufficiency is a syslog message, most commonly seen when you currently boot all the cluster nodes:

```
nfsd: too many open TCP sockets, consider increasing the number of nfsd threads
```

Scyld ClusterWare automatically increases the nfsd thread count to at least one thread per compute node, with a lowerbound of eight (for =64 nodes). If this increase is insufficient, then increase the thread count (e.g., to 16) by executing: echo 16 > /proc/fs/nfsd/threads Ideally, the chosen thread count should be sufficient to eliminate the syslog complaints, but not significantly higher, as that would unnecessarily consume system resources. One approach is to repeatedly double the thread count until the syslog error messages stop occurring, then make the satisfactory value *N* persistent across master node reboots by creating the file `/etc/sysconfig/nfs`, if it does not already exist, and adding to it an entry of the form: RPCNFSDCOUNT=*N* A value *N* of 1.5x to 2x the number of nodes is probably adequate, although perhaps excessive. See the *Administrator's Guide* for a more detailed discussion of NFS configuration.

Optionally increase the max number of processID values

The kernel defaults to using a maximum of 32,768 processID values. Scyld ClusterWare automatically increases this default to 98,304 [= 3*32768], which likely is adequate for small- to medium-size clusters and which keeps pid values at a familiar 5-column width maximum. Because BProc manages a common process space across the cluster, even the increase to 98,304 may be insufficient for very large clusters and/or workloads that create large numbers of concurrent processes. The cluster administrator can increase the value further by using the `sysctl` command, e.g.,

```
sysctl -w kernel.pid_max=N
```

directs the kernel to use pid values up to *N*. The kernel (and BProc) supports an upperbound of 4,194,304 [= (4*1024*1024)]. To set a value *N* that persists across master node reboots, add an entry

```
kernel.pid_max=N
```

to `/etc/sysctl.conf`. NOTE: Even though `/etc/beowulf/conf.d/sysctl.conf` is referenced by the `sysctl` command that executes at boot time on each node, any `kernel.pid_max` entry in that file is ignored. The master node's `kernel.pid_max` value prevails cluster-wide for Scyld ClusterWare nodes.

Optionally increase the max number of open files

RHEL6 defaults to a maximum of 1024 concurrently open files. This value may be too low for large clusters. The cluster administrator can add a *nofile* override entry to `/etc/security/limits.conf` to specify a larger value. Caution: for *nofile*, use only a numeric upperbound value, never *unlimited*, as that will result in being unable to login.

Issues with Ganglia

The Ganglia cluster monitoring tool may fail for large clusters. If the `/var/log/httpd/error_log` shows a fatal error of the form *PHP Fatal error: Allowed memory size of 8388608 bytes exhausted*, then edit the file `/etc/php.ini` to increase the *memory_limit* parameter. The default is *memory_limit = 8M* can be safely doubled and re-doubled until the error goes away.

1.1.6 Post-Installation Release of Updated Packages

From time to time, Penguin Computing releases updated Scyld ClusterWare 6 rpms to track Red Hat kernel security or bug fix errata, or to fix Scyld ClusterWare problems or to introduce enhancements. Download the latest version of the Scyld ClusterWare 6 *Release Notes* from https://www.penguincomputing.com/support/documentation to ensure you have the latest guidance before updating your cluster.

First check for the availability of updated rpms:

```
yum check-update
```

and ascertain if the base distribution and/or Scyld ClusterWare would update to a newer kernel, or even more significantly to a new major-minor release. Upgrading the kernel will require updating, perhaps even rebuilding, any 3rd-party drivers that are installed and linked against the current kernel, and you should be prepared to do that if you proceed with the updates. Updating to a newer major-minor release may also affect 3rd-party applications that are validated only for the current base distribution release.

In general, if you choose to update software, then you should use:

```
install-scyld -u
```

and update all available packages.

If your cluster uses Panasas storage, then before updating Scyld ClusterWare you must ensure that a Panasas kernel module is available that matches the SCW kernel that will be installed. See *Important for clusters using Panasas storage* for more information.

1.1.7 Notable Feature Enhancements And Bug Fixes

v6.10.14 - September 22, 2020

1. The base kernel updates to 2.6.32-754.33.1.el6.61014g0000. See https://access.redhat.com/errata/RHSA-2020:3548 for details.
2. The Slurm job manager updates to version 19.05.7, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide* *SLURM Release Information* for details.
3. The openmpi-3.1-scyld packages update to version 3.1.6. Updating openmpi-3.1 only affects the version 3.1.x series. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. The libraries were built with Gnu version 4.4.7-23, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.
4. The openmpi-4.0-scyld packages update to version 4.0.5. Updating openmpi-4.0 only affects the version 4.0.x series. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. The libraries were built with Gnu version 4.4.7-23, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.

v6.10.13 - August 5, 2020

1. The base kernel updates to 2.6.32-754.31.1.el6.61013g0000. See https://access.redhat.com/errata/RHSA-2020:2933 for details.
2. Enhance `install-scyld` to version 1.45 for improved detection of an install or update that leaves the master node with no ClusterWare kernel and associated bproc kernel modules; automatic restart of `install-scyld` after a runtime update to a newer version; and terser output.

v6.10.12 - June 17, 2020

1. The base kernel updates to 2.6.32-754.30.2.el6.61012g0000. See https://access.redhat.com/errata/RHSA-2020:2430 for details.
2. Update `beoserv` to version 2.9.5: fix a problem with config file 'kernelcommandline' specifying node number or range.

v6.10.11 - May 27, 2020

1. The base kernel updates to 2.6.32-754.29.2.el6.61011g0000. See https://access.redhat.com/errata/RHSA-2020:2103 for details.

v6.10.10 - May 6, 2020

1. The base kernel updates to 2.6.32-754.29.1.el6.61010g0000. See https://access.redhat.com/errata/RHSA-2020:1524 for details.
2. The Slurm job manager updates to version 20.02.1, derived from https://slurm.schedmd.com, and is available **if desired** in the ClusterWare *updates.next* repo, together in that repo with the various openmpi-*-scyld packages that have been rebuilt for consistency with the new Slurm library for v20.02.1. See the ClusterWare *User's Guide SLURM Release Information* for details.
3. The openmpi-4.0-scyld packages update to version 4.0.3. Updating openmpi-4.0 only affects the version 4.0.x series. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. The libraries were built with Gnu version 4.4.7-23, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the ClusterWare *User's Guide OpenMPI Release Information* for details.

v6.10.9 - April 1, 2020

1. The base kernel updates to 2.6.32-754.28.1.el6.61009g0000. See https://access.redhat.com/errata/RHSA-2020:0790 for details.
2. Update `beosi` to version 1.64: capture all modified files in packages distributed by ClusterWare.
3. Update `beobootutils` to version 1.4.44: add `/sbin/ldconfig` to the rootfs to support installing Python v3.6 directly on compute nodes.

v6.10.8 - February 20, 2020

1. The base kernel updates to 2.6.32-754.27.1.el6.61008g0000. See https://access.redhat.com/errata/RHBA-2020:0256 for details.
2. Update `beoserv` to version 2.9.4: increase the permit size of an incoming TFTP request to values that some motherboard BIOS employ.
3. Update `beobootutils` to version 1.4.43: broaden permissions of `/var/beowulf/boot/pxelinux.cfg/default` to allow `beoserv` v2.9.4 to read as a non-root user.
4. Update `beostat` to version 0.9.4: fix a problem sending periodic stats from compute nodes to master nodes for large per-node CPU counts and mismatched MTU values.
5. The Slurm job manager updates to version 19.05.5, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide SLURM Release Information* for details.

6. The MPICH3 mpich-scyld release updates to version 3.3.2, derived from https://www.mpich.org. See the User's Gude, *MPICH-3 Release Information* for details.

v6.10.7 - January 7, 2020

1. The base kernel updates to 2.6.32-754.25.1.el6.61007g0000. See https://access.redhat.com/errata/RHSA-2019:4256 for details.

v6.10.6 - December 3, 2019

1. The base kernel updates to 2.6.32-754.24.3.el6.61006g0000. See https://access.redhat.com/errata/RHSA-2019:2736 and https://access.redhat.com/errata/RHSA-2019:3878 for details.
2. Update `beoserv` to version 2.9.3, which aborts at ClusterWare startup if it detects a duplicate MAC address in the `/etc/beowulf/config` list of *node* entries.
3. The Slurm job manager updates to version 19.05.3-2, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide SLURM Release Information* for details.
4. The openmpi-4.0-scyld packages update to version 4.0.2. Updating openmpi-4.0 does not affect any other OpenMPI version. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. The libraries were built with Gnu version 4.4.7-23, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the ClusterWare *User's Guide OpenMPI Release Information* for details.

v6.10.5 - August 23, 2019

1. The base kernel updates to 2.6.32-754.18.2.el6.61005g0000. See https://access.redhat.com/errata/RHBA-2019:1651.html and https://access.redhat.com/errata/RHSA-2019:2473 for details.
2. Singularity updates to version 3.2.1-1. See https://www.sylabs.io/docs/ and the ClusterWare *User's Guide Using Singularity* for details.
3. The Slurm job manager updates to version 19.05.1-2, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide SLURM Release Information* for details.
4. The openmpi-3.1-scyld packages update to version 3.1.4, openmpi-3.0-scyld updates to version 3.0.4, and openmpi-2.1-scyld updates to version 2.1.6. The remaining openmpi-*-scyld packages have been rebuilt for compatiblility with the updated Slurm.

v6.10.4 - July 16, 2019

1. The base kernel updates to 2.6.32-754.15.3.el6.61004g0000. See https://access.redhat.com/errata/RHSA-2019:0717.html, https://access.redhat.com/errata/RHSA-2019:1169.html, and https://access.redhat.com/errata/RHSA-2019:1488 for details.
2. Update `beoserv` to version 2.8.10 to tweak the multi-master behavior of boot ordering.
3. The Slurm job manager updates to version 18.08.7, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide SLURM Release Information* for details. (Note: the openmpi-* packages have been rebuilt for compatibility with the new Slurm.)
4. ClusterWare now distributes openmpi-4.0-scyld packages, which are initially version 4.0.1. Installation of openmpi-4.0 does not affect any other OpenMPI version. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. The libraries were built with Gnu version 4.4.7-23, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the User's Guide *OpenMPI Release Information* for details.

5. The MPICH3 mpich-scyld release updates to version 3.3, derived from https://www.mpich.org. See the User's Guide, *MPICH-3 Release Information* for details.
6. MVAPICH2 updates to version 2.3.1 for the `mvapich2-psm-scyld` and `mvapich2-scyld` packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. This software suite derives from http://mvapich.cse.ohio-state.edu/. See the ClusterWare *User's Guide MVAPICH2 Release Information* for details.
7. Singularity updates to version 2.6.1. See https://www.sylabs.io/docs/ and the ClusterWare *User's Guide Using Singularity* for details.

v6.10.3 - October 15, 2018

1. The base kernel updates to 2.6.32-754.6.3.el6.61003g0000. See https://access.redhat.com/errata/RHSA-2018:2846.html for details.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-754.3.5.el6.61002g0000.x86_64 kernel. This *panfs* works properly in a 2.6.32-754.6.3.el6.61003g0000 environment using *weak-updates* linking.
3. The Slurm job manager updates to version 18.08.1, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide SLURM Release Information* for details. (Note: the openmpi-* packages have been rebuilt for compatibility with the new Slurm.)

v6.10.2 - September 27, 2018

1. The base kernel updates to 2.6.32-754.3.5.el6.61002g0000. See https://access.redhat.com/errata/RHSA-2018:2390.html for details.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-754.3.5.el6.61002g0000 kernel.
3. Intel-processor nodes that do not support *invpcid* suffer a kernel panic when used as either a compute node or a master node. See *Kernel panic using non-invpcid old Intel nodes* for details.
4. Fix `bpsh` command hangs and misbehavior that was occasionally seen on large (e.g., >300 nodes) clusters.
5. Enhance the `beoserv` daemon to log more information for a TFTP client download hang infrequently seen during an EFI PXEboot.
6. Singularity updates to version 2.6.0. See https://www.sylabs.io/docs/ and the ClusterWare *User's Guide Using Singularity* for details.
7. The Slurm job manager updates to version 17.11.9-2, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide SLURM Release Information* for details.
8. The openmpi-2.1-scyld packages update to version 2.1.5, which by default update and replace only earlier version 2.1 packages and do not affect any other installed OpenMPI version. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. The libraries were built with Gnu version 4.4.7-23, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the User's Guide *OpenMPI Release Information* for details.
9. The openmpi-3.1-scyld packages update to version 3.1.2, which by default update and replace only earlier version 3.1 packages and do not affect any other installed OpenMPI version. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. The libraries were built with Gnu version 4.4.7-23, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the User's Guide *OpenMPI Release Information* for details.

10. Installing or updating the v6.10.2 (and later) `beonss` rpm relocates `/etc/beowulf/nsswitch.conf` to `/etc/beowulf/conf.d/nsswitch.conf`, thus moving it to where the other ClusterWare `.conf` files reside. The `node_up` script similarly relocates any optional existing compute node-specific `/etc/beowulf/nsswitch.conf.<nodenum>` file to `/etc/beowulf/conf.d/` if encountered when booting node `<nodenum>`.

v6.10.1 - July 27, 2018

1. The base kernel updates to 2.6.32-754.2.1.el6.61001g0000. See https://access.redhat.com/errata/RHSA-2018:2164.html for details.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-754.2.1.el6.61001g0000 kernel.
3. Intel-processor nodes that do not support *invpcid* suffer a kernel panic when used as either a compute node or a master node. See *Kernel panic using non-invpcid old Intel nodes* for details.
4. The Slurm job manager updates to version 17.11.8, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide SLURM Release Information* for details.
5. MVAPICH2 updates to version 2.3 for the `mvapich2-psm-scyld` and `mvapich2-scyld` packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. This software suite derives from http://mvapich.cse.ohio-state.edu/. See the ClusterWare *User's Guide MVAPICH2 Release Information* for details.

v6.10.0 - July 14, 2018

1. This is the first ClusterWare release that is compatible with the Red Hat RHEL6 Update 10 and CentOS 6.10 base distribution environments. Cluster administrators and users are encouraged to visit https://docs.redhat.com/docs/en-US/Red_Hat_Enterprise_Linux and read the RHEL *6.10 Release Notes* and *6.10 Technical Notes* in order to understand the differences between the 6.10 base distribution versus earlier base distributions.
2. The base kernel updates to 2.6.32-754.el6.61000g0000. See https://access.redhat.com/errata/RHSA-2018:1854.html for details.
3. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-754.el6.61000g0000 kernel.
4. Intel-processor nodes that do not support *invpcid* suffer a kernel panic when used as either a compute node or a master node. See *Kernel panic using non-invpcid old Intel nodes* for details.
5. **IMPORTANT**: ClusterWare v6.10.0 does not yet include a new version of the optional `beoweb` rpm. If an earlier beoweb is currently installed and you are updating to ClusterWare v6.10.0, then beoweb will continue to work. However, beoweb is not currently available for a fresh install of ClusterWare v6.10.0.
6. ClusterWare v6.10 (and beyond) no longer distributes the mpich v1.2.7p1, mvapich-scyld v0.9.9, and mpiexec v0.83 packages. These have been supplanted by the newer mpich2, mvapich2, and mpich-scyld v3 packages, in addition to the various openmpi packages. Also, ClusterWare v6.10 (and beyond) no longer distributes the net-snmp-scyld, beonetconf, and netpipe packages.
7. The Slurm job manager updates to version 17.11.6, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide SLURM Release Information* for details.
8. ClusterWare now distributes openmpi-3.1-scyld packages, which are initially version 3.1.1. Installation of openmpi-3.1 does not affect any earlier OpenMPI version. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. The libraries were built with Gnu version 4.4.7-23, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the User's Guide *OpenMPI Release Information* for details.

9. The openmpi-3.0-scyld packages update to version 3.0.2, which by default update and replace only earlier version 3.0 packages and do not affect any other installed OpenMPI version. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. The libraries were built with Gnu version 4.4.7-23, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the User's Guide *OpenMPI Release Information* for details.
10. Singularity updates to version 2.5.2. See https://www.sylabs.io/docs/ and the ClusterWare *User's Guide Using Singularity* for details.

v6.9.12 - June 1, 2018

1. The base kernel updates to 2.6.32-696.30.1.el6.6912g0000. See https://access.redhat.com/errata/RHSA-2018:1319.html and https://access.redhat.com/errata/RHSA-2018:1651.html for details.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-696.30.1.el6.6912g0000 kernel.
3. Intel-processor nodes that do not support *invpcid* suffer a kernel panic when used as either a compute node or a master node. See *Kernel panic using non-invpcid old Intel nodes* for details.
4. Fix a `bpmaster` segfault that occurs when the `/etc/beowulf/config` file's *nodes* and *iprange* upperbound IP address contradict each other.
5. The `bpcp` command now supports a new `-a` option, which specifies to copy the local source file(s) to every *up* compute node.
6. Singularity updates to version 2.5.1. See https://www.sylabs.io/docs/ and the ClusterWare *User's Guide* for details.
7. The openmpi-3.0-scyld packages update to version 3.0.1, which by default update and replace only earlier version 3.0 packages and do not affect any other installed OpenMPI version. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the User's Guide *OpenMPI Release Information* for details.
8. Distribute a new *clusterware-docs* rpm that replaces the earlier *scyld-doc* rpms. It installs the ClusterWare documentation in the form of a single combined *clusterware-docs.pdf* PDF file and a single combined HTML package to `/var/www/html` for local access, and installs ClusterWare manpages. The https://www.penguincomputing.com/support/documentation web page now contains the same PDF and HTML choices for viewing ClusterWare documentation, vs. the earlier set of individual PDF files. A combined document simplifies searching and allows for full cross-referencing between the individual documents.

v6.9.10 - March 23, 2018

1. The base kernel updates to 2.6.32-696.23.1.el6.6910g0000. See https://access.redhat.com/errata/RHSA-2018:0512 for details.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-696.23.1.el6.6910g0000 kernel.
3. Intel-processor nodes that do not support *invpcid* suffer a kernel panic when used as either a compute node or a master node. See *Kernel panic using non-invpcid old Intel nodes* for details.
4. Fix the `beoserv` daemon, which executes on the master node, to properly service DHCP requests from motherboard BMCs (Baseboard Management Controllers) and CMCs (Chassis Management Controllers). This functionality broke beginning with the v6.9.5 release.
5. Fix the `beoclient` daemon, which executes on a booting compute node as the *init* process, to properly generate and print to the node's console a message that clearly explains that the daemon cannot find an appropriate network driver for communication back to the master node. The most common reason for that failure is because that driver has not been mentioned as a "bootmodule" in */etc/beowulf/config*.

6. The openmpi-2.1-scyld packages update to version 2.1.3, which by default update and replace only earlier version 2.1 packages and do not affect any other installed OpenMPI version. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the User's Guide *OpenMPI Release Information* for details.
7. TORQUE 6 updates to version 6.1.2, from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.
8. Singularity updates to version 2.4.5. See https://www.sylabs.io/docs/ and the Scyld ClusterWare *User's Guide Using Singularity* for details.
9. The `install-scyld` script now appends its logging messages to */etc/beowulf/install-scyld.log*, instead of writing a logging file to the current working directory. This file is now being backed up into */etc/beowulf/backups/* for every beowulf service start, restart, and reload, just as various other */etc/beowulf/* configuration files have been saved.

v6.9.9 - February 8, 2018

1. The base kernel updates to 2.6.32-696.20.1.el6.699g0000. See https://access.redhat.com/errata/RHSA-2018:0169 for details.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-696.20.1.el6.699g0000 kernel.
3. Intel-processor nodes that do not support *invpcid* suffer a kernel panic when used as either a compute node or a master node. See *Kernel panic using non-invpcid old Intel nodes* for details.
4. A `service beowulf start`, `service beowulf restart`, or `service beowulf reload` rebuilds the `initrd` (initial root directory) file for compute nodes. That file now contains the latest Intel and AMD CPU microcode files found in `/lib/firmware/intel-ucode/` and `/lib/firmware/amd-ucode/`. A booting node's kernel chooses an appropriate microcode file (if available) to dynamically reload every CPU's microcode.
5. The Slurm job manager updates to version 17.11.2, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide SLURM Release Information* for details.
6. Singularity updates to version 2.4.2. See https://www.sylabs.io/docs/ and the ClusterWare *User's Guide Using Singularity* for details.

v6.9.8 - January 11, 2018

1. The base kernel updates to 2.6.32-696.18.7.el6.698g0000. See https://access.redhat.com/errata/RHSA-2018:0008 for details.

   This kernel fixes the security issues noted in https://access.redhat.com/security/cve/CVE-2017-5753 and https://access.redhat.com/security/cve/CVE-2017-5715, which affects both Intel and AMD x86_64, and https://access.redhat.com/security/cve/CVE-2017-5754, which affects only Intel x86_64.

   These fixes may result in performance degradation, especially for applications that perform high rates of syscalls and interrupts. See https://access.redhat.com/security/vulnerabilities/speculativeexecution for more information, and https://access.redhat.com/articles/3311301 for extraordinary methods to disable these security fixes and thereby expose the cluster to security vulnerabilities.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-696.18.7.el6.698g0000 kernel.
3. Intel-processor nodes that do not support *invpcid* suffer a kernel panic when used as either a compute node or a master node. See *Kernel panic using non-invpcid old Intel nodes* for details.

4. The Slurm job manager updates to version 17.11.0, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide SLURM Release Information* for details.
5. The various openmpi packages update because they have been rebuilt in order to maintain compatibility with this new version of Slurm.

v6.9.7 - November 29, 2017

1. The base kernel updates to 2.6.32-696.16.1.el6.697g0000. See https://access.redhat.com/errata/RHSA-2017:3200 for details.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-696.16.1.el6.697g0000 kernel.
3. Fix a bproc problem involving a master node that employs the latest Intel microarchitecture (codenamed "Skylake", succeeding "Broadwell") resulting in a kernel panic in task_packer_save_cpu() when booting a compute node.
4. Fix a problem with the `install-scyld` script that left `/etc/yum.conf` with too-restrictive permissions: *0600* instead of the proper *0644*. Improper permissions breaks commands like `yum grouplist` executed by non-root users.
5. The podtools and beoweb packages are now optional and thus not installed by default. `install-scyld -u` will continue to update already-installed packages.
6. The openmpi-2.0-scyld packages update to version 2.0.4, which by default update and replace only earlier version 2.0 packages and do not affect version 1.10 or any earlier installed OpenMPI version. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide OpenMPI Release Information* for details.
7. The MPICH3 mpich-scyld release updates to version 3.2.1, derived from https://www.mpich.org. See the ClusterWare *User's Guide MPICH-3 Release Information* for details.

   The libraries were built with Gnu version 4.4.7-18, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families.

v6.9.6 - October 18, 2017

1. The base kernel updates to 2.6.32-696.13.2.el6.696g0000. See https://access.redhat.com/errata/RHSA-2017:2863 for details.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-696.13.2.el6.696g0000 kernel.
3. Singularity updates to version 2.4. See https://www.sylabs.io/docs/ and the ClusterWare *User's Guide Using Singularity* for details.

v6.9.5 - October 9, 2017

1. The base kernel updates to 2.6.32-696.10.3.el6.695g0000. See https://access.redhat.com/errata/RHSA-2017:2795 for details. This kernel fixes the security issue noted in https://access.redhat.com/security/cve/CVE-2017-1000253.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-696.10.2.el6.695g0000 kernel.
3. The igb Ethernet driver updates to version 5.3.5.12, derived from http://sourceforge.net/projects/e1000/.

4. The e1000e Ethernet driver updates to version 3.3.6, derived from http://sourceforge.net/projects/e1000/.

5. The Slurm job manager updates to version 17.02.7, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide* *SLURM Release Information* for details.

6. Scyld ClusterWare now distributes openmpi-3.0-scyld packages, which are initially version 3.0.0. Installation of openmpi-3.0 does not affect any earlier OpenMPI version. The openmpi-2.1-scyld packages update to version 2.1.2, which by default update and replace only earlier version 2.1 packages and do not affect any installed OpenMPI version 2.0 and earlier packages. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.

7. Each ClusterWare compute node employs a custom syslog server daemon that forwards the node's syslog messages to the central syslog server – typically the master node's `rsyslogd` daemon – which writes those messages to `/var/log/messages`. Previously, many compute node syslog messages were written to `/var/log/messages` containing a redundant date-time string, which is both unnecessary and violates the RFC 3164 format standard. The ClusterWare compute node server daemon now strips out that redundant date-time string before forwarding a message to the master node's `rsyslogd`. If for some reason a local cluster administrator wishes to revert to the previous behavior, then edit the `/etc/beowulf/config`'s *kernelcommandline* directive to add *legacy_syslog=1*.

v6.9.4 - July 26, 2017

1. The base kernel updates to 2.6.32-696.6.3.el6.694g0000. See https://access.redhat.com/errata/RHSA-2017:1723 for details.

2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-696.6.3.el6.694g0000 kernel.

v6.9.3 - July 6, 2017

1. The base kernel updates to 2.6.32-696.3.2.el6.693g0000. See https://access.redhat.com/errata/RHSA-2017:1486 for details.

2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-696.3.2.el6.693g0000 kernel.

3. Update `/lib64/scyld/libc-2.12*` to match the latest `/lib64/libc-2.12.so`. See https://access.redhat.com/security/cve/CVE-2017-1000364 for details.

4. Singularity updates to version 2.3.1. See https://www.sylabs.io/docs/ and the ClusterWare *User's Guide* *Using Singularity* for details.

5. The Slurm job manager updates to version 17.02.5, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide* *SLURM Release Information* for details.

v6.9.2 - June 12, 2017

1. The base kernel updates to 2.6.32-696.3.1.el6.692g0000. See https://access.redhat.com/errata/RHSA-2017:1372 for details.

2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-696.3.1.el6.692g0000 kernel.

3. TORQUE 6 updates to version 6.1.1.1, from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.

4. The Slurm job manager updates to version 17.02.3, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide* *SLURM Release Information* for details.

5. The openmpi-2.1-scyld packages update to version 2.1.1, which by default update and replace only earlier version 2.1 packages and do not affect any installed OpenMPI version 2.0 and earlier packages. The openmpi-2.0-scyld packages update to version 2.0.3, which by default update and replace only earlier version 2.0 packages and do not affect any installed OpenMPI version 1.10 and earlier packages. The openmpi-1.10-scyld packages update to version 1.10.7, which by default update and replace only earlier version 1.10 packages and do not affect any installed OpenMPI version 1.8 and earlier packages. See *Installing and managing concurrent versions of packages* or general issues about supporting multiple concurrent versions. The libraries were built with Gnu version 4.4.7-18, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.

6. Singularity updates to version 2.3. See https://www.sylabs.io/docs/ and the ClusterWare *User's Guide* *Using Singularity* for details.

v6.9.1 - May 3, 2017

1. The base kernel updates to 2.6.32-696.1.1.el6.691g0000. See https://access.redhat.com/errata/RHSA-2017:0892 for details.

2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-696.1.1.el6.691g0000 kernel.

3. The bproc *filecache* functionality now properly downloads files from the master node that were previously rejected because the files have restricted read access permissions. Now all files are downloaded to compute nodes - and, as always, downloaded files are given access permissions that are replicated from the master node.

v6.9.0 - April 14, 2017

1. The base kernel updates to 2.6.32-696.el6.690g0000. See https://rhn.redhat.com/errata/RHSA-2017-0817.html for details. Scyld ClusterWare v6.9.0 expects to execute in a RHEL6 Update 9 or CentOS6.9 environment.

2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-696.el6.690g0000 kernel.

3. TORQUE 6 updates to version 6.1.1, from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.

4. Scyld ClusterWare now distributes openmpi-2.1-scyld packages, which are initially version 2.1.0. Installation of openmpi-2.1 does not affect any earlier OpenMPI version. The libraries were built with Gnu version 4.4.7-18, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.

5. Scyld ClusterWare now distributes Singularity, which is initially version 2.2.1. See https://www.sylabs.io/docs/ and the ClusterWare *User's Guide* *Using Singularity* for details.

v6.8.8 - March 2, 2017

1. The base kernel updates to 2.6.32-642.15.1.el6.688g0000. See https://rhn.redhat.com/errata/RHSA-2017-0307.html for details.

2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-642.15.1.el6.688g0000 kernel.

3. The Slurm job manager updates to version 17.02.0, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide SLURM Release Information* for details. (Note: the openmpi-* packages have been rebuilt for compatibility with the new Slurm.)

4. The openmpi-1.10-scyld packages update to version 1.10.6, which by default update and replace only earlier 1.10.z packages and do not affect any other installed openmpi-x.y-scyld packages other than 1.10. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. The libraries were built with Gnu version 4.4.7-17, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide OpenMPI Release Information* for details.

v6.8.7 - February 10, 2017

1. The base kernel updates to 2.6.32-642.13.1.el6.687g0000. See https://rhn.redhat.com/errata/RHSA-2017-0036.html for details.

2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-642.13.1.el6.687g0000 kernel.

3. A new *install-scyld* package contains a script that greatly simplifies installing and updating software on the master:

```
yum install install-scyld
```

   We strongly encourage using this script. See *First Installation of Scyld ClusterWare 6 On A Server* and *Upgrading An Earlier Release of Scyld ClusterWare 6 to 6.10* for details.

4. The igb Ethernet driver updates to version 5.3.5.4, derived from http://sourceforge.net/projects/e1000/.

5. The e1000e Ethernet driver updates to version 3.3.5.3, derived from http://sourceforge.net/projects/e1000/.

6. The Slurm job manager updates to version 16.05.8, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide SLURM Release Information* for details.

7. The openmpi-2.0-scyld packages update to version 2.0.2, which by default update and replace only earlier version 2.0 packages and do not affect any installed OpenMPI version 1.10 and earlier packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. The libraries were built with Gnu version 4.4.7-17, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide OpenMPI Release Information* for details.

8. Various scripts in `/etc/beowulf/init.d/` have been renamed with different numeric prefixes in order to adjust the execution ordering: `95sudo`, `98slurm`, and `98torque`. If any of these scripts has been copied and modified locally (see *Caution when modifying Scyld ClusterWare scripts* for details), then you should rename the local copy to match the new numeric prefix.

v6.8.6 - December 9, 2016

1. The base kernel updates to 2.6.32-642.11.1.el6.686g0000. See https://rhn.redhat.com/errata/RHSA-2016-2766.html for details.

2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-642.11.1.el6.686g0000 kernel.

3. The Slurm job manager updates to version 16.05.6, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide SLURM Release Information* for details.

4. TORQUE version 6 updates to version 6.1.0, from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.
5. The script `/etc/beowulf/init.d/85run2complete` now supports optional `/etc/beowulf/config` overriding of the *idle_threshold* and *idle_time* values that were previously hardcoded in `85run2complete`. See the *r2c* comments in the `config` file.

v6.8.5 - November 7, 2016

1. The base kernel updates to 2.6.32-642.6.2.el6.685g0000. See https://rhn.redhat.com/errata/RHSA-2016-2105.html for details.

   This kernel differs from the previous 2.6.32-642.6.1.el6.684g0000 only by the inclusion of a fix for the Red Hat CVE-2016-5195 (“kernel: mm: privilege escalation via MAP_PRIVATE COW breakage”, aka “dirty COW”) security exploit described by Red Hat Bugzilla #1384344.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-642.6.2.el6.685g0000 kernel.

v6.8.4 - October 13, 2016

1. The base kernel updates to 2.6.32-642.6.1.el6.684g0000. See https://rhn.redhat.com/errata/RHSA-2016-2006.html for details.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-642.6.1.el6.684g0000 kernel.
3. The default `/etc/beowulf/fstab` no longer suggests mounting `/dev/cpuset` for TORQUE.
4. The *torque-scyld* and *torque-nocpuset-scyld* packages are replaced by *torque-4-scyld* and *torque-4-nocpuset-scyld* (still version 4.2.10). Also added to the Scyld ClusterWare distribution are *torque-5-scyld* and *torque-5-nocpuset-scyld* (version 5.1.3), and *torque-6-scyld* and *torque-6-nocpuset-scyld* (version 6.0.2), all from https://www.adaptivecomputing.com/products/opensource/torque. Only one *torque* can be installed at any point in time. See the ClusterWare *User’s Guide* *TORQUE and Maui Release Information* for details.

   NOTE: The first time updating from *torque-scyld* to the new packaging scheme, the cluster administrator must explicitly install one (and only one) of the *N* packages, e.g., `yum install torque-4-scyld`. That will both install the new package and remove the obsolete *torque-scyld* package. See *Issues with TORQUE* for details.
5. The Slurm job manager updates to version 16.05.5, derived from https://slurm.schedmd.com. See the ClusterWare *User’s Guide* *SLURM Release Information* for details.
6. Scyld ClusterWare now distributes openmpi-2.0-scyld packages, which are initially version 2.0.1. Installation of openmpi-2.0 does not affect any earlier OpenMPI version.

   Additionally, the openmpi-1.10-scyld packages update to version 1.10.4, which by default update and replace only earlier version 1.10 packages and do not affect any installed OpenMPI version 1.8, 1.7, 1.6, or 1.5 packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. The libraries were built with Gnu version 4.4.7-17, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User’s Guide* *OpenMPI Release Information* for details.
7. MVAPICH2 updates to version 2.2 for the `mvapich2-psm-scyld` and `mvapich2-scyld` packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. This software suite derives from http://mvapich.cse.ohio-state.edu/. See the ClusterWare *User’s Guide* *MVAPICH2 Release Information* for details.

v6.8.3 - September 8, 2016

1. The base kernel updates to 2.6.32-642.4.2.el6.683g0000. See https://rhn.redhat.com/errata/RHSA-2016-1664.html for details.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-642.4.2.el6.683g0000 kernel.
3. Fix another rare bproc bug that panics compute nodes with "soft lockup" or "hard lockup" messages.
4. Make additional bproc enhancements that improve the performance of multithreaded applications that concurrently execute multiple dozens of threads across multiple dozens of cores.
5. Introduce various "helper" routines in libbeoconfig.so that assist in parsing the `/etc/beowulf/config` *iprange* directive. The several consumers of that directive (*beonss*, *beoserv*, *bpmaster*) now use these helper routines to provide a consistent implementation. These changes should be transparent to users, although they serve as part of the foundation for upcoming enhancements to the *iprange* functionality and to SCW's handling of very large clusters.

v6.8.2 - July 26, 2016

1. The base kernel updates to 2.6.32-642.3.1.el6.682g0000. See https://rhn.redhat.com/errata/RHSA-2016-1406.html for details.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-642.3.1.el6.682g0000 kernel.
3. The openmpi-1.10-scyld packages update to version 1.10.3, which by default update and replace only earlier version 1.10 packages and do not affect any installed OpenMPI version 1.8, 1.7, 1.6, or 1.5 packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. The libraries were built with Gnu version 4.4.7-17, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.
4. The Slurm job manager updates to version 16.05.0, derived from https://slurm.schedmd.com. See the ClusterWare *User's Guide* *SLURM Release Information* for details.
5. Eliminate a harmless error message that may be generated by the `/etc/beowulf/init.d/30cpuspeed` script.

v6.8.1 - July 26, 2016

1. The base kernel updates to 2.6.32-642.1.1.el6.681g0000. See https://rhn.redhat.com/errata/RHBA-2016-1185.html for details.
2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-642.1.1.el6.681g0000 kernel.
3. Fix rare bproc bugs that panic compute nodes with "soft lockup" or "hard lockup" messages.
4. Improve bproc performance on compute nodes when handling processes with multi-gigabytes of allocated memory.

v6.8.0 - June 3, 2016

1. The base kernel updates to 2.6.32-642.el6.680g0000. See https://rhn.redhat.com/errata/RHSA-2016-0855.html for details.

2. For Panasas support, search the Panasas website (see *Important for clusters using Panasas storage* for details) for an rpm that matches the 2.6.32-642.el6.680g0000 kernel.
3. Supports the Intel Xeon E5-2600 "Broadwell" microarchitecture family.
4. The igb Ethernet driver updates to version 5.3.4.4, derived from http://sourceforge.net/projects/e1000/.

v6.7.7 - November 7, 2016

1. The base kernel updates to 2.6.32-573.26.1.el6.677g0001. This kernel differs from the previous 2.6.32-573.26.1.el6.677g0000 only by the inclusion of a fix for the Red Hat Bugzilla #1384344 security exploit ("kernel: mm: privilege escalation via MAP_PRIVATE COW breakage"). This kernel, together with the matching kmod-* rpms which were built from the same source code files as they were in 677g0000, is currently only available in the Scyld ClusterWare 6.7 `updates.next` yum repo. NOTE: the matching Panasas kernel module is *not* yet available for this kernel, so do not install and use this kernel if your cluster employs Panasas storage.

   To install, ensure that the `/etc/yum.repos.d/clusterware.repo` file (or whatever the name of the ClusterWare repo file is being used) has URLs that refer to the `6.7` repo, then:

```
yum --disablerepo=* --enablerepo=cw-next update
```

v6.7.7 - May 31, 2016

1. The base kernel updates to 2.6.32-573.26.1.el6.677g0000. See https://rhn.redhat.com/errata/RHSA-2016-0715.html for details.
2. Introduce a new `/etc/beowulf/init.d/98entropy` script to optionally enable the `entropyd` daemon on compute nodes that adds entropy to /dev/random.
3. The `beoserv` daemon increases the max number of master nodes supported by the config file's `masterorder` directive from four to eight.
4. The `beosi` script is now more tolerant about network controller names. Previously, the script recognized only names beginning with *eth*, *lo*, and *virbr*.
5. The *scyld-release* rpm now installs the base distribution's *yum-plugin-priorities* rpm as a dependency. This supports adding the line `priority=3` to a Scyld ClusterWare yum repo config file, which assigns a higher priority to ClusterWare package names that are the same as base distribution package names, assuming that the base distribution yum repo config files use the default priority=99. (Lower priority values are higher priorities.) For example, this means that a base distribution's newer kernel-* rpms will not update an existing and older ClusterWare's kernel-* rpms, without needing to execute `yum` with a combination of `--disablerepo=* --enablerepo=cw-*` or `--disablerepo=cw* --exclude=kernel-*` arguments. See https://wiki.centos.org/PackageManagement/Yum/Priorities for details.

v6.7.6 - May 9, 2016

1. Scyld ClusterWare now redistributes a non-default TORQUE package that does not employ the base distribution's cpuset functionality. See *Optionally install a different TORQUE package*.

v6.7.6 - April 7, 2016

1. The base kernel updates to 2.6.32-573.22.1.el6.676g0000. See https://rhn.redhat.com/errata/RHSA-2016-0494.html for details.
2. The e1000e Ethernet driver updates to version 3.3.3, derived from http://sourceforge.net/projects/e1000/.

3. The `node_up` script now adds the line *vm.zone_reclaim_mode=1* to the file `/etc/beowulf/conf.d/sysctl.conf`, which gets populated to `/etc/sysctl.conf` for each booting compute node. See *Optionally configure vm.zone_reclaim_mode on compute nodes* for details.
4. Scyld ClusterWare now redistributes the Slurm job manager with the package name *slurm-scyld*, together with the Munge authentication plugin (package *munge-scyld*). This initial Slurm version is 15.08.6-1, derived from https://slurm.schedmd.com. The *slurm* service is initially chkconfig'ed *off*. The *torque-scyld* package continues to be distributed, and the *torque* service is also initially chkconfig'ed *off*. The two job management packages coexist on the master node, although only one of them should be enabled at any point in time. See *Optionally enable job manager* for details.

v6.7.5 - March 8, 2016

1. The base kernel updates to 2.6.32-573.18.1.el6.675g0000. See https://rhn.redhat.com/errata/RHBA-2016-0150.html for details.
2. The igb Ethernet driver updates to version 5.3.3.5, derived from http://sourceforge.net/projects/e1000/.
3. Introduce a new `/etc/beowulf/init.d/97phi` script to optionally enable Intel Xeon Phi cards on compute nodes.
4. The openmpi-1.10-scyld packages update to version 1.10.2, which by default update and replace only earlier version 1.10 packages and do not affect any installed OpenMPI version 1.8, 1.7, 1.6, or 1.5 packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. The libraries were built with Gnu version 4.4.7-16, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.

v6.7.4 - December 29, 2015

1. The base kernel updates to 2.6.32-573.12.1.el6.674g0000. See https://rhn.redhat.com/errata/RHSA-2015-2636.html for details.
2. Introduce a new `/etc/beowulf/init.d/50autofs` script to optionally enable automount on compute nodes. See *Optionally configure automount on compute nodes*
3. Beginning with *nodescripts-1.4.3-674g0001.x86_64.rpm*, Scyld ClusterWare now forcibly enables the `/etc/beowulf/init.d/30cpuspeed` script. Penguin Computing has determined that optimal CPU performance requires that this script (or something like it) should be enabled. See *Optionally configure and enable compute node CPU speed/power management* and the comments inside the 30cpuspeed script and inside the associated configuration file /etc/beowulf/conf.d/cpuspeed.conf for details.

v6.7.3 - November 30, 2015

1. The base kernel updates to 2.6.32-573.8.1.el6.673g0000. See https://rhn.redhat.com/errata/RHBA-2015-1992.html for details.
2. Fix a rare bproc race condition that typically exhibits itself as a NULL pointer dereference doing a process exit on a compute node, which results in a kernel panic.
3. The openmpi-1.10-scyld packages update to version 1.10.1, which by default update and replace only earlier version 1.10 packages and do not affect any installed OpenMPI version 1.8, 1.7, 1.6, or 1.5 packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. The libraries were built with Gnu version 4.4.7-16, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.

4. The MPICH3 mpich-scyld release updates to version 3.2, derived from https://www.mpich.org. The libraries were built with Gnu version 4.4.7-16, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the ClusterWare *User's Guide* *MPICH-3 Release Information* for details.

5. Populate compute nodes with standard /dev/std* devices.

v6.7.2 - October 20, 2015

1. The base kernel updates to 2.6.32-573.7.1.el6.672g0000. See https://rhn.redhat.com/errata/RHBA-2015-1827.html for details.

2. Fix a compute node "soft lockup" that syslogs the offender as *filecache_sys_open*. This fix has also been applied to newer versions of the `kmod-filecache` rpm for Scyld ClusterWare releases 6.6.1 onward.

3. Fix a master node and compute node Out-Of-Memory (OOM) failure that is due to a bproc memory leak of the kernel's *size-512* dynamic memory slab. This leak occurs when a user program on the node executes the *execve()* or *execl()* intrinsic. Use `slabtop` to view the current usage of *size-512* dynamic memory, and compare that *SIZE* value to the total amount of physical memory on that node in order to gauge the current vulnerability to an OOM failure. Without the fix, the *size-512* size continually increases. This fix has also been applied to newer versions of the `kmod-bproc` rpm for Scyld ClusterWare releases 6.5.8 onward.

4. Introduce a new `/etc/beowulf/init.d/14rpc` script to manage startup of the *rpc.statd* daemon on a compute node, vs. the previous (and sometimes flawed) startup done by the `/usr/lib/beoboot/bin/node_up` script. Use `beochkconfig` to disable `14rpc` if *rpc.statd* is not needed.

5. Introduce a warning during `service beowulf start` and for each booting node (logged in `/var/log/beowulf/node.N`) to remind the cluster administrator that a *kernel.pid_max* entry in `/etc/beowulf/conf.d/sysctl.conf` is ignored, and that the master node's *kernel.pid_max* prevails cluster-wide.

v6.7.1 - September 3, 2015

1. The base kernel updates to 2.6.32-573.3.1.el6.671g0000. See https://rhn.redhat.com/errata/RHSA-2015-1623.html for details.

2. Scyld ClusterWare now distributes openmpi-1.10-scyld packages, which are a redistribution of OpenMPI version 1.10 and derived from https://www.open-mpi.org. These openmpi-1.10-scyld packages do not affect any installed OpenMPI version 1.8, 1.7, 1.6, or 1.5 packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. The libraries were built with Gnu version 4.4.7-16, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.

3. The `/etc/beowulf/init.d/15openib` (sets up the Infiniband devices) node startup script updates to support additional QLogic devices and to use the generic udev functionality for a cleaner implementation.

4. The *beoserv* daemon's dhcp server functionality now accepts client packets that contain a `vendor_info` field as small as 8 bytes, vs. the previous minimum of 60 bytes, and thereby accepts client requests from some models of "smart" switches that were previously rejected.

v6.7.0 - August 13, 2015

1. The base kernel updates to 2.6.32-573.1.1.el6.670g0000. See https://rhn.redhat.com/errata/RHSA-2015-1272.html and https://rhn.redhat.com/errata/RHBA-2015-1466.html for details.

2. The Scyld ClusterWare distribution of ganglia has been repackaged down from four rpms to two: `ganglia-scyld`, now updated to version 3.7.1-1, and `ganglia-web-scyld`, now updated to version 3.7.0-1.

v6.6.7 - November 7, 2016

1. The base kernel updates to 2.6.32-504.30.3.el6.667g0001. This kernel differs from the previous 2.6.32-504.30.3.el6.667g0000 only by the inclusion of a fix for the Red Hat Bugzilla #1384344 security exploit ("kernel: mm: privilege escalation via MAP_PRIVATE COW breakage"). This kernel, together with the matching kmod-* rpms which were built from the same source code files as they were in 677g0000, is currently only available in the Scyld ClusterWare 6.6 `updates.next` yum repo. NOTE: the matching Panasas kernel module is *not* yet available for this kernel, so do not install and use this kernel if your cluster employs Panasas storage.

   To install, ensure that the `/etc/yum.repos.d/clusterware.repo` file (or whatever the name of the ClusterWare repo file is being used) has URLs that refer to the `6.6` repo, then:

```
yum --disablerepo=* --enablerepo=cw-next update
```

v6.6.7 - August 12, 2015

1. The base kernel updates to 2.6.32-504.30.3.el6.667g0000. See https://rhn.redhat.com/errata/RHSA-2015-1221.html for details.

2. The openmpi-1.8-scyld packages update to version 1.8.8, which by default update and replace only earlier version 1.8 packages and do not affect any installed OpenMPI version 1.7, 1.6, or 1.5 packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. The libraries were built with Gnu version 4.4.7, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide OpenMPI Release Information* for details.

3. Relax a constraint in the part of the beoserv daemon that functions as the private cluster network's DHCP server. Previously, it silently rejected client requests that contain a *vendor_info* field shorter than 60 bytes. It now accepts a client packet with a *vendor_info* field as short as eight bytes, and it will issue an informative syslog warning about why a DHCP client request is being rejected, versus silently rejecting the packet for one of several possible reasons.

v6.6.6 - June 29, 2015

1. The base kernel updates to 2.6.32-504.23.4.el6.666g0000. See https://rhn.redhat.com/errata/RHSA-2015-1081.html for details.

2. Fix the `/etc/beowulf/init.d/25cuda` script to correctly support MPI+CUDA functionality.

v6.6.5 - June 4, 2015

1. The base kernel updates to 2.6.32-504.16.2.el6.665g0000. See https://rhn.redhat.com/errata/RHSA-2015-0864.html for details.

2. MVAPICH2 updates to version 2.1 for the `mvapich2-psm-scyld` and `mvapich2-scyld` packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. This software suite derives from http://mvapich.cse.ohio-state.edu/. NOTE: MVAPICH2-2.1 introduces an algorithm to determine CPU topology on the node, and this new algorithm does not work properly for older Mellanox controllers and firmware, resulting in software threads not spreading out across a node's

cores by default. See *Issues with MVAPICH2 and CPU Sets* or the ClusterWare *User's Guide MVAPICH2 Release Information* for details.

3. TORQUE updates to version 4.2.10, from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details. This release enables support of CPU Sets; see http://docs.adaptivecomputing.com/torque/4-1-4/help.htm#topics/3-nodes/linuxCpusetSupport.htm for details. Also, the Scyld ClusterWare `torque` rpm renames to `torque-scyld` and disallows the concurrent installation of the base distribution's `torque` packages.

4. The openmpi-1.8-scyld packages update to version 1.8.5, which by default update and replace only earlier version 1.8 packages and do not affect any installed OpenMPI version 1.7, 1.6, or 1.5 packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. The libraries were built with Gnu version 4.4.7, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide OpenMPI Release Information* for details.

v6.6.4 - April 1, 2015

1. The base kernel updates to 2.6.32-504.12.2.el6.664g0000. See https://rhn.redhat.com/errata/RHSA-2015-0674.html for details.

2. The `/etc/beowulf/init.d/15openib` script updates to support both QLogic and Mellanox Infiniband controllers. Previously, clusters with QLogic controllers have employed a custom init script that should now be explicitly disabled by the cluster administrator.

3. Introduce a new MVAPICH2 version 2.0.0 package `mvapich2-psm-scyld`, which employs the Performance Scaled Messaging (PSM) interface to provide superior performance for QLogic Infiniband controllers. We continue to distribute the `mvapich2-scyld` package (currently also version 2.0.0) that employs the traditional Verbs interface, which supports both Mellanox and QLogic controllers. This software suite derives from http://mvapich.cse.ohio-state.edu/. See the ClusterWare *User's Guide MVAPICH2 Release Information* for details.

4. The MPICH3 mpich-scyld release updates to version 3.1.4, derived from https://www.mpich.org. The libraries were built with Gnu version 4.4.7, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the ClusterWare *User's Guide MPICH-3 Release Information* for details.

5. `beoconfig-libs` updates to version 2.0.18 to fix an infrequent *glibc detected *** /usr/bin/python: double free or corruption* error, most often seen (if at all) when executing `yum`.

v6.6.3 - February 11, 2015

1. The base kernel updates to 2.6.32-504.8.1.el6.663g0000. See https://rhn.redhat.com/errata/RHSA-2015-0087.html for details.

2. The igb Ethernet driver updates to version 5.2.15, derived from http://sourceforge.net/projects/e1000/.

3. The e1000e Ethernet driver updates to version 3.1.0.2, derived from http://sourceforge.net/projects/e1000/.

4. Updates the `/etc/beowulf/init.d/30cpuspeed` script that manages CPU speed/power on compute nodes. See the Administrator's Guide, *Configuring CPU speed/power for Compute Nodes* for details.

v6.6.2 - December 31, 2014

1. The base kernel updates to 2.6.32-504.3.3.el6.662g0000. See https://rhn.redhat.com/errata/RHSA-2014-1997.html for details.

2. The openmpi-1.8-scyld packages update to version 1.8.4, which by default update and replace only earlier version 1.8 packages and do not affect OpenMPI version 1.7, 1.6, or 1.5 packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. The libraries were built with Gnu version 4.4.7, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.

v6.6.1 - December 6, 2014

1. The base kernel updates to 2.6.32-504.1.3.el6.661g0000. See https://rhn.redhat.com/errata/RHSA-2014-1843.html for details.
2. Fix a compute node `bpslave` "soft lockup" that would occasionally occur during node boot.
3. The bproc *filecache* functionality now downloads to a compute node a mirror image of the master node's symlinks that follow a path to the final leaf file. For example, opening `/lib64/libcrypt.so.1` creates the symlink `/lib64/libcrypt.so.1` and downloads the leaf file `/lib64/libcrypt-2.12.so`. Previously, bproc *filecache* downloaded only the final leaf file and named it `/lib64/libcrypt.so.1`. This requires a coordinated update to the *beoserv*, *beoclient3*, and *bproc* packages.
4. The beonss `kickbackproxy` daemon that executes on each compute node now throttles its attempts to reconnect to the master node `kickbackdaemon` server if that connection has been lost. Previously, the `kickbackproxy` would rapidly attempt to reconnect, thereby keeping an otherwise idle orphaned compute node busy and thus constraining a run-to-completion reboot.

v6.6.0 - November 17, 2014

1. The base kernel updates to 2.6.32-504.el6.660g0000. See https://rhn.redhat.com/errata/RHSA-2014-1392.html for details.
2. The Scyld ClusterWare igb Ethernet driver that we typically derive from http://sourceforge.net/projects/e1000/ has been temporarily removed from the Penguin Computing distribution until we can locate or craft a version that is compatible with RHEL Update 6 and CentOS 6.6. Meanwhile, the 2.6.32-504.el6.660g0000 kernel will use the native igb driver provided by Red Hat.
3. *IMPORTANT:* The Red Hat RHEL Update 6 and CentOS 6.6 base distributions now include an *mpich* version 3 package that conflicts with the Scyld ClusterWare *mpich* version 1.2.7p1 packages. See *Issues with Mpich* for details.

v6.5.8 - November 7, 2014

1. The base kernel updates to 2.6.32-431.29.2.el6.658g0001. This kernel differs from the previous 2.6.32-431.29.2.el6.658g0000 only by the inclusion of a fix for the Red Hat Bugzilla #1384344 security exploit ("kernel: mm: privilege escalation via MAP_PRIVATE COW breakage"). This kernel, together with the matching kmod-* rpms which were built from the same source code files as they were in 658g0000, is currently only available in the Scyld ClusterWare 6.5 `updates.next` yum repo. NOTE: the matching Panasas kernel module is *not* yet available for this kernel, so do not install and use this kernel if your cluster employs Panasas storage.

   To install, ensure that the `/etc/yum.repos.d/clusterware.repo` file (or whatever the name of the ClusterWare repo file is being used) has URLs that refer to the `6.5` repo, then:

   ```
   yum --disablerepo=* --enablerepo=cw-next update
   ```

v6.5.8 - October 17, 2014

1. The base kernel updates to 2.6.32-431.29.2.el6.658g0000. See https://rhn.redhat.com/errata/RHSA-2014-1167.html for details.
2. Populate each compute node at boot time by pushing the master node's file `/etc/beowulf/conf.d/limits.conf` to the the node as `/etc/security/limits.conf`. This master node's file is initially a concatenation of the master node's `/etc/security/limits.conf` and the files in the directory `/etc/security/limits.d/`. The cluster administrator may edit `/etc/beowulf/conf.d/limits.conf` as desired.
3. Fix a compute node hang that can occur when attempting to link an application that references a nonexistent library file.
4. Support bproc *filecache* pathnames that include embedded `/../` strings. Previously, these were rejected without resolving the true pathname.
5. Fix a rare bug that exhibits itself as a compute node that continually retries an unsuccessful boot, complaining that the communication `bpslave-bpmaster` communication (which defaults to port 932) cannot be established.
6. TORQUE updates to version 4.2.9, from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.
7. The openmpi-1.8-scyld packages update to version 1.8.3, which by default update and replace only earlier version 1.8 packages and do not affect OpenMPI version 1.7, 1.6, or 1.5 packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. The libraries were built with Gnu version 4.4.7, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.
8. The MPICH3 mpich-scyld release updates to version 3.1.3, derived from https://www.mpich.org. The libraries were built with Gnu version 4.4.7, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the ClusterWare *User's Guide* *MPICH-3 Release Information* for details.
9. Fix a problem in PVM that results in a hung application with unkillable threads.
10. NVIDIA K40 GPU now executes in *persistence* mode for quicker startup of GPU operations.

v6.5.7 - August 18, 2014

1. The base kernel updates to 2.6.32-431.23.3.el6.657g0001. See https://rhn.redhat.com/errata/RHSA-2014-0924.html and https://rhn.redhat.com/errata/RHSA-2014-0981.html for details.
2. Fix a timing problem in `bproc` that can put a compute node's `bpslave` into a "soft lockup" state, with a stack traceback that identifies the culprit as *_spin_lock* called from *get_task_mm*.
3. Introduces a fix/workaround in bproc to avoid a timing problem that exhibits itself most frequently when doing a *bproc_move* from a compute node to another node, followed immediately by another *bproc_move* back to the same compute node. The workaround is to add a small delay prior to the second *bproc_move*. A complete fix will follow in a subsequent release.
4. The MPICH3 mpich-scyld release updates to version 3.1.2, derived from https://www.mpich.org. The libraries were built with Gnu version 4.4.7, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families. See the ClusterWare *User's Guide* *MPICH-3 Release Information* for details.

v6.5.6 - July 21, 2014

1. The base kernel updates to 2.6.32-431.20.3.el6.656g0000. See https://rhn.redhat.com/errata/RHSA-2014-0771.html for details.

   `service beowulf reload` now re-reads the `/etc/beowulf/config` *libraries* entries and rebuilds the list of libraries managed by the bproc *filecache* functionality for the master node and all the *up* compute nodes.

2. TORQUE updates to version 4.2.8, from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.
3. MVAPICH2 updates to version 2.0, derived from http://mvapich.cse.ohio-state.edu/. See the ClusterWare *User's Guide MVAPICH2 Release Information* for details.
4. The MPICH3 mpich-scyld release updates to version 3.1.1, derived from https://www.mpich.org. See the ClusterWare *User's Guide MPICH-3 Release Information* for details.
5. The various MPI library suites (OpenMPI, MPICH, MPICH2, MVAPICH2, MPICH3) have been rebuilt with newer versions of the Gnu version 4.4.7, Intel version 2013_sp1.3.174, and PGI version 14.6 compiler families.

v6.5.5 - June 10, 2014

1. The base kernel updates to 2.6.32-431.17.1.el6.655g0000. See https://rhn.redhat.com/errata/RHSA-2014-0475.html for details.
2. The Scyld ClusterWare igb Ethernet driver updates to version 5.2.5, derived from http://sourceforge.net/projects/e1000/.

v6.5.4 - April 14, 2014

1. The base kernel updates to 2.6.32-431.11.2.el6.654g0000. See https://rhn.redhat.com/errata/RHSA-2014-0328.html for details.
2. Previously, Scyld ClusterWare distributed the `env-modules` package, which was a semi-customized redistribution of the RHEL `environment-modules` package. These two Scyld ClusterWare and RHEL packages could not co-exist, which meant that the various Scyld ClusterWare packages that employed environment modules (e.g., mpich2-scyld, mvapich2-scyld, mpich-scyld, openmpi-1.*-scyld) could not co-exist with RHEL packages that need the RHEL6 `environment-modules` (e.g., mpich2, mvapich2, openmpi, mpich). Beginning with Scyld ClusterWare 6.5.4, Scyld ClusterWare no longer distributes `env-modules`, and ClusterWare packages instead use the RHEL `environment-modules`, which now allows those Scyld ClusterWare and RHEL packages to co-exist.
3. TORQUE updates to version 4.2.7, from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.
4. Scyld ClusterWare now distributes openmpi-1.8-scyld packages, which are a redistribution of OpenMPI version 1.8 and derived from https://www.open-mpi.org. See the ClusterWare *User's Guide OpenMPI Release Information* for details.
5. The openmpi-1.7-scyld packages updates to version 1.7.5, which by default update and replace only earlier version 1.7 packages and do not affect OpenMPI version 1.6 or 1.5 packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide OpenMPI Release Information* for details.

6. `service beowulf start` and `restart` now check the size of `/usr/lib/locale/locale-archive` and issue a warning if the file is huge and thus would impact cluster performance. See the *Administrator's Guide* for details.

v6.5.3 - March 4, 2014

1. The base kernel updates to 2.6.32-431.5.1.el6.653g0000. See https://rhn.redhat.com/errata/RHSA-2014-0159.html for details.
2. The mpich-scyld release updates to version 3.1, derived from https://www.mpich.org. See the ClusterWare *User's Guide MPICH-3 Release Information* for details.
3. The Scyld ClusterWare igb Ethernet driver updates to version 5.1.2, derived from http://sourceforge.net/projects/e1000/.
4. Scyld ClusterWare now redistributes an optional e1000e Ethernet driver version 3.0.4.1, derived from http://sourceforge.net/projects/e1000/. If a local cluster administrator wishes to update the default RHEL/CentOS 6 e1000e-2.3.2-k to the latest e1000e from SourceForge, then `yum install kmod-e1000e` and `depmod`.
5. Eliminate the unnecessary requirement that TORQUE Python libraries be installed in order for `beostatus` filtering to work.

v6.5.2 - January 15, 2014

1. The base kernel updates to 2.6.32-431.3.1.el6.652g0000. See https://rhn.redhat.com/errata/RHBA-2014-0004.html for details.

v6.5.1 - January 3, 2014

1. The base kernel updates to 2.6.32-431.1.2.el6.651g0000. See https://rhn.redhat.com/errata/RHSA-2013-1801.html for details. In addition to containing the usual Scyld ClusterWare "hooks", this Scyld ClusterWare kernel decreases the kernel's compiled-in TCP_TIMEWAIT_LEN timeout from its original 60 seconds down to 30 seconds. This reduces the potential for a node to be unable to allocate a socket due to an application voraciously creating and closing sockets so rapidly that all available sockets are either open or have been closed and are sitting in TIME_WAIT limbo state.
2. Fix a bug in `beosi` that causes the script to hang doing a `find /sys/class/infiniband` under some circumstances.
3. Fix various obscure timing problems in `bproc` that can panic the master node or a compute node, or hang a compute node, or lead to a kernel *soft lockup* state. These infrequent events would generally only occur following a network disconnect between a compute node and the master, or while shutting down the *beowulf* service, while a compute node's `bpslave` is mid-transaction with the master's `bpmaster`.

v6.5.0 - December 9, 2013

1. The base kernel updates to 2.6.32-431.el6.650g0000. See https://rhn.redhat.com/errata/RHSA-2013-1645.html for details.
2. The Scyld ClusterWare igb Ethernet driver updates to version 5.0.6, derived from http://sourceforge.net/projects/e1000/.

3. TORQUE updates to version 4.2.6.1, from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.

4. MVAPICH2 updates to version 2.0b, derived from http://mvapich.cse.ohio-state.edu/. See the ClusterWare *User's Guide MVAPICH2 Release Information* for details.

5. Bash *process substitution* now works, e.g., `diff <(sort file1) <(sort file2)`.

6. Improve the synchronization between the `beoserv` and `bpmaster` daemons with respect to what port number the latter wishes to use to communicate with the compute node `bpslave` daemons.

v6.4.7 - October 28, 2013

1. The base kernel is updated to 2.6.32-358.23.2.el6.647g0000. See https://rhn.redhat.com/errata/RHSA-2013-1436.html for details.

2. Fix a bug in run-to-completion that was mistakenly introduced in SCW 6.4.6 that caused *orphaned* compute nodes to always reboot after one hour.

3. The openmpi-1.7-scyld packages are updated to version 1.7.3, which by default update and replace only earlier version 1.7 packages and do not affect OpenMPI version 1.6 or 1.5 packages. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. ClusterWare releases of OpenMPI derive from https://www.open-mpi.org. See the ClusterWare *User's Guide OpenMPI Release Information* for details.

4. The `sendstats` daemon more reliably avoids being started more than once per compute node.

v6.4.6 - September 27, 2013

1. TORQUE updates to version 4.2.5, from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details. Scyld ClusterWare inclusion of the *Maui* scheduler, where the installation of *Maui* perturbed an optionally preexisting installation of the *Moab* scheduler. Both *Maui* and *Moab* can now coexist as installed packages, although the local cluster administrator must perform a one-time selection of which scheduler to use, if both are installed. See *Optionally enable TORQUE scheduler* for details.

v6.4.6 - September 11, 2013

1. The base kernel is updated to 2.6.32-358.18.1.el6.646g0000. See https://rhn.redhat.com/errata/RHSA-2013-1173.html for details.

2. The MVAPICH2 release is updated to version 2.0a, derived from http://mvapich.cse.ohio-state.edu/. See the ClusterWare *User's Guide MVAPICH2 Release Information* for details.

v6.4.5 - September 6, 2013

1. TORQUE updates to version 4.2.4.1, from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details. This TORQUE also fixes a *pbs_mom* security vulnerability that was announced by Adaptive Computing on Sept. 6, 2013, that afflicts all TORQUE releases to date.

v6.4.5 - August 26, 2013

1. The base kernel is updated to 2.6.32-358.14.1.el6.645g0000. See https://rhn.redhat.com/errata/RHSA-2013-1051.html for details.
2. TORQUE updates to version 4.2.4, from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details. This Scyld ClusterWare distribution changes the default job scheduler from the problematic built-in *pbs_sched* to Adaptive Computing's *Maui*, currently version 3.3.1. Maui distributes as a separate rpm and is required by TORQUE 4.2.4. See the ClusterWare *User's Guide* *TORQUE and Maui Release Information* for details.
3. The mpich2, mvapich2, mpich-scyld, and openmpi-1.5, -1.6, and -1.7 packages have been rebuilt using newer Intel and PGI compiler suites: Intel composer_xe 2013.5.192 vs. composerxe-2011.4.191, and PGI 13.6 vs. 11.9.

v6.4.4 - July 8, 2013

1. The base kernel is updated to 2.6.32-358.11.1.el6.644g0000. See https://rhn.redhat.com/errata/RHSA-2013-0911.html for details.
2. The Scyld ClusterWare packaging for OpenMPI has changed in order to more easily install and retain multiple co-existing versions on the master node. See *Installing and managing concurrent versions of packages* for general issues about supporting multiple concurrent versions. This ClusterWare release updates openmpi-1.7-scyld with OpenMPI version 1.7.2, which by default replaces the earlier version 1.7.1 rpms. This release also includes the first release of openmpi-1.6-scyld for OpenMPI version 1.6.5. These openmpi-1.6-scyld rpms will only update (and replace) earlier openmpi-1.6-scyld rpms and will not update any existing openmpi-scyld rpms, which will likely be version 1.6.4. ClusterWare releases of OpenMPI are derived from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.

   Yet again improve the run-to-completion algorithm for determining if an orphaned compute node is effective idle (and thus can reboot). See the Administrator's Guide *When Master Nodes Fail - With Run-to-Completion* for details, and `man bpctl` for a summary.

v6.4.3 - June 13, 2013

1. The base kernel is updated to 2.6.32-358.6.2.el6.643g0000. See https://rhn.redhat.com/errata/RHSA-2013-0830.html for details.
2. The Scyld ClusterWare packaging for OpenMPI has changed in order to more easily install and retain multiple co-existing versions on the master node. The openmpi-scyld packaging, which last distributed version 1.6.4, is deprecated. It has been replaced by new packaging which incorporates the OpenMPI *x.y* family name into the package name, e.g., openmpi-1.7-scyld, openmpi-1.6-scyld, and openmpi-1.5-scyld. This release installs by default the openmpi-1.7-scyld version 1.7.1 rpms. The yum repo also contains (but does not install by default) openmpi-1.6-scyld version 1.6.4 and openmpi-1.5-scyld version 1.5.5 rpms, which may be manually installed if desired. The OpenMPI releases are derived from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.
3. The env-modules package now properly recognizes `module load` defaults that are declared in `.version` files found in the `/opt/scyld/modulefiles/` subdirectories.
4. Fix a rare deadlock of a master or compute node BProc I/O Daemon that can occur under very high workloads.
5. Suppress various redundant BProc syslog messages, e.g., a flurry of redundant ECONNREFUSED warnings.

v6.4.2 - May 15, 2013

1. The base kernel is updated to 2.6.32-358.6.1.el6.642g0000. See https://rhn.redhat.com/errata/RHSA-2013-0744.html for details about 1.7.1, and .
2. The MVAPICH2 release is updated to version 1.9.0, derived from http://mvapich.cse.ohio-state.edu/. See the ClusterWare *User's Guide* *MVAPICH2 Release Information* for details.
3. The mpich-scyld release is updated to version 3.0.4, derived from https://www.mpich.org. See the ClusterWare *User's Guide* *MPICH-3 Release Information* for details.
4. Supports forwarding compute node log messages to an alternative `syslogd` server other than to the default master node server. See the *Administrator's Guide* for details.

v6.4.1 - April 10, 2013

1. The base kernel is updated to 2.6.32-358.2.1.el6.641g0000. See https://rhn.redhat.com/errata/RHSA-2013-0630.html for details.
2. TORQUE updates to version 4.2.2, from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.
3. The MVAPICH2 release is updated to version 1.9b, derived from http://mvapich.cse.ohio-state.edu/. See the ClusterWare *User's Guide* *MVAPICH2 Release Information* for details.
4. The mpich-scyld release is updated to version 3.0.3, derived from https://www.mpich.org. See the ClusterWare *User's Guide* *MPICH-3 Release Information* for details.
5. A `service beowulf start` (or `restart`) and `reload` now saves timestamped backups of various `/etc/beowulf/` configuration files, e.g., `config` and `fstab`, to assist a cluster administrator to recover a working configuration after an invalid edit.

v6.4.0 - March 13, 2013

1. The base kernel is updated to 2.6.32-358.0.1.el6.640g0001. See https://rhn.redhat.com/errata/RHSA-2013-0496.html and https://rhn.redhat.com/errata/RHSA-2013-0567.html for details.
2. The TORQUE updates to version 4.2.1, derived from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.
3. The OpenMPI release is updated to version 1.6.4, derived from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.
4. Includes the first release of mpich-scyld, which is the Scyld ClusterWare distribution of mpich-3, version 3.0.2, derived from https://www.mpich.org. See the ClusterWare *User's Guide* *MPICH-3 Release Information* for details.

v6.3.7 - March 4, 2013

1. The base kernel is updated to 2.6.32-279.22.1.el6.637g0002. See https://rhn.redhat.com/errata/RHSA-2013-0223.html for details. This kernel includes built-in firmware to properly boot some compute node server models that employ a bnx2 Ethernet controller, in addition to the bnx2 server models previously supported by the 2.6.32-279.19.1.el6.636g0001 kernel, as well as some models that employ a cxgb3 Ethernet controller.

2. The TORQUE release is a "refresh" version 4.2.0, derived from https://www.adaptivecomputing.com/products/opensource/torque. Adaptive Computing refreshed their "Limited GA" 4.2.0 on February 14, 2013, and Scyld ClusterWare subsequently distributed it as torque-4.2.0-636g0001. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.

3. `/etc/beowulf/config` supports a new directive, *firmware*, to assist in loading firmware for *bootmodule* drivers on compute nodes. See *Issues with bootmodule firmware* and the *Administrator's Guide* for details.

v6.3.6 - February 8, 2013

1. The base kernel is updated to 2.6.32-279.19.1.el6.636g0001. See https://rhn.redhat.com/errata/RHSA-2012-1580.html for details. This kernel differs from the earlier 2.6.32-279.19.1.el6.636g0000 in that it includes built-in firmware to properly boot some compute node server models that employ a bnx2 Ethernet controller.

2. The Scyld ClusterWare igb Ethernet driver is version 4.1.2, derived from http://sourceforge.net/projects/e1000/.

3. Include a working `beonetconf` command.

4. Improve the run-to-completion algorithm for determining if an orphaned compute node is effective idle (and thus can reboot).

v6.3.6 - January 2, 2013

1. The base kernel is updated to 2.6.32-279.19.1.el6.636g0000. See https://rhn.redhat.com/errata/RHSA-2012-1580.html for details.

2. The TORQUE release updates to version 4.2.0, derived from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.

3. Fix a problem with compute node server models that employ a *radeon* controller which failed to load firmware during node bootup.

4. Fix a BProc problem wherein the `/bin/ps` and `/bin/top` commands were not correctly reporting the CPU usage of processes executing on compute nodes.

v6.3.5 - November 30, 2012

1. The base kernel is updated to 2.6.32-279.14.1.el6.635g0000. See https://rhn.redhat.com/errata/RHSA-2012-1426.html for details.

2. The TORQUE release updates to version 4.1.3, derived from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.

v6.3.4 - November 5, 2012

1. The base kernel is updated to 2.6.32-279.11.1.el6.634g0000. See https://rhn.redhat.com/errata/RHSA-2012-1366.html for details.

2. Fix a BProc problem that panics the master node when bpmaster terminates (e.g., doing `service beowulf restart` or `stop`).

3. The OpenMPI release is updated to version 1.6.3, derived from https://www.open-mpi.org. See the ClusterWare *User's Guide OpenMPI Release Information* for details.

v6.3.3 - October 24, 2012

1. The base kernel is updated to 2.6.32-279.9.1.el6.633g0001. See https://rhn.redhat.com/errata/RHSA-2012-1304.html for details.
2. The OpenMPI release is updated to version 1.6.2, derived from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.
3. The MPICH2 release is version 1.5, derived from http://www.mcs.anl.gov/research/projects/mpich2/. See the ClusterWare *User's Guide* *MPICH2 Release Information* for details.
4. The MVAPICH2 release is updated to version 1.8.1, derived from http://mvapich.cse.ohio-state.edu/. See the ClusterWare *User's Guide* *MVAPICH2 Release Information* for details. Since the Scyld ClusterWare 6 MVAPICH2 transport mechanism is *ssh*, the cluster administrator will likely need to configure the cluster to allow *ssh* access for non-root users. See *Optionally enable SSHD on compute nodes* and the *Administrator's Guide* for details.

v6.3.2 - September 19, 2012

1. The base kernel is updated to 2.6.32-279.5.2.el6.632g0001. See https://rhn.redhat.com/errata/RHSA-2012-1156.html and https://rhn.redhat.com/errata/RHBA-2012-1199.html for details.
2. Fix a BProc problem that left a "lingering ghost" process on the master node that was not associated with any process on a compute node.
3. Add two *bootmodule* entries to `/etc/beowulf/config` to support the latest Penguin servers: `ahci` and `isci`.
4. Support the *nonfatal* mount option for harddrive entries specified in `/etc/beowulf/fstab` to more gracefully handle clusters that have some nodes with harddrives and some nodes without, thus perhaps avoiding needing node-specific `/etc/beowulf/fstab.`*N* file(s).
5. The OpenMPI release is updated to version 1.6.1, derived from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.

v6.3.1 - August 13, 2012

1. The base kernel is updated to 2.6.32-279.2.1.el6.631g0000. See https://rhn.redhat.com/errata/RHBA-2012-1104.html for details.

v6.3.0 - August 3, 2012

1. The base kernel is updated to 2.6.32-279.1.1.el6.630g0001. See https://rhn.redhat.com/errata/RHSA-2012-0862.html and https://rhn.redhat.com/errata/RHSA-2012-1064.html for details.
2. The Scyld ClusterWare igb Ethernet driver is version 3.4.8, derived from http://sourceforge.net/projects/e1000/. Most noticeably, this newer driver eliminates the "HBO bit set" syslogged messages that were introduced by version 3.4.7.
3. The OpenMPI environment modules now define *MPI_HOME*, *MPI_LIB*, *MPI_INCLUDE*, and *MPI_SYSCONFIG*.
4. The file `/etc/beowulf/conf.d/sysctl.conf` now gets copied at boot time to every compute node as `/etc/sysctl.conf` to establish basic `sysctl` values. The master node's `/etc/sysctl.conf` serves as the initial contents of `/etc/beowulf/conf.d/sysctl.conf`.
5. Scyld ClusterWare 6 compute nodes can now function properly as NFS clients of a RHEL5 NFS server.

v6.2.1 - June 18, 2012

1. The base kernel is updated to 2.6.32-220.17.1.el6.621g0000. See https://rhn.redhat.com/errata/RHSA-2012-0571.html for details.
2. The Scyld ClusterWare Adaptec aacraid driver is version 1.1.7-29100, useable for the 6805 controller, and is derived from http://www.adaptec.com/en-us/support/raid/sas_raid/sas-6805/.

v6.2.0 - May 17, 2012

1. The base kernel is 2.6.32-220.13.1.el6.620g0001. See https://rhn.redhat.com/errata/RHSA-2012-0481.html for details.
2. The Scyld ClusterWare igb Ethernet driver is version 3.4.7, derived from http://sourceforge.net/projects/e1000/.
3. The Scyld ClusterWare Adaptec aacraid driver is version 1.1.7-28801, useable for the 6805 controller, and is derived from http://www.adaptec.com/en-us/support/raid/sas_raid/sas-6805/.
4. The TORQUE release updates to version 2.5.10, derived from https://www.adaptivecomputing.com/products/opensource/torque. See https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.
5. The OpenMPI release updates to version 1.6, derived from https://www.open-mpi.org. See the ClusterWare *User's Guide* *OpenMPI Release Information* for details.
6. The MPICH2 release is version 1.4.1p1, derived from http://www.mcs.anl.gov/research/projects/mpich2/. See the ClusterWare *User's Guide* *MPICH2 Release Information* for details.
7. The MVAPICH2 release is version 1.8, derived from http://mvapich.cse.ohio-state.edu/. See the ClusterWare *User's Guide* *MVAPICH2 Release Information* for details. Since the Scyld ClusterWare 6 MVAPICH2 transport mechanism is *ssh*, the cluster administrator will likely need to configure the cluster to allow *ssh* access for non-root users. See *Optionally enable SSHD on compute nodes* and *Administrator's Guide* for details.

1.1.8 Known Issues And Workarounds

The following are known issues of significance with the latest version of Scyld ClusterWare v6.10.14 and suggested workarounds.

Issues with bootmodule firmware

RHEL introduced externally visible discrete firmware files that are associated with specific kernel software drivers. When `modprobe` attempts to load a kernel module that contains such a software driver, and that driver determines that the controller hardware needs one or more specific firmware images (which are commonly found in `/lib/firmware`), then the kernel first looks at its list of built-in firmware files. If the desired file is not found in that list, then the kernel sends a request to the `udevd` daemon to locate the file and to pass its contents back to the driver, which then downloads the contents to the controller. This functionality is problematic if the kernel module is an `/etc/beowulf/config` *bootmodule* and is an Ethernet driver that is necessary to boot a particular compute node in the cluster. The number of `/lib/firmware/` files associated with every possible *bootmodule* module is too large to embed into the `initrd` image common to all compute nodes, as that burdens every node with a likely unnecessarily oversized `initrd` to download. Accordingly, the cluster administrator must determine which specific firmware file(s) are actually required for a particular cluster and are not yet built-in to the kernel, then add *firmware* directive(s) for those files. See the *Administrator's Guide* for details.

Kernel panic using non-*invpcid* old Intel nodes

Intel-processor nodes that do not support *invpcid* will suffer a kernel panic when used as a ClusterWare compute node or a master node. Examples of such processors are "Westmere" and "Sandy Bridge", dating back to the 2010-2012 time frame. Currently, the only available workaround is to disable the kernel's Spectre/Meltdown "independent page table" fixes that were introduced in the ClusterWare v6.9.8 kernel.

If all compute nodes are affected, then add the keyword *nopti* to the "kernelcommandline" directive in `/etc/beowulf/config`. For a cluster with a mix of affected and unaffected compute nodes, then you need only add an additional "kernelcommandline [nodes] [options]" line that specifies just the affected nodes. The [nodes] argument can be comma-separated no-blanks list of individual node number(s) and/or node number range(s), e.g., `kernelcommandline 128` or `kernelcommandline 128,129` or `kernelcommandline 48-52,60,72-70`.

For an affected master node, edit `/etc/grub/conf` to add *nopti* to the `kernel` line and reboot the master node.

Managing environment modules .version files

Several Scyld ClusterWare packages involve the use of environment modules. This functionality allows for users to dynamically set up a shell's user environment for subsequent compilations and executions of applications, and for viewing the manpages for commands that are associated with those compilations and executions.

The ClusterWare packages are found in the various `/opt/scyld/`*package/* subdirectories, and for each package there are subdirectories organized by package version number, compiler suite type, and per-version per-compiler subdirectories containing the associated scripts, libraries, executable binaries, and manpages for building and executing applications for that package. The `/opt/scyld/modulefiles/`*package/* subdirectories contain per-package per-version per-compiler files that contain various pathname strings that are prepended to the shell's $PATH, $LD_LIBRARY_PATH, and $MANPATH variables that properly find those `/opt/scyld/`*package/* scripts, libraries, executable files, and manpages.

For example, `module load mpich2/intel/1.5` sets up the environment so that the `mpicc` and `mpirun` commands build and execute MPI applications using using the Intel compiler suite and the `mpich2` libraries specifically crafted for mpich2 version 1.5. The `module load` command also understands defaults. For example, `module load mpich2/gnu` defaults to use the *gnu* compiler and the mpich2 version specified by the contents of the file `/opt/scyld/modulefiles/mpich2/gnu/.version` (if that file exists). Similarly, `module load mpich2` first looks at the contents of `/opt/scyld/modulefiles/mpich2/.version` to determine the default compiler suite, then (supposing *gnu* is that default) looks at the contents of `/opt/scyld/modulefiles/mpich2/gnu/.version` to determine which mpich2 software version to use.

As a general rule, after updating one of these ClusterWare packages that employs environment modules, the associated `/opt/scyld/modulefiles/`*package*'s subdirectories' `.version` files remain untouched. The responsibility for updating any `.version` file remains with the cluster administrator, presumably after consulting with users. If the contents of a `.version` points to a compiler suite or to a package version number that no longer exists, then a subsequent `module load` for that package which expects to use a default selection will fail with a message of the form:

```
ERROR:105: Unable to locate a modulefile
```

The user must then perform `module load` commands that avoid any reference to the offending `.version`, e.g., use the explicit `module load mpich2/intel/1.5`, until the cluster administrator resets the `.version` contents to the desired default. Each module-employing ClusterWare package installs sample files with the name `.version.`*versionNumber*.

The openmpi packages manage defaults differently. Suppose `openmpi-2.0-scyld` is currently version 2.0.1 and is updating to 2.0.2. Just as the default update behavior is to replace all 2.0.1 packages with the newer 2.0.2 packages, this openmpi-2.0 update also silently changes the `gnu`, `intel`, and `pgi` `.version` files which happen to specify the same major-minor version, e.g., those that specify version 2.0.1 are silently updated to the newer 2.0.2. If, however, the current `.version` files specify an older major-minor release, e.g., 1.10.4, then updating `openmpi-2.0-scyld` does not change any of these older major-minor `.version` specifiers.

Additionally, each set of openmpi-x.y-scyld packages maintain a major-minor symlink that points to the newest major-minor-release module file. For example, when `openmpi-2.0-scyld` version 2.0.1 is currently installed, then the `/opt/scyld/modulefiles/openmpi/gnu/2.0` symlink changes to the `2.0.1` module file. When `openmpi-2.0-scyld` updates to 2.0.2, then `/opt/scyld/modulefiles/openmpi/gnu/2.0` changes that symlink to point to the `2.0.2` module file. This convenient symlink allows for users to maintain job manager scripts that simply specify a major-minor number, e.g., `module load openmpi/intel/2.0`, that survives updates from openmpi-2.0-scyld 2.0.1 to 2.0.2 to 2.0.3, et al, versus using scripts that contain the more specific `module load openmpi/intel/2.0.1` that break when 2.0.1 packages update to 2.0.2.

Note that each compiler suite can declare a different default package version, although most commonly the cluster administrator edits the `/opt/scyld/modulefiles/`*package/compiler/*`.version` files so that for a given *package*, all compiler suites reference the same default version number.

One method to check the current package defaults is to execute:

```
cd /opt/scyld/modulefiles
module purge
module avail
for m in $(ls); do module load $m; done
module list
module purge
```

and then verify each loaded default against the `module avail` available alternatives.

Installing and managing concurrent versions of packages

Scyld ClusterWare distributes various repackaged Open Source software suites, including several variations of “MPI”, e.g., `openmpi`, `mpich-scyld`, `mpich2-scyld`, `mvapich2-scyld`. Users manage the selection of which software stack to use via the `module load` command. See *Managing environment modules .version files* for details.

By default, `install-scyld -u` updates each existing package with the newest version of that package by installing the newest version and removing all earlier (i.e., lower-numbered) versions, thereby retaining only a single version of each software suite. For example, the `openmpi-2.0-scyld` packages update to the latest 2.0.x version (major 2, minor 0, version x), and the `openmpi-1.10-scyld` packages update to the latest latest 1.10.y (major 1, minor 10, version y). Thus, a default update of package `openmpi-2.0` installs the newest version 2.0.x and removes earlier versions of 2.0, leaving versions 1.10.x, 1.8.x, 1.7.x, etc. untouched.

Because Scyld ClusterWare installs a package’s files into unique `/opt/scyld/`*package/version* version-specific directories, this permits multiple versions of each major-minor package to potentially co-exist on the master node, e.g., openmpi versions 2.0.2 and 2.0.1. Each such *package/version* subdirectory contains one or more *compiler* suite subdirectories, e.g., `gnu`, `intel`, and `pgi`, and each of those contain scripts, libraries, executable binaries, and manpages associated with that particular package, version, and compiler suite.

Some customers (albeit rarely) may wish to install multiple concurrent x.y.z versions for a given x.y major-minor because specific applications might only work properly when linked to a specific version, or applications might perform differently for different versions. For example, to retain openmpi version 2.0.1 prior to using `install-scyld -u` or `yum update`, which might replace those 2.0.1 packages with a newer 2.0.z version, first edit `/etc/yum.conf` to add the line:

```
exclude=openmpi-2.0-scyld*
```

which blocks `yum` from updating any and all currently installed `openmpi-2.0-scyld` packages. If the cluster administrator wishes to install (for example) the 2.0.2 packages and not disturb the 2.0.1 installation, then temporarily comment-out that `exclude=openmpi-2.0-scyld*` line and execute:

```
yumdownloader openmpi-2.0-scyld-*2.0.2*
```

and then re-enable the `exclude=` line to again protect against any inadvertent `openmpi-2.0-scyld` updates. Manually install these additional downloaded rpms using `rpm -iv` – and *not* use `rpm -Uv` or even `yum install`, as both of those commands will remove older `openmpi-2.0-scyld` packages.

Issues with OpenMPI

Scyld ClusterWare distributes repackaged releases of the Open Source OpenMPI, derived from https://www.open-mpi.org. The Scyld ClusterWare distributions consist of a `openmpi-x.y-scyld` base package for the latest OpenMPI version *x.y.z*, plus several compiler-environment-specific packages for `gnu`, `intel`, and `pgi`. For example, the distribution of OpenMPI non-psm2 version 2.0.1 consists of the base rpm `openmpi-2.0-scyld-2.0.1` and the various compiler-specific rpms: `openmpi-2.0-scyld-gnu-2.0.1`, `openmpi-2.0-scyld-intel-2.0.1`, and `openmpi-2.0-scyld-pgi-2.0.1`.

Scyld ClusterWare distributes versions `openmpi-2.0-scyld`, `openmpi-1.10-scyld`, and `openmpi-1.8-scyld`, as well as `openmpi-psm2-2.0-scyld` and `openmpi-psm2-1.10-scyld` for clusters using the Intel Omni-Path Architecture (OPA) networking (which also requires `hfi1-psm` rpms from the Intel OPA software bundle).

A set of `openmpi-x.y-scyld` packages installs *x.y.z* version-specific libraries, executable binaries, and manpages for each particular compiler into `/opt/scyld/openmpi/`*version/compiler* subdirectories, and installs modulefiles into `/opt/scyld/modulefiles/openmpi/`*compiler/version* files. The directory `/opt/scyld/openmpi/`*version*`/examples/` contains source code examples. The `openmpi-psm2` packages similarly install into `/opt/scyld/openmpi-psm2/` and `/opt/scyld/modulefiles/openmpi-psm2/`.

The modulefiles appends the current shell's $PATH, $LD_LIBRARY_PATH, and $MANPATH with pathnames that point to the associated compiler-specific version-specific `/opt/scyld/openmpi/`*version/compiler/* (or `/opt/scyld/openmpi-psm2/`*version/compiler/*) subdirectories. This permits multiple versions to co-exist on the master node, with each variation being user-selectable at runtime using the `module load` command.

Many customers support multiple OpenMPI versions because some applications might only work properly when linked to specific OpenMPI versions. Sometimes an application needs only to be recompiled and relinked against a newer version of the libraries. Other applications may have a dependency upon a particular OpenMPI version that a simple recompilation won't fix. The cluster administrator can specify which compiler and version is the default by manipulating the contents of the various `.version` files in the `/opt/scyld/modulefiles/openmpi/` (or `openmpi-psm2`) subdirectories. For example, a `module load openmpi` might default to specify version 1.10.4 of the gnu libraries, while `module load openmpi-psm2` might default to specify version 2.0.1 of the intel libraries, while at the same time a version-specific `module load openmpi-psm2/gnu/1.10.4` or `module load openmpi/pgi/1.8.8` allows the use of different compilers and libraries for different OpenMPI versions.

The latest Open Source release of `openmpi-2.0-scyld` is a "mandatory" install, and `openmpi-1.10-scyld`, `openmpi-1.8-scyld`, `openmpi-psm2-2.0-scyld`, and `openmpi-psm2-1.10-scyld` are "optional" and can be manually installed by the cluster administrator using (for example) `yum install openmpi-psm2-1.10-scyld-*`. A subsequent `yum update` will update each and every installed `openmpi-x.y-scyld` and installed `openmpi-psm2-x.y-scyld` to the latest available version *x.y.z*. If the cluster administrator wishes to retain additional *x.y.z* releases within an *x.y* family, then instead of doing `yum update`, the administrator should `yum update --exclude=openmpi*scyld-*`, then download specific rpms from the yum repo as desired using `yumdownloader`, and then manually install (not update) the rpms using `rpm -i`. Note that the use of `yumdownloader` and `rpm -i` is necessary because doing a simple (for example) `yum install openmpi-1.10-scyld-1.10.4` will not, in fact, execute a simple *install* and retain older 1.10.z packages. Rather, it actually executes an *update* and removes any and all older installed versions of `openmpi-1.10-scyld-1.10.z` rpms.

Issues with Mpich

Beginning with Red Hat RHEL6 Update 6 and CentOS 6.6, the base distribution includes an *mpich* package, currently version 3. Scyld ClusterWare distributes three versions of mpich: *mpich* version 1.2.7p1, *mpich2-scyld* with some version 2 enhancements, and *mpich-scyld* version 3, which typically is a newer version than the RHEL or CentOS6 *mpich* version 3.

The RHEL/CentOS6 *mpich* does not conflict with either Scyld ClusterWare *mpich2-scyld* or *mpich-scyld* because of their different names, but it does conflict with the Scyld ClusterWare *mpich*. Any attempt to install the new RHEL or CentOS6 *mpich* (version 3) triggers an update (and removal) of the older Scyld ClusterWare *mpich* (version 1.2.7p1), and that update fails because other Scyld ClusterWare packages have a dependency on Scyld ClusterWare mpich-1.2.7p1.

The cluster administrator can either manually remove all Scyld ClusterWare mpich-1.2.7p1 packages and proceed with a normal install or update of the RHEL or CentOS6 base distribution *mpich*, or the administrator can install or update RHEL or CentOS6 and explicitly exclude its *mpich* package. We recommend this latter approach for its simplicity, and because it retains the Scyld ClusterWare mpich-1.2.7p1 for users, and because there is no obvious need for the base distribution's *mpich* when the Scyld ClusterWare *mpich-scyld* version 3 will be the same or newer than the RHEL/CentOS6 *mpich*. The straightforward way to exclude this is to edit the file `/etc/yum.conf` and add the line:

```
exclude=" mpich-3* "
```

NOTE: The Scyld ClusterWare mpich-1.2.7p1 packages are deprecated and will eventually be unavailable in future Scyld ClusterWare releases. We encourage user to migrate applications to *mpich-scyld* or to *openmpi*, both of which which support inter-thread communication using either Ethernet or Infiniband.

Issues with Scyld ClusterWare process migration in heterogeneous clusters

In a homogeneous cluster, all nodes (master and compute) are identical server models, including having identical amounts of RAM. In a heterogeneous cluster, the nodes are not all identical. The advantage of a homogeneous cluster is simplicity in scheduling work on the nodes, since every node is identical and interchangeable. However, in the real world, many if not most clusters are heterogeneous. Some nodes may have an attached GPU or different amounts of available RAM, or may even be different server models with different x86_64 processor technologies.

Scyld ClusterWare users have always needed to be aware of potential problems running applications on heterogeneous clusters. For example, applications expecting to employ a GPU have needed to take care to execute only on nodes with an attached GPU, and an application that is specifically compiled or linked to libraries that employ newer x86_64 instructions that are not universally understood by every x86_64 processor must ensure that the application only execute on the nodes with processors that understand those newer instructions.

However, RHEL6 heterogeneous clusters present a new set of challenges to users. The essence of the issue is this: when a software thread begins execution, some libraries (e.g., libc) make a one-time determination of which processor model is being used, and the library self-configures certain routines (e.g., strcmp) to use implementations that exploit processor model-specific instructions for optimal performance. However, if the software thread subsequently migrates to a different node in the cluster, then the thread's one-time determination state migrates to the destination node. If the destination node does not support the same x86_64 instructions that are supported by the original node, then the software thread will likely suffer a fatal "invalid opcode" trap if it attempts to execute one of these optimized library routines.

Scyld ClusterWare performs such a thread migration through the use of the bproc_move() or bproc_rfork() library routines found in `libbproc`. These bproc routines are employed by the MPICH and MVAPICH libraries and by the `bpcp` command.

One workaround to the problem is simple: use MPICH2 instead of MPICH, and use MVAPICH2 instead of MVAPICH, or use OpenMPI instead of either. None of those alternative MPI execution environments employ bproc_move() or bproc_rfork(). Another workaround is to execute all threads of a multithreaded application on identical nodes. More subtly, another workaround is to start executing the application on a node that employs the oldest processor technology; thus, any subsequent thread migration is guaranteed to find a node with a processor that supports a superset of the instructions supported by that initial node.

The `bpcp` command in Scyld ClusterWare 6.3.0 and beyond links with a special ClusterWare libc that uses only generic, universally acceptable x86_64 instructions. Users may similarly link applications to this special library by adding:

```
Xlinker -rpath=/lib64/scyld
```

as a linker option.

Issues with MVAPICH2 and mpirun_rsh or mpispawn

Scyld ClusterWare has applied a workaround to `mpiexec` to fix a problem with MPICH2 and MVAPICH2 exec'ing the application executable binary across NFS. The problem is *not* fixed for launching the application using `mpirun_rsh` or `mpispawn`, which likely will result in the application hanging as it attempts to execve() the application. We strongly encourage using only `mpiexec` to launch MPICH2 and MVAPICH2 applications.

Issues with MVAPICH2 and CPU Sets

MVAPICH2-2.1 introduces an algorithm to determine CPU topology on the node, and this new algorithm does not work properly for older Mellanox controllers and firmware, resulting in software threads not spreading out across a node's cores by default.

This problem has been fixed in MVAPICH-2.2 and beyond.

Prior to updating to MVAPICH2-2.1, the cluster administrator should determine the potential vulnerability to this problem. For each node that contains an Infiniband controller, execute `ibstat`, and if the first output line is:

```
CA 'mthca0'
```

then that node *may* exhibit the problem. The cluster administrator has two choices: either avoid updating the `mvapich2-scyld` packages (keeping in mind that the `mvapich2-psm-scyld` packages can be updated, as those packages are only used by QLogic Infiniband controllers, which don't have the problem); or update `mvapich2-scyld`, execute tests to determine if the problem exists for those Mellanox *mthca* nodes, and if the problem does exist, then instruct users to employ explicit CPU Mapping. See http://mvapich.cse.ohio-state.edu/static/media/mvapich/mvapich2-2.1-userguide.html#x1-540006.5 for details.

Issues with beosetup

The `beosetup` tool is deprecated in Scyld ClusterWare 5 and is eliminated from Scyld ClusterWare 6.

Issues with xpvm

`xpvm` is not currently supported in ClusterWare 6.

Issues with ptrace

Cluster-wide `ptrace` functionality is not yet supported in Scyld ClusterWare 6. For example, you cannot use a debugger running on the master node to observe or manipulate a process that is executing on a compute node, e.g., using `gdb -p procID`, where *procID* is a processID of a compute node process. `strace` does function in its basic form, although you cannot use the `-f` or `-F` options to trace forked children if those children move away from the parent's node.

Issues with rsh

Currently, `rsh` is unavailable as a communication method between nodes. Consider `ssh` as an alternative.

Issues with IP Forwarding

If the *beowulf* service has started, then a subsequent `service iptables stop` (or `restart`) will hang because it attempts to unload the ipt_MASQUERADE kernel module while the *beowulf* service is using (and not releasing) that module. For a workaround, edit `/etc/sysconfig/iptables-config` to change:

```
IPTABLES_MODULES_UNLOAD="yes"
```

to:

```
IPTABLES_MODULES_UNLOAD="no"
```

Issues with kernel modules

The `modprobe` command uses /usr/lib/‘uname -r‘/modules.dep.bin to determine the pathnames of the specified kernel module and that module's dependencies. The `depmod` command builds the human-readable `modules.dep` and the binary `module.dep.bin` files, and it should be executed *on the master node* after installing any new kernel module.

Executing `modprobe` on a compute node requires additional caution. The first use of `modprobe` retrieves the current `modules.dep.bin` from the master node using bproc's *filecache* functionality. Since any subsequent `depmod` on the master node rebuilds `modules.dep.bin`, then a subsequent `modprobe` on a compute node will only see the new `modules.dep.bin` if that file is copied to the node using `bpcp`, or if the node is rebooted and thereby silently retrieves the new file.

In general, you should not execute `depmod` on a compute node, since that command will only see those few kernel modules that have previously been retrieved from the master node, which means the node's newly built `modules.dep.bin` will only be a sparse subset of the master node's full `module.dep.bin`. Bproc's *filecache* functionality will always properly retrieve a kernel module from the master node, as long as the node's `module.dep.bin` properly specifies the pathname of that module, so the key is to have the node's `module.dep.bin` be a current copy of the master's file.

Issues with port numbers

Scyld ClusterWare employs several daemons that execute in cooperating pairs: a server daemon that executes on the master node, and a client daemon that executes on compute nodes. Each daemon pair communicates using TCP or UDP through a presumably unique port number. By default, Scyld ClusterWare uses ports 932 (*beofs2*), 933 (*bproc*), 3045 (*beonss*), and 5545 (*beostats*). In the event that one or more of these port numbers collides with a non-Scyld ClusterWare daemon using the same port number, the cluster administrator can override Scyld ClusterWare default port numbers to use different, non-colliding unused ports using the `/etc/beowulf/config` file's *server* directive. See `man beowulf-config` and `/etc/beowulf/config` for a discussion of the *server* directive.

The official list of assigned ports and their associated services is http://www.iana.org/assignments/port-numbers, and `/etc/services` is a list shipped with your base distribution. However, the absence in either list of a specific port number is no guarantee that the port will not be used by some software on your cluster. Use `lsof -i :`*portNumber* to determine if a particular port number is in active use.

A common collision is with *beofs2* port 932 or *bproc* port 933, since the `rpc.statd` or `rpc.mountd` daemons may randomly grab either of those ports before ClusterWare can grab them. However, ClusterWare automatically recognizes the conflict and tries alternative ports until it finds an unused port. If this flexible search causes problems with other daemons, you can edit /etc/beowulf/config to specify a tentative override value using the *server beofs2* or *server bproc* directive, as appropriate.

Less common are collisions with *beonss* port 3045 or *beostats* port 5545. The *server beonss* and *server beostats* override values are used as-specified and not adjusted by ClusterWare at runtime.

Issues with TORQUE

Scyld ClusterWare repackages the TORQUE resource manager available from Adaptive Computing, https://www.adaptivecomputing.com/products/opensource/torque. In every new TORQUE release, the Adaptive Computing developers fix bugs, add new features, and on occasion change configuration and scripting options. View the Adaptive Computing's TORQUE Release Notes and https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation for details.

TORQUE version 4.2.0 exhibits a problem with mpiexec and MPICH. Currently, the only known workaround is to alternatively use MPICH2 or OpenMPI.

Beginning with version 684g0000 (ClusterWare 6.8.4), Scyld ClusterWare has changed its naming of TORQUE packages. The older *torque-scyld* and *torque-nocpuset-scyld* became version-specific *torque-4-scyld* and *torque-4-nocpuset-scyld*, *torque-5-scyld* and *torque-5-nocpuset-scyld*, and *torque-6-scyld* and *torque-6-nocpuset-scyld*. One and *only* one of these TORQUE packages *must* be installed on the master node at any point in time. If the older *torque-scyld* or *torque-nocpuset-scyld* is currently installed, then you must do an explicit one-time install of one of the newer package names, e.g., yum install torque-4-scyld, which will install the new package and remove the older *torque-scyld* package.

Issues with Spanning Tree Protocol and portfast

Network switches with Spanning Tree Protocol (STP) enabled will block packets received on a port for the first 30 seconds after the port comes online, giving the switch and the Spanning Tree algorithm time to determine if the device on the new link is a switch, and to determine if Spanning Tree will block or forward packets from this port. This is done to prevent "loops" which can cause packets to be endlessly repeated at a high rate and consume all network bandwidth. Each time the link goes down and comes back up, another 30-second blocking delay occurs. This delay can prevent PXE/DHCP from obtaining an IP address, or can prevent the node's initial kernel from downloading its initial root filesystem, which results in the node endlessly iterating in the early boot sequence, or can delay the node's ongoing *filecache* provisioning of libraries to the node.

We recommend disabling STP if feasible. If not feasible, then we recommend reconfiguring the switch to use *Rapid STP* or *portfast*, which avoids the 30-second delay, or employing some other port mode that will forward packets as a port comes up. There is no generic procedure for enabling these options. For Cisco switches, see http://www.cisco.com/en/US/products/hw/switches/ps700/products_tech_note09186a00800b1500.shtml. For other switch models, see the model-specific documentation.

If that reconfiguration is also not possible, you may need to increase the default Scyld ClusterWare timeout used by the node to a value safely greater than the STP delay: e.g., add *rootfs_timeout=120 getfile_timeout=120* to the /etc/beowulf/config *kernelcommandline* entry to increase the timeouts to 120 seconds.

Issues with Gdk

If you access a cluster master node using ssh -X from a workstation, some graphical commands or program may fail with:

```
Gdk-ERROR **: BadMatch (invalid parameter attributes)
  serial 798 error_code 8 request_code 72 minor_code 0
Gdk-ERROR **: BadMatch (invalid parameter attributes)
  serial 802 error_code 8 request_code 72 minor_code 0
```

Remedy this by doing:

```
export XLIB_SKIP_ARGB_VISUALS=1
```

prior to running the failing program. If this workaround is successful, then consider adding this line to `/etc/bashrc` or to `~/.bashrc`. See https://bugs.launchpad.net/ubuntu/+source/xmms/+bug/58192 for details.

Caution when modifying Scyld ClusterWare scripts

Scyld ClusterWare installs various scripts in `/etc/beowulf/init.d/` that `node_up` executes when booting each node in the cluster. Any site-local modification to one of these scripts will be lost when a subsequent Scyld ClusterWare update overwrites the file with a newer version. If a cluster administrator believes a local modification is necessary, we suggest:

Copy the to-be-edited original script to a file with a unique name, e.g.:

```
cd /etc/beowulf/init.d
cp 20ipmi 20ipmi_local
```

Remove the executable state of the original:

```
beochkconfig 20ipmi off
```

Edit `20ipmi_local` as desired.

Thereafter, subsequent Scyld ClusterWare updates may install a new `20ipmi`, but that update will not re-enable the non-executable state of that script. The locally modified `20ipmi_local` remains untouched. However, keep in mind that the newer Scyld ClusterWare version of `20ipmi` may contain fixes or other changes that need to be reflected in `20ipmi_local` because that edited file was based upon an older Scyld ClusterWare version.

Caution using tools that modify config files touched by Scyld ClusterWare

Software tools exist that might make modifications to various system configuration files that Scyld ClusterWare also modifies. These tools do not have knowledge of the Scyld ClusterWare specific changes and therefore may undo or cause damage to the changes or configuration. Care must be taken when using such tools. One such example is `/usr/sbin/authconfig`, which manipulates `/etc/nsswitch.conf`.

Scyld ClusterWare modifies these system configuration files at install time:

```
/etc/exports
/etc/nsswitch.conf
/etc/security/limits.conf
/etc/sysconfig/syslog
```

Additionally, Scyld ClusterWare uses `chkconfig` to enable *nfs*.

Running nscd service on master node may cause kickbackdaemon to misbehave

The `nscd` (Name Service Cache Daemon) service executes by default on the master node, and `/usr/sbin/nscd` executes by default on each compute node via `/etc/beowulf/init.d/09nscd`. However, if this service is also enabled and executes on the master node, then it may cause the Scyld ClusterWare name service `kickbackdaemon` to misbehave.

Accordingly, when the ClusterWare starts, if it detects that the `nscd` service is running on the master node, then ClusterWare automatically stops that service. ClusterWare does not permanently disable that service on the master node. To do that:

```
chkconfig nscd off
```

Note: even after stopping `nscd` on the master node,

```
service nscd status
```

will report that `nscd` is running because the daemon continues to execute on each compute node, as controlled by `/etc/beowulf/init.d/09nscd`.

Scyld ClusterWare MVAPICH CPU affinity management

The default MVAPICH behavior is to assign threads of each multithreaded job to specific CPUs in each node, starting with cpu0 and incrementing upward. Keeping threads pinned to a specific CPU may be an optimal NUMA and CPU cache strategy for nodes that are dedicated solely to a single job, it is usually suboptimal if multiple multithreaded jobs share a node, as each job's threads get permanently assigned to the same low-numbered CPUs. The default Scyld ClusterWare MVAPICH behavior is to not impose strict CPU affinity assignments, but rather to allow the kernel CPU scheduler to migrate threads as it sees fit to load-balance the node's CPUs as workloads change over time.

However, the user may override this default using:

```
export VIADEV_ENABLE_AFFINITY=1
```

Conflicts with base distribution of OpenMPI

Scyld ClusterWare v6.10.14 includes MPI-related packages that conflict with certain packages in the RHEL6 or CentOS6 base distribution.

If `yum` informs you that it cannot install or update Scyld ClusterWare because various `mpich` and `mpiexec` packages conflict with various `openmpi` packages from the base distribution, then run the command:

```
yum remove openmpi mvapich
```

to remove the conflicting base distribution packages, then retry the *groupupdate* of *Scyld-ClusterWare*.

Beofdisk does not support local disks without partition tables

Currently, `beofdisk` only supports disks that already have partition tables, even if those tables are empty. Compute nodes with preconfigured hardware RAID, where partition tables have been created on the LUNs, should be configurable. Contact Customer Service for assistance with a disk without partition tables.

Issues with bproc and the getpid() syscall

BProc interaction with *getpid()* may return incorrect processID values.

Details: The Red Hat's glibc implements the *getpid()* syscall by asking the kernel once for the current processID value, then caching that value for subsequent calls to *getpid()*. If a program calls *getpid()* before calling *bproc_rfork()* or *bproc_vrfork()*, then bproc silently changes the child's processID, but a subsequent *getpid()* continues to return the former cached processID value.

Workaround: do not call *getpid()* prior to calling *bproc_rfork* or *bproc_vrfork*.

CHAPTER

TWO

INSTALLATION GUIDE

2.1 Preface

Congratulations on purchasing Scyld ClusterWare, the most scalable and configurable Linux Cluster Software on the market. This guide describes how to install Scyld ClusterWare using Penguin's installation repository. You should read this document in its entirety, and should perform any necessary backups of the system before installing this software. You should pay particular attention to keeping a copy of any local configuration files.

The Scyld ClusterWare documentation set consists of:

- The *Installation Guide* containing detailed information for installing and configuring your cluster.
- The *Release Notes* containing release-specific details, potentially including information about installing or updating the latest version of Scyld ClusterWare.
- The *Administrator's Guide* and *User's Guide* describing how to configure, use, maintain, and update the cluster.
- The *Programmer's Guide* and *Reference Guide* describing the commands, architecture, and programming interface for the system.

These product guides are available in two formats, HTML and PDF. You can browse the documentation on the Penguin Computing Support Portal at https://www.penguincomputing.com/support/documentation.

Once you have completed the Scyld ClusterWare installation, you can view the HTML and PDF documentations in */var/www/html/*, or visit http://localhost/clusterware-docs/ and http://localhost/clusterware-docs.pdf in a web browser. Note that if you are visiting the web page from a computer other than the cluster's master node, then you must change localhost to the master node's hostname. For example, if the hostname is "iceberg", then you may need to use its fully qualified name, such as http://iceberg.penguincomputing.com/clusterware-docs/ and http://iceberg.penguincomputing.com/clusterware-docs.pdf.

Note: If your reseller pre-installed Scyld ClusterWare on your cluster, you may skip these installation instructions and visit the *User's Guide* and *Reference Guide* for helpful insights about how to use Scyld ClusterWare.

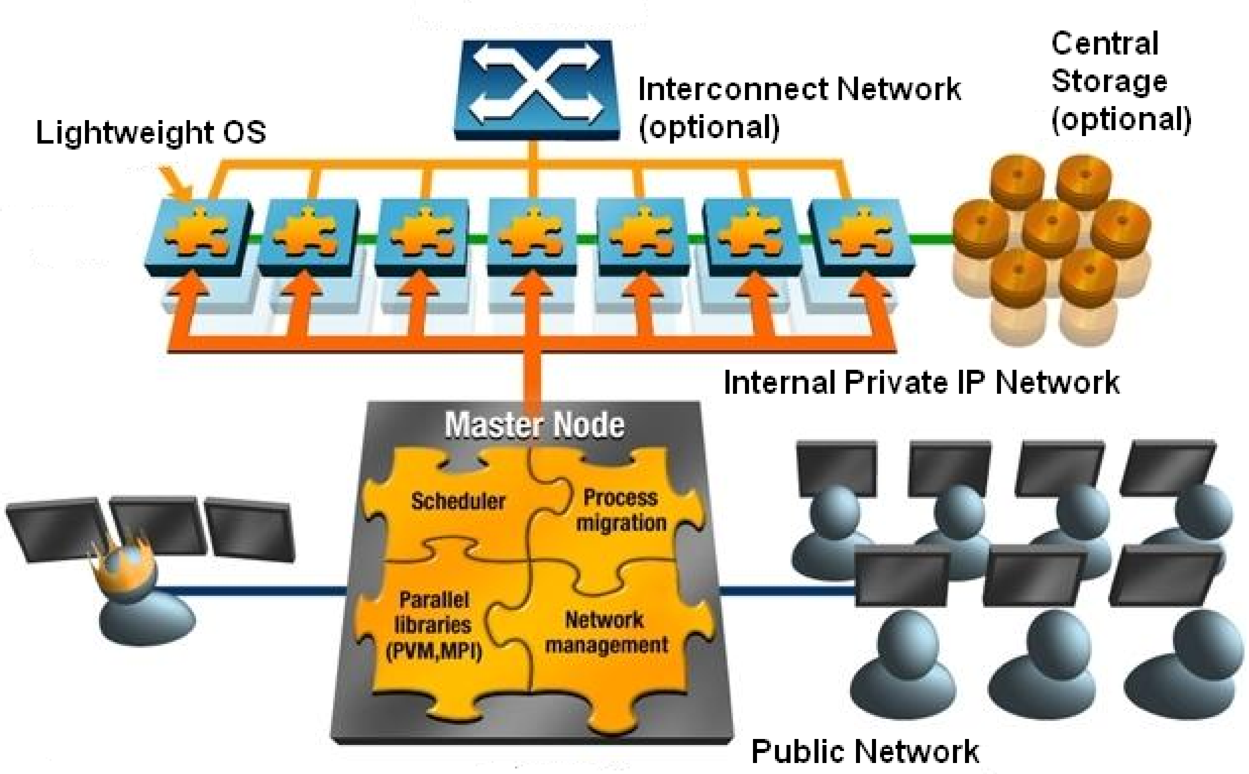
2.2 Scyld ClusterWare System Overview

Scyld ClusterWare streamlines the processes of configuring, running, and maintaining a Linux cluster using a group of commodity off-the-shelf (COTS) computers connected through a private network.

The front-end "master node" in the cluster is configured with a full Linux installation, distributing computing tasks to the other "compute nodes" in the cluster. Nodes communicate across a private network and share a common process execution space with common, cluster-wide process ID values.

A compute node is commonly diskless, as its kernel image is downloaded from the master node at node startup time using the Preboot eXecution Environment (*PXE*), and libraries and executable binaries are transparently transferred from the master node as needed. A compute node may access data files on locally attached storage or across NFS from an NFS server managed by the master node or some other accessible server.

In order for the master node to communicate with an outside network, it needs two network interface controllers (*NIC*s): one for the private internal cluster network, and the other for the outside network. It is suggested that the master node be connected to an outside network so multiple users can access the cluster from remote locations.


Lightweight OS
Interconnect Network (optional)
Central Storage (optional)
Internal Private IP Network
Master Node
Scheduler
Process migration
Parallel libraries (PVM,MPI)
Network management
Public Network

Cluster Layout

Figure 1. Cluster Configuration

2.3 Recommended Components

Hardware selection for a ClusterWare system is based on the price/performance ratio. ClusterWare recommends the components listed below:

Processors. 64-bit Intel® or AMD ™ x86_64 architecture **required**, single-core or multi-core

Architecture. 1 or multiple sockets per motherboard

Physical Memory. 4096 MBytes (4 GBytes) or more preferred, minimum 2048 MBytes (2 GBytes)

Operating System. Red Hat Enterprise Linux 6 (RHEL6) or CentOS6 **required**

The Scyld ClusterWare *Release Notes* state the specific version and update of Red Hat or CentOS required to support the ClusterWare release you are installing.

Network Interface Controllers (NIC). Gigabit Ethernet (Fast Ethernet at a minimum) PCI-X or PCI-Express adapters (with existing Linux driver support) in each node for the internal private IP network.

The master node typically employs an additional NIC for connecting the cluster to the external network. This NIC should be selected based on the network infrastructure (e.g., Fast Ethernet if the external network you are connecting the cluster to is Fast Ethernet).

Network Switch. The master node private network NIC and all compute nodes should be connected to a non-blocking Gigabit Ethernet switch for the internal private network. At a minimum, the network switch should match the speed of the network cards.

The switch is a critical component for correct operation and performance of the cluster. In particular, the switch must be able to handle all network traffic over the private interconnect, including cluster management traffic, process migration, library transfer, and storage traffic. It must also properly handle DHCP and PXE.

> **Tip**
>
> It is sometimes confusing to identify which NIC is connected to the private network. Take care to connect the master node to the private switch through the NIC with the same or higher speed than the NICs in the compute nodes.

Disk Drives. For the master node, we recommend using either Serial ATA (SATA) or SCSI disks in a RAID 1 (mirrored) configuration. The operating system on the master node requires approximately 3 GB of disk space. We recommend configuring the compute nodes without local disks (disk-less).

If local disks are required on the compute nodes, we recommend using them for storing data that can be easily re-created, such as scratch storage or local copies of globally-available data.

In the default configuration, `/home` on the master node is exported to the compute nodes; other file systems may be exported as well. After installing Scyld ClusterWare, see the file `/etc/beowulf/fstab` for the full list of default mounts for compute nodes. If you expect heavy file system traffic, we recommend that you provide a second pair of disks in a RAID 1 (mirrored) configuration for these exported file systems. Otherwise, it is possible for accesses to the exported file systems to interfere with the master node accessing its system files, thus affecting the master node's ability to launch new processes and manage the cluster.

Optional Hardware Components. Gigabit Ethernet with a non-blocking switch serves most users. However, some applications benefit from a lower-latency interconnect.

Infiniband is an industry standard interconnect providing low-latency messaging, IP, and storage support. Infiniband can be configured as a single universal fabric serving all of the cluster's interconnect needs.

More information about Infiniband may be found at the Infiniband Trade Association web site at http://www.infinibandta.org. ClusterWare supports Infiniband as a supplemental messaging interconnect in addition to Ethernet for cluster control communications.

2.4 Assembling the Cluster

The full Scyld ClusterWare Cluster Virtualization Software and the underlying Linux operating system are installed only on the master node.

Most recent hardware supports network boot (PXE boot), which ClusterWare requires for booting the compute nodes.

2.5 Software Components

The following are integral components of Scyld ClusterWare:

- beostatus: A graphic utility for monitoring the status of a ClusterWare cluster.
- Scyld ClusterWare: Allows processes to be started on compute nodes in the cluster and tracked in the process table on the master node. Scyld ClusterWare also provides process migration mechanisms to help in creating remote processes, and removes the need for most binaries on the remote nodes.
- MPICH2, MVAPICH2, and OpenMPI: Message Passing Interfaces, customized to work with Scyld ClusterWare.

For more detailed information on these software components, see the *Administrator's Guide* and the *User's Guide*.

2.6 Quick Start Installation

2.6.1 Introduction

Scyld ClusterWare is supported on Red Hat Enterprise Linux 6 (RHEL6) and CentOS6. This document describes installing on Red Hat, though installing on CentOS will be identical, except where explicitly noted. Scyld ClusterWare is installed on the master node after installing a RHEL6 or CentOS6 base distribution. You must configure your network interface and network security settings to support Scyld ClusterWare.

The compute nodes join the cluster without any explicit installation. Having obtained a boot image via PXE, the nodes are converted to a Scyld-developed network boot system and seamlessly appear as part of a virtual parallel computer.

This chapter introduces you to the Scyld ClusterWare installation procedures, highlights the important steps in the Red Hat installation that require special attention, and then steps you through the installation process. Installation is done using the `/usr/bin/yum` command, installing from a repository of rpms, typically across a network connection. See *Detailed Installation Instructions* for more detailed instructions. Refer to the Red Hat documentation for information on installing RHEL6.

2.6.2 Network Interface Configuration

> **Tip**
>
> To begin, you must know which interface is connected to the public network and which is connected to the private network. Typically, the public interface is eth0 and the private interface is eth1.

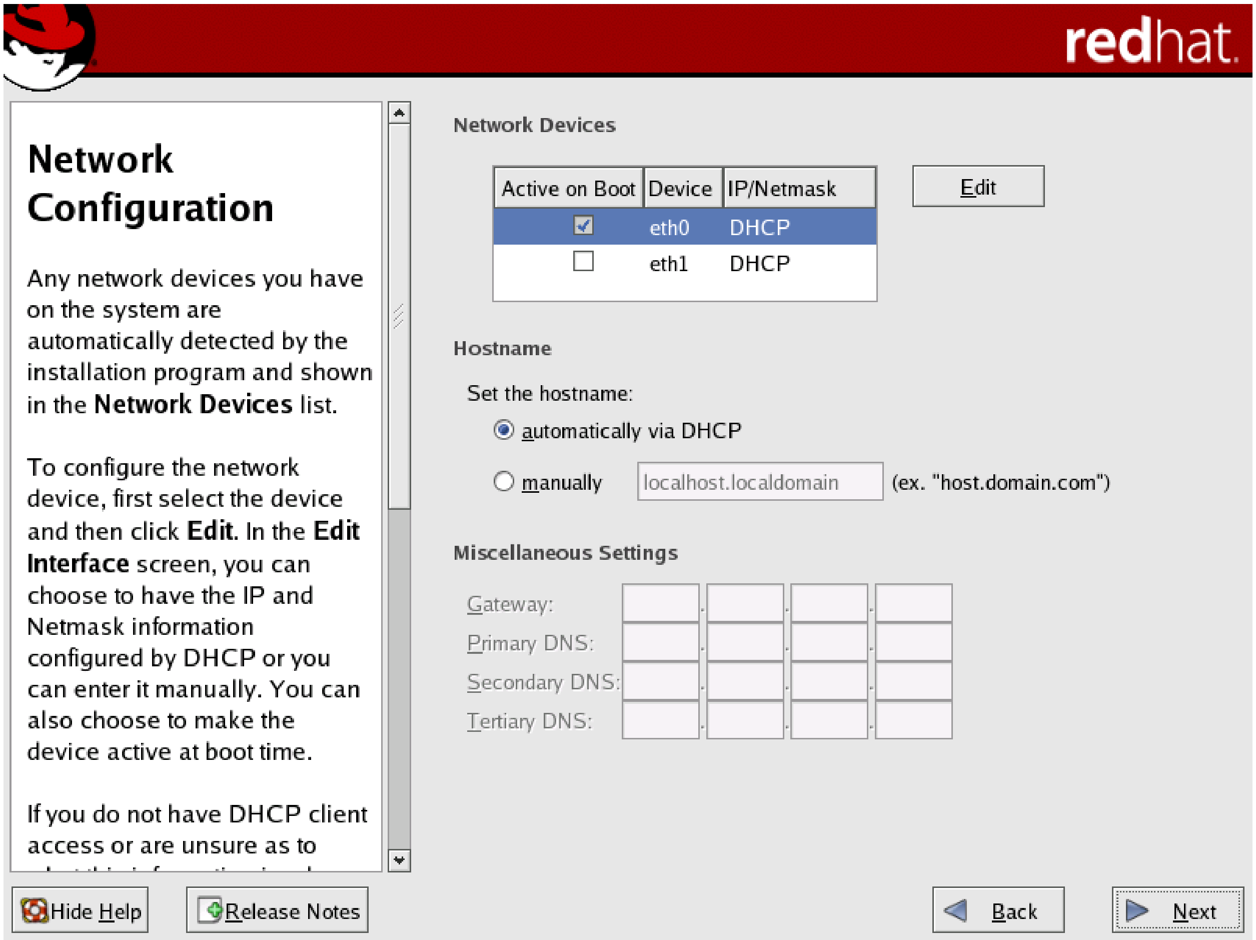
It is important to properly configure the network interfaces to support Scyld ClusterWare. The Network Configuration screen is presented during the RHEL6 installation; it can be accessed post-installation via the *Applications* -> *System Settings* -> *Network* menu options.

Cluster Public Network Interface

For the public network interface (typically eth0), the following settings are typical, but can vary depending on your local needs:

- DHCP is the default, and is recommended for the public interface.
- If your external network is set up to use static IP addresses, then you must configure the public network interface manually. Select and edit this interface, setting the IP address and netmask as provided by your Network Administrator.
- If you use a static IP address, the subnet must be different from that chosen for the private interface. You must set the hostname manually and also provide gateway and primary DNS IP addresses.

  > **Tip**
  >
  > When configuring the network security settings (see *Network Security Settings*), Scyld recommends setting a firewall for the public interface.



Network Configuration

Any network devices you have on the system are automatically detected by the installation program and shown in the **Network Devices** list.

To configure the network device, first select the device and then click **Edit**. In the **Edit Interface** screen, you can choose to have the IP and Netmask information configured by DHCP or you can enter it manually. You can also choose to make the device active at boot time.

If you do not have DHCP client access or are unsure as to

Network Devices

Active on Boot	Device	IP/Netmask
☑	eth0	DHCP
□	eth1	DHCP

Hostname

Set the hostname:

● automatically via DHCP

○ manually localhost.localdomain (ex. "host.domain.com")

Miscellaneous Settings

Gateway: . . .
Primary DNS: . . .
Secondary DNS: . . .
Tertiary DNS: . . .

Figure 1. Public Network Interface Configuration

Cluster Private Network Interface

Caution

For the private network interface (typically eth1), DHCP is shown as default, but this option cannot be used. You must configure the network interface manually and assign a static IP address and netmask.

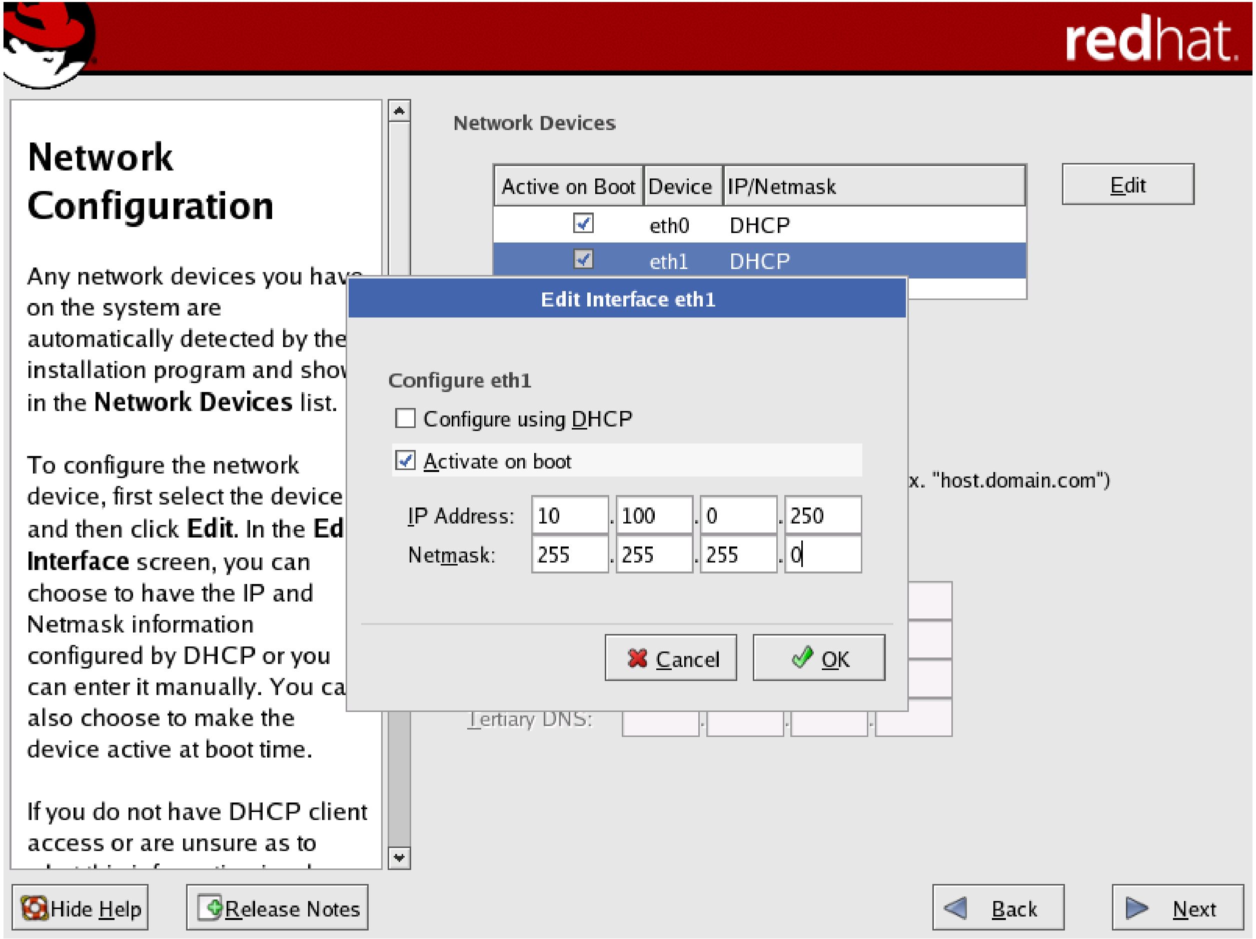
Caution

The cluster will not run correctly unless the private network interface is trusted. You can set this interface as a "trusted device" when configuring the network security settings post-installation; see *Trusted Devices*.

For the cluster private interface (typically eth1), the following settings are required for correct operation of Scyld ClusterWare:

- Do not configure this interface using DHCP. You must select this interface in the Network Configuration screen and edit it manually in the Edit Interface dialog.
- Set this interface to "activate on boot" to initialize the specific network device at boot-time.
- Specify a static IP address. We recommend using a non-routable address (such as 192.168.x.x, 172.16.x.x to 172.30.x.x, or 10.x.x.x).
- If the public subnet is non-routable, then use a different non-routable range for the private subnet (e.g., if the public subnet is 192.168.x.x, then use 172.16.x.x to 172.30.x.x or 10.x.x.x for the private subnet).

- Once you have specified the IP address, set the subnet mask based on this address. The subnet mask must accommodate a range large enough to contain all of your compute nodes.



Network Configuration

Any network devices you hav on the system are automatically detected by the installation program and shov in the **Network Devices** list.

To configure the network device, first select the device and then click **Edit**. In the **Ed Interface** screen, you can choose to have the IP and Netmask information configured by DHCP or you can enter it manually. You ca also choose to make the device active at boot time.

If you do not have DHCP client access or are unsure as to

Network Devices

Active on Boot	Device	IP/Netmask
☑	eth0	DHCP
☑	eth1	DHCP

Edit Interface eth1

Configure eth1

□ Configure using DHCP

☑ Activate on boot

IP Address: 10 . 100 . 0 . 250

Netmask: 255 . 255 . 255 . 0

Figure 2. Private Network Interface Configuration

Tip

You must first select the private interface in the Network Configuration screen, then click `Edit` to open the Edit Interface dialog box.

Tip

Although you can edit the private interface manually during the Red Hat installation, making this interface a "trusted device" must be done post-installation.

2.6.3 Network Security Settings

Caution

The security features provided with this system do not guarantee a completely secure system.

The Firewall Configuration screen presented during the RHEL6 installation applies to the public network interface and should be set according to your local standards.

The RHEL6 installer allows you to select some, but not all, of the security settings needed to support Scyld ClusterWare. The remaining security settings must be made post-installation; see *Trusted Devices*.

Scyld has the following recommendations for configuring the firewall:

- Set a firewall for the public network interface (typically eth0).
- If you chose to install a firewall, you must make the private network interface (typically eth1) a “trusted device” to allow all traffic to pass to the internal private cluster network; otherwise, the cluster will not run correctly. This setting must be made post-installation.
- The Red Hat installer configures the firewall with most services disabled. If you plan to use SSH to connect to the master node, be sure to select SSH from the list of services in the Firewall Configuration screen to allow SSH traffic to pass through the firewall.

2.6.4 Red Hat RHEL6 or CentOS6 Installation

Scyld ClusterWare depends on the prior installation of certain RHEL6 or CentOS6 packages from the base distribution. Ideally, each Scyld ClusterWare rpm names every dependency, which means that when you use `/usr/bin/yum` to install Scyld ClusterWare, `yum` attempts to gracefully install those dependencies if the base distribution yum repository (or repositories) are accessible and the dependencies are found. If a dependency cannot be installed, then the Scyld installation will fail with an error message that describes what rpm(s) or file(s) are needed.

> **Caution**
>
> Check the Scyld ClusterWare *Release Notes* for your release to determine whether you must update your Red Hat or CentOS base installation. If you are not familiar with the `yum` command, see *Updating Red Hat or CentOs Installation* for details on the update procedures.

2.6.5 Scyld ClusterWare Installation

Scyld ClusterWare is installed using the Penguin Yum repository http://updates.penguincomputing.com/clusterware/. Each Scyld ClusterWare release is continuously tested with the latest patches from Red Hat and CentOS6. Before installing or updating your master node, be sure to visit the Support Portal to determine if any patches should be excluded due to incompatibility with ClusterWare. Such incompatibilities should be rare. Then, update RHEL6 or CentOS6 on your master node before proceeding (excluding incompatible packages if necessary) with installing or updating your Scyld ClusterWare.

Configure Yum To Support ClusterWare

The Yum repo configuration file for Scyld ClusterWare must be downloaded from the Penguin Computing Support Portal and properly configured:

Login to the Support Portal at https://www.penguincomputing.com/support.

Click on *Download your Yum repo file* to download this `clusterware.repo` file and place the it in the `/etc/yum.repos.d/` directory.

Set the permissions:

```
[root@scyld ~]# chmod 644 /etc/yum.repos.d/clusterware.repo
```

With this setup complete, your master node is ready to retrieve Scyld ClusterWare installations and updates.

Install ClusterWare

You can use Yum to install ClusterWare and all updates up to and including the latest ClusterWare release, assuming you have updated your RHEL6 or CentOS6 base distribution as prescribed in the ClusterWare *Release Notes*.

1. Verify the version you are running with the following:

```
[root@scyld ~]# cat /etc/redhat-release
```

This should return a string similar to “Red Hat Enterprise Linux Server release 6.10” or “CentOS release 6.10 (Final)”.

2. Install the Scyld ClusterWare script that simplifies installing (and later updating) software, then execute that script:

```
[root@scyld ~]# yum install install-scyld
[root@scyld ~]# install-scyld
```

3. Configure the network for Scyld ClusterWare: edit `/etc/beowulf/config` to specify the cluster interface, the maximum number of compute nodes, and the beginning IP address of the first compute node. See the remainder of this guide and the *Administrator’s Guide* for details.

4. Reboot your system.

5. To verify that ClusterWare was installed successfully, do the following:

```
[root@scyld ~]# uname -r
```

The result should match the specific ClusterWare kernel version noted in the *Release Notes*.

2.6.6 Trusted Devices

If you chose to install a firewall, you must make the private network interface (typically eth1) a “trusted device” to enable all traffic on this interface to pass through the firewall; otherwise, the cluster will not run properly. This must be done post-installation.

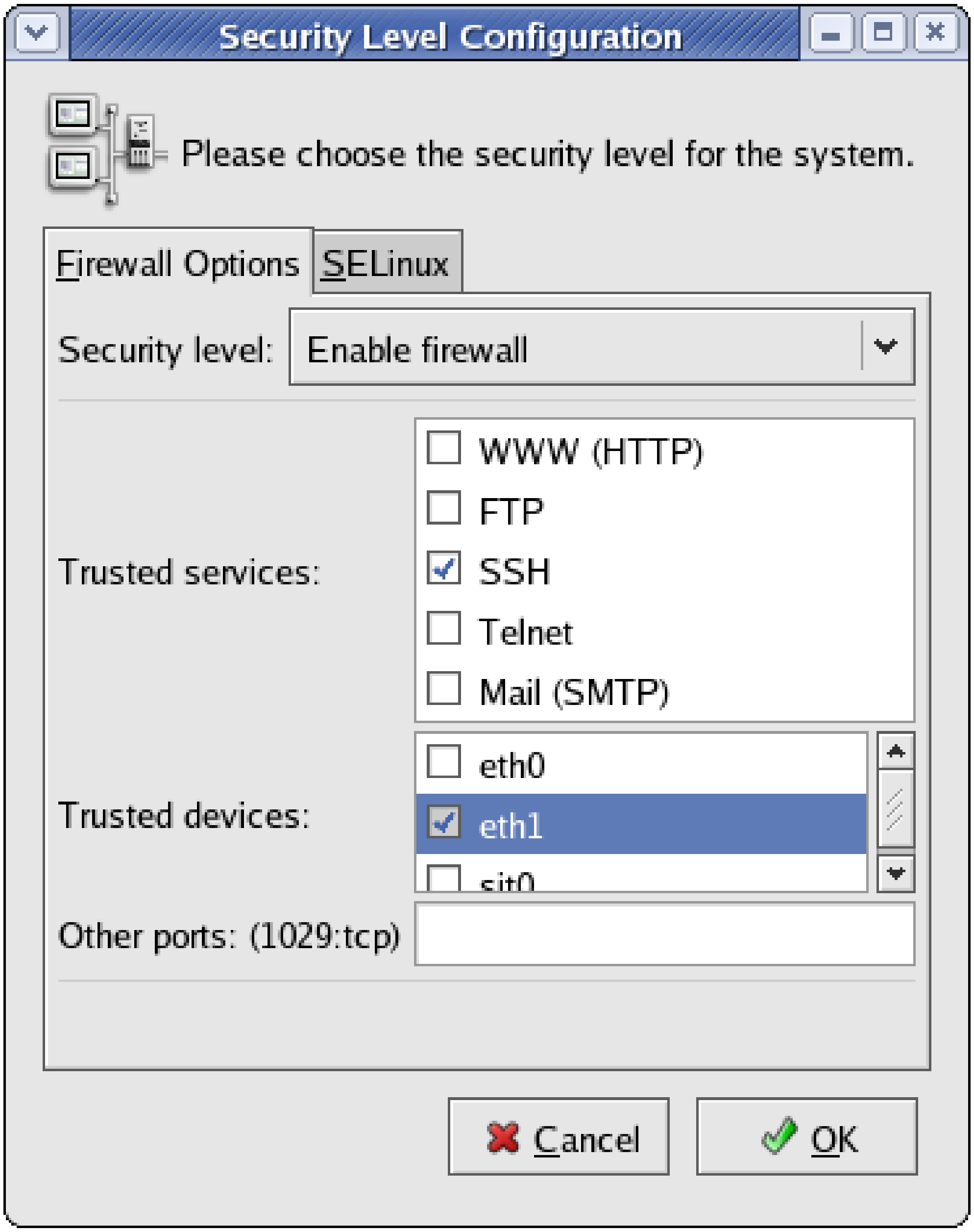
After you have installed Red Hat and Scyld ClusterWare, reboot the system and log in as “root”.

Access the security settings through the Red Hat *Applications* -> *System Settings* -> *Security Level* menu options.

In the Security Level Configuration dialog box, make sure the private interface is checked in the “trusted devices” list, then click OK.

Tip

If you plan to use SSH to connect to the master node, be sure that SSH is checked in the “trusted services” list.



Please choose the security level for the system.

Security level: Enable firewall

Trusted services:
- ☐ WWW (HTTP)
- ☐ FTP
- ☑ SSH
- ☐ Telnet
- ☐ Mail (SMTP)

Trusted devices:
- ☐ eth0
- ☑ eth1
- ☐ sit0

Other ports: (1029:tcp)

Figure 3. Security Settings Post-Installation

You are now ready to boot and configure the compute nodes, as described in the next section.

2.6.7 Compute Nodes

In a Scyld cluster, the master node controls booting, provisioning, and operation of the compute nodes. You do not need to explicitly install Scyld ClusterWare on the compute nodes.

Scyld requires configuring your compute nodes to boot via PXE and using the auto-activate node options, so that each node automatically joins the cluster as it powers on. Nodes do not need to be added manually.

If you are not already logged in as root, log into the master node using the root username and password.

Use the command `bpstat -U` in a terminal window on the master node to view a continuously updated table of node status information.

Set the BIOS on each compute node to boot via PXE. Using the auto-activate option with PXE booting allows each node to automatically boot and join the cluster as it powers on.

Node numbers are initially assigned in order of connection with the master node. Boot the compute nodes by powering them up in the order you want them to be numbered, typically one-by-one from the top of a rack downwards (or from the bottom up). You can reorder nodes later as desired; see the *Administrator's Guide*.

The nodes transition through the boot phases. As the nodes join the cluster and are ready for use, they will be shown as "Up" by the `bpstat -U` command.

The cluster is now fully operational with disk-less compute nodes. See *Cluster Verification Procedures* for more about bpstat and node states.

2.7 Detailed Installation Instructions

This chapter provides detailed instructions for installing Scyld ClusterWare. This software installation is intended for the first computer ("node") of the cluster, which functions as the "master node" to control and monitor other nodes and distribute jobs.

Scyld ClusterWare is installed on the master node that is running with a base distribution of RHEL6 or CentOS6.

It is assumed that you are familiar with the concepts outlined in the previous chapters, and that you have correctly assembled the hardware for your cluster. If this is not the case, please refer to the previous chapters to acquaint yourself with Scyld ClusterWare, and then verify that your hardware configuration is set up properly.

2.7.1 Red Hat Installation Specifics

During a RHEL6 installation, you have the option to configure various aspects of the installation to support Scyld ClusterWare. Important points include the following:

- *Disk partitioning* — Scyld recommends letting the installer automatically partition the disk; refer to the Red Hat documentation if you plan to manually partition instead.
- *Network interface configuration* — To support your Scyld cluster, you need to configure one interface dedicated to the external public network (typically eth0) and one to your internal private cluster network (typically eth1). Detailed instructions are provided in the section on *Network Interface Configuration*.
- *Network security settings* — You can configure some of your firewall settings during a RHEL6 installation. Other settings needed to support a Scyld cluster must be made post-installation. Detailed instructions are provided in the sections on *Network Security Settings* and *Trusted Devices*.
- *Package group selection* — Scyld recommends installing all Red Hat packages. See *Package Group Selection*.

The following sections provide instructions and/or recommendations for specific portions of the RHEL6 installation that are relevant to an optimal Scyld ClusterWare installation. This guide does not cover all steps in the RHEL6 installation; you should refer to the Red Hat documentation for more complete information.

Network Interface Configuration

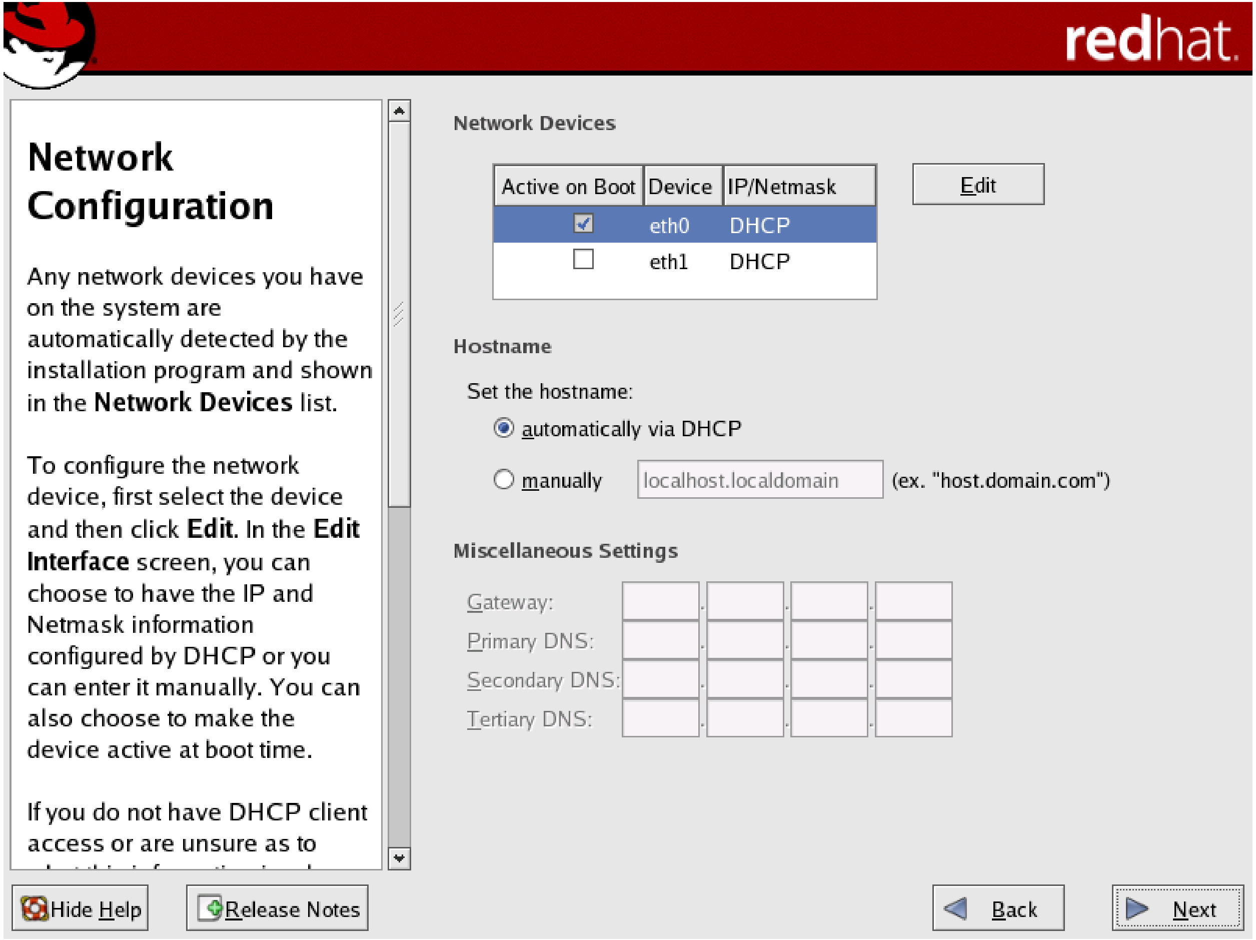
> **Tip**
>
> To begin, you must know which interface is connected to the public network and which is connected to the private network. Typically, the public interface is eth0 and the private interface is eth1.

A typical Scyld cluster has one interface dedicated to the external public network (typically eth0) and one dedicated to your internal private cluster network (typically eth1). It is important to properly to configure both of these interfaces to support your Scyld ClusterWare installation.

The network interface configuration screen will be presented to you during a RHEL6 installation. For an existing Red Hat installation, you can access the network configuration screens through the Red Hat *Applications* -> *System Settings* -> *Network* menu options.

Cluster Public Network Interface

DHCP is selected by default for all network devices, as shown below in the Red Hat Network Configuration Screen. For the public network interface (typically eth0), this option is recommended.



Network Configuration

Any network devices you have on the system are automatically detected by the installation program and shown in the **Network Devices** list.

To configure the network device, first select the device and then click **Edit**. In the **Edit Interface** screen, you can choose to have the IP and Netmask information configured by DHCP or you can enter it manually. You can also choose to make the device active at boot time.

If you do not have DHCP client access or are unsure as to

Network Devices

Active on Boot	Device	IP/Netmask
☑	eth0	DHCP
□	eth1	DHCP

Hostname

Set the hostname:

● automatically via DHCP

○ manually localhost.localdomain (ex. "host.domain.com")

Miscellaneous Settings

Gateway:

Primary DNS:

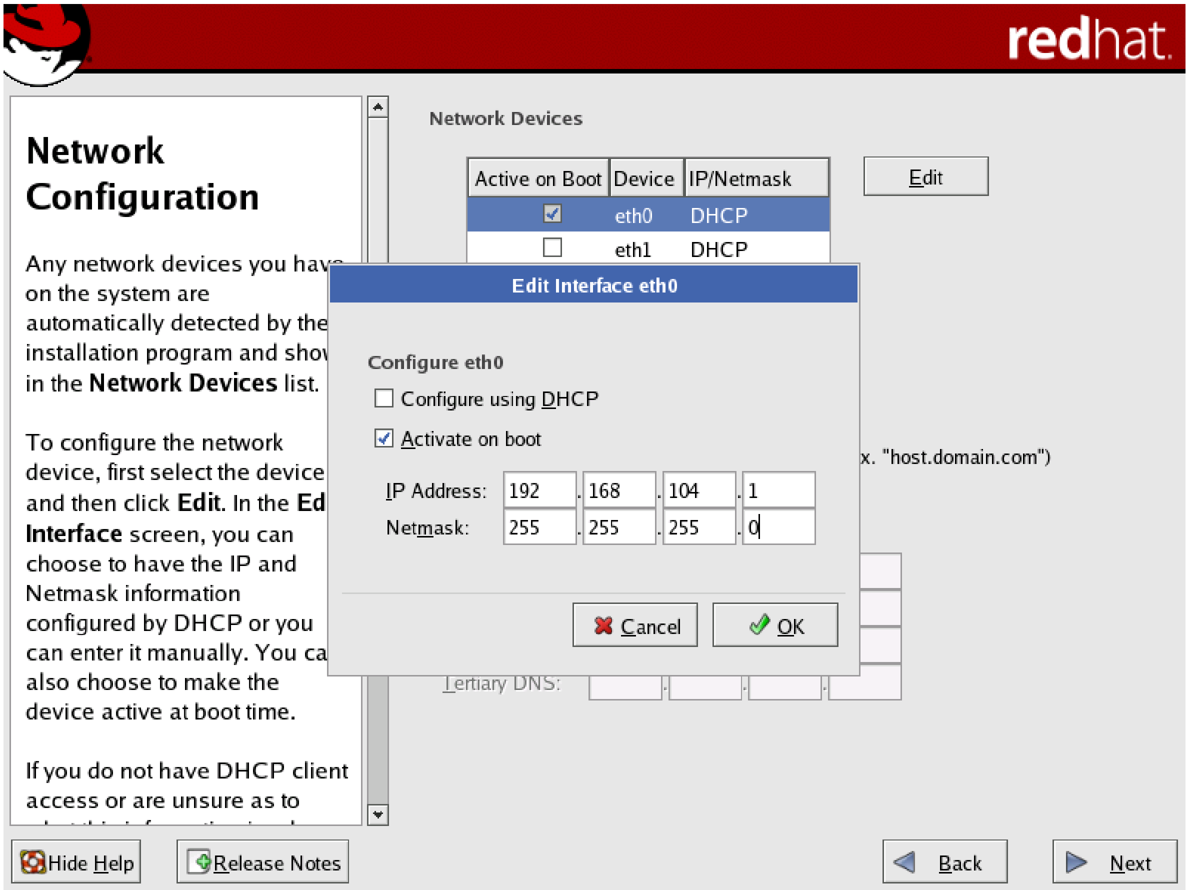
Secondary DNS:

Tertiary DNS:

Figure 1. Public Network Interface (DHCP Default is Recommended)

However, if your external network is set up to use static IP addresses, then follow these steps to manually configure the interface:

1. In the Network Configuration screen, select the public network interface (typically eth0) in the Network Devices list, then click *Edit* to open the Edit Interface dialog box.



Network Configuration

Any network devices you hav on the system are automatically detected by the installation program and show in the **Network Devices** list.

To configure the network device, first select the device and then click **Edit**. In the **Ed Interface** screen, you can choose to have the IP and Netmask information configured by DHCP or you can enter it manually. You ca also choose to make the device active at boot time.

If you do not have DHCP client access or are unsure as to

Network Devices

Active on Boot	Device	IP/Netmask
☑	eth0	DHCP
□	eth1	DHCP

Configure eth0

□ Configure using DHCP

☑ Activate on boot

IP Address: 192 . 168 . 104 . 1

Netmask: 255 . 255 . 255 . 0

Figure 2. Public Network Interface (Manual Configuration is Optional)

2. In the Edit Interface dialog box:

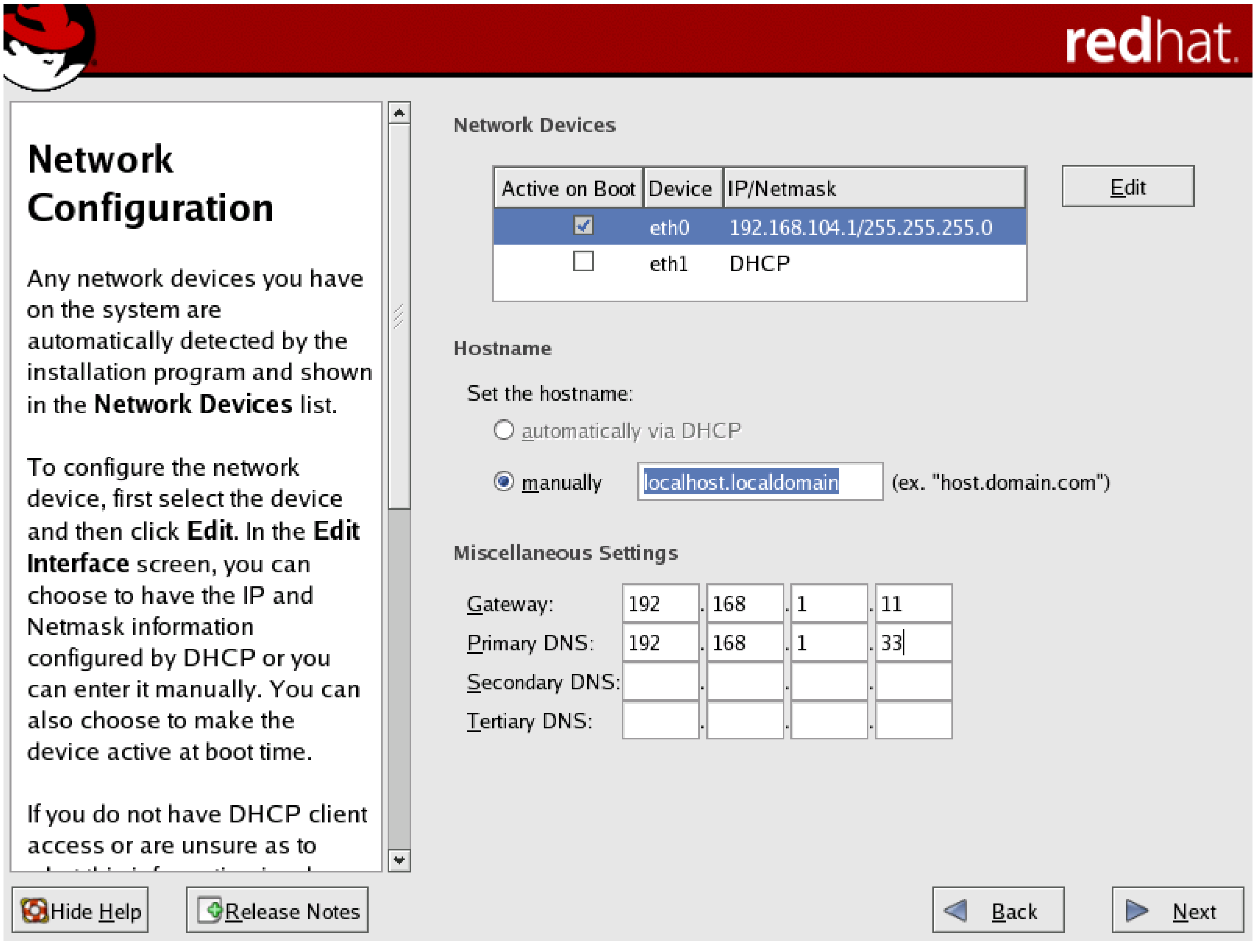
    a. Select the *Activate on boot* checkbox to initialize the specific network device at boot-time.

    b. Specify the IP address and netmask provided by your network administrator.

    When you have completed these settings, click OK to return to the Network Configuration screen.

3. In the *Set the hostname* area of the Network Configuration screen, select the manually radio button and provide a host name.

4. In the *Miscellaneous Settings* area of the screen, enter the gateway and primary DNS IP addresses provided by your Network Administrator.



Network Configuration

Any network devices you have on the system are automatically detected by the installation program and shown in the **Network Devices** list.

To configure the network device, first select the device and then click **Edit**. In the **Edit Interface** screen, you can choose to have the IP and Netmask information configured by DHCP or you can enter it manually. You can also choose to make the device active at boot time.

If you do not have DHCP client access or are unsure as to

Network Devices

Active on Boot	Device	IP/Netmask
☑	eth0	192.168.104.1/255.255.255.0
□	eth1	DHCP

Hostname

Set the hostname:

○ automatically via DHCP

● manually localhost.localdomain (ex. "host.domain.com")

Miscellaneous Settings

Gateway:	192	168	1	11
Primary DNS:	192	168	1	33
Secondary DNS:				
Tertiary DNS:				

Figure 3. Public Network Interface (Miscellaneous Settings for Manual Configuration)

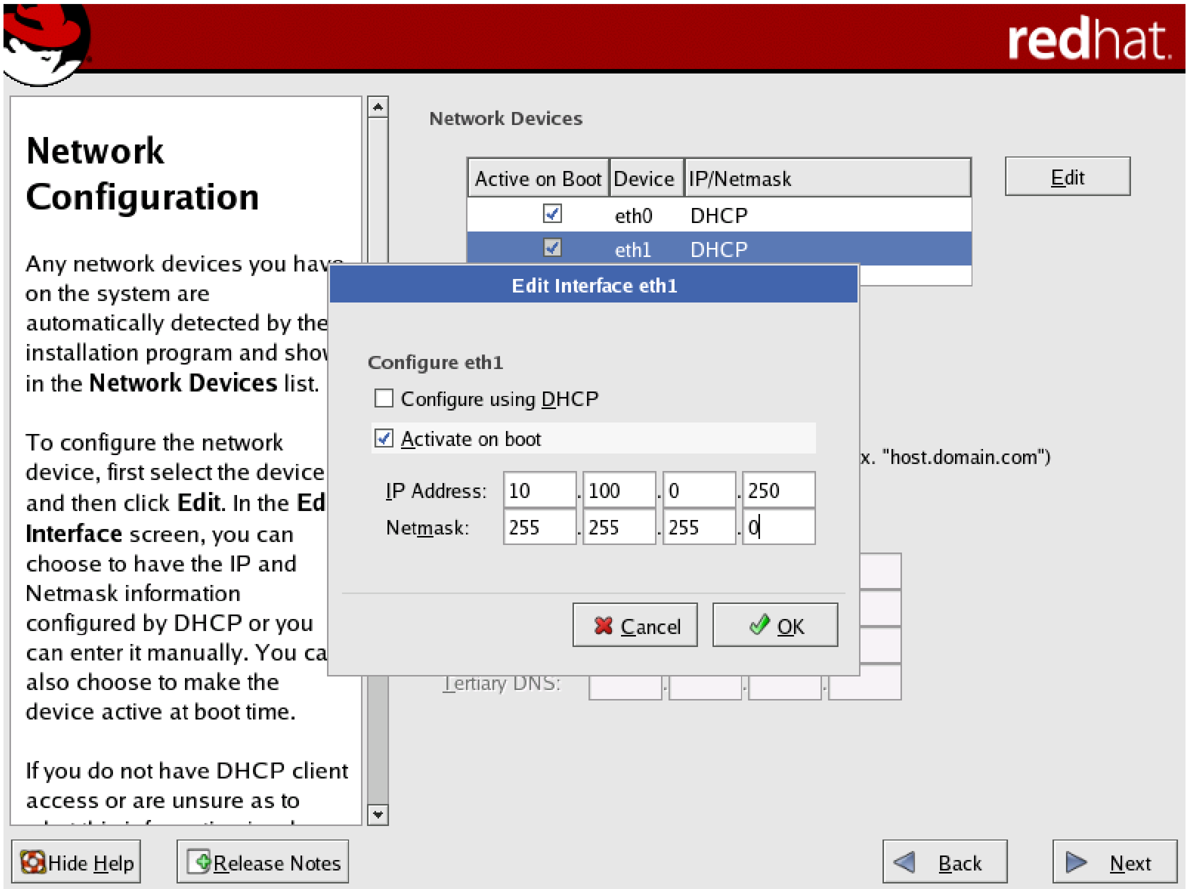
Cluster Private Network Interface

Caution

For the private network interface (typically eth1), DHCP is shown as default, but this option cannot be used. The configuration tool `Beonetconf` requires a static IP address for the private interface. Therefore, you must configure the network interface manually and assign a static IP address and netmask.

The cluster will not run correctly unless the private network interface is trusted. You can set this interface as a "trusted device" when configuring the network security settings post-installation; see *Trusted Devices*.

1. In the Network Configuration screen, select the private network interface (typically eth1) in the Network Devices list, then click Edit to open the Edit Interface dialog box.



Network Configuration

Any network devices you hav
on the system are
automatically detected by the
installation program and shov
in the **Network Devices** list.

To configure the network
device, first select the device
and then click **Edit**. In the **Ed**
Interface screen, you can
choose to have the IP and
Netmask information
configured by DHCP or you
can enter it manually. You ca
also choose to make the
device active at boot time.

If you do not have DHCP client
access or are unsure as to

Network Devices

Active on Boot	Device	IP/Netmask
☑	eth0	DHCP
☑	eth1	DHCP

Edit Interface eth1

Configure eth1

☐ Configure using DHCP

☑ Activate on boot

IP Address: 10 . 100 . 0 . 250

Netmask: 255 . 255 . 255 . 0

x. "host.domain.com")

Tertiary DNS:

Figure 4. Private Network Interface (Manual Configuration Required)

2. In the Edit Interface dialog box:

   a. Select the Activate on boot checkbox to initialize the specific network device at boot-time.

   b. Specify a static IP address. We recommend using a non-routable address (such as 192.168.x.x, 172.16.x.x to 172.30.x.x, or 10.x.x.x).

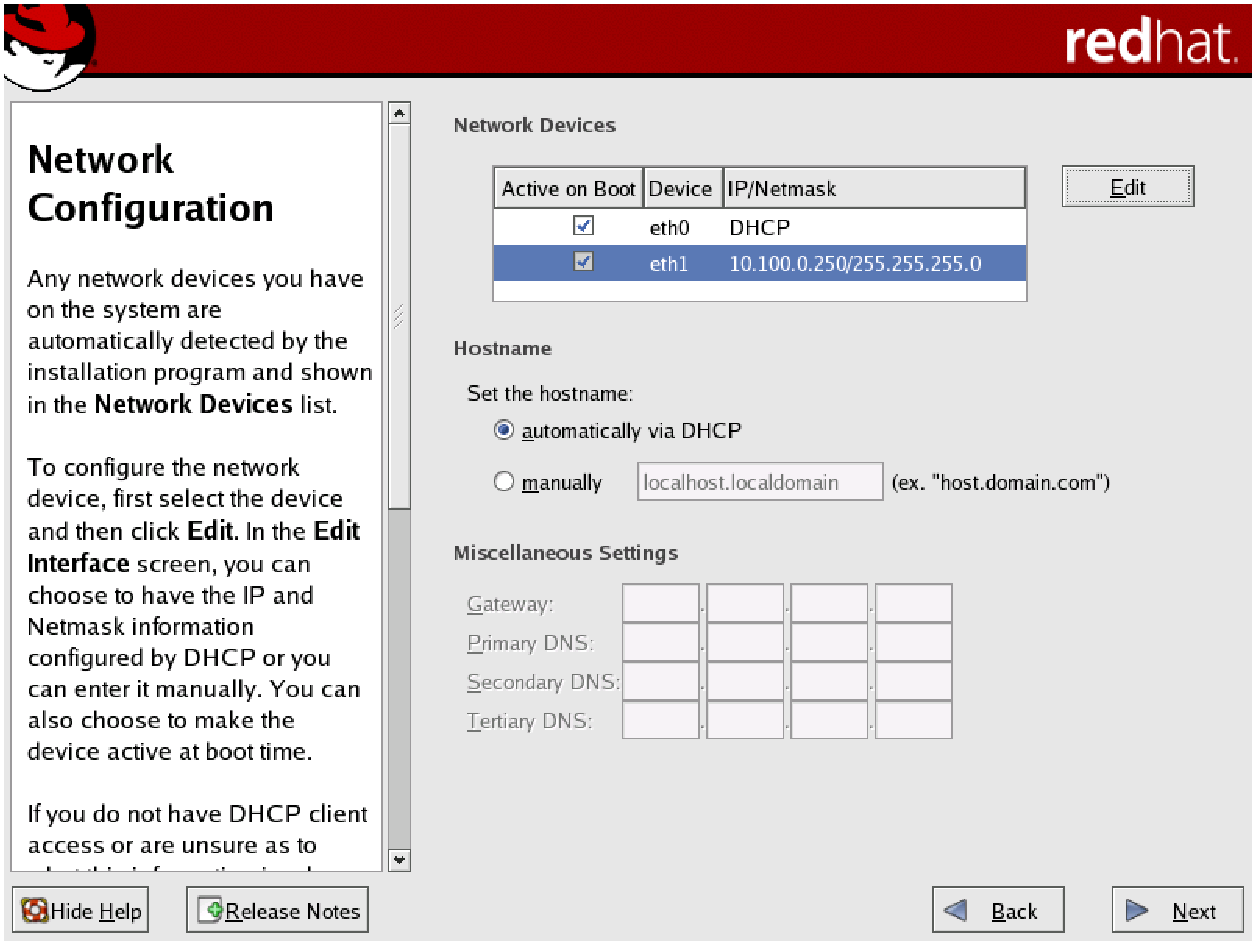
   c. If the public subnet is non-routable, then use a different non-routable range for the private subnet (e.g., if the public subnet is 192.168.x.x, then use 172.16.x.x to 172.30.x.x or 10.x.x.x for the private subnet).

   d. Once you have specified the IP address, set the subnet mask based on this address. The subnet mask must accommodate a range large enough to contain all of your compute nodes.

   When you have completed these settings, click *OK* to return to the Network Configuration screen.

3. In the *Set the hostname* area of the Network Configuration screen, you have the option to set the hostname automatically via the DHCP server or to provide one manually; this can be done according to your local standards.

The following figure illustrates a completed typical configuration for both the public and private network interfaces.



Network Configuration

Any network devices you have on the system are automatically detected by the installation program and shown in the **Network Devices** list.

To configure the network device, first select the device and then click **Edit**. In the **Edit Interface** screen, you can choose to have the IP and Netmask information configured by DHCP or you can enter it manually. You can also choose to make the device active at boot time.

If you do not have DHCP client access or are unsure as to

Network Devices

Active on Boot	Device	IP/Netmask
☑	eth0	DHCP
☑	eth1	10.100.0.250/255.255.255.0

Hostname

Set the hostname:

● automatically via DHCP

○ manually localhost.localdomain (ex. "host.domain.com")

Miscellaneous Settings

Gateway: . . .
Primary DNS: . . .
Secondary DNS: . . .
Tertiary DNS: . . .

Figure 5. Public and Private Network Interfaces (Typical Configuration Completed)

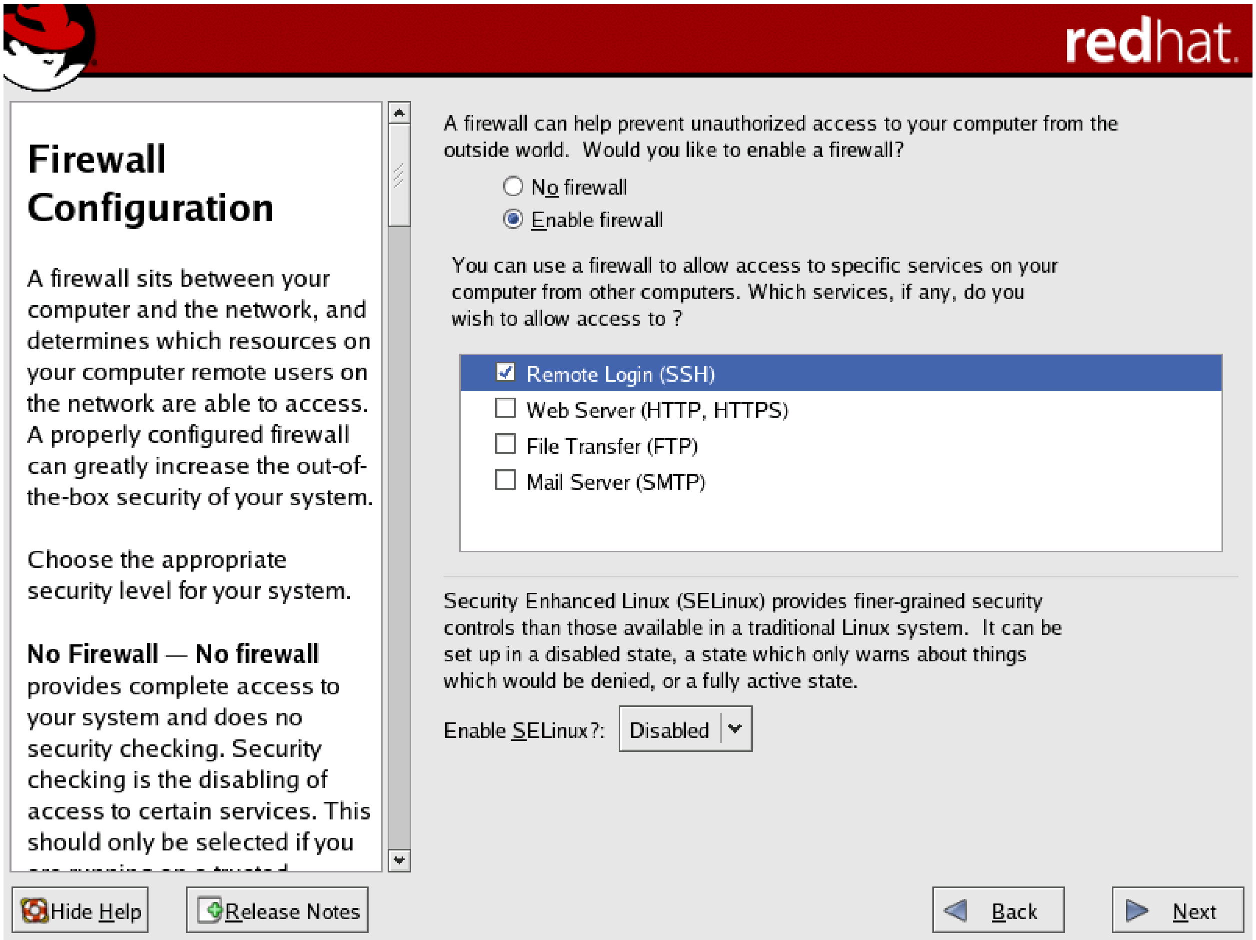
Network Security Settings

Caution

The security features provided with this system do not guarantee a completely secure system.

The Firewall Configuration screen presented during the RHEL6 installation applies to the public network interface and should be set according to your local standards. This screen allows you to customize several aspects of the firewall that protects your cluster from possible network security violations.

The RHEL6 installer allows you to select some, but not all, of the security settings needed to support Scyld ClusterWare. The remaining security settings must be made post-installation; see *Trusted Devices*.



Firewall Configuration

A firewall sits between your computer and the network, and determines which resources on your computer remote users on the network are able to access. A properly configured firewall can greatly increase the out-of-the-box security of your system.

Choose the appropriate security level for your system.

No Firewall — No firewall provides complete access to your system and does no security checking. Security checking is the disabling of access to certain services. This should only be selected if you

A firewall can help prevent unauthorized access to your computer from the outside world. Would you like to enable a firewall?

○ No firewall
● Enable firewall

You can use a firewall to allow access to specific services on your computer from other computers. Which services, if any, do you wish to allow access to ?

☑ Remote Login (SSH)
□ Web Server (HTTP, HTTPS)
□ File Transfer (FTP)
□ Mail Server (SMTP)

Security Enhanced Linux (SELinux) provides finer-grained security controls than those available in a traditional Linux system. It can be set up in a disabled state, a state which only warns about things which would be denied, or a fully active state.

Enable SELinux?: Disabled

Figure 6. Security Settings During Installation

Scyld recommends setting a firewall for the public network interface (typically eth0). You can configure the following security settings during the Red Hat install:

Select from the following firewall options:

1. *No Firewall* — Allows all connections to your system and does no security checking. This option is not recommended unless you plan to configure your firewall after the installation.
2. *Enable Firewall* — Blocks any connections to your system that are not defaults or explicitly defined by you. By default, connections are allowed in response to outbound requests, such as DNS replies or DHCP requests.

Select services for which you want to allow possible connections. You can select any combination of the services listed.

> **Tip**
>
> If you plan to use SSH to connect to the master node, be sure that SSH is checked in the Trusted Services list.

Set the Enable SELinux? dropdown to “Disabled”.

If you chose to install a firewall, you must make the private network interface (typically eth1) a “trusted device” to enable all traffic on this interface to pass through the firewall. See *Trusted Devices*.

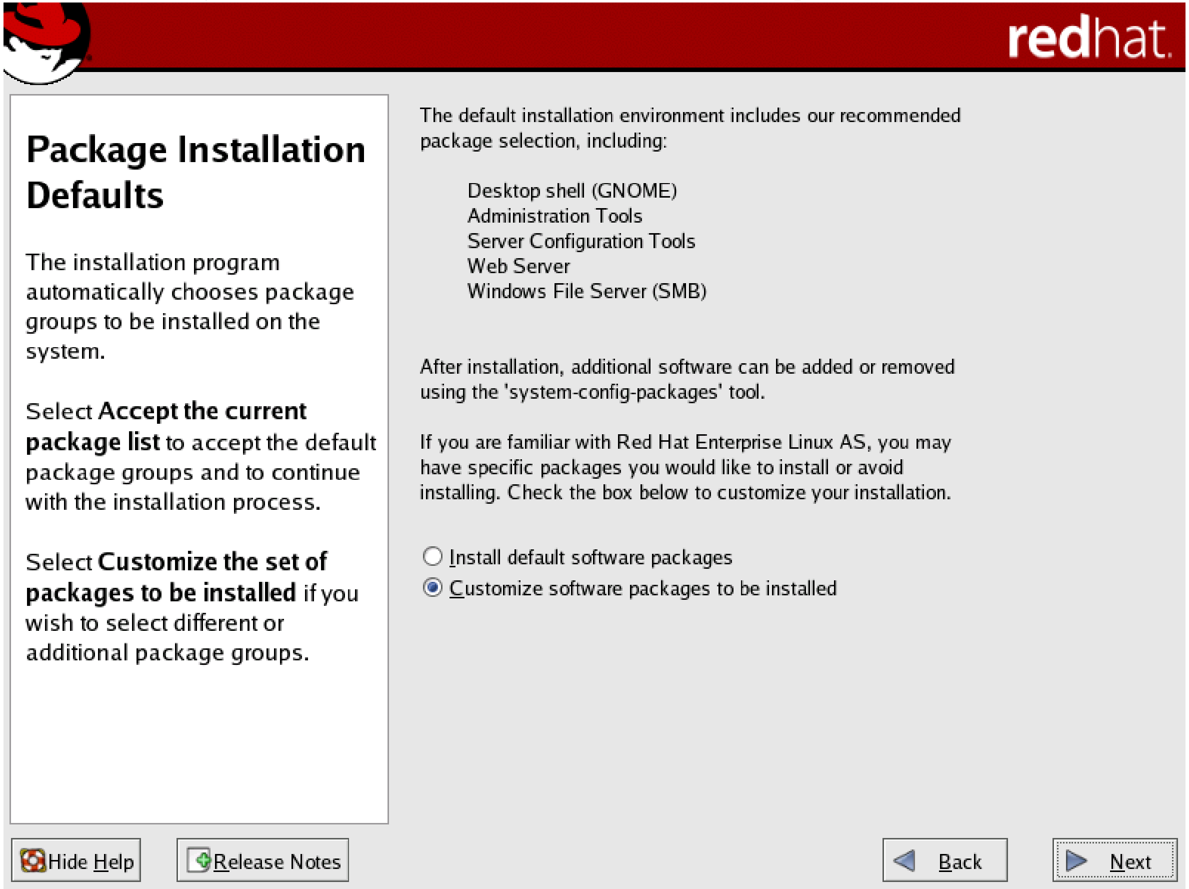
Package Group Selection

Caution

Scyld ClusterWare depends on certain Red Hat packages, and the Scyld installation may fail if the necessary Red Hat packages are not installed. Therefore, Scyld recommends that you install all Red Hat packages.

The Red Hat package selection screens enable you to select the particular software packages that you wish to install.

1. In the Package Installation Defaults screen, select the *Customize...* option.



Package Installation Defaults

The installation program automatically chooses package groups to be installed on the system.

Select **Accept the current package list** to accept the default package groups and to continue with the installation process.

Select **Customize the set of packages to be installed** if you wish to select different or additional package groups.

The default installation environment includes our recommended package selection, including:

Desktop shell (GNOME)
Administration Tools
Server Configuration Tools
Web Server
Windows File Server (SMB)

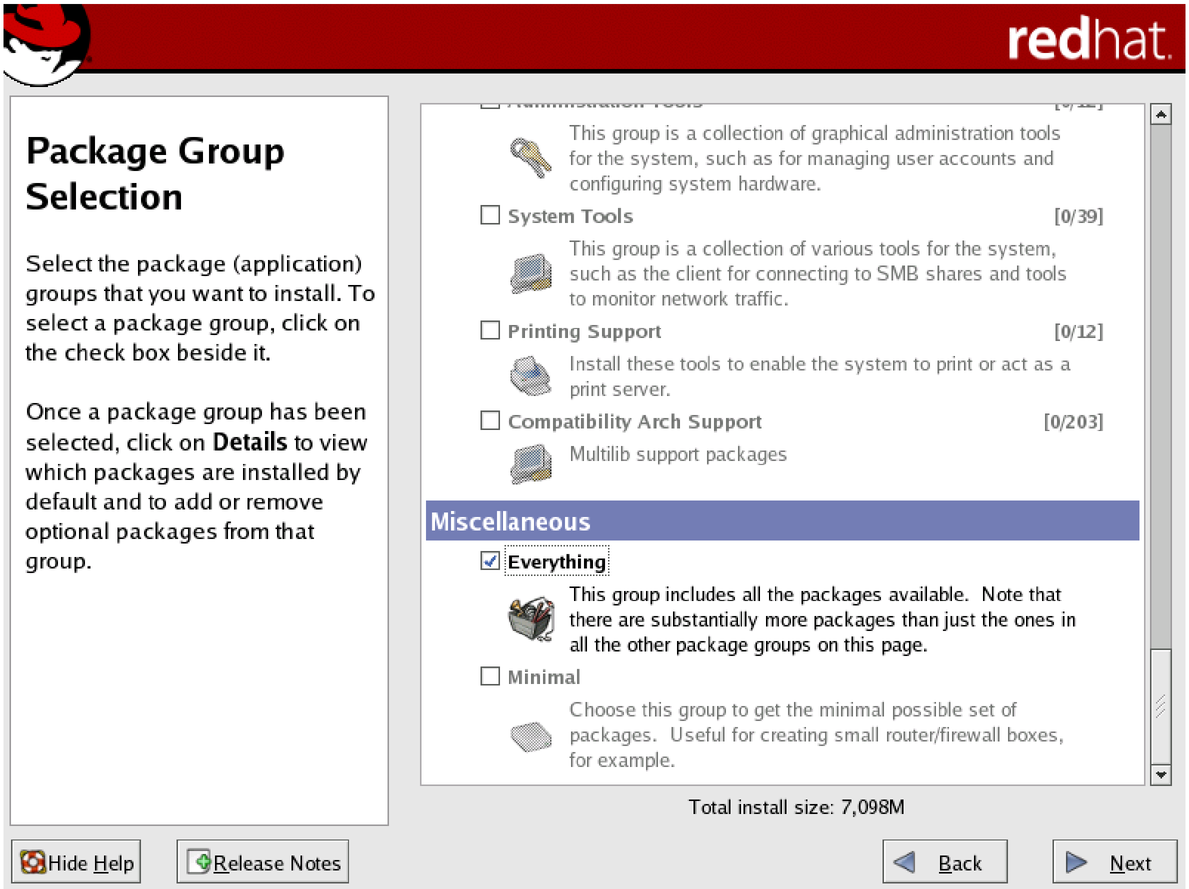
After installation, additional software can be added or removed using the 'system-config-packages' tool.

If you are familiar with Red Hat Enterprise Linux AS, you may have specific packages you would like to install or avoid installing. Check the box below to customize your installation.

○ Install default software packages
● Customize software packages to be installed

Figure 7. Customize Package Installation

2. In the Package Group Selection screen, scroll down to the Miscellaneous section. Select the Everything checkbox, then continue the installation process.



Package Group Selection

Select the package (application) groups that you want to install. To select a package group, click on the check box beside it.

Once a package group has been selected, click on **Details** to view which packages are installed by default and to add or remove optional packages from that group.

□ Administration Tools [0/12]

This group is a collection of graphical administration tools for the system, such as for managing user accounts and configuring system hardware.

□ System Tools [0/39]

This group is a collection of various tools for the system, such as the client for connecting to SMB shares and tools to monitor network traffic.

□ Printing Support [0/12]

Install these tools to enable the system to print or act as a print server.

□ Compatibility Arch Support [0/203]

Multilib support packages

Miscellaneous

☑ Everything

This group includes all the packages available. Note that there are substantially more packages than just the ones in all the other package groups on this page.

□ Minimal

Choose this group to get the minimal possible set of packages. Useful for creating small router/firewall boxes, for example.

Total install size: 7,098M

Figure 8. Install Everything

Tip

To update an existing Red Hat installation to include all packages, insert the first Red Hat CD and invoke the Red Hat update program. Check the Everything box in the Package Group Selection screen, then continue with the update process.

2.7.2 Updating Red Hat or CentOs Installation

Update RHEL6 or CentOS6 either using `yum`, or using Red Hat or CentOS distribution media. Note that Penguin continually tests ClusterWare with new patches from Red Hat and CentOS. Visit the Penguin Computing Support Portal at https://www.penguincomputing.com/support to see the most recent errata fix tested with ClusterWare, and see any cautions about updated packages which may cause problems with ClusterWare.

Updating Using Yum

Use the following command:

```
[root@scyld ~]# yum update --disablerepo=cw*
```

(`--disablerepo-cw*` is used above in case the ClusterWare repo is already installed in `/etc/yum.repos.d`, you must exclude it during the `yum update`). You can also exclude other packages using the `--exclude=$package` parameter. See the `yum` man page for instructions on using `yum`. The CentOS web site also provides an online manual for `yum` at http://www.centos.org/docs/4/html/yum/.

Updating Using Media

If you update your system via distribution media, be sure to select an “upgrade install” rather than a “full install”, then follow the instructions provided with the media.

> **Tip**
>
> The just-installed newest base distribution kernel becomes the default in `/etc/grub.conf`. However, the Scyld ClusterWare includes a customized kernel that must be the kernel that is booted when running Scyld ClusterWare.

2.7.3 Scyld ClusterWare Installation

Scyld ClusterWare is installed using the Penguin Yum repository http://updates.penguincomputing.com/clusterware/. Each Scyld ClusterWare release is continuously tested with the latest patches from Red Hat and CentOS6. Before installing or updating your master node, be sure to visit the Support Portal to determine if any patches should be excluded due to incompatibility with ClusterWare. Such incompatibilities should be rare. Then, update RHEL6 or CentOS6 on your master node before proceeding (excluding incompatible packages if necessary) with installing or updating your Scyld ClusterWare.

Configure Yum To Support ClusterWare

The Yum repo configuration file for Scyld ClusterWare must be downloaded from the Penguin Computing Support Portal and properly configured:

Login to the Support Portal at https://www.penguincomputing.com/support.

Click on *Download your Yum repo file* to download this `clusterware.repo` file and place the it in the `/etc/yum.repos.d/` directory.

Set the permissions:

```
[root@scyld ~]# chmod 644 /etc/yum.repos.d/clusterware.repo
```

With this setup complete, your master node is ready to retrieve Scyld ClusterWare installations and updates.

Install ClusterWare

You can use Yum to install ClusterWare and all updates up to and including the latest ClusterWare release, assuming you have updated your RHEL6 or CentOS6 base distribution as prescribed in the ClusterWare *Release Notes*.

1. Verify the version you are running with the following:

```
    [root@scyld ~]# cat /etc/redhat-release
```

   This should return a string similar to “Red Hat Enterprise Linux Server release 6.10” or “CentOS release 6.10 (Final)”.

2. Install the Scyld ClusterWare script that simplifies installing (and later updating) software, then execute that script:

```
    [root@scyld ~]# yum install install-scyld
    [root@scyld ~]# install-scyld
```

3. Configure the network for Scyld ClusterWare: edit `/etc/beowulf/config` to specify the cluster interface, the maximum number of compute nodes, and the beginning IP address of the first compute node. See the remainder of this guide and the *Administrator’s Guide* for details.

4. Reboot your system.
5. To verify that ClusterWare was installed successfully, do the following:

```
[root@scyld ~]# uname -r
```

   The result should match the specific ClusterWare kernel version noted in the *Release Notes*.

2.7.4 Trusted Devices

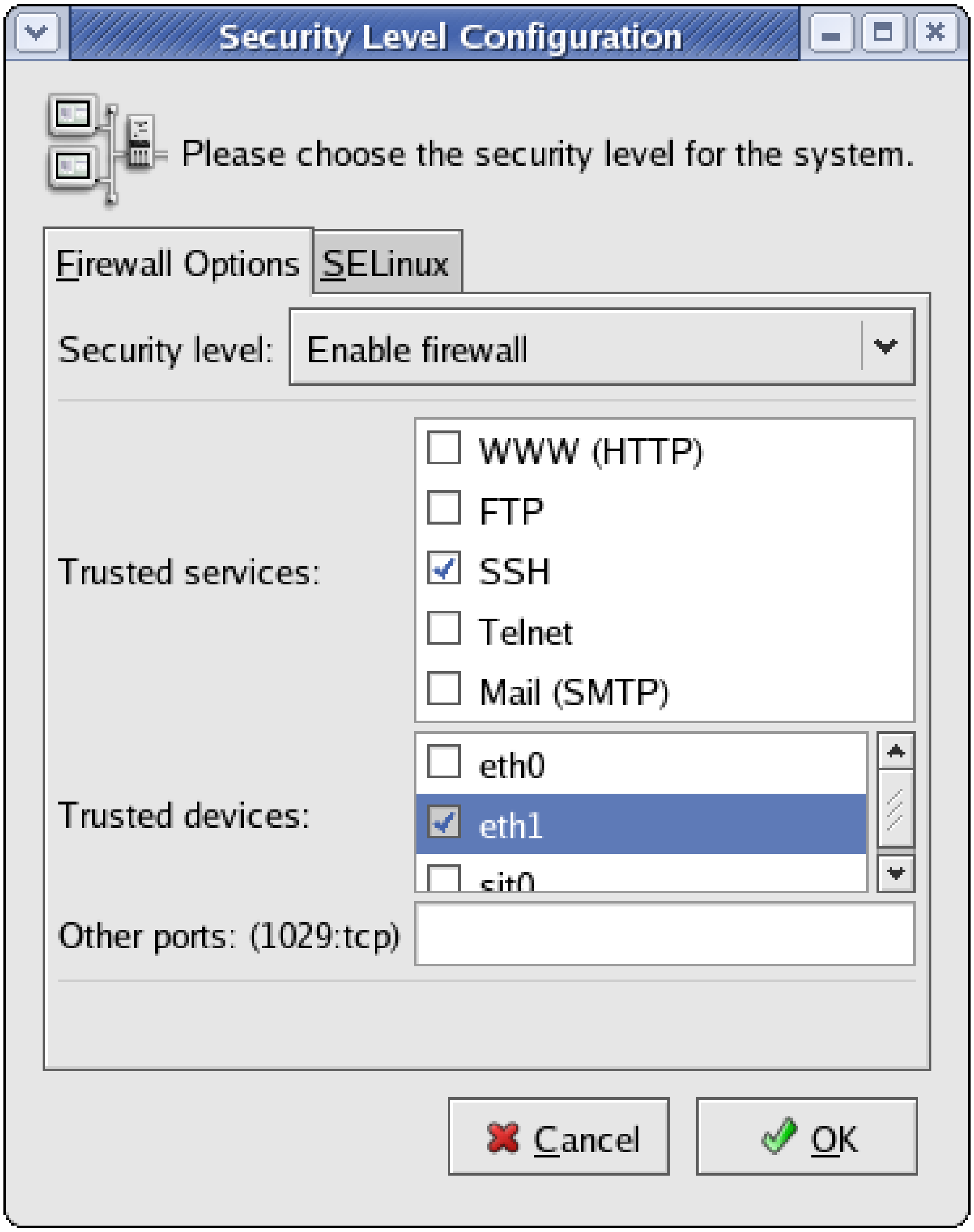
If you chose to install a firewall, you must make the private network interface (typically eth1) a “trusted device” to enable all traffic on this interface to pass through the firewall; otherwise, the cluster will not run properly. This must be done post-installation.

After you have installed Red Hat and Scyld ClusterWare, reboot the system and log in as “root”.

Access the security settings through the Red Hat *Applications* -> *System Settings* -> *Security Level* menu options.

In the Security Level Configuration dialog box, make sure the private interface is checked in the “trusted devices” list, then click OK.

> **Tip**
>
> If you plan to use SSH to connect to the master node, be sure that SSH is checked in the “trusted services” list.



Please choose the security level for the system.

Security level: Enable firewall

Trusted services:
☐ WWW (HTTP)
☐ FTP
☑ SSH
☐ Telnet
☐ Mail (SMTP)

Trusted devices:
☐ eth0
☑ eth1
☐ sit0

Other ports: (1029:tcp)

Figure 3. Security Settings Post-Installation

You are now ready to boot your compute nodes.

2.7.5 Enabling Access to External License Servers

1. Enable ipforward in the /etc/beowulf/config file. The line should read as follows:

   ipforward yes

2. Restart the cluster services as "root":

```
[root@scyld ~]# service beowulf restart
```

2.7.6 Post-Installation Configuration

Following a successful update or install of Scyld ClusterWare, you may need to make one or more configuration changes, depending upon the local requirements of your cluster. Larger cluster configurations have additional issues to consider. Accordingly, review the Release Notes sections titled *Post-Installation Configuration Issues* and *Post-Installation Configuration Issues For Large Clusters* for important detailed information.

2.7.7 Scyld ClusterWare Updates

You can use Yum update to update ClusterWare once you have upgraded your RHEL6 or CentOS6 base distribution. See *Updating Red Hat or CentOs Installation* or details on updating your base distribution, and *Scyld ClusterWare Installation* for how to set up the Yum repo configuration files.

To verify which distribution you are currently running, do the following:

```
[root@scyld ~]# cat /etc/redhat-release
```

Updating ClusterWare

1. It is advisable to update the base distribution prior to updating Scyld ClusterWare, taking care to exclude the base distribution's kernel-* packages to avoid potentially updating to a newer kernel than is currently available in the Scyld ClusterWare yum repos:

   ```
   [root@scyld ~]# yum --disablerepo=cw* --exclude=kernel-* update
   ```

2. Update the Scyld ClusterWare package that contains a useful script that simplifies updating ClusterWare, then execute that script:

   ```
   [root@scyld ~]# yum update install-scyld
   [root@scyld ~]# install-scyld -u
   ```

3. Compare `/etc/beowulf/config`, which remains untouched by the Scyld ClusterWare update, with the new `config.rpmnew` (if that file exists), and examine the differences:

   ```
   [root@scyld ~]# cd /etc/beowulf
   [root@scyld ~]# diff config config.rpmnew
   ```

   and carefully merge the `config.rpmnew` differences into `/etc/beowulf/config`. Similarly, the preexisting `/etc/beowulf/fstab` may have been saved as `fstab.rpmsave` if it was locally modified. If so, merge those local changes back into `/etc/beowulf/fstab`

4. Reboot your system.

5. To verify that ClusterWare was installed successfully, do the following:

   ```
   [root@scyld ~]# uname -r
   ```

   The result should match the ClusterWare kernel version noted in the *Release Notes*.

6. Restart the compute nodes.

2.8 Cluster Verification Procedures

Once the master node and compute nodes have been configured and rebooted, you should run through the cluster verification to identify common software and hardware configuration problems. This chapter describes the Scyld ClusterWare tools for monitoring cluster status and running jobs across the cluster.

Cluster verification is generally required by reseller technical support when starting on a new issue. When you call your reseller for support, they will require that you have completed the cluster verification procedures outlined in this chapter, and that you capture information using the `beosi` script.

Also see the *Administrator's Guide* and the *User's Guide* for more detailed information.

2.8.1 Monitoring Cluster Status

You can monitor the status of the nodes in your cluster using the `bpstat` or `beostatus` commands.

bpstat

The `bpstat` command, run at a shell prompt on the master node, shows a table of status information for each node in the cluster. You do not need to be a privileged user to use this command.

Following is an example of the outputs from `bpstat` for a cluster with 10 compute nodes.

```
Node(s)      Status       Mode       User       Group
5-9          down         ---------- root       root
4            up           ---x--x--x any        any
0-3          up           ---x--x--x root       root
```

Some things to keep in mind for `bpstat`:

- Ensure that each node is listed as *up*. The node count is based upon the *nodes* and *iprange* entries in the `/etc/beowulf/config` configuration file.
- Nodes that have not yet been configured are marked as *down*.
- Nodes currently booting are temporarily shown with a status of *boot*.
- An *error* status indicates a node initialization problem. Check for error messages in the log file `/var/log/beowulf/node.N` (where N is the node number). Typical problems are failing network connections, unpartitioned harddrives, or unavailable network file systems.

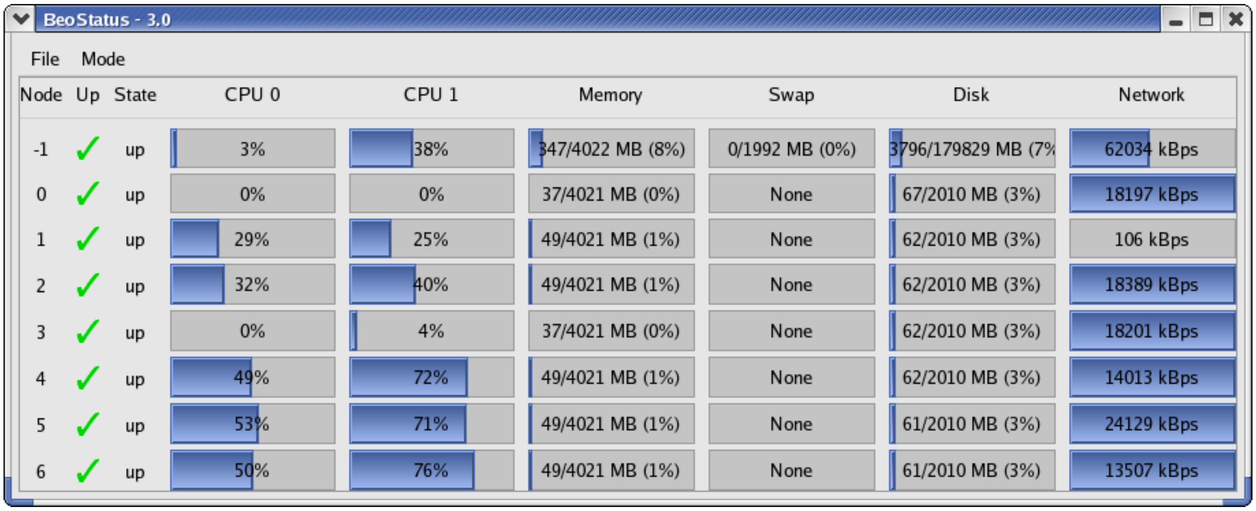
BeoStatus

The BeoStatus tool is a graphical user interface (GUI) program. You can start it by clicking the BeoStatus icon on the desktop.

Alternatively, type the command `beostatus` in a terminal window on the master node; you do not need to be a privileged user to use this command.

You can also view the status of the cluster in text mode by typing the command `beostatus -c` at a terminal window on the master node.

The default BeoStatus GUI mode (shown below) is a tabular format known as the "Classic" display. Each row corresponds to a different node, with specific state and resource usage information displayed per node.



Node	Up	State	CPU 0	CPU 1	Memory	Swap	Disk	Network
-1	✓	up	3%	38%	347/4022 MB (8%)	0/1992 MB (0%)	3796/179829 MB (7%	62034 kBps
0	✓	up	0%	0%	37/4021 MB (0%)	None	67/2010 MB (3%)	18197 kBps
1	✓	up	29%	25%	49/4021 MB (1%)	None	62/2010 MB (3%)	106 kBps
2	✓	up	32%	40%	49/4021 MB (1%)	None	62/2010 MB (3%)	18389 kBps
3	✓	up	0%	4%	37/4021 MB (0%)	None	62/2010 MB (3%)	18201 kBps
4	✓	up	49%	72%	49/4021 MB (1%)	None	62/2010 MB (3%)	14013 kBps
5	✓	up	53%	71%	49/4021 MB (1%)	None	61/2010 MB (3%)	24129 kBps
6	✓	up	50%	76%	49/4021 MB (1%)	None	61/2010 MB (3%)	13507 kBps

Figure 1. BeoStatus in the "Classic" Display Mode

You should sanity-check the information shown in the BeoStatus window. The configured nodes that are powered up (those with a green checkmark in the "Up" column) should show expected values in the associated usage columns. When there are no active jobs on your cluster, the CPU and Network columns should be fairly close to zero. The memory usage columns (Memory, Swap, and Disk) should be showing reasonable values.

- *Node* — The node's assigned node number, starting at zero. Node -1, if shown, is the master node. The total number of node entries shown is set by the "iprange" or "nodes" keywords in the file `/etc/beowulf/config`, rather than the number of detected nodes. The entry for an inactive node displays the last reported data in a grayed-out row.
- *Up* — A graphical representation of the node's status. A green checkmark is shown if the node is up and available. Otherwise, a red "X" is shown.
- *State* — The node's last known state. This should agree with the state reported by both the `bpstat` and `beostatus` commands.
- *CPU "X"* — The CPU loads for the node's processors; at minimum, this indicates the CPU load for the first processor in each node. Since it is possible to mix uni-processor and multi-processor machines in a Scyld cluster, the number of CPU load columns is equal to the maximum number of processors for any node in your cluster. The label "N/A" will be shown for nodes with less than the maximum number of processors.
- *Memory* — The node's current memory usage.
- *Swap* — The node's current swap space (virtual memory) usage.
- *Disk* — The node's harddrive usage. If a RAM disk is used, the maximum value shown is one-half the amount of physical memory. As the RAM disk competes with the kernel and application processes for memory, not all the RAM may be available.
- *Network* — The node's network bandwidth usage. The total amount of bandwidth available is the sum of all network interfaces for that node.

2.8.2 Running Jobs Across the Cluster

Jobs can be executed on a Scyld cluster using either "directed execution" with the `bpsh` command or "dynamic execution" with the `beorun` or `mpprun` commands.

Directed Execution with bpsh

In the directed execution mode, the user explicitly defines which node (or nodes) will run a particular job. This mode is invoked using the `bpsh` command, the ClusterWare shell command analogous in functionality to both the `rsh` (remote shell) and `ssh` (secure shell) commands. Following are some examples of using `bpsh`:

- This example runs `hostname` on the compute node and writes the output back to the user's screen from compute node 0:

```
    [user@cluster user]$ bpsh 0 /bin/hostname
      .0
```

- The following example runs the uptime utility on node 0, assuming it is installed in /usr/bin:

```
    [user@cluster user]$ bpsh 0 /usr/bin/uptime
      12:56:44 up  4:57,  5 users,  load average: 0.06, 0.09, 0.03
```

Dynamic Execution with beorun and mpprun

In the dynamic execution mode, Scyld decides which node is the most capable of executing the job at that moment in time. Scyld includes two parallel execution tools that dynamically select nodes, `beorun` and `mpprun`. They differ only in that `beorun` runs the job on the selected nodes concurrently, while `mpprun` runs the job sequentially on one node at a time.

The following example shows the difference in the amount of time the system uses to run a command with `beorun` vs. `mpprun`:

```
[user@cluster user]$ date;beorun -np 8 sleep 1;date
  Fri Aug 18 11:48:30 PDT 2006
  Fri Aug 18 11:48:31 PDT 2006
```

```
[user@cluster user]$  date;mpprun -np 8 sleep 1;date
  Fri Aug 18 11:48:46 PDT 2006
  Fri Aug 18 11:48:54 PDT 2006
```

2.9 Troubleshooting ClusterWare

2.9.1 Failing PXE Network Boot

If a compute node fails to join the cluster when booted via PXE network boot, there are several places to look, as discussed below.

Rule out physical problems.. Check for disconnected Ethernet cables, malfunctioning network equipment, etc.

Check the system logs.. There are several log files:

- The master node's `/var/log/messages` file combines rsyslog output from the master node and each compute node. The master node's Scyld ClusterWare `beoserv` daemon serves as the cluster's DHCP server, and it logs the basic PXEboot interactions with each compute node. If a compute node shows no PXEboot logging, then the `beoserv` daemon is not seeing the initial PXEboot or DHCP request. Verify that the master node's private cluster network firewall is not blocking incoming requests.
- If the syslog shows a compute node is making repeated PXEboot responses without ever reaching *boot*, *error*, or *up* state, then the Scyld ClusterWare `beoclient` daemon on the compute node is unable to start up the node.

Commonly, beoclient is failing to load the appropriate kernel binary module for the Ethernet interface. Ensure that /etc/beowulf/config specifies a *bootmodule* for the Ethernet controller hardware used by that specific compute node server, and that any *modarg* module options are valid for that particular kernel driver. Scyld ClusterWare distributes *bootmodule* entries for all Penguin Computing servers. If your compute node is not a Penguin Computing server, then verify that the necessary kernel driver is named as a *bootmodule*.

Definitive diagnosis may require viewing the compute node's console output, either by attaching a graphical monitor to the console port, attaching a serial cable from the compute node's serial console output to another server and using /usr/bin/minicom to capture the output, or capturing the compute node's serial console output using the IPMI serial console functionality.

- If a compute node reaches *boot* state, then example the node's individual /var/log/beowulf/node. log file, where N is the node number.

Check for the correct DHCP server.. If a node fails to appear initially (on power-up), or appears then subsequently disappears, then the node may be unable to find the master node's DHCP server. Another DHCP server may be answering and supplying IP addresses.

To check whether the master is seeing the compute node's DHCP requests, or whether another server is answering, use the Linux tcpdump utility. The following example shows a correct dialog between compute node 0 (10.10.100.100) and the master node.

```
[root@cluster ~]# tcpdump -i eth1 -c 10
Listening on eth1, link-type EN10MB (Ethernet),
        capture size 96 bytes
18:22:07.901571 IP master.bootpc > 255.255.255.255.bootps:
        BOOTP/DHCP, Request from .0, length: 548
18:22:07.902579 IP .-1.bootps > 255.255.255.255.bootpc:
        BOOTP/DHCP, Reply, length: 430
18:22:09.974536 IP master.bootpc > 255.255.255.255.bootps:
        BOOTP/DHCP, Request from .0, length: 548
18:22:09.974882 IP .-1.bootps > 255.255.255.255.bootpc:
        BOOTP/DHCP, Reply, length: 430
18:22:09.977268 arp who-has .-1 tell 10.10.100.100
18:22:09.977285 arp reply .-1 is-at 00:0c:29:3b:4e:50
18:22:09.977565 IP 10.10.100.100.2070 > .-1.tftp:  32 RRQ
        "bootimg::loader" octet tsize 0
18:22:09.978299 IP .-1.32772 > 10.10.100.100.2070:
        UDP, length 14
10 packets captured
32 packets received by filter
0 packets dropped by kernel
```

Check the network interface.. Verify that the master node's network interface is properly set up. Then check the network interface settings using beonetconf. Reconfigure as needed, and restart cluster services again.

Verify that ClusterWare services are running.. Check the status of ClusterWare services by entering the following command in a terminal window:

```
[root@cluster ~]# service beowulf status
```

Restart ClusterWare services from the command line using:

```
[root@cluster ~]# service beowulf restart
```

Check the switch configuration.. If the compute nodes fail to boot immediately on power-up but successfully boot later, the problem may lie with the configuration of a managed switch.

Some Ethernet switches delay forwarding packets for approximately one minute after link is established, attempting to verify that no network loop has been created ("spanning tree"). This delay is longer than the PXE boot timeout on some servers.

Disable the spanning tree check on the switch; the parameter is typically named "fast link enable". See the *Administrator's Guide* for more details.

2.9.2 Mixed Uni-Processor and SMP Cluster Nodes

The Scyld ClusterWare system architecture eliminates the problem of unintentionally running different versions of a program over the cluster's compute nodes.

The cluster nodes are required to run the same kernel version, typically with the same features and optimization enabled. Uni-processor machines can run the SMP kernel. The best choice for a mixed cluster is to run the SMP kernel. Beginning with CW4.1.1, support for uniprocessor kernels was dropped.

2.9.3 IP Forwarding

If IP forwarding is enabled in `/etc/beowulf/config` but is still not working, then check `/etc/sysctl.conf` to see if it is disabled.

Check for the line "net.ipv4.ip_forward = 1". If the value is set to 0 (zero) instead of 1, then IP forwarding will be disabled, even if it is enabled in `/etc/beowulf/config`.

2.9.4 SSH Traffic

The Red Hat installer configures the firewall with most services disabled. If SSH traffic isn't passing through the firewall, then check your firewall settings to make sure SSH is selected as a trusted service.

To do this, log in as a root user and choose the Red Hat *Applications* -> *System Settings* -> *Security Level* menu option to open the Security Level Configuration window. Then make sure that SSH is checked in the list of trusted services.

2.9.5 Device Driver Updates

Scyld ClusterWare releases are tested on many different machine configurations, but it is impossible to provide device drivers for hardware unknown at release time.

Most problems with unsupported hardware or device-specific problems are resolved by updating to a newer device driver. Some devices may not yet be supported under Linux. Check with your hardware vendor.

The Scyld ClusterWare architecture makes most driver updates simple. Drivers are installed and updated on the master node exactly as with a single machine installation. The new drivers are immediately available to compute nodes, although already-loaded drivers are not replaced.

There are two irregular device driver types that require special actions: disk drivers and network drivers, both of which apply to the compute nodes. In both cases, the drivers must be available to load additional drivers and programs, and are thus packaged in initial RAM disk images.

Another irregular instance is where drivers must execute scripts when they load; one example is Infiniband. Contact the hardware vendor or Scyld support if you have difficulty with the script that loads the driver.

2.9.6 Finding Further Information

If you encounter a problem installing your Scyld cluster and find that this *Installation Guide* cannot help you, the following are sources for more information:

- See the *Release Notes* for special installation or upgrade procedures that must be taken for your particular version of ClusterWare. It is available on the master node or on the documentation CD included in the Scyld installation kit.
- See the *Administrator's Guide*, which includes descriptions of more advanced administration and setup options. It is available on the master node or on the documentation CD included in the Scyld installation kit.
- See the *Reference Guide*, a complete technical reference to Scyld ClusterWare. It is available on the master node or on the documentation CD included in the Scyld installation kit.

For the most up-to-date product documentation and other helpful information about Scyld ClusterWare, visit the Scyld Customer Support website at https://www.penguincomputing.com/support. and online documentation at https://www.penguincomputing.com/support/documentation.

2.10 Compute Node Disk Partitioning

2.10.1 Architectural Overview

The Scyld ClusterWare system uses a "disk-less administration" model for compute nodes. This means that the compute nodes boot and operate without the need for mounting any file system, either on a local disk or a network file system. By using this approach, the cluster system does not depend on the storage details or potential misconfiguration of the compute nodes, instead putting all configuration information and initialization control on the master.

This does not mean that the cluster cannot or does not use local disk storage or network file systems. Instead it allows the storage to be tailored to the needs of the application rather than the underlying cluster system.

The first operational issue after installing a cluster is initializing and using compute node storage. While the concept and process is similar to configuring the master machine, the "disk-less administration" model makes it much easier to change the storage layout on the compute nodes.

2.10.2 Operational Overview

Compute node hard disks are used for three primary purposes:

- *Swap Space* — Expands the Virtual Memory of the local machine.
- *Application File Storage* — Provides scratch space and persistent storage for application output.
- *System Caching* — Increases the size and count of executables and libraries cached by the local node.

In addition, a local disk may be used to hold a cluster file system (used when the node acts as a file server to other nodes). To make this possible, Scyld provides programs to create disk partitions, a system to automatically create and check file systems on those partitions, and a mechanism to mount file systems.

2.10.3 Disk Partitioning Procedures

Deciding on a partitioning schema for the compute node disks is no easier than with the master node, but it can be changed more easily.

Compute node hard disks may be remotely partitioned from the master using `beofdisk`. This command automates the partitioning process, allowing all compute node disks with a matching hard drive geometry (cylinders, heads, sectors) to be partitioned simultaneously.

If the compute node hard disks have not been previously partitioned, you can use `beofdisk` to generate default partition tables for the compute node hard disks. The default partition table allocates three partitions, as follows:

- A BeoBoot partition equal to 2 MB (currently unused)
- A swap partition equal to 2 times the node's physical memory
- A single root partition equal to the remainder of the disk

The partition table for each disk geometry is stored in the directory `/etc/beowulf/fdisk` on the master node, with the filename specified in nomenclature that reflects the disk type, position, and geometry. Example filenames are `hda:2495:255:63`, `hdb:3322:255:63`, and `sda:2495:255:63`.

The `beofdisk` command may also be used to read an existing partition table on a compute node hard disk, as long as that disk is properly positioned in the cluster. The command captures the partition table of the first hard disk of its type and geometry (cylinder, heads, sectors) in each position on a compute node's controller (e.g., sda or hdb). The script sequentially queries the compute nodes numbered 0 through *N-1*, where *N* is the number of nodes currently in the cluster.

Typical Partitioning

While it is not possible to predict every configuration that might be desired, the typical procedure to partition node disks is as follows:

1. From the master node, capture partition tables for the compute nodes:

```
[root@cluster ~]# beofdisk -q
```

   With the *-q* parameter, `beofdisk` queries all compute nodes. For the first drive found with a specific geometry (cylinders, heads, sectors), it reads the partition table and records it in a file. If the compute node disk has no partition table, this command creates a default partition set and reports the activity to the console.

   If the partition table on the disk is empty or invalid, it is captured and recorded as described, but no default partition set is created. You must create a default partition using the ‘‘beofdisk -d ‘‘ command; see *Default Partitioning*.

2. Based on the specific geometry of each drive, write the appropriate partition table to each drive of each compute node:

```
[root@cluster ~]# beofdisk -w
```

   This technique is useful, for example, when you boot a single compute node with a local hard disk that is already partitioned, and you want the same partitioning applied to all compute nodes. You would boot the prototypical compute node, capture its partition table, boot the remaining compute nodes, and write that prototypical partition table to all nodes.

3. Reboot all compute nodes to make the partitioning effective.

4. If needed, update the file `/etc/beowulf/fstab` on the master node to record the mapping of the partitions on the compute node disks to the file systems.

Default Partitioning

To apply the recommended default partitioning to each disk of each compute node, follow these steps:

1. Generate default partition maps to `/etc/beowulf/fdisk`:

```
[root@cluster ~]# beofdisk -d
```

2. Write the partition maps out to the nodes:

```
[root@cluster ~]# beofdisk -w
```

3. You must reboot the compute nodes before the new partitions are usable.

Generalized, User-Specified Partitions

To create a unique partition table for each disk type/position/geometry triplet, follow these steps:

1. Remotely run the `fdisk` command on each compute node where the disk resides:

```
[root@cluster ~]# bpsh n fdisk device
```

where n is the node number or the first compute node with the drive geometry you want to partition, and device is the device you wish to partition (e.g., `/dev/sda`, `/dev/hdb`).

2. Once you have created the partition table and written it to the disk using `fdisk`, capture it and write it to all disks with the same geometry using:

```
[root@cluster ~]# beofdisk -w
```

3. You must reboot the compute nodes before the new partitioning will be effective.
4. You must then map file systems to partitions as described later in this chapter.

Unique Partitions

To generate a unique partition for a particular disk, follow these steps:

1. Partition your disks using either default partitioning or generalized partitions as described above.
2. From the master node, remotely run the `fdisk` command on the appropriate compute node to re-create a unique partition table using:

```
[root@cluster ~]# bpsh n fdisk device
```

where n is the compute node number for which you wish to create a unique partition table and device is the device you wish to partition (e.g., `/dev/sda`).

3. You must then map file systems to partitions as described below.

2.10.4 Mapping Compute Node Partitions

If your compute node hard disks are already partitioned, edit the file `/etc/beowulf/fstab` on the master node to record the mapping of the partitions on your compute node disks to your file systems. This file contains example lines (commented out) showing the mapping of file systems to drives; read the comments in the `fstab` file for guidance.

1. Query the disks on the compute nodes to determine how they are partitioned:

```
[root@cluster ~]# beofdisk -q
```

This creates a partition file in `/etc/beowulf/fdisk`, with a name similar to `sda:512:128:32` and containing lines similar to the following:

```
[root@cluster root]# cat sda:512:128:32
/dev/sda1  :  start=    32,  size=  8160,   id=89,  bootable
/dev/sda2  :  start=    8192,   size=    1048576,  Id=82
/dev/sda3  :  start=    1056768,    size=    1040384,  Id=83
/dev/sda4  :  start=    0, size=  0,  Id=0
```

2. Read the comments in `/etc/beowulf/fstab`. Add the lines to the file to use the devices named in the `sda` file:

```
# This is the default setup from beofdisk
#/dev/hda2        swap     swap   defaults     0 0
#/dev/hda3        /        ext2   defaults     0 0
/dev/sda1         /boot    ext23  defaults     0 0
/dev/sda2         swap     swap   defaults     0 0
/dev/sda3         /scratch ext3   defaults     0 0
```

3. After saving `fstab`, you must reboot the compute nodes for the changes to take affect.

2.11 Changes to Configuration Files

2.11.1 Changes to Red Hat Configuration Files

An installation of Red Hat sets a default configuration optimized for a stand-alone server. Installing ClusterWare on a Red Hat installation changes some of these default configuration parameters to better support a cluster. The following sections describe the changes the ClusterWare installation automatically makes to the Red Hat configuration. Any of these may be reversed; however, reversing them may adversely affect the operation of the ClusterWare cluster.

1. `/etc/grub.conf` has been modified.

   After ClusterWare has been installed, the default boot becomes the newest ClusterWare kernel.

2. NFS Services default configuration has been modified.

   By default, Red Hat configures NFS to “off” for security reasons. However, most cluster applications require that at least the home directory of the master node be accessible to the compute nodes. NFS services on the master are set with the default to “on” for run levels 3, 4, and 5.

   The default out-of-box chkconfig for NFS on RHEL6 is as follows:

```
[root@scyld ~]# chkconfig --list nfs
nfs             0:off   1:off   2:off   3:off   4:off   5:off   6:off
```

   ClusterWare has changed the default to the following:

```
[root@scyld ~]# chkconfig --list nfs
nfs             0:off   1:off   2:off   3:on    4:on    5:on    6:off
```

   To get NFS to mount directories from the master to the compute nodes, the file `/etc/exports` needs one entry per line for each file system to export from the master to the compute nodes (the RHEL-MAJOR default is a blank/non-existent file). ClusterWare creates this file if it didn’t already exist, and adds several new entries of the form:

   ExportedDirectoryPathname `@cluster`(*accessMode*,*syncMode*,no_root_squash)

   The export for `/home` from the master is configured with an *accessMode* of `rw` (read-write) and a *syncMode* of `sync` by default for data reliability reasons, and the non-/home directories are exported `ro` (read-only) for security reasons and `async` for performance reasons.

   See the ClusterWare *Release Notes* for details about which directories are added by Scyld.

3. `/etc/sysconfig/syslog` has been modified.

   Compute nodes will forward messages to the master node’s syslogd daemon, which places them in `/var/log/messages`. In order for this to function correctly, ClusterWare modifies the `/etc/sysconfig/syslog` file by adding the `-r` option to the `SYSLOGD_OPTIONS` line:

```
SYSLOGD_OPTIONS="-m 0 -r"
```

2.11.2 Possible Changes to ClusterWare Configuration Files

A clean install of ClusterWare introduces various ClusterWare configuration files that include default settings that a local sysadmin may choose to modify. A subsequent upgrade from one ClusterWare release to a newer release will avoid replacing these potentially modified files. Instead, an update installs a new version of the default file as a file of the form `CWconfigFile.rpmnew`. Therefore, after a ClusterWare upgrade, the sysadmin is encouraged to compare each such existing `CWconfigFile` with the new default version to ascertain which of the new default entries are appropriate to manually merge into the preexisting `CWconfigFile` file.

1. `/etc/beowulf/config` and `config.rpmnew`

   ClusterWare specifies additional libraries for compute nodes that may help various applications and scripts execute out-of-the-box

2. `/etc/beowulf/fstab` and `fstab.rpmnew`

   ClusterWare specifies additional `/dev` devices and NFS-mounted directories for compute nodes that may help various applications and scripts execute out-of-the-box.

CHAPTER

THREE

EVAL INSTALLATION GUIDE

3.1 Evaluation Installation Instructions

Thank you for your interest in evaluating Scyld ClusterWare. This guide describes how to install an evaluation copy of Scyld ClusterWare using Penguin's installation repository. You should perform any necessary backups of the system before installing this software, and should pay particular attention to keeping a copy of any local configuration files.

To proceed with the evaluation, you will only need this document, together with two files which you should have received by email: `clusterware.repo` and `scyld.lic`.

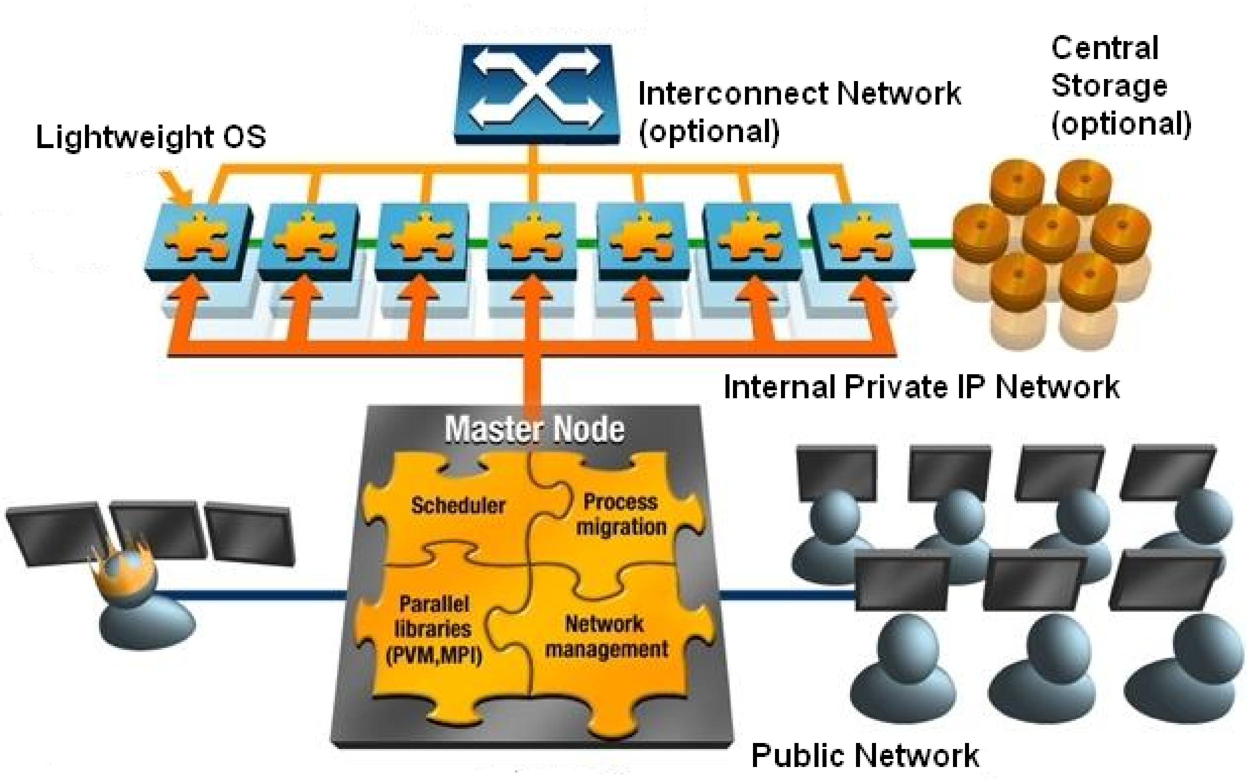
3.2 Scyld ClusterWare System Overview

Scyld ClusterWare streamlines the processes of configuring, running, and maintaining a Linux cluster using a group of commodity off-the-shelf (COTS) computers connected through a private network.

The front-end "master node" in the cluster is configured with a full Linux installation, distributing computing tasks to the other "compute nodes" in the cluster. Nodes communicate across a private network and share a common process execution space with common, cluster-wide process ID values.

A compute node is commonly diskless, as its kernel image is downloaded from the master node at node startup time using the Preboot eXecution Environment (*PXE*), and libraries and executable binaries are transparently transferred from the master node as needed. A compute node may access data files on locally attached storage or across NFS from an NFS server managed by the master node or some other accessible server.

In order for the master node to communicate with an outside network, it needs two network interface controllers (*NIC*s): one for the private internal cluster network, and the other for the outside network. It is suggested that the master node be connected to an outside network so multiple users can access the cluster from remote locations.


Central Storage (optional)
Interconnect Network (optional)
Lightweight OS
Internal Private IP Network
Master Node
Scheduler
Process migration
Parallel libraries (PVM,MPI)
Network management
Public Network

Cluster Layout

Figure 1. Cluster Configuration

3.3 Hardware Requirements

64-bit Intel® or AMD ™ x86_64 processor architecture.

1024 MBytes (1 GByte) main memory, with 2048 MBytes (2 GBytes) or more preferred.

At least one Gigabit Ethernet Network Interface Controller on each compute node.

Preferably two Gigabit Ethernet Network Interface Controllers on the master node.

A Gigabit network switch for the private cluster network.

Optional: An Infiniband network infrastructure for compute nodes. Infiniband controllers must use the Mellanox ™ chipset.

3.4 BIOS Requirements

Compute nodes must support the PXE network boot protocol. If an operating system has already been installed on a compute node's local disk, the node's BIOS must be configured to prioritize PXE network booting ahead of booting from the local disk.

3.5 Software Requirements

Scyld ClusterWare should be installed on a system running a base distribution of Red Hat Enterprise Linux (RHEL) or CentOS version 6 or 7.

The Infiniband interconnects (if present) must be supported by the *mthca* driver. When in doubt, you should contact your Infiniband hardware vendor to determine if your hardware is supported by this driver.

Scyld ClusterWare includes a customized version of the base distribution kernel that can co-exist with the kernel(s) currently installed on your master node.

NOTE: The Scyld ClusterWare kernel packages contain only those kernel modules that are included in the base distribution. This means that if your non-ClusterWare kernel is using a 3rd-party kernel module, e.g., for Panasas storage, or an Infiniband controller not supported by the *mthca* driver found in the base distribution, then that 3rd-party module (and whatever hardware it controls) is unavailable in the Scyld ClusterWare kernel environment.

3.6 Install Yum Configuration File and License File

You will have received two files by email that need to be installed in the appropriate places on your master node:

Install the `clusterware.repo` yum configuration file as `/etc/yum.repos.d/clusterware.repo`. This contains the credentials to identify your master node to Penguin Computing and to access Scyld ClusterWare software for download.

Install the `scyld.lic` evaluation license file as `/etc/scyld.lic`. This grants free use of ClusterWare for a month beginning from the date the license file was generated.

3.7 Update Base Distribution and Install Scyld Clusterware Software

We recommend that you visit https://www.penguincomputing.com/support/documentation to examine the *Release Notes* for the version you intend to install.

Once your master node's `/etc/yum.repos.d/` directory contains working yum repo files for both the base distribution (RHEL or CentOS) and for Scyld ClusterWare, then install and execute the very useful `install-scyld` script that guides you through the updating (if necessary) of software from the RHEL or CentOS base distribution and Scyld ClusterWare:

```
yum install install-scyld
install-scyld
```

Ideally, the script should have prompted you to accept the End User License Agreement (EULA).

3.8 Configure the Private and Public Networks

On the master node, execute `ip addr` to view the available Ethernet devices. These are typically named *eth0* and *eth1*, although the names may vary for your master node. The controller that is connected to the private cluster network must have a static IP address and be able to communicate with all the compute nodes, which themselves will be assigned a dynamic IP address when booting. The controller that is connected to the public cluster network can have a dynamic IP address or a static IP address, although the latter is preferable for consistency in accessing the master node from some other machine in the public network space.

Edit the `/etc/beowulf/config` configuration file to specify the private network interface details. Find the "interface" directive, and change the initially undefined "none" name to the actual interface name, and change the "iprange" directive to be the base address of the first compute node, which is typically node n0. Then change the "nodes" directive to specify the maximum number of compute nodes that are connected to the private cluster network.

For example, suppose the interface name is "eth1", the master node's IP address is 10.20.0.1, and there are currently eight compute nodes connected, with a plan to add an additional eight later. The `config` file may then specify:

```
interface eth1
nodes 16
iprange 10.20.0.4
```

Note that the above "iprange" allows room for three additional master nodes, if desired, each with an unique IP address in the range 10.20.0.0 to 10.20.0.3. The 16 compute nodes span 10.20.0.4 to 10.20.0.19.

3.9 Start Cluster Operations

Reboot the master node:

```
[root@scyld ~]# reboot
```

After rebooting, run:

```
[root@scyld ~]# uname -r
```

and confirm that the master node is running a Scyld ClusterWare kernel.

Normally, Scyld ClusterWare services automatically start whenever the master node reboots. However, Scyld ClusterWare requires that you have read and accepted an End User License Agreement (EULA). You should have done this when executing the `install-scyld` script. Additionally, any error in the `/etc/beowulf/config` configuration file will result in a beowulf service startup error.

Test for a functional ClusterWare by executing the simple command to view the cluster status: `bpstat`. A successful first output line should begin with *Node(s)*. If that does not appear, then attempt to start the ClusterWare service manually and look for an error message:

```
[root@scyld ~]# service beowulf start
```

Once the `beowulf` service is up and running, the master node can PXE boot as many compute nodes into the cluster as were defined by the "nodes" directive in the `/etc/beowulf/config` file. You can monitor the cluster status with the graphical `beostatus`, with the text-based `beostatus -c`, or with a simple `bpstat -U`.

Note: Depending upon BIOS settings, the compute nodes' DHCP requests may timeout because the master node hadn't been ready to respond, and compute nodes would then revert to a BIOS prompt waiting for human input. If `bpstat` continues to show that compute nodes are *down*, then 'reset' or powercycle each compute node, either manually or using an already configured `ipmitool`.

3.10 Documentation and Support

- For a complete reference, the Scyld ClusterWare documentation set consists of:
  - The full *Installation Guide* containing broader, more detailed information for installing and configuring the cluster.
  - The *Administrator's Guide* describing how to configure, maintain, and update the cluster.
  - The *User's Guide* and *Reference Guide* describing the commands, architecture, and programming interface for the cluster, including sample programs.

  - The *Release Notes* containing release-specific details, including information about known issues and workarounds.

  These product guides are available in two formats, HTML and PDF.

- Visit the Penguin Computing Support Portal at https://www.penguincomputing.com/support using the username and password you received for this evaluation, and click on *Application Notes* for information about running specific applications.
- Note: If you `ssh -X` from a remote system that executes a more recent version of X11 to the master node, some graphical programs may fail with an error of the form:

```
Gdk-ERROR **: BadMatch (invalid parameter attributes)
  serial 798 error_code 8 request_code 72 minor_code 0
```

  For a workaround, try setting the ssh client host X11 depth to 8:

```
[root@scyld ~]# export XLIB_SKIP_ARGB_VISUALS=1
```

  on the master node before running the failing program. If that is successful, then consider adding that export to `/etc/bashrc` or to an individual's `~/.bashrc`.

- For additional support, contact Customer Support at `scyldEval@penguincomputing.com`.

3.11 Purchasing Scyld ClusterWare

To license Scyld ClusterWare, please email support@penguincomputing.com

3.12 Uninstalling Scyld ClusterWare

1. Reboot the master node into a non Scyld ClusterWare kernel.
2. Use `yum groupremove` to uninstall ClusterWare:

```
[root@scyld ~]# yum groupremove Scyld-ClusterWare
```

3. Restore any base distribution packages that were explicitly removed when you installed Scyld ClusterWare, e.g., `openmpi* mvapich*`.

CHAPTER

FOUR

ADMINISTRATOR'S GUIDE

4.1 Preface

Welcome to the Scyld ClusterWare Administrator's Guide. It is written for use by Scyld ClusterWare administrators and advanced users. This document covers cluster configuration, maintenance, and optimization. As is typical for any Linux-based system, the administrator must have root privileges to perform the administrative tasks described in this document.

The beginning of this guide describes the Scyld ClusterWare system architecture and design; it is critical to understand this information in order to properly configure and administer the cluster. The guide then provides specific information about tools and methods for setting up and maintaining the cluster, the cluster boot process, ways to control cluster usage, methods for batching jobs and controlling the job queue, how load balancing is handled in the cluster, and optional tools that can be useful in administrating your cluster. Finally, the an appendix covers the important files and directories that pertain to operation of Scyld ClusterWare.

This guide is written with the assumption that the administrator has a background in a Unix or Linux operating environment; therefore, the document does not cover basic Linux system administration. If you do not have sufficient knowledge for using or administering a Linux system, we recommend that you first consult Linux in a Nutshell and other useful books published by O'Reilly and Associates.

When appropriate, this document refers the reader to other parts of the Scyld documentation set for more detailed explanations of the topic at hand. For information on the initial installation of Scyld ClusterWare, refer to the *Installation Guide*, which provides explicit detail on setting up the master node and booting the compute nodes. For administrators who are new to the ClusterWare concept, we recommend reading the *User's Guide* first, as it introduces ClusterWare computing concepts.

4.2 Scyld ClusterWare Design Overview

This chapter discusses the design behind Scyld ClusterWare, beginning with a high-level description of the system architecture for the cluster as a whole, including the hardware context, network topologies, data flows, software context, and system level files. From there, the discussion moves into a technical description that includes the compute node boot procedure, the process migration technology, compute node categories and states, and miscellaneous components. Finally, the discussion focuses on the ClusterWare software components, including tools, daemons, clients, and utilities.

As mentioned in the preface, this document assumes a certain level of knowledge from the reader and therefore, it does not cover any system design decisions related to a basic Linux system. In addition, it is assumed the reader has a general understanding of Linux clustering concepts and how the second generation Scyld ClusterWare system differs from the traditional Beowulf. For more information on these topics, see the *User's Guide*.

4.2.1 System Architecture

Scyld ClusterWare provides a software infrastructure designed specifically to streamline the process of configuring, administering, running, and maintaining commercial production Linux cluster systems. Scyld ClusterWare installs on top of a standard Linux distribution on a single node, allowing that node to function as the control point or "master node" for the entire cluster of "compute nodes".

This section discusses the Scyld ClusterWare hardware context, network topologies, system data flow, system software context, and system level files.

System Hardware Context

A Scyld cluster has three primary components:

- The master node
- Compute nodes
- The cluster private network interface

These components are illustrated in the following block diagram. The remaining element in the diagram is the public/building network interface connected to the master node. This network connection is not required for the cluster to operate properly, and may not even be connected (for example, for security reasons).

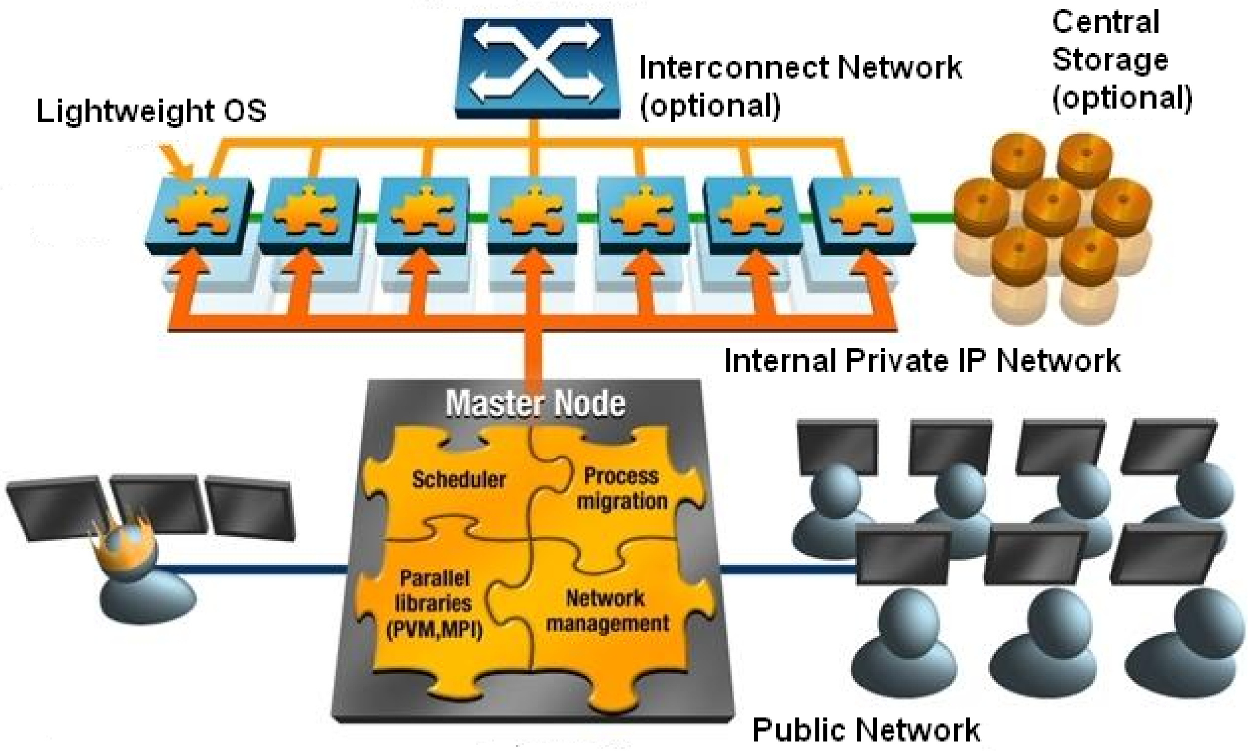

Lightweight OS
Interconnect Network (optional)
Central Storage (optional)
Internal Private IP Network
Master Node
Scheduler
Process migration
Parallel libraries (PVM,MPI)
Network management
Public Network

Figure 1. Cluster Configuration

The master node and compute nodes have different roles in Scyld ClusterWare, and thus they have different hardware requirements. The master node is the central administration console for the cluster; it is the machine that all users of the cluster log into for starting their jobs. The master node is responsible for sending these jobs out to the appropriate compute node(s) for execution. The master node also performs all the standard tasks of a Linux machine, such as queuing print jobs or running shells for individual users.

Master Node

Given the role of the master node, it is easy to see why its hardware closely resembles that of a standard Linux machine. The master node will typically have the standard human user interface devices such as a monitor, keyboard, and mouse. It may have a fast 3D video card, depending on the cluster's application.

The master is usually equipped with two network interface cards (NICs). One NIC connects the master to the cluster's compute nodes over the private cluster network, and the other NIC connects the master to the outside world.

The master should be equipped with enough hard disk space to satisfy the demands of its users and the applications it must execute. The Linux operating system and Scyld ClusterWare together use about 7 GB of disk space. We recommend at least a 20 GB hard disk for the master node.

The master node should contain a minimum of 2 GB of RAM, or enough RAM to avoid swap during normal operations; a minimum of 4 GB is recommended. Having to swap programs to disk will degrade performance significantly, and RAM is relatively cheap.

Any network attached storage should be connected to both the private cluster network and the public network through separate interfaces.

In addition, if you plan to create boot CDs for your compute nodes, the master node requires a CD-RW or writeable DVD drive.

Compute Nodes

In contrast to the master node, the compute nodes are single-purpose machines. Their role is to run the jobs sent to them by the master node. If the cluster is viewed as a single large-scale parallel computer, then the compute nodes are its CPU and memory resources. They don't have any login capabilities, other than optionally accepting ssh connections from the master node, and aren't running many of the daemons typically found on a standard Linux box. These nodes don't need a monitor, keyboard, or mouse.

Video cards aren't required for compute nodes either (but may be required by the BIOS). However, having an inexpensive video card installed may prove cost effective when debugging hardware problems.

To facilitate debugging of hardware and software configuration problems on compute nodes, Scyld ClusterWare provides forwarding of all kernel log messages to the master's log, and all messages generated while booting a compute node are also forwarded to the master node. Another hardware debug solution is to use a serial port connection back to the master node from the compute nodes. The kernel command line options for a compute node can be configured to display all boot information to the serial port. See *Compute node command-line options* or details about the *console=* configuration setting..

Compute node RAM requirements are dependent upon the needs of the jobs that execute on the node. Compute node physical memory is shared between its RAM-based root filesystem (*rootfs*) and the runtime memory needs of user applications and the kernel itself. As more space is consumed by the root filesystem for files, less physical memory is available to applications' virtual memory and kernel physical memory, a shortage of which leads to Out-Of-Memory (*OOM*) events that result in application failure(s) and potentially total node failure.

Various remedies exist if the workloads fill the root filesystem or trigger Out-Of-Memory events, including adding RAM to the node and/or adding a local harddrive, which can be configured to add adequate swap space (which expands the available virtual memory capacity) and/or to add local filesystems (to reduce the demands on the RAM-based root filesystem). Even if local swap space is available and sufficient to avoid OOM events, optimal performance will only be achieved when there is sufficient physical memory to avoid swapping in the first place. See *Compute Node Failure* for a broader discussion of node failures, and *Compute node command-line options* for a discussion of the *rootfs_size=* configuration setting that limits the maximum size of the root filesystem.

A harddrive is not a required component for a compute node. If employed, we recommend using such local storage for data that can be easily re-created, such as swap space, scratch storage, or local copies of globally-available data.

If the compute nodes do not support PXE boot, a bootable CD-ROM drive is required.

Network Topologies

For many applications that will be run on Scyld ClusterWare, an inexpensive Ethernet network is all that is needed. Other applications might require multiple networks to obtain the best performance; these applications generally fall into two categories, “message intensive” and “server intensive”. The following sections describe a minimal network configuration, a performance network for “message intensive” applications, and a server network for “server intensive” applications.

Minimal Network Configuration

Scyld ClusterWare requires that at least one IP network be installed to enable master and compute node communications. This network can range in speed from 10 Mbps (Fast Ethernet) to over 1 Gbps, depending on cost and performance requirements.

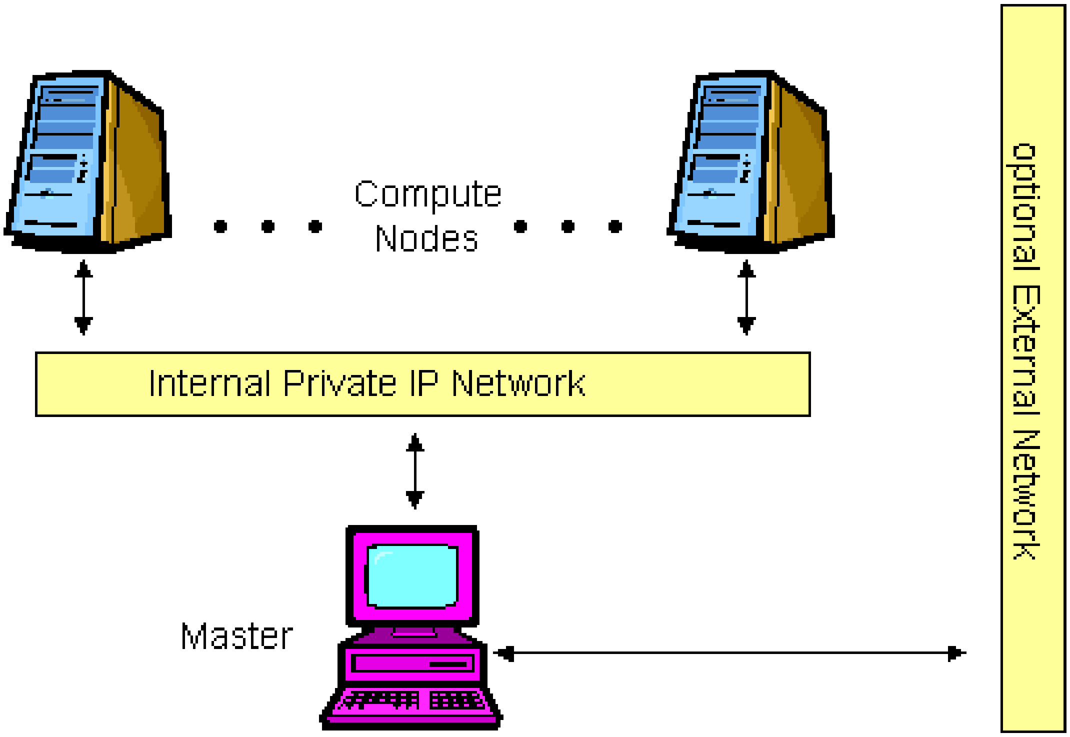


Figure 2. Minimal Network Configuration

Performance Network Configuration

The performance network configuration is intended for applications that can benefit from the low message latency of proprietary networks like Infiniband, TOE Ethernet, or RDMA Ethernet. These networks can optionally run without the overhead of an IP stack with direct memory-to-memory messaging. Here the lower bandwidth requirements of the Scyld software can be served by a standard IP network, freeing the other network from any OS-related overhead completely.

It should be noted that these high performance interfaces may also run an IP stack, in which case they may also be used in the other configurations as well.

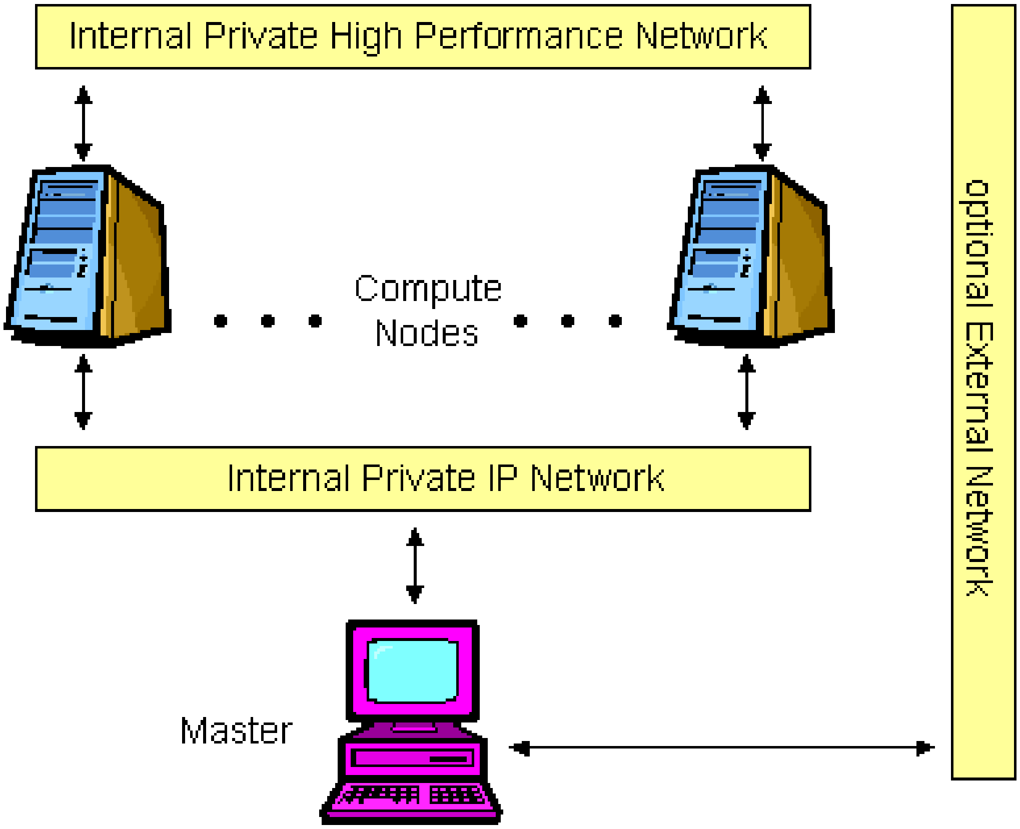

Internal Private High Performance Network
Compute
Nodes
Internal Private IP Network
Master
optional External Network

Figure 3. Performance Network Configuration

Server Network Configuration

The server network configuration is intended for web, database, or application servers. In this configuration, each compute node has multiple network interfaces, one for the private control network and one or more for the external public networks.

The Scyld ClusterWare security model is well-suited for this configuration. Even though the compute nodes have a public network interface, there is no way to log into them. There is no `/etc/passwd` file or other configuration files to hack. There are no shells on the compute nodes to execute user programs. The only open ports on the public network interface are the ones your specific application opened.

To maintain this level of security, you may wish to have the master node on the internal private network only. The setup for this type of configuration is not described in this document, because it is very dependent on your target deployment. Contact Scyld's technical support for help with a server network configuration.

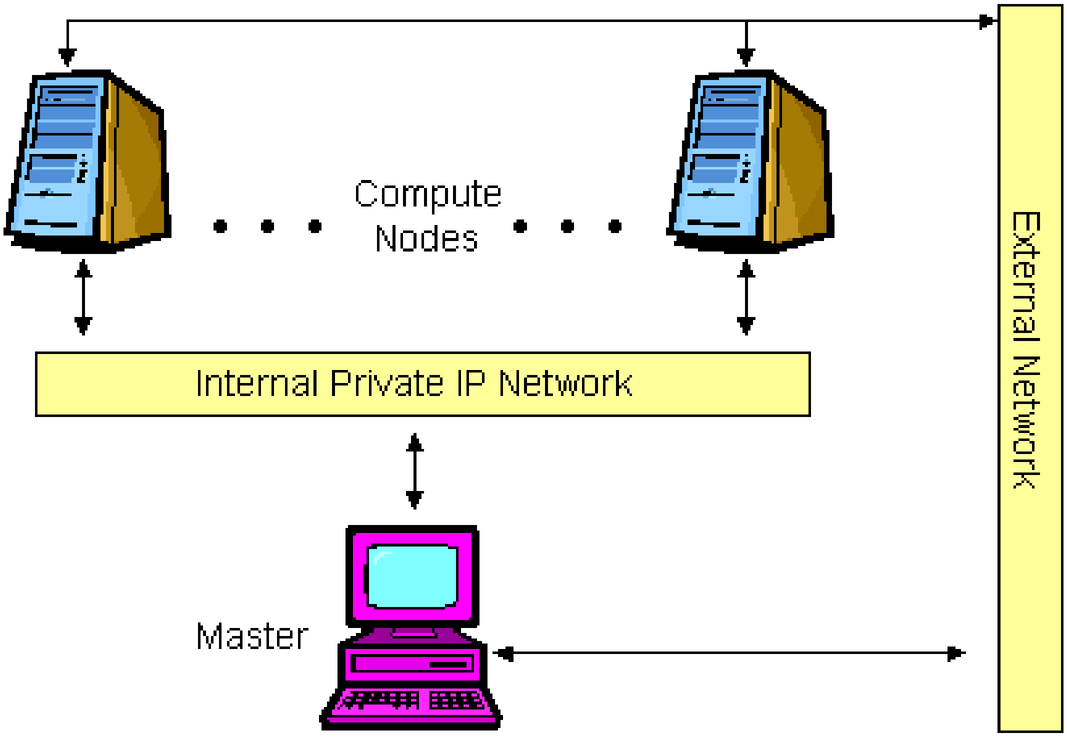


Figure 4. Server Network Configuration

System Data Flow

The following data flow diagram shows the primary messages sent over the private cluster network between the master node and compute nodes in a Scyld cluster. Data flows in three ways:

- From the master node to the compute nodes
- From the compute nodes to the master node
- From the compute nodes to other compute nodes

The job control commands and cluster admin commands shown in the data flow diagram represent inputs to the master from users and administrators.

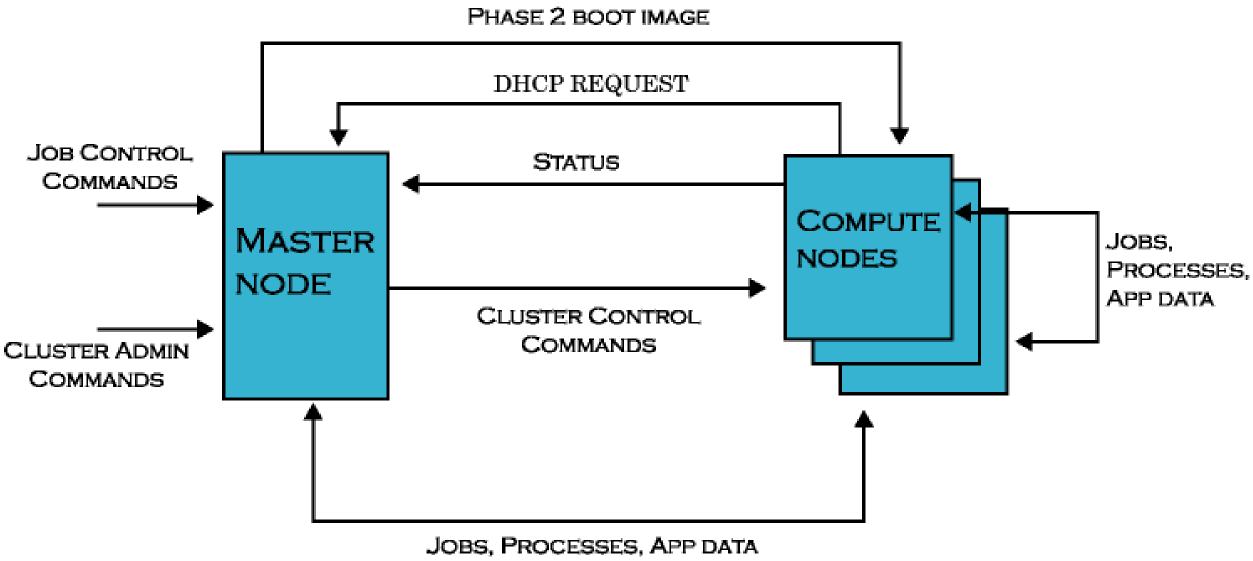


Figure 5. Scyld ClusterWare Data Flow Diagram

Master Node to Compute Node

Following is a list of the data items sent from the master node to a compute node, as depicted in the data flow diagram.

- *Cluster control commands* — These are the commands sent from the master to the compute node telling it to perform such tasks as rebooting, halting, powering off, etc.
- *Files to be cached* — The master node send the files to be cached on the compute nodes under Scyld JIT provisioning.
- *Jobs, processes, signals, and app data* — These include the process snapshots captured by `Beowulf` for migrating processes between nodes, as well as the application data sent between jobs. `Beowulf` is the collection of software that makes up Scyld, including `beoserv` for PXE/DHCP, `BProc`, `beomap`, `beonss`, and `beostat`.
- *Final boot images* — The final boot image (formerly called the Phase 2 boot image) is sent from the master to a compute node in response to its Dynamic Host Configuration Protocol (DHCP) requests during its boot procedure.

Compute Node to Master Node

Following is a list of the data items sent from a compute node to the master node, as depicted in the data flow diagram.

- *DHCP and PXE requests* — These requests are sent to the master from a compute node while it is booting. In response, the master replies back with the node's IP address and the final boot image.
- *Jobs, processes, signals, and app data* — These include the process snapshots captured by `Beowulf` for migrating processes between nodes, as well as the application data sent between jobs.
- *Performance metrics and node status* — All the compute nodes in a Scyld cluster send periodic status information back to the master.

Compute Node to Compute Node

Following is a list of the data items sent between compute nodes, as depicted in the data flow diagram.

- *Jobs, processes, app data* — These include the process snapshots captured by `Beowulf` for migrating processes between nodes, as well as the application data sent between jobs.

System Software Context

The following diagram illustrates the software components available on the nodes in a Scyld cluster.

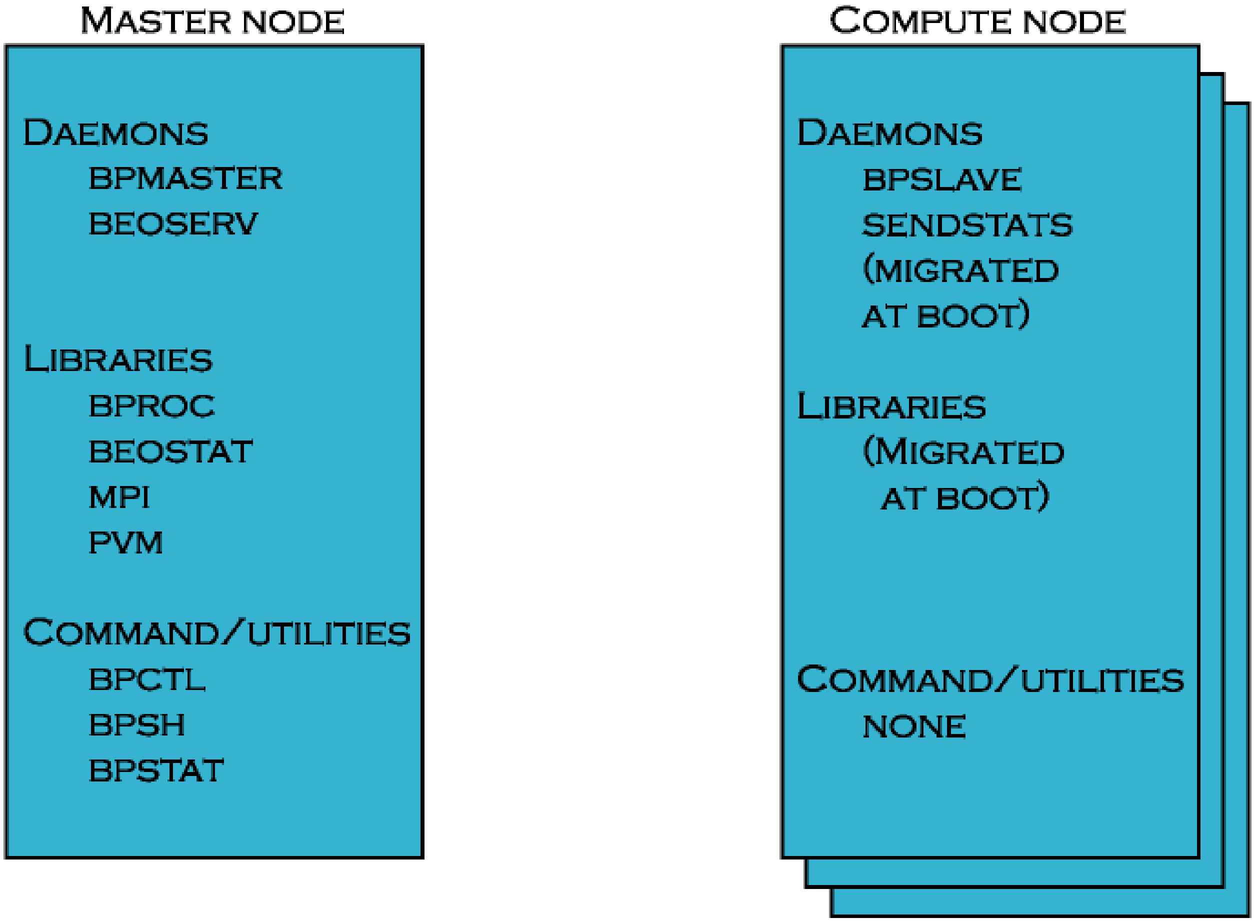


Figure 6. System Software Context Diagram

Master Node Software Components

The master node runs the `bpmaster`, `beoserv`, and `recvstats` daemons. This node also stores the Scyld-specific libraries `libbproc` and `libbeostat`, as well as Scyld-modified versions of utilities such as MPICH, LAM, and PVM. The commands and utilities are a small subset of all the software tools available on the master node.

Compute Node Software Components

The compute nodes run the `beoclient` daemon, which serves as the init process on the compute nodes, and run the Scyld `beoklogd`, `bpslave`, and `sendstats` daemons:

- `beoklogd` is run as soon as the compute node establishes a network connection to the master node, ensuring that the master node begins capturing compute node kernel messages as early as possible.

- `bpslave` is the compute node component of `BProc`, and is necessary for supporting the unified process space and for migrating processes.
- `sendstats` is necessary for monitoring the load on the compute node and for communicating the data to the master node's `recvstats` daemon.
- `kickbackproxy` communicates with the master node's `kickbackdaemon` daemon to retrieve Name Service (NSS) information from the master node, e.g., hostnames and user names.

In general, minimal binaries reside on compute nodes, thus minimizing space consumed in a node's RAM filesystem. By default, the directories that contain common commands (e.g., `/usr/bin`) are NFS-mounted. User applications are migrated from the master node to a compute node at run-time, using a command such as `bpsh`, or are accessed using an NFS mount. Libraries are pulled to a compute node on demand, as needed.

System Level Files

The following sections briefly describe the system level files found on the master node and compute nodes in a Scyld cluster.

Master Node Files

The file layout on the master node is the layout of the base Linux distribution. For those who are not familiar with the file layout that is commonly used by Linux distributions, here are some things to keep in mind:

- `/bin`, `/usr/bin` — directories with user level command binaries
- `/sbin`, `/usr/sbin` — directories with administrator level command binaries
- `/lib`, `/usr/lib` — directories with static and shared libraries
- `/usr/include` — directory with include files
- `/etc` — directory with configuration files
- `/var/log` — directory with system log files
- `/var/beowulf` — directory with various ClusterWare image and status files
- `/usr/share/doc` — directory with various documentation files

Scyld ClusterWare also has some special directories and files on the master node that are useful to know about. The per-node boot logs are stored in `/var/log/beowulf/node.`*N*, where *N* is the node number. The master node's kernel and syslog messages are received by the `syslog` or `rsyslog` service, which appends these log messages to the master's `/var/log/messages` file. By default, each compute node's kernel and syslog messages are forwarded to the master node's logging service and are also appended to the same `/var/log/messages`. However, the compute node logging can be optionally forwarded to the `syslog` or `rsyslog` service on another server. See the *syslog_server=* option in *Compute node command-line options* for details.

The legacy behavior of the the compute node's syslog handling has been to introduce a date-time string to the message text, then forward the message to the syslog server (typically on the master node), which would add its own date-time string. This redundant timestamp violates the RFC 3164 format standard, and recent ClusterWare releases strips the compute node's timestamp before sending the text to the master server. If for some reason a local cluster administrator wishes to revert to the previous behavior, then edit the `/etc/beowulf/config`'s *kernelcommandline* directive to add *legacy_syslog=1*.

Configuration files for Scyld ClusterWare are found in `/etc/beowulf/`. The directory `/usr/lib/beoboot/bin/` contains various scripts that are used to configure compute nodes during boot, including the `node_up` and `setup_fs` scripts.

For more information on the special directories, files, and scripts used by Scyld ClusterWare, see *Special Directories, Configuration Files, and Scripts*. Also see the *Reference Guide*.

Compute Node Files

Only a very few files exist on the compute nodes. For the most part, these files are all dynamic libraries; there are almost no actual binaries. For a detailed list of exactly what files exist on the compute nodes, see *Special Directories, Configuration Files, and Scripts*.

4.2.2 Technical Description

The following sections discuss some of the technical details of a Scyld cluster, such as the compute node boot procedure, the `BProc` distributed process space and `Beowulf` process migration software, compute node categories and states, and miscellaneous components.

Compute Node Boot Procedure

The Scyld cluster architecture is designed around light-weight provisioning of compute nodes using the master node's kernel and Linux distribution. Network booting ensures that what is provisioned to each compute node is properly version-synchronized across the cluster.

Earlier Scyld distributions supported a 2-phase boot sequence. Following PXE boot of a node, a fixed Phase 1 kernel and initial RAM disk (`initrd`) were copied to the node and installed. Alternatively, this Phase 1 kernel and `initrd` were used to boot from local hard disk or removable media. This Phase 1 boot package then built the node root filesystem `rootfs` in RAM disk, requested the run-time (Phase 2) kernel and used 2-Kernel-Monte to switch to it, then loaded the Scyld daemons and initialized the `BProc` system. Means were provided for installing the Phase 1 boot package on local hard disk and on removable floppy and CD media.

Beginning with Scyld 30-series, PXE is the supported method for booting nodes into the cluster. For some years, all servers produced have supported PXE booting. For servers that cannot support PXE booting, Scyld ClusterWare provides the means to easily produce Etherboot media on CD to use as compute node boot media. ClusterWare can also be configured to boot a compute node from a local disk. See *Special Directories, Configuration Files, and Scripts*.

The Boot Package

The compute node boot package consists of the kernel, `initrd`, and `rootfs` for each compute node. The `beoboot` command builds this boot package.

By default, the kernel is the one currently running on the master node. However, other kernels may be specified to the `beoboot` command and recorded on a node-by-node basis in the Beowulf configuration file. This file also includes the kernel command line parameters associated with the boot package. This allows each compute node to potentially have a unique kernel, `initrd`, `rootfs`, and kernel command lines.

> **Caution**
>
> Note that if you specify a different kernel to boot specific compute nodes, these nodes cannot be part of the `BProc` unified process space.

The path to the `initrd` and `rootfs` are passed to the compute node on the kernel command line, where it is accessible to the booting software.

Each time the ClusterWare service restarts on the master node, the `beoboot` command is executed to recreate the default compute node boot package. This ensures that the package contains the same versions of the components as are running on the master node.

Booting a Node

A compute node begins the boot process by sending a PXE request over the cluster private network. This request is handled by the beoserv daemon on the master node, which provides the compute node with an IP address and (based on the contents of the Beowulf configuration file) a kernel and initrd. If the cluster config file does not specify a kernel and initrd for a particular node, then the defaults are used.

The cluster config file specifies the path to the kernel, the initrd, and the rootfs. The initrd contains the minimal set of programs for the compute node to establish a connection to the master and request additional files. The rootfs is an archive of the root filesystem, including the filesystem directory structure and certain necessary files and programs, such as the bproc, filecache, and task_packer kernel modules and bpslave daemon.

The beoserv daemon logs its dialog with the compute node, including its MAC address, all of the node's requests, and the responses. This facilitates debugging of compute node booting problems.

The initrd and beoclient

Once the initrd is loaded, control is transferred to the kernel. Within the Scyld architecture, booting is tightly controlled by the compute node's beoclient daemon, which also serves as the compute node's init process. The beoclient daemon uses configuration files and executable binaries in the initrd and initial root filesystem to load the the necessary kernel modules to establish the TCP/IP connection back to the master node and basic access to local harddrives, and starts various other daemons, such as beoklogd, which serves as the node's local system log server to forward kernel and syslog messages (prefixed with the identify of the compute node) to the cluster's syslog server, and the bpslave daemon. Once beoclient has initialized this basic BProc functionality, then the remaining boot sequence is directed by and controlled by the master node through the node_up and setup_fs scripts and various configuration files, bootstrapping on top of the BProc functionality now executing on the node.

The beoklogd daemon normally forwards the kernel and syslog messages from the compute node to the master node's syslog or rsyslog service. However, this compute node logging can be optionally directed to an alternate server. See the *syslog_server=* option in *Compute node command-line options* for details. To facilitate debugging node booting problems, the kernel logging daemon on a compute node is started as soon as the network driver is loaded and the network connection to the syslog server is established.

The rootfs

Once the network connection to the master node is established and kernel logging has been started, beoclient requests the rootfs archive, using the path passed on the kernel command line. beoserv provides the rootfs tarball, which is then uncompressed and expanded into a RAM disk.

bpslave

The bpslave daemon establishes a connection to bpmaster on the master node, and indicates that the compute node is ready to begin accepting work. bpmaster then launches the node_up script, which runs on the master node but completes initialization of the compute node using the BProc commands (bpsh, bpcp, and bpctl).

BProc Distributed Process Space

Scyld Beowulf is able to provide a single system image through its use of BProc, the Scyld process space management kernel enhancement. BProc enables the processes running on cluster compute nodes to be visible and manageable on the master node. Processes start on the master node and are migrated to the appropriate compute node by BProc process migration code. Process parent-child relationships and UNIX job control information are maintained with the migrated jobs, as follows:

- All processes appear in the master node's process table.
- All standard UNIX signals (kill, suspend, resume, etc.) can be sent to any process on a compute node from the master.
- The *stdin*, *stdout* and *stderr* output from jobs is redirected back to the master through a socket.

`BProc` is one of the primary features that makes a Scyld cluster different from a traditional Beowulf cluster. It is the key software component that makes compute nodes appear as attached computational resources to the master node. The figure below depicts the role `BProc` plays in a Scyld cluster.

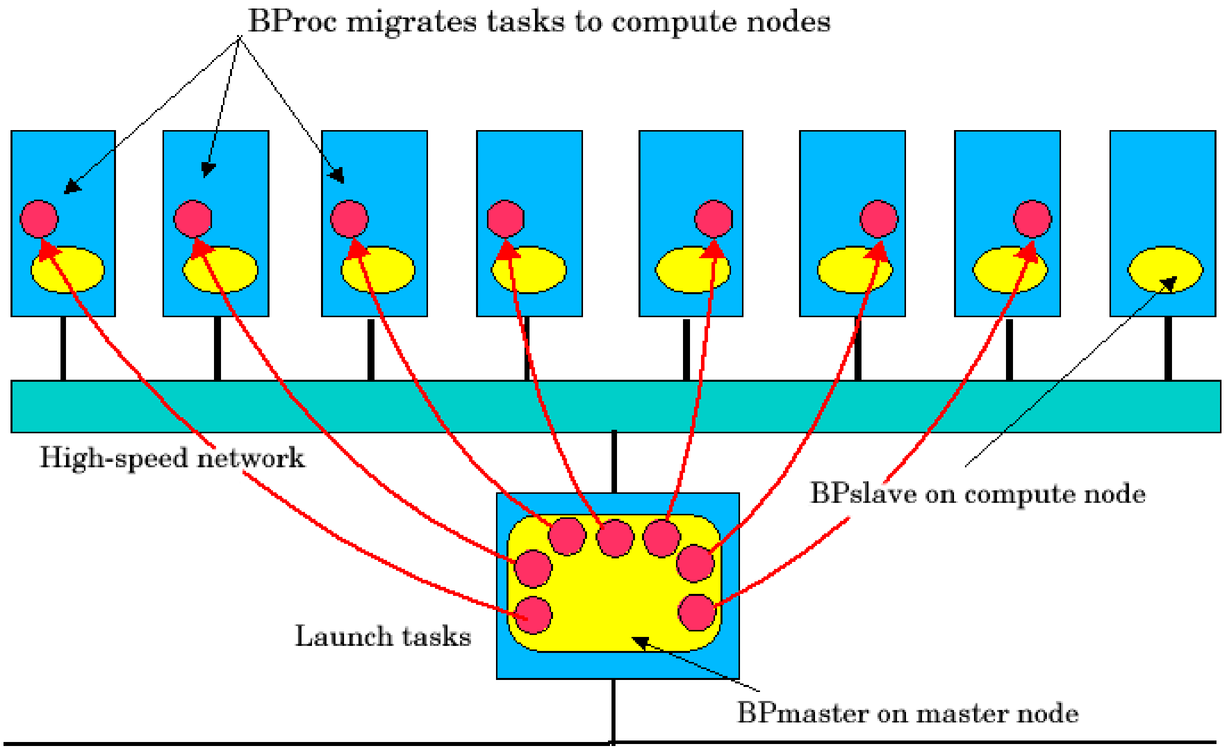


Figure 7. BProc Data Flows in a Scyld Cluster

`BProc` itself is divided into three components:

- `bpmaster` — a daemon program that runs on the master node at all times
- `bpslave` — a daemon program that runs on each of the compute nodes
- `libbproc` — a library that provides a user programming interface to BProc runtime intrinsics.

The user of a Scyld cluster will never need to directly run or interact with these daemons. However, their presence greatly simplifies the task of running parallel jobs with Scyld ClusterWare.

The `bpmaster` daemon uses a process migration module (`VMADump` in older Scyld systems or `TaskPacker` in newer Scyld systems) to freeze a running process so that it can be transferred to a remote node. The same module is also used by the `bpslave` daemon to thaw the process after it has been received. In a nutshell, the process migration module saves or restores a process's memory space to or from a stream. In the case of `BProc`, the stream is a TCP socket connected to the remote machine.

`VMADump` and `TaskPacker` implement an optimization that greatly reduces the size of the memory space required for storing a frozen process. Most programs on the system are dynamically linked; at run-time, they will use `mmap` to map copies of various libraries into their memory spaces. Since these libraries are *demand* paged, the entire library is always mapped even if most of it will never be used. These regions must be included when copying a process's memory space and included again when the process is restored. This is expensive, since the C library dwarfs most programs in size.

For example, the following is the memory space for the program `sleep`. This is taken directly from `/proc/pid/maps`.

```
08048000-08049000 r-xp 00000000 03:01 288816     /bin/sleep
08049000-0804a000 rw-p 00000000 03:01 288816     /bin/sleep
40000000-40012000 r-xp 00000000 03:01 911381     /lib/ld-2.1.2.so
40012000-40013000 rw-p 00012000 03:01 911381     /lib/ld-2.1.2.so
40017000-40102000 r-xp 00000000 03:01 911434     /lib/libc-2.1.2.so
40102000-40106000 rw-p 000ea000 03:01 911434     /lib/libc-2.1.2.so
40106000-4010a000 rw-p 00000000 00:00 0
bfffe000-c0000000 rwxp fffff000 00:00 0
```

The total size of the memory space for this trivial program is 1,089,536 bytes; all but 32K of that comes from shared libraries. `VMADump` and `TaskPacker` take advantage of this; instead of storing the data contained in each of these regions, they store a reference to the regions. When the image is restored, `mmap` will map the appropriate files to the same memory locations.

In order for this optimization to work, `VMADump` and `TaskPacker` must know which files to expect in the location where they are restored. The `bplib` utility is used to manage a list of files presumed to be present on remote systems.

Compute Node Categories

Each compute node in the cluster is classified into one of three categories by the master node: "configured", "ignored", or "unknown". The classification of a node is dictated by whether or where it is listed in one of the following files:

- The cluster config file `/etc/beowulf/config` (includes both "configured" and "ignored nodes")
- The unknown addresses file `/var/beowulf/unknown_addresses` (includes "unknown" nodes only)

When a compute node completes its initial boot process, it begins to send out DHCP requests on all the network interface devices that it finds. When the master node receives a DHCP request from a new node, the new node will automatically be added to the cluster as "configured" until the maximum configured node count is reached. After that, new nodes will be classified as "ignored". Nodes will be considered "unknown" only if the cluster isn't configured to auto-insert or auto-append new nodes.

The cluster administrator can change the default node classification behavi by manually editing the `/etc/beowulf/config` file (discussed in *Configuring the Cluster Manually*). The classification of any specific node can also be changed manually by the cluster administrator. Also see *Special Directories, Configuration Files, and Scripts* to learn about special directories, configuration files, and scripts.

Following are definitions of the node categories.

Configured A "configured" node is one that is listed in the cluster config file `/etc/beowulf/config` using the *node* tag. These are nodes that are formally part of the cluster, and are recognized as such by the master node. When running jobs on your cluster, the "configured" nodes are the ones actually used as computational resources by the master.

Ignored An "ignored" node is one that is listed in the cluster config file `/etc/beowulf/config` using the *ignore* tag. These nodes are not considered part of the cluster, and will not receive the appropriate responses from the master during their boot process. New nodes that attempt to join the cluster after it has reached its maximum configured node count will be automatically classified as "ignored".

The cluster administrator can also classify a compute node as "ignored" if for any reason you'd like the master node to simply ignore that node. For example, you may choose to temporarily reclassify a node as "ignored" while performing hardware maintenance activities when the node may be rebooting frequently.

Unknown An "unknown" node is one not formally recognized by the cluster as being either "configured" or "ignored". When the master node receives a DHCP request from a node not already listed as "configured" or "ignored" in the cluster configuration file, and the cluster is not configured to auto-insert or auto-append new nodes, it classifies the node as "unknown". The node will be listed in the `/var/beowulf/unknown_addresses` file.

Compute Node States

Cluster compute nodes may be in any of several functional states, such as *down*, *up*, or *unavailable*. Some of these states are transitional (*boot* or *shutdown*); some are informational variants of the *up* state (*unavailable* and *error*). `BProc` actually handles only 3 node operational variations:

- The node is not communicating — *down*. Variations of the *down* state may record the reason, such as *halted* (known to be halted by the master) or *reboot* (the master shut down the node with a reboot command).
- The node is communicating — *up*, *[up]*, *alive*, *unavailable*, or *error*. Here the strings indicate different levels of usability.
- The node is transitioning — *boot*. This state has varying levels of communication, operating on scripted sequence.

During a normal power-on sequence, the user will see the node state change from *down* to *boot* to *up*. Depending on the machine speed, the *boot* phase may be very short and may not be visible due to the update rate of the cluster monitoring tools. All state information is reset to *down* whenever the `bpmaster` daemon is started/restarted.

In the following diagram, note that these states can also be reached via imperative commands such as `bpctl`. This command can be used to put the node into the *error* state, such as in response to an error condition detected by a script.

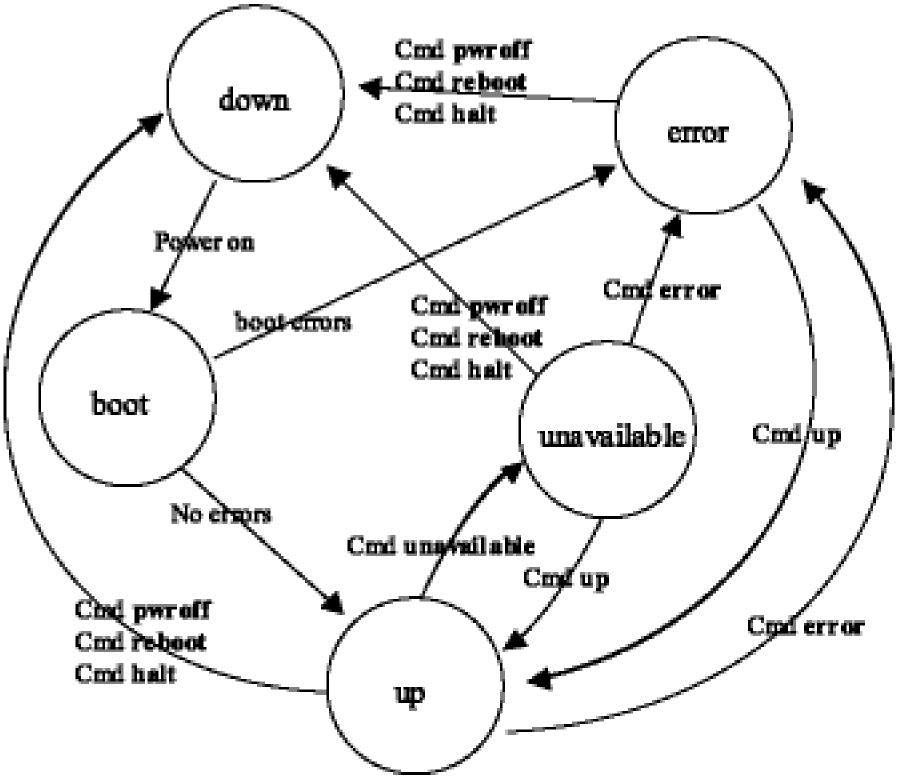


Figure 8. Node State Transition Diagram

Following are definitions of the compute node states:

`down` From the master node's view, *down* means only that there is no communication with the compute node. A node is *down* when it is powered off, has been halted, has been rebooted, has a network link problem, or has some other hardware problem that prevents communication.

`boot` This is a transitional state, during which the node will not accept user commands. The *boot* state is set when the `node_up` script has started and will transition to *up* or *error* when the script has completed. While in the *boot* state, the node will respond to administrator commands, but indicates that the node is still being configured for normal operation. The duration of this state varies with the complexity of the `node_up` script.

`up` This is a functional state, set when the `node_up` script has completed without encountering any errors. `BProc` checks the return status of the script and sets the node state to *up* if the script was successful. This is the only state where the node is available to non-administrative users, as `BProc` checks this before moving any program to a node; administrator programs bypass this check. This state may also be commanded when the previous state was *unavailable* or *error*.

`error` This is an informational state, set when the `node_up` script has exited with errors. The administrator may access the node, or look in the `/var/log/beowulf/node.`*x* (where *x* is a node number) file to determine the problem. If a problem is seen to be non-critical, the administrator may then set the node to *up*.

`unavailable` This is a functional state. The node is not available for non-administrative users; however, it is completely available to the administrator. Currently running jobs will not be affected by a transition to this state. With respect to job control, this state comes into play only when attempting to run new jobs, as new jobs will fail to migrate to a node marked *unavailable*. This state is intended to allow node maintenance without having to bring the node offline.

`[up]` This Scyld ClusterWare node is *up* and is being actively managed by another master node, which for now is the node's primary master. The secondary master node(s) see the node as *[up]*. A secondary master can ssh to the node (if ssh is enabled), but the node only responds to `BProc` commands from its primary master (e.g., `bpsh` and `bpcp`). See *Managing Multiple Master Nodes* for details.

`alive` This non-Scyld node is alive to the extent that it is running the `sendstats` daemon to report various `/proc` statistics about the node state, and it is integrated as a compute node in the cluster. For example, the Job Manager may be able to run jobs on this node. See *Managing Non-Scyld Nodes* for details.

Miscellaneous Components

Scyld ClusterWare includes several miscellaneous components, such as name lookup functionality (`beonss`), IP communications ports, library caching, and external data access.

beonss

`beonss` provides name service lookup functionality for Scyld ClusterWare. The information it provides includes hostnames, netgroups, and user information. In general, whatever name service information is available to the master node, using whatever query methods available to the master node (e.g., NIS, LDAP), is also transparently available to the compute nodes through the `beonss` functionality. The Scyld ClusterWare installation automatically (and silently) configures `beonss`.

`Hostnames` `beonss` provides dynamically generated hostnames for all the nodes in the cluster. The hostnames are of the form *.<nodenumber>*, so the hostname for node 0 would be *.0*, the hostname for node 50 would be *.50*, and the hostname for the master node would be *.-1*.

The *nodename* entries in the `/etc/beowulf/config` file allow for the declaration of additional hostname aliases for compute nodes. For instance,

```
nodename n%N
```

declares aliases for nodes, e.g., *n4* is an alias for node *.4*. For another example, suppose the IP address of node 4 is 10.0.0.4, and suppose that node 4 has its IPMI interface configured to respond to the IP address 10.1.0.4. Then the line:

```
nodename n%N-ipmi 0.1.0.0 ipmi
```

declares aliases for the hostnames in the group called *ipmi*. The hostname *n4-ipmi* is the arithmetic sum of *n4*‘s IP address 10.1.0.4 plus the offset 0.1.0.0, forming the IP address 10.1.0.4. See `man beowulf-config` and the comments in the file `/etc/beowulf/config` for details and other examples.

`beonss` also provides the hostname *master*, which always points to the IP of the master node on the cluster's internal network. The hostnames *.-1* and *master* always point to the same IP.

These hostnames will always point to the right IP address based on the configuration of your IP range. You don't need to do anything special for these hostnames to work. Also, these hostnames will work on the master node or any of the compute nodes.

Note that `beonss` does not know the hostname and IP address that the master node uses for the outside network. Suppose your master node has the public name *mycluster* and uses the IP address 1.2.3.4 for the outside network. By default, a compute node on the private network will be unable to open a connection to *mycluster* or to 1.2.3.4. However, by enabling IP forwarding in both the `/etc/beowulf/config` file and the `/etc/sysctl.conf` file, compute nodes can resolve hostnames and access hosts that are accessible by the master through the master's public network interface, provided you have your DNS services working and available on the compute nodes.

> **Tip**
>
> When you enable IP forwarding, the master node will set up NAT routing between your compute nodes and the outside world, so your compute nodes will be able to make outbound connections. However, this does not enable outsiders to access or "see" your compute nodes.
>
> **Caution**
>
> On compute nodes the NFS directories must be mounted using either the NFS server's IP address or the "$MASTER" keyword, as is specified in the `/etc/beowulf/fstab` file. Hostnames cannot be used because the compute node's NFS mounting is performed before the node's name service is active, which would otherwise be able to translate a hostname to its IP address.

`Netgroups` Netgroups are a concept from NIS. They make it easy to specify an arbitrary list of machines, then treat all those machines the same when carrying out an administrative procedure (for example, specifying what machines to export NFS filesystems to).

`beonss` creates one netgroup called *cluster*, which includes all of the nodes in the cluster. This is used in the default `/etc/exports` file in order to easily export `/home` to all of the compute nodes.

`User Information` When jobs are running on the compute nodes, `beonss` allows the standard `getpwnam()` and `getpwuid()` functions to successfully retrieve information (such as username, home directory, shell, and uid), as long as these functions are retrieving information on the user that is running the program. All other information that `getpwnam()` and `getpwuid()` would normally retrieve will be set to "NULL".

IP Communications Ports

Scyld ClusterWare uses a few TCP/IP and UDP/IP communication ports when sending information between nodes. Normally, this should be completely transparent to the user. However, if the cluster is using a switch that blocks various ports, it may be important to know which ports are being used and for what.

Following are key components of Scyld ClusterWare and the ports they use:

- beoserv — This daemon is responsible for replying to the DHCP request from a compute node when it is booting. The reply includes a new kernel, the kernel command line options, and a small final boot RAM disk. The daemon supports both multi-cast and uni-cast file serving.

  By default, beoserv uses TCP port 932. This can be overridden by changing the value of the *server beofs2* directive (formerly *server tcp*, which is deprecated but continues to be accepted) in the /etc/beowulf/config file to the desired port number.

- BProc — This ClusterWare component provides unified process space, process migration, and remote execution of commands on compute nodes. By default, BProc uses TCP port 933. This can be overridden by changing the value of the *server bproc* directive in the /etc/beowulf/config file to the desired port number.

- BeoStat — This service is composed of compute node daemons (sendstats), a master node daemon (recvstats), and a master node library (libbeostat) that collects performance metrics and status information from compute nodes and transmits this information to the master node for cacheing and for distribution to the various cluster monitoring display tools. The daemons use UDP port 5545 by default.

Library Caching

One of the features Scyld ClusterWare uses to improve the performance of transferring jobs to and from compute nodes is to cache libraries. When BProc needs to migrate a job between nodes, it uses the process migration code (VMADump or TaskPacker) to take a snapshot of all the memory the process is using, including the binary and shared libraries. This memory snapshot is then sent across the private cluster network during process migration.

VMADump and TaskPacker take advantage of the fact that libraries are being cached on the compute nodes. The shared library data is *not* included in the snapshot, which reduces the amount of information that needs to be sent during process migration. By not sending over the libraries with each process, Scyld ClusterWare is able to reduce network traffic, thus speeding up cluster operations.

External Data Access

There are several common ways for processes running on a compute node to access data stored externally to the cluster, as discussed below.

Transfer the data. You can transfer the data to the master node using a protocol such as scp or ftp, then treat it as any other file that resides on the master node.

Access the data through a network filesystem, such as NFS or AFS. Any remote filesystem mounted on the master node can't be re-exported to the compute node. Therefore, you need to use another method to access the data on the compute nodes. There are two options:

- Use bpsh to start your job, and use shell redirection on the master node to send the data as stdin for the job
- Use MPI and have the rank 0 job read the data, then use MPI's message passing capabilities to send the data.

If you have a job that is natively using Beowulf functions, you can also have your job read the data on the master node before it moves itself to the compute nodes.

NFS mount directories from external file servers. There are two options:

- For file servers directly connected to the cluster private network, this can be done directly, using the file server's IP address. Note that the server name cannot be used, because the name service is not yet up when /etc/beowulf/fstab is evaluated.
- For file servers external to the cluster, setting up IP forwarding on the master node allows the compute nodes to mount exported directories using the file server's IP address.

Use a cluster filesystem. If you have questions regarding the use of any particular cluster filesystem with Scyld ClusterWare, contact Scyld Customer Support for assistance.

4.2.3 Software Components

The following sections describe the various software packages in Scyld ClusterWare, along with their individual components. For additional information, see the *Reference Guide*.

BeoBoot Tools

The following tools are associated with the `beoboot` package. For additional information, see the *Reference Guide*.

`BeoBoot` This utility is used to generate boot images for the compute nodes in the cluster. Earlier versions of Scyld used two types of images, initial (Phase 1) and final (Phase 2). The initial images were placed on the hard disk or a floppy disk, and were used to boot the nodes. The final image was downloaded from the master node by the initial image. Currently, only the final image is used by Scyld ClusterWare; support for initial images has been dropped.

By default, the final image is stored on the master node in the `/var/beowulf/boot.img` file; this is where the `beoserv` daemon expects to find it. Where initial images were used to begin the network boot process for systems that lacked PXE support, Scyld now provides PXELinux for this purpose. Bootable PXELinux media may be created for CD-ROM booting.

`beoserv` This is the `BeoBoot` daemon. It responds to DHCP requests from the compute nodes in the cluster and serves them their final boot images over the private cluster network.

BProc Daemons

The following daemons are associated with `BProc`. For additional information, see the *Reference Guide*.

`bpmaster` This is the `BProc` master daemon. It runs on the master node, listening on a TCP port and accepting connections from `bpslave` daemons. Configuration information comes from the `/etc/beowulf/config` file.

`bpslave` This is the `BProc` compute daemon. It runs on a compute node to accept jobs from the master, and connects to the master through a TCP port.

BProc Clients

The following command line utilities are closely related to `BProc`. For additional information, see the *Reference Guide*.

`bpsh` This is a replacement for `rsh` (remote shell). It runs a specified command on an individually referenced node. The “nodenum” parameter may be a single node number, a comma delimited list of nodes, “-a” for all nodes that are up, or “-A” for all nodes that are not down.

`bpsh` will forward standard input, standard output, and standard error for the remote processes it spawns. Standard output and error are forwarded subject to specified options; standard input will be forwarded to the remote processes. If there is more than one remote process, standard input will be duplicated for every remote node. For a single remote process, the exit status of `bpsh` will be the exit status of the remote process.

`bpctl` This is the `BProc` control utility. It can be used to apply various commands to individually referenced nodes. `bpctl` can be used to change the user and group ownership settings for a node; it can also be used to set a node’s state. Finally, this utility can be used to query such information as the node’s IP address.

bpcp This utility can be used to copy files between machines in the cluster. Each file (f1...fn) or directory argument (dir) is either a remote file name of the form *node:path*, or a local file name (containing no colon ":" characters).

bpstat This command displays various pieces of status information about the compute nodes. The display is formatted in columns specifying node number, node status, node permission, user access, and group access. This program also includes a number of options intended to be useful for scripts.

ClusterWare Utilities

Following are various command line and graphical user interface (GUI) utilities that are part of Scyld ClusterWare. For additional information, see the *Reference Guide*.

beostat The `beostat` command line tool is a text-based utility used to monitor cluster status and performance. This tool provides a text listing of the information from the `/proc` structure on each node. See *Monitoring the Status of the Cluster* for a discussion of this tool.

beostatus The `beostatus` GUI tool is used to monitor cluster status and performance. See *Monitoring the Status of the Cluster* for a discussion of this tool.

4.3 Monitoring the Status of the Cluster

Scyld ClusterWare provides several methods to monitor cluster performance and health, with a Web browser, a GUI, the command line, and "C" language interfaces. In general, these tools provide easy access to the information available through the Linux `/proc` filesystem, as well as `BProc` information for each of the cluster nodes. The monitoring programs are available to both administrators and regular users, since they provide no cluster command capabilities.

4.3.1 Monitoring Utilities

Cluster Monitoring Interfaces

Scyld ClusterWare provides several cluster monitoring interfaces. Following is brief summary of these interfaces; more detailed information is provided in the sections that follow:

- `libbeostat` — The `libbeostat` library, together with the compute nodes' `sendstats` daemons and the master node's `recvstats` daemon, provides the underpinning for the various display tools. Users can also create custom displays or create more sophisticated resource scheduling software by interfacing directly to libbeostat.
- `beostat` — The `beostat` command provides a detailed command-line display using the underlying libbeostat library. With no options, `beostat` lists information for the master node and all compute nodes that is retrieved from `/proc/cpuinfo`, `/proc/meminfo`, `/proc/loadavg`, `/proc/net/dev`, and `/proc/stat`. Alternatively, you can use the arguments to select any combination of those statistics.
- `beostatus` — The `beostatus` cluster monitoring utility uses the underlying libbeostat functionality to display CPU utilization, memory usage, swap usage, disk usage, and network utilization. It defaults to a bar graph X-window GUI, but can display the information in several text formats. For large clusters, a small footprint GUI can be selected, with colored dots depicting the overall status on each node.
- `bpstat` — This displays a text-only snapshot of the current cluster state. The bpstat utility only reports nodes that are part of the BProc unified process space, vs. beostat and beostatus, which report on all nodes (BProc and non-BProc) that execute a sendstats daemon.
- `Ganglia` — Scyld installs the popular `Ganglia` monitoring package by default, but does not configure it to execute by default. For information on configuring Ganglia, see *Ganglia*.

- beoweb — Beoweb is an optional Web service that can execute on the cluster's master node. Built with Pylons (a Python-based Web framework), beoweb exposes an API for cluster status and remote job submission and monitoring.

Monitoring Daemons

Underlying the libbeostat monitoring facility are two daemons: sendstats and recvstats. The recvstats daemon is started by the /etc/rc.d/init.d/beowulf script and only executes on the master node. A sendstats daemon executes on each compute node and sends status information at regular intervals (currently once per second) to the master's recvstats daemon. For more information on the daemon options, see man recvstats and man sendstats, or the *Reference Guide*.

The optional beoweb service employs the paster daemon on the master node. See *beoweb* for details.

4.3.2 Using the Data

The outputs from the monitoring utilities can provide insights into obtaining the best performance from your cluster. If you are new to cluster computing, you will want to note the relationship between the different machine resources, including CPU utilization, swap usage, and network utilization. Following are some useful guidelines:

- Low CPU usage with high network traffic might indicate that your system is I/O bound and could benefit from faster network components.
- Low network load and high CPU usage indicate that your system performance could improve with faster CPUs.
- Medium to high swap usage is always bad. This indicates that memory is oversubscribed, and application pieces must be moved to the much slower disk sub-system. This can be a substantial bottleneck, and is a sure sign that additional RAM is needed.

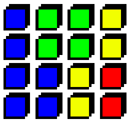
Any of these issues could be helped with application optimization, but sometimes it is more economical to add resources than to change working software.

For best performance of a computational workload, make sure your compute nodes have ample memory for the application and problem set. Also, use diskless compute nodes or configure local disks for scratch file space rather than swap space.

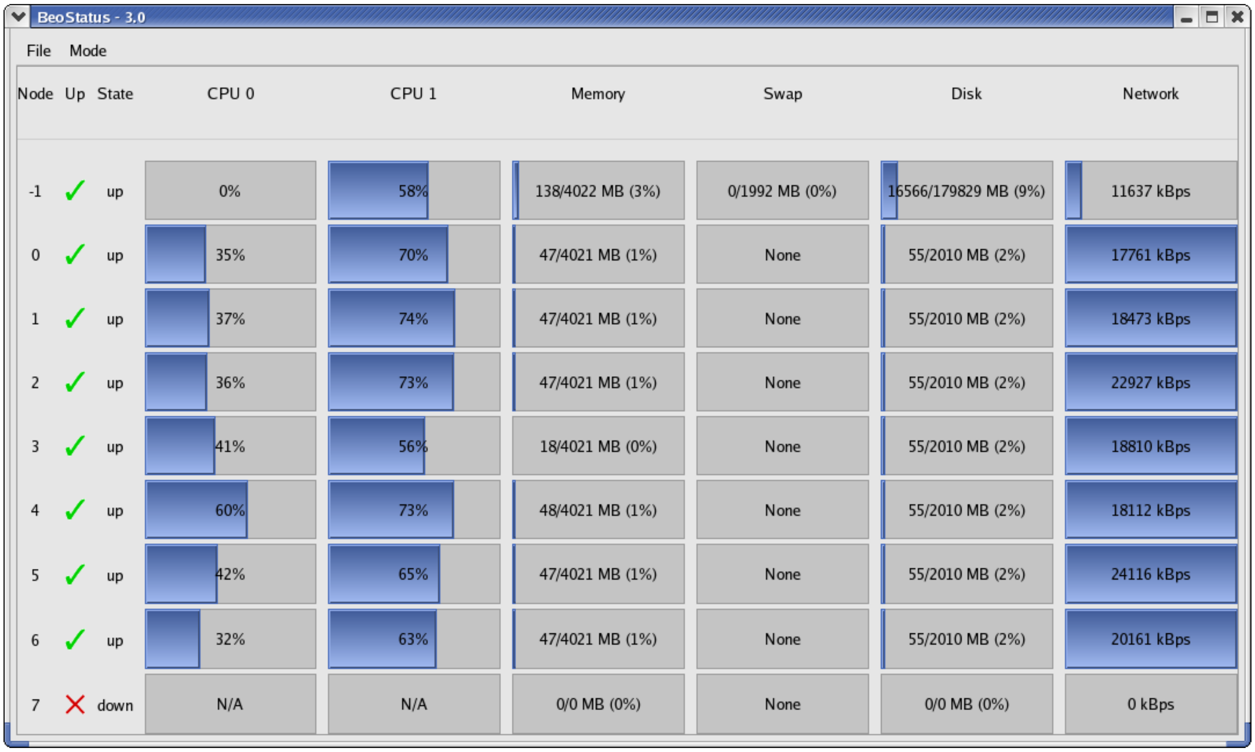
4.3.3 beostatus

The beostatus GUI display is a Gnome X-window that supports four different types of display generation, all of which can be operated simultaneously. Output in bar graph mode (also known as "Classic" mode) is the default, and is provided by a Gnome/GTK+ GUI display. This display is updated once every 5 seconds by default, but the update rate may be changed using the -u option.

You can start beostatus by clicking the "blocks" icon on the desktop.



Alternatively, type the command beostatus in a terminal window on the master node; you do not need to be a privileged user to use this command.



Node	Up	State	CPU 0	CPU 1	Memory	Swap	Disk	Network
-1	✓	up	0%	58%	138/4022 MB (3%)	0/1992 MB (0%)	16566/179829 MB (9%)	11637 kBps
0	✓	up	35%	70%	47/4021 MB (1%)	None	55/2010 MB (2%)	17761 kBps
1	✓	up	37%	74%	47/4021 MB (1%)	None	55/2010 MB (2%)	18473 kBps
2	✓	up	36%	73%	47/4021 MB (1%)	None	55/2010 MB (2%)	22927 kBps
3	✓	up	41%	56%	18/4021 MB (0%)	None	55/2010 MB (2%)	18810 kBps
4	✓	up	60%	73%	48/4021 MB (1%)	None	55/2010 MB (2%)	18112 kBps
5	✓	up	42%	65%	47/4021 MB (1%)	None	55/2010 MB (2%)	24116 kBps
6	✓	up	32%	63%	47/4021 MB (1%)	None	55/2010 MB (2%)	20161 kBps
7	✗	down	N/A	N/A	0/0 MB (0%)	None	0/0 MB (0%)	0 kBps

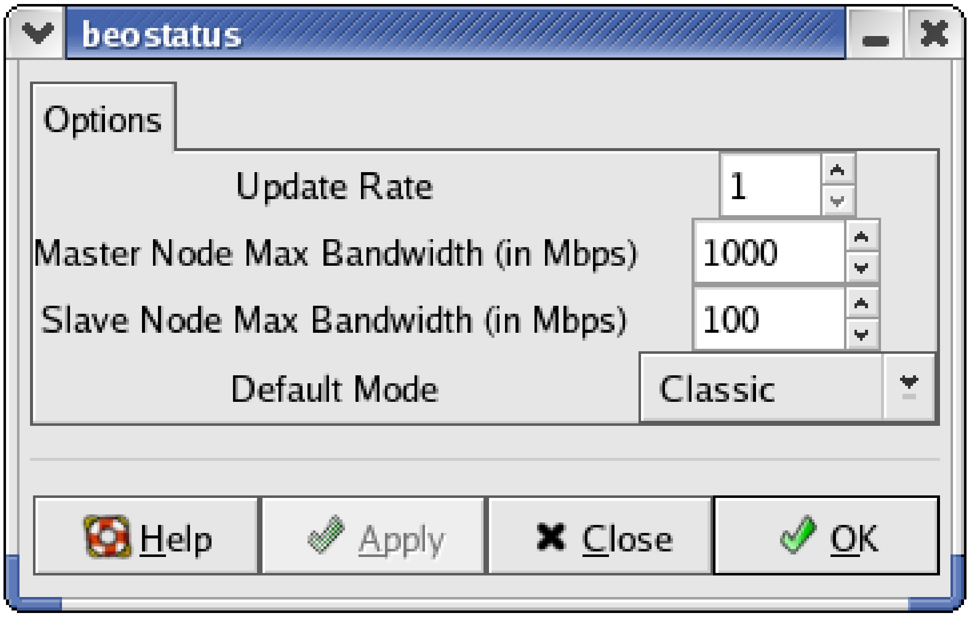
Figure 1. beostatus GUI Display (in “Classic” Mode)

beostatus File Menu

The File menu in the `beostatus` GUI display includes two options, Preferences and Quit, as described below.

Preferences

Selecting Preferences from the File menu displays the Options dialog box (shown below). You can change the values for update rate, master node maximum bandwidth, slave (compute node) maximum bandwidth, and the default display mode.



Update Rate 1
Master Node Max Bandwidth (in Mbps) 1000
Slave Node Max Bandwidth (in Mbps) 100
Default Mode Classic

Figure 2. beostatus Preference Options

Quit

Selecting Quit from the File menu closes the `beostatus` GUI display.

beostatus Modes

The Mode menu in the `beostatus` GUI display allows you to choose between the various display options.

Some display options can also be accessed using command line options, including *Dots* mode, *Curses* mode, and *Text* mode. These display options are described in the following sections.

beostatus *Dots* Mode

Output in *Dots* mode (`beostatus -d`) provides a Gnome/GTK+ GUI display. Each node is represented by a colored dot. This output provides a small "footprint", intended for quick overviews and for situations where the screen size needed for the full display for large clusters is unavailable.

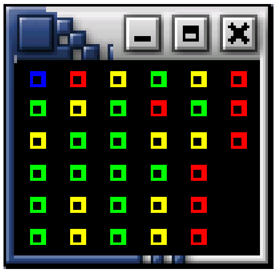


Figure 3. beostatus GUI Display in Dots Mode

Following are the color indicators used in *Dots* mode:

- `Red` — No access; node state*down*

- `Yellow` — Admin access only; node state *unavailable*, *boot*, or *error*
- `Green` — Ready; node state *up* and node load less than/equal 48%
- `Blue` — Busy; node state *up* and node load greater than 48%

Note that SMP is considered for node load calculation as load(CPU1) + load(CPU2) > 48%.

beostatus *Curses* Mode

Output in *Curses* mode (`beostatus -c`) prints a column header and a line for each node without a linefeed. This continuous output provides a method to monitor the system over text-only connections, such as the installed `ssh` server. Following is an example of the output in *Curses* mode:

```
BeoStatus - 3.0
Node    State   CPU 0   Memory  Swap    Disk    Network
 -1 up  2.5%    91.7%   0.0%    9.2%    1 kBps
  0 up  0.2%    20.5%   0.0%    25.0%   1 kBps
  1 up  0.1%    20.5%   0.0%    25.0%   1 kBps
  2 up  0.1%    20.5%   0.0%    25.0%   1 kBps
  3 up  0.2%    20.4%   0.0%    25.0%   1 kBps
  4 up  0.1%    20.3%   0.0%    25.0%   1 kBps
  5 up  0.1%    20.3%   0.0%    25.0%   1 kBps
  6 up  0.2%    20.6%   0.0%    25.0%   1 kBps
  7 up  0.1%    20.4%   0.0%    25.0%   1 kBps
```

4.3.4 beostat

The `beostat` utility is a command-line program that provides a text listing of the information from `/proc` on each node. Following is example output from a single node.

```
============== Node: .0 (index 0) ==================

 *** /proc/cpuinfo *** Tue Sep 12 14:38:04 2006
num processors  : 2
vendor_id       : AuthenticAMD
cpu family      : 15
model           : 5
model name      : AMD Opteron(tm) Processor 248
stepping        : 10
cpu MHz         : 2211.355
cache size      : 1024 KB
fdiv_bug        : no
hlt_bug         : no
sep_bug         : no
f00f_bug        : no
coma_bug        : no
fpu             : yes
fpu_exception   : yes
cpuid level     : 1
wp              : yes
bogomips        : 4422.05

 *** /proc/meminfo *** Tue Sep 12 14:38:04 2006
        total:    used:    free:  shared: buffers:  cached:
Mem:  4216758272 18960384 4197797888        0        0        0
Swap:        0        0        0
```

```
MemTotal:   4117928 kB
MemFree:    4099412 kB
MemShared:        0 kB
Buffers:          0 kB
Cached:           0 kB
SwapTotal:        0 kB
SwapFree:         0 kB

 *** /proc/loadavg *** Tue Sep 12 14:38:04 2006
0.00 0.00 0.00 28/28 0

 *** /proc/net/dev *** Tue Sep 12 14:38:04 2006
Inter-|   Receive                                                 |  Transmit
 face |bytes packets errs drop fifo frame compressed multicast | bytes packets errs drop fifo colls c
  eth0:105630479    73832        0        0        0     0          0         0  5618030  35864
  eth1:       0        0        0        0        0     0          0         0        0     0

 *** /proc/stat ***
cpu0 0 0 115 203357             Tue Sep 12 14:38:04 2006
cpu1 4 0 125 203261             Tue Sep 12 14:38:04 2006

 *** statfs ("/") *** Tue Sep 12 14:38:04 2006
path:           /
f_type:         0x1021994
f_bsize:        4096
f_blocks:       514741
f_bfree:        500311
f_bavail:       500311
f_files:        514741
f_ffree:        514630
f_fsid:         000000 000000
f_namelen:      255
```

The `libbeostat` library contains the "C" language functions listed below. You compile with the header files `sys/bproc.h` and `sys/beostat.h`, adding the linker commands `-lbproc -lbeostat`.

```
beostat-get-cpu-count
beostat-get-name
beostat-get-time
beostat-get-cpuinfo-x86
beostat-get-meminfo
beostat-get-loadavg
beostat-get-net-dev
beostat-get-stat-cpu
beostat-get-MHz
beostat-get-statfs-p
beostat-get-last-multicast
beostat-set-last-multicast
beostat-get-cpu-percent
beostat-get-net-rate
beostat-get-disk-usage
beostat-count-idle-cpus
beostat-count-idle-cpus-on-node
beostat-get-avail-nodes-by-id
beostat-is-node-available
```

4.3.5 bpstat

`bpstat` displays a text-only snapshot of the current cluster state/configuration:

```
[root@cluster ~] # bpstat
Node(s) Status  Mode        User    Group
16-31   down    ----------  root    root
0-15    up  ---x--x--x  root    root
```

You can include the master node in the display, which is especially useful if the master node has non-default access permissions:

```
[root@cluster ~] # bpstat
Node(s) Status  Mode        User    Group
16-31   down    ----------  root    root
-1  up  ---x--x---  root    root
0-15    up  ---x--x--x  root    root
```

Using the `-p` option, you can view the PID for each user process running on the nodes. You can then pipe the `ps` command into `grep` to get the command string associated with it, such as `ps -aux |grep 8370`. Normal process signaling will work with these PIDs, such as `kill -9 8369`.

```
PID Node    Ghost
8367    0   -1
8368    1   -1
8369    2   -1
8370    3   -1
```

See the *Reference Guide* for more details on the command options.

4.3.6 Ganglia

`Ganglia` is an open source distributed monitoring technology for high-performance computing systems, such as clusters and grids. In current versions of Scyld ClusterWare, `Ganglia` provides network metrics for the master node, time and string metrics (`boottime`, `machine_type`, `os_release`, and `sys_clock`), and constant metrics (`cpu_num` and `mem_total`). `Ganglia` uses a web server to display these statistics; thus, to use `Ganglia`, you must run a web server on the cluster's master node.

When installing Scyld ClusterWare, make sure the `Ganglia` package is selected among the package groups to be installed. Once you have completed the Scyld installation and configured your compute nodes, you will need to configure `Ganglia` as follows:

1. Name your cluster.

   By default, `Ganglia` will name your cluster "my cluster". You should change this to match the master node's hostname. In the file `/etc/gmetad.conf`, and on or about line 39, change:

```
    data_source "my cluster" localhost
```

   to replace *my cluster* with the master's hostname. Note that `Ganglia` will not collect or display statistics without at least one entry for `data_source`.

2. Turn on the *Ganglia Data Collection Service*.

```
    [root@cluster ~] # chkconfig beostat on
```

3. Enable the Ganglia Master Daemon to start on boot.

```
    [root@cluster ~] # chkconfig gmetad --level 345 on
```

4. Enable the web server to start on boot.

```
    [root@cluster ~] # chkconfig httpd --level 345 on
```

5. Restart the xinetd service.

```
    [root@cluster ~] # service xinetd restart
```

6. Start the httpd service:

```
    [root@cluster ~] # service httpd start
```

   Note that you will not need to start httpd each time the cluster reboots if you've correctly enabled the web server to start on boot (see step 3 above).

7. Start the Ganglia Master Daemon.

```
    [root@cluster ~] # service gmetad start
```

   Note that you will not need to start gmetad each time the cluster reboots if you've correctly enabled the Ganglia Master Daemon to start on boot (see step 2 above).

8. Visit `http://localhost/ganglia` in a web browser.

Note that if you are visiting the web page from a computer other than the cluster's master node, then you must change `localhost` to the master node's hostname. For example, if the hostname is "iceberg", then you may need to use its fully qualified name, such as `http://iceberg.penguincomputing.com/ganglia`.

4.3.7 beoweb

The `beoweb` service does not execute by default. To enable it:

```
chkconfig beoweb on
```

and then it will start automatically the next time the master node boots. It can be started immediately by doing:

```
[root@cluster ~] # service beoweb start
```

Beoweb exposes an API for cluster status monitoring and remote job submission and monitoring. In its current state, beoweb is best used when paired with `PODTools` to enable remote job submission. (See the *User's Guide* for details about PODTools.) Beoweb does not yet support being viewed with a web browser; rather, it merely provides a web service accessible through APIs. Beoweb supports job submission using the TORQUE resource manager or SGE.

Beoweb is installed in `/opt/scyld/beoweb`, and the main configuration file, `beoweb.ini`, is located there. Some key settings to inspect are:

- `host = 0.0.0.0`

  This specifies the interface on which Beoweb will bind/listen. *0.0.0.0* specifies all available interfaces. Use an actual IP address to limit this to a single interface.

- `port = 5000`

  The port number on which beoweb listens. Change to a different port number as needed.

- `ssl_pem = %(here)s/data/beoweb.pem`

  The ssl_pem parameter controls whether or not beoweb uses SSL/TLS encryption for communication. It is strongly encouraged that you use SSL. When beoweb is installed, a temporary PEM file will be created at %(here)s/data/beoweb.pem. This certificate is good for 365 days.

- `auth.use_system_shadow = True`

  The value defaults to True. Unless explicitly disabled, beoweb will read `/etc/shadow` for user authentication. If this is set to False, you must use `auth.auth_file` to specify a different list of authorized users.

- `auth.auth_file = %(here)s/data/shadow`

  This file allows for user passwords to be stored independently from the master node's `/etc/shadow` file. Currently, beoweb only supports shadow-type login accounts. For example, if you put user credentials in `%(here)s/data/shadow` and not in `/etc/shadow`, then that user can access the master node's beoweb services without being allowed to actually login to the master node. The format for this file is identical to `/etc/shadow`.

- `stage.jobs_dir = podsh_jobs`

  This names a folder that will be created and used in a user's home directory for job scripts uploaded through PODTools.

- `stage.port_range = 10000-11000`

  When file uploads and downloads are requested through beoweb using PODTools, the files are transferred through a TCP socket connection. Beoweb opens a socket on the port in the range given in this entry, then sends that port number back to PODTools for use. This range should be chosen such that it does not conflict with other services on your system.

4.4 Configuring the Cluster

The Scyld ClusterWare configuration is defined by the contents of several flat ASCII files. Most of these files reside in the `/etc/beowulf/` directory. Various ClusterWare scripts (which mostly reside in `/usr/lib/beoboot/bin`), daemons, and commands read (and some occasionally update) these flat files.

The *root* user can manipulate the configuration manually using a text editor.

4.4.1 Configuring the Cluster Manually

This section discusses how to configure a cluster. Penguin Computing strongly recommends that the administrator use Manual editing of configuration files, especially the centerpiece `/etc/beowulf/config` file, should only be done with care, together with sufficient understanding of the ramifications of the manual manipulations.

> **Caution**
>
> If manual edits are made to the `config` file for a running cluster, then after saving the file, but sure to execute `service beowulf reload`, which will immediately send a *SIGHUP* signal to the `bpmaster` and `beoserv` daemons that notifies each to re-read the `config` file.

Configuration Files

/etc/beowulf/config

The file `/etc/beowulf/config` is the principal configuration file for the cluster. The `config` file is organized using keywords and values, which are used to control most aspects of running the cluster, including the following:

- The name, IP address and netmask of the network interface connected to the private cluster network
- The network port numbers used by ClusterWare for various services
- The IP address range to assign to the compute nodes

- The MAC (hardware) address of each identified node accepted into the cluster
- The node number and IP address assigned to each hardware address
- The default kernel and kernel command line to use when creating a boot file
- A list of kernel modules to be available for loading on compute nodes at runtime
- A list of shared library directories to cache on the compute nodes
- A list of files to prestage on the compute nodes
- Compute node filesystem startup policy
- The name of the final boot file to send to the compute nodes at boot time
- The hostname and hostname aliases of compute nodes
- Compute node policies for handling local disks and filesystems, responding to master node failure, etc.

The following sections briefly discuss some key aspects of the configuration file. See the *Reference Guide* (or `man beowulf-config`) for details on the specific keywords and values in `/etc/beowulf/config`.

Setting the IP Address Range The IP address range should be kept to a minimum, as all the cluster utilities will loop through this range. Having a few spare addresses is a good idea to allow for growth in the cluster. However, having a large number of addresses that will never be used will be an unnecessary waste of resources.

Identifying New Nodes When a new node boots, it issues a DHCP request to the network in order to get an IP address assigned to it. The master's `beoserv` detects these DHCP packets, and its response is dependent upon the current *nodeassign* policy. With a default *append* policy, `beoserv` appends a new *node* entry to the end of the `/etc/beowulf/config` file. This new entry identifies the node's MAC address(es), and the relative ordering of the *node* entry defines the node's number and what IP address is assigned to it. With a *manual* policy, `beoserv` appends the new node's MAC address to the file `/var/beowulf/unknown_addresses`, and then assigns a temporary IP address to the node that is outside the *iprange* address range and which does not integrate this new node into the cluster. It is expected that the cluster administrator will eventually assign this new MAC address to a cluster node, giving it a *node* entry with an appropriate position and node number. Upon cluster restart, when the node reboots (after a manual reset or an IPMI powercycle), the node will assume its assigned place in the cluster. With a *locked* policy, the new node gets ignored completely: no recording of its MAC address, and no IP address assignment.

Assigning Node Numbers and IP Addresses Two `config` file keywords control the assignment of IP addresses to compute nodes on the private cluster network: *nodes* and *iprange*. The *nodes* keyword specifies the max number of compute nodes, and the *iprange* specifies the range of IP addresses that are assigned to those compute nodes.

By default and in general practice, node numbers and IP addresses are assigned to the compute nodes in the order that their *node* entries appear in the config file, beginning with node 0 and the first IP address specified by the *iprange* entry in the config file. For example, the config file entries:

```
nodes 8
iprange 10.20.30.100 10.20.30.107
node 00:01:02:03:04:1A 00:01:02:03:05:2A
node 00:01:02:03:04:1B 00:01:02:03:05:2B
node 00:01:02:03:04:1C 00:01:02:03:05:2B
node 00:01:02:03:04:1D 00:01:02:03:05:2B
```

specify a network that contains a maximum of eight nodes, with four nodes currently known, and with an IP address range that falls between the 10.20.30.100 lowerbound and the 10.20.30.107 upperbound. Here the node with MAC address `00:01:02:03:04:1C` is node 2 and will be assigned an IP address 10.20.30.102.

ClusterWare treats the upperbound IP address as optional, so all that is necessary to specify is:

```
nodes 8
iprange 10.20.30.100
```

and ClusterWare calculates the upperbound IP address. This is especially useful when dealing with large *nodes* counts, e.g.:

```
nodes 1357
iprange 10.20.30.100
```

when it becomes increasingly clumsy for the cluster administrator to accurately calculate the upperbound address.

An optional node number can explicitly specify an override node number:

```
node 00:01:02:03:04:1A 00:01:02:03:05:2A
node 00:01:02:03:04:1B 00:01:02:03:05:2B
node 2 00:01:02:03:04:1C 00:01:02:03:05:2B
node 00:01:02:03:04:1D 00:01:02:03:05:2B
```

explicitly (and redundantly) specifies the node 2 numbering. Alternatively:

```
node 00:01:02:03:04:1A 00:01:02:03:05:2A
node 00:01:02:03:04:1B 00:01:02:03:05:2B
node 5 00:01:02:03:04:1C 00:01:02:03:05:2B
node 00:01:02:03:04:1D 00:01:02:03:05:2B
```

explicitly names that node as node 5 with IP address 10.20.30.105, and the next node (with MAC address `00:01:02:03:04:1D` will now be node 6 with IP address 10.20.30.106.

In another variation, commenting-out the MAC address(es) leaves a node numbering gap for node 2, and MAC address `00:01:02:03:04:1D` continues to be known as node 3:

```
node 00:01:02:03:04:1A 00:01:02:03:05:2A
node 00:01:02:03:04:1B 00:01:02:03:05:2B
node # 00:01:02:03:04:1C 00:01:02:03:05:2B
node 00:01:02:03:04:1D 00:01:02:03:05:2B
```

However, if the node with that commented-out MAC address `00:01:02:03:04:1C` does attempt to PXE boot, then `beoserv` assigns a new node number (4) to that physical node and automatically appends a new *node* entry to the list (assuming the *nodeassign* policy is *append*, and assuming the *iprange* and *nodes* entries allow room for expansion). This appending results in:

```
node 00:01:02:03:04:1A 00:01:02:03:05:2A
node 00:01:02:03:04:1B 00:01:02:03:05:2B
node # 00:01:02:03:04:1C 00:01:02:03:05:2B
node 00:01:02:03:04:1D 00:01:02:03:05:2B
node 00:01:02:03:04:1C 00:01:02:03:05:2B
```

If you want to have `beoserv` ignore that physical node and keep the remaining nodes numbered without change, then use the keyword *off*:

```
node 00:01:02:03:04:1A 00:01:02:03:05:2A
node 00:01:02:03:04:1B 00:01:02:03:05:2B
node off 00:01:02:03:04:1C 00:01:02:03:05:2B
node 00:01:02:03:04:1D 00:01:02:03:05:2B
```

A *node* entry can identify itself as a non-Scyld node and can direct `beoserv` to respond to the node in a variety of ways, including telling the node to boot from a local harddrive, or provisioning the node with specific kernel and initrd images. See *Managing Non-Scyld Nodes* for details.

Caching Shared Libraries To add a shared library to the list of libraries cached on the compute nodes, specify the pathname of the individual file or the pathname of the entire directory in which the file resides using the *libraries* directive. An open() syscall on a compute node to open a file thus named, or to open a file that resides in a named directory, will cause that file to be pulled from the master node to the compute node and saved in the local RAM filesystem.

The *prestage* directive names specific files to be pulled onto each compute node at node boot time. If a file pathname resides in one of the *libraries* directories, then BProc's filecache functionality pulls the file from the master node. Otherwise, the specified file is pushed from the master to the compute node at startup, with directories created as needed.

Specifying node names and aliases The *nodename* keyword in the master's `/etc/beowulf/config` affects the behavior of the ClusterWare NSS. Using the *nodename* keyword, one may redefine the primary host-name of the cluster, define additional hostname aliases for compute nodes, and define additional hostname (and hostname aliases) for entities loosely associated with the compute node's cluster position.

```
nodename [name-format] <IPv4 Offset or base> <netgroup>
```

The presence of the optional IPv4 argument defines if the entry is for "compute nodes" (i.e. the entry will resolve to the 'dot-number' name) or if the entry is for non-cluster entities that are loosely associated with the compute node. In the case where there `is` an IPv4 argument, the *nodename* keyword defines an additional hostname name that maps to an IPv4 address loosely associated with the node number. In case where IPv4 argument is present, the *nodename* keyword defines hostname and hostname aliases for the clustering interface (i.e. the compute nodes). Subsequent *nodename* entries without an IPv4 argument specify additional hostname aliases for compute nodes. In either case, the format string must contain a conversion specification for node number substitution. The conversion specification is introduced by a '%'. An optional following digit in the range 1..5 specifies a zero-padded minimum field width. The specification is completed with an 'N'. An unspecified or zero field width allows numeric interpretation to match compute node host names. For example, *n%N* will match *n23*, *n+23*, and *n0000023*. By contrast, *n%3N* will only match *n001* or *node023*, but not *n1* or *n23*.

Compute node command-line options The *kernelcommandline* directive is a method of passing various options to the compute node's kernel and to Beowulf on the node. There are a large number of different command line options that you can employ. This section covers some of them.

Some options are interpreted by the kernel on the compute node and ignored by Beowulf:

apic This option turns on APIC support on the compute node. APIC is the newer of two different mechanisms Intel provides for invoking interrupts. It works better with SMP systems than the older mechanism, called XT-PIC. However, not every motherboard and chipset works correctly with APIC, so this option is disabled by default to avoid problems for those machines that do not support it.

If you find that your cluster nodes kernel panic or crash immediately upon boot, you probably want to turn off APIC by specifying *noapic* in the command line options. If you have many devices that generate interrupts (such as hard disk controllers, network adapters, etc.) you may want to try turning on APIC to see if there is any performance advantage for your cluster.

panic=<seconds> This option allows you to specify how many seconds the kernel should wait to reboot after a kernel panic. For example, if you specify *panic=60*, then the kernel will wait 60 seconds before rebooting. Note that Beowulf automatically adds *panic=30* to final boot images.

apm=<action> This option allows you to specify APM options on the compute node. Acceptable <action> values are *on* (to turn APM completely on), *off* (to turn it completely off), *debug* (to turn on debugging), and *power-off* (to turn on only the power-off part of APM).

APM is not SMP-safe in the kernel; it will auto-disable itself if turned completely *on* for an SMP box. However, the *power-off* part of APM is SMP safe; thus, if you want to be able to power-off SMP boxes, you can do so by specifying *apm=power-off*. Note that *apm=power-off* is specified in the default *kernelcommandline* directive.

console=<device>, <options> This option is used to select which device(s) to use for console output. For <device> use *tty0* for the foreground virtual console, *ttyX* (e.g., *tty1*) for any other virtual console, and *ttySx* (e.g., *ttyS0* for a serial port.

For the serial port, <options> defines the baud rate/parity/bits of the port in the format "BBBBPN", where "BBBB" is the speed, "P" is parity (n/o/e), and "N" is bits. The default setting is *9600n8*, and the maximum baud rate is 115200. For example, to use the serial port at the maximum baud rate, specify *console=ttyS0,115200n8r*

Other options are interpreted by Beowulf on the compute node:

rootfs_size=<size> A compute node employs a RAM-based root filesystem for local non-persistent storage, typically used to contain BProc's filecache libraries and other files, the `/tmp` directory, and other directories that are not mounted using some variety of global storage (e.g., NFS or Panfs) or on local harddrives. This *tmpfs* root filesystem consumes physical memory only as needed, which commonly is about 100- to 200-MBytes unless user workloads impose greater demands on (for example) `/tmp` space. However, by default the rootfs is allowed to grow to consume a maximum of 50% of physical memory, which has the potential of allowing users to consume (perhaps inadvertently) an excessive amount of RAM that would otherwise be available to applications' virtual memory needs.

This 50% default can be overridden by the judicious use of the <size> option, where <size> can be expressed as numeric bytes, megabytes (appending "m" or "M"), or gigabytes (appending "g" or "G"), or as a percentage of total physical memory (appending numeric value and "%"). Examples:

```
rootfs_size=2048m
rootfs_size=1G
rootfs_size=15%
```

Note that this override is rarely needed, and it must be utilized with care. An inappropriately constrained root filesystem will cripple the node, just as an inadequate amount of physical memory that is available for virtual memory will trigger Out-Of-Memory failures. The cluster administrator is encouraged to limit user filespace usage in other ways, such as declaring `/etc/security/limits.conf` limits on the max number of open files and/or the maximum filesize.

rootfs_timeout=<seconds>; getfile_timeout=<seconds> The `beoclient` daemon on each compute node manages the early boot process, such as using tftp to read the kernel image and initrd files from the master node's `beoserv` daemon, and using tcp to read the initial root filesystem image (*rootfs*) from beoserv. After the node boots, BProc's filecache functionality on the compute node also uses tcp to read files from the master, as needed by applications.

The default timeout for these tcp reads is *30* seconds. If this timeout is too short, then add one of these options to the *kernelcommandline* to override the default. The option *getfile_timeout* overrides the timeout for all beoclient tcp read operations. The option *rootfs_timeout* overrides the timeout only for the tcp read of the root filesystem at node boot time.

syslog_server=<IPaddress> By default, a compute node forwards its kernel messages and syslog messages back to the master node's `syslog` or `rsyslog` service, which then appends these log messages to the master's `/var/log/messages` file. Alternatively, the cluster administrator may choose to instead forward these compute node log messages to another server by using the *syslog_server* option to identify the <IPaddress> of that server. This should be an IPv4 address, e.g., *syslog_server=10.20.30.2*.

Scyld ClusterWare automatically configures the master node's log service to handle incoming log messages from remote compute nodes. However, the cluster administrator must manually configure the alternate syslog server:

For the `syslog` service (Scyld ClusterWare 4 and 5), edit `/etc/sysconfig/syslog` on the alternate server to add "-r -x" to the variable SYSLOGD_OPTIONS.

For the `rsyslog` service (Scyld ClusterWare 6), edit `/etc/sysconfig/rsyslog` on the alternate server to add "-x" to the variable SYSLOGD_OPTIONS, and edit `/etc/rsyslog.conf` to un-comment the following lines to expose them, i.e., just as Scyld ClusterWare has done in the master node's `/etc/rsyslog.conf` file:

```
    $ModLoad imudp.so
    $UDPServerRun 514
```

Finally, restart the service on both the master node and the alternate syslog server before restarting the cluster.

legacy_syslog=<num> The legacy behavior of the the compute node's syslog handling has been to introduce a date-time string to the message text, then forward the message to the syslog server (typically on the master node), which would add its own date-time string. This redundant timestamp violates the RFC 3164 format standard, and recent ClusterWare releases strips the compute node's timestamp before sending the text to the master server. If for some reason a local cluster administrator wishes to revert to the previous behavior, then add *legacy_syslog=1*. The default is *legacy_syslog=0*.

Specifying kernel modules for use on compute nodes Each *bootmodule* entry identifies a kernel module to be added to the initrd that is passed to each compute node at boot time. These entries typically name possible Ethernet drivers used by nodes supplied by Penguin Computing. If the cluster contains nodes not supplied by Penguin Computing, then the cluster administrator should examine the default list and add new *bootmodule* entries as needed.

At boot time, Beowulf scans the node's PCI bus to determine what devices are present and what driver is required for each device. If the specified driver is named by a *bootmodule* entry, then Beowulf loads the module and all its dependencies. However, some needed modules are not found by this PCI scan, e.g., those used to manage specific filesystem types. These modules require adding an additional `config` file entry: *modprobe*. For example:

```
modprobe xfs
```

Note that each named *modprobe* module must also be named as a *bootmodule*.

You may also specify module-specific arguments to be applied at module load time, e.g.,

```
modarg forcedeth optimization_mode=1
```

RHEL6 introduced externally visible discrete firmware files that are associated with specific kernel software drivers. When `modprobe` attempts to load a kernel module that contains such a software driver, and that driver determines that the controller hardware needs one or more specific firmware images (which are commonly found in `/lib/firmware`), then the kernel first looks at its list of built-in firmware files. If the desired file is not found in that list, then the kernel sends a request to the `udevd` daemon to locate the file and to pass its contents back to the driver, which then downloads the contents to the controller. This functionality is problematic if the kernel module is an `/etc/beowulf/config` *bootmodule* and is an Ethernet driver that is necessary to boot a particular compute node in the cluster. The number of `/lib/firmware/` files associated with every possible *bootmodule* module is too large to embed into the `initrd` image common to all compute nodes, as that burdens every node with a likely unnecessarily oversized `initrd` to download. Accordingly, the cluster administrator must determine which specific firmware file(s) are actually required for a particular cluster and are not yet built-in to the kernel, then add *firmware* directive(s) for those files.

A *bootmodule* firmware problem exhibits itself as a compute node which does not boot because the needed Ethernet driver cannot be `modprobe`'d because it cannot load a specific firmware file. After a timeout waiting for `udevd` to unsuccessfully find the file, the compute node typically reboots - endlessly, as it continues to be unable to load the needed firmware file.

The cluster administrator can use the *firmware* directive to add specific firmware files to the compute node `initrd`, as needed. The compute node kernel writes the relevant firmware filename information to its console, e.g. a line of the form:

```
Failed to load firmware "bnx2/bnx2-mips-06-6.2.1.fw"
```

Ideally, the administrator gains access to the node's console to see the specific filename, then adds a directive to `/etc/beowulf/config`:

```
firmware bnx2/bnx2-mips-06-6.2.1.fw
```

and rebuilds the initrd:

```
[root@cluster ~] # service beowulf reload
```

(Note: *reload*, not *restart*)

If the node continues to fail to boot, then the failure is likely due to another missing firmware file. Check the node's console output again, and add the specified file to the *firmware* directive.

If the cluster administrator cannot easily see the node's console output to determine what firmware files are needed, then if the administrator knows the likely *bootmodule* module culprit, then the administrator can brute-force every known firmware file for that module using a directive of the form:

```
firmware bnx2
```

that names an entire `/lib/firmware/` subdirectory. This will likely create a huge `initrd` that will (if the correct *bootmodule* module is specified) successfully boot the compute node. The administrator should then examine the node's syslog output, which is typically seen in `/var/log/messages`, to determine the specific individual firmware filenames that were actually needed, and then the administrator replaces the subdirectory name with the now-known specific firmware filenames. Subsequently, the cluster administrator should contact Penguin Computing Support to inform us what those needed firmware files are, so that we can build-in these files into future kernel images and thus allow the cluster administrator to remove the *firmware* directives and thus reduce the `initrd` size, which contains not only the firmware images, but additionally includes various executable binaries and libraries that are only needed for this dynamic `udevd` functionality.

/etc/beowulf/fdisk

The `/etc/beowulf/fdisk` directory is created by the `beofdisk` utility when it evaluates local disks on individual compute nodes and creates partition tables for them. For each unique drive geometry discovered among the local disks on the compute nodes, `beofdisk` creates a file within this directory. The file naming convention is "head;ccc;hhh;sss", where "ccc" is the number of cylinders on the disk, "hhh" is the number of heads, and "sss" is the number of sectors per track.

These files contain the partition table information as read by `beofdisk`. Normally, these files should not be edited by hand.

You may create separate versions of this directory that end with the node number (for example, `/etc/beowulf/fdisk.3`). The master's `BeoBoot` software will look for these directories before using the general `/etc/beowulf/fdisk` directory.

For more information, see the section on `beofdisk` in the *Reference Guide*.

/etc/beowulf/fstab

This is the filesystem table for the mount points of the partitions on the compute nodes. It should be familiar to anyone who has dealt with an `/etc/fstab` file in a standard Linux system, though with a few Scyld ClusterWare extensions. For details, see the *Reference Guide* or execute `man beowulf-fstab`.

You may create separate node-specific versions by appending the node number, e.g., `/etc/beowulf/fstab.3` for node 3. The master's beoboot `node_up` script looks first for a node_specific `fstab.`*N* file, then if no such file exists will use the default `/etc/beowulf/fstab` file.

Caution

> On compute nodes, NFS directories must be mounted using either the IP address or the *$MASTER* keyword; the master node's hostname cannot be used. This is because /etc/beowulf/fstab is evaluated before the Scyld ClusterWare name service is initialized, which means hostnames cannot be resolved on a compute node at that point.

/etc/beowulf/backups/

This directory contains time-stamped backups of older versions of various configuration files, e.g., /etc/beowulf/config and /etc/beowulf/fstab, to assist in the recovery of a working configuration after an invalid edit.

/etc/beowulf/conf.d/

This directory contains various configuration files that are involved when booting a compute node. In particular, the node_up script pushes the master node's /etc/beowulf/conf.d/limits.conf to each compute node as /etc/security/limits.conf, and pushes /etc/beowulf/conf.d/sysctl.conf to each compute node as /etc/sysctl.conf. If /etc/beowulf/conf.d/limits.conf does not exist, then node_up creates an initial file as a concatenation of the master node's /etc/security/limits.conf plus all files in the directory /etc/security/limits.d/. Similarly, node_up creates an initial /etc/beowulf/conf.d/sysctl.conf (if it doesn't already exist) as a copy of the master's /etc/sysctl.conf. The cluster administrator may subsequently modify these initial "best guess" configuration files as needed for compute nodes.

Command Line Tools

bpstat

The command bpstat can be used to quickly check the status of the cluster nodes and/or see what processes are running on the compute nodes. See the *Reference Guide* for details on usage.

bpctl

To reboot or set the state of a node via the command line, one can use the bpctl command. For example, to reboot node 5:

```
[root@cluster ~] # bpctl -S 5 -R
```

As the administrator, you may at some point have reason to prevent other users from running new jobs on a specific node, but you do not want to shut it down. For this purpose we have the *unavailable* state. When a node is set to *unavailable* non-root users will be unable to start new jobs on that node, but existing jobs will continue running. To do this, set the state to *unavailable* using the bpctl command. For example, to set node 5 to *unavailable*:

```
[root@cluster ~] # bpctl -S 5 -s unavailable
```

node_down

If you are mounting local filesystems on the compute nodes, you should shut down the node cleanly so that the filesystems on the harddrives stay in a consistent state. The node_down script in /usr/lib/beoboot/bin does exactly this. It takes two arguments; the first is the node number, and the second is the state to which you want the node to go. For example, to cleanly reboot node 5:

```
[root@cluster ~] # /usr/lib/beoboot/bin/node_down 5 reboot
```

Alternatively, to cleanly power-off node 5:

```
[root@cluster ~] # /usr/lib/beoboot/bin/node_down 5 pwroff
```

The node_down script works by first setting the node's state to unavailable, then remounting the filesystems on the compute node read-only, then calling bpctl to change the node state. This can all be done by hand, but the script saves some keystrokes.

To configure node_down to use IPMI, set the ipmi value in /etc/beowulf/config to *enabled* as follows:

```
[root@cluster ~] # beoconfig ipmi enabled
```

Configuring CPU speed/power for Compute Nodes

Modern motherboards and processors support a degree of administrator management of CPU frequency within a range defined by the motherboard's BIOS. Scyld ClusterWare provides the /etc/beowulf/init.d/30cpuspeed script and its associated /etc/beowulf/conf.d/cpuspeed.conf configuration file to implement this management for compute nodes. The local cluster administrator is encouraged to review the cpuspeed.conf config file's section labeled *Scaling governor values* and potentially adjust the environment variable SCALINGGOV as desired, and then to enable the 30cpuspeed script:

```
[root@cluster ~] # beochkconfig 30cpuspeed on
```

The administrator should also ensure that no other *cpuspeed* or *cpupower* script is enabled for compute nodes.

In brief, the administrator can choose among four CPU scaling governor settings:

- *performance*, which directs the CPUs to execute at the maximum frequency supported by the motherboard and processor, as specified by the motherboard BIOS.
- *powersave*, which directs the CPUs to execute at the minimum frequency supported by the motherboard and processor.
- *ondemand*, which directs the kernel to adjust the CPU frequency between the minimum and maximum. An idle CPU executes at the minimum. As a load appears, the frequency increases relatively quickly to the maximum, and if and when the load subsides, then the frequency decreases back to the minimum. This is the default setting.
- *conservative*, which similarly directs the kernel to adjust the CPU frequency between the minimum and maximum, albeit making those adjustments with somewhat longer latency than is done for *ondemand*.

The upside of the *performance* scaling governor is that applications running on compute nodes always enjoy the maximum CPU frequencies that are supported by the node hardware. The downside is that even idle CPUs consume that same maximum power and thus generate maximum heat. For the scaling governors *performance*, *ondemand*, and *conservative*, a computebound workload drives the CPU frequencies (and power and heat) to the maximum, and thus computebound application performance will exhibit little or no difference among those governors. However, a workload of rapid context switching and frequent idle time will show perhaps 10-20% lower performance for *ondemand* versus *performance*, and possibly an even larger decline with *conservative*. The *powersave* governor is typically only employed when a need to minimize the cluster power consumption and/or minimize thermal levels outweighs a need to achieve maximum performance.

A broader discussion can be found in the /usr/share/doc/kernel-doc-2.6.32/Documentation/cpu-freq/ documents, e.g., governors.txt. Install the RHEL6 or CentOS6 base distribution's *kernel-doc* package to access these documents.

Adding New Kernel Modules

The modprobe command uses /usr/lib/`uname -r`/modules.dep.bin to determine the pathnames of the specified kernel module and that module's dependencies. The depmod command builds the human-readable modules.dep and the binary module.dep.bin files, and it should be executed *on the master node* after installing any new kernel module.

Executing modprobe on a compute node requires additional caution. The first use of modprobe retrieves the current modules.dep.bin from the master node using bproc's *filecache* functionality. Since any subsequent depmod on the master node rebuilds modules.dep.bin, then a subsequent modprobe on a compute node will only see the new modules.dep.bin if that file is copied to the node using bpcp, or if the node is rebooted and thereby silently retrieves the new file.

In general, you should not execute depmod on a compute node, since that command will only see those few kernel modules that have previously been retrieved from the master node, which means the node's newly built modules.dep.bin will only be a sparse subset of the master node's full module.dep.bin. Bproc's *filecache* functionality will always properly retrieve a kernel module from the master node, as long as the node's module.dep.bin properly specifies the pathname of that module, so the key is to have the node's module.dep.bin be a current copy of the master's file.

Many device drivers are included with Scyld ClusterWare and are supported out-of-the-box for both the master and the compute nodes. If you find that a device, such as your Ethernet adapter, is not supported and a Linux source code driver exists for it, then you will need to build the driver modules for the master.

To do this, you will need to install the RPM of kernel source code (if you haven't already done so). Next, compile the source code using the following extra GNU C Compiler (gcc) options.

```
-D__BOOT_KERNEL_SMP=1 -D__BOOT_KERNEL_UP=0
```

The compiled modules must be installed in the appropriate directories under /lib/modules. For example, if you are currently running under the 2.6.9-67.0.4.ELsmp kernel version, the compiled module for an Ethernet driver would be put in the following directory:

/lib/modules/2.6.9-67.0.4.ELsmp/kernel/drivers/net

Any kernel module that is required to boot a compute node, e.g., most commonly the Ethernet driver(s) used by compute nodes, needs special treatment. Edit the config file /etc/beowulf/config to add the name of the driver to the *bootmodule* list; you can add more *bootmodule* lines if needed. See *Compute Node Boot Options*.

Next, you need to configure how the device driver gets loaded. You can set it up so that the device driver only loads if the specific device is found on the compute node. To do this, you need to add the PCI vendor/device ID pair to the PCI table information in the /usr/share/hwdata/pcitable file. You can figure out what these values are by using a combination of lspci and lspci -n.

So that your new kernel module is always loaded on the compute nodes, include the module in the initial RAM disk by adding a *modprobe* line to /etc/beowulf/config. The line should look like the following:

```
modprobe <module>
```

where <module> is the kernel module in question.

Finally, you can regenerate the BeoBoot images by running service beowulf reload. For more details, see *Compute Node Boot Options*.

Accessing External License Servers

To configure the firewall for accessing external license servers, enable ipforward in the /etc/beowulf/config file. The line should read as follows:

```
ipforward yes
```

You must then reboot the compute nodes and restart the cluster services. To do so, run the following two commands as root in quick succession:

```
[root@cluster ~] # bpctl -S all -R
[root@cluster ~] # service beowulf restart
```

Tip

If IP forwarding is enabled in `/etc/beowulf/config` but is still not working, then check `/etc/sysctl.conf` to see if it is disabled.

Check for the line “net.ipv4.ip_forward = 1”. If the value is set to 0 (zero) instead of 1, then IP forwarding will be disabled, even if it is enabled in `/etc/beowulf/config`.

Configuring SSH for Remote Job Execution

Most applications that leverage `/usr/bin/ssh` on compute nodes can be configured to use `/usr/bin/rsh`. In the event that your application requires SSH access to compute nodes, ClusterWare provides this ability through `/etc/beowulf/init.d/81sshd`. To start `sshd` on compute nodes, enable the `81sshd` script and reboot your nodes:

```
[root@cluster ~] # beochkconfig 81sshd on
[root@cluster ~] # bpctl -S all -R
```

When each node boots, `81sshd` starts `sshd` on the node, and the master’s root user will be able to SSH to a compute node without a password, e.g.:

```
[root@cluster ~] # ssh n0 ls
```

By default, compute node `sshd` daemons do not allow for password-based authentication – only key-based authentication is available – and only the root user’s SSH keys have been configured.

If a non-root user needs SSH access to compute nodes, the user’s SSH keys will need to be configured. For example, create a DSA key using ssh-keygen, and hit *Enter* when prompted for a password if you want password-less authentication:

```
[user1@cluster ~] $ ssh-keygen -t dsa
```

Since the master’s `/home` directory is mounted (by default) as `/home` on the compute nodes, just copy the public key to ~/.ssh/authorized_keys:

```
[user1@cluster ~] $ cp -a ~/.ssh/id_dsa.pub ~/.ssh/authorized_keys
```

Now the user can run commands over SSH to any node using shared key authentication:

```
[user1@cluster ~] $ ssh n0 date
```

If you wish to modify `sshd`‘s settings, you can edit `/etc/beowulf/conf.d/sshd_config` and then reboot the nodes. Node-specific `sshd` configuration settings can be saved as `/etc/beowulf/conf.d/sshd_config.$NODE`.

Client behavior for SSH on the nodes can be adjusted by editing the global `/etc/beowulf/conf.d/ssh_config` or a node-specific `/etc/beowulf/conf.d/ssh_config.$NODE`. This SSH client configuration will only be useful when using SSH from node to node. For example:

```
[user1@cluster ~] $ ssh n0 ssh n1 ls
```

Note that `/etc/beowulf/conf.d/sshd_config` and `ssh_config` only affect SSH behavior on compute nodes. The master's SSH configuration will not be affected.

Interconnects

There are many different types of network fabric one can use to interconnect the nodes of your cluster. The least expensive and most common is Fast (100Mbps) and Gigabit (1000Mbps) Ethernet. Other cluster-specific network types, such Infiniband, offer lower latency, higher bandwidth and features such as RDMA (Remote Direct Memory Access).

Ethernet

Switching fabric is always the most important (and expensive) part of any interconnected sub-system. Ethernet switches with up to 48 ports are extremely cost effective; however, anything larger becomes expensive quickly. Intelligent switches (those with software monitoring and configuration) can be used effectively to partition sets of nodes into separate clusters using VLANs; this allows nodes to be easily reconfigured between clusters if necessary.

Adding a New Ethernet Driver Drivers for most Ethernet adapters are included with the Linux distribution, and are supported out of the box for both the master and the compute nodes. If you find that your card is not supported, and a Linux source code driver exists for it, you need to compile it against the master's kernel, and then add it to the cluster config file using the *bootmodule* keyword. See the *Reference Guide* for a discussion on the cluster config file.

For details on adding new kernel modules, see *Adding New Kernel Modules*.

Gigabit Ethernet vs. Specialized Cluster Interconnects Surprisingly, the packet latency for Gigabit Ethernet is approximately the same as for Fast Ethernet. In some cases, the latency may even be slightly higher, as the network is tuned for high bandwidth with low system impact utilization. Thus Gigabit Ethernet will not give significant improvement over Fast Ethernet to fine-grained communication-bound parallel applications, where specialized interconnects have a significant performance advantage.

However, Gigabit Ethernet can be very efficient when doing large I/O transfers, which may dominate the overall run-time of a system.

Other Interconnects

Infiniband is a new, standardized interconnect for system area networking. While the hardware interface is an industry standard, the details of the hardware device interface are vendor specific and change rapidly. Contact Scyld Customer Support for details on which Infiniband host adapters and switches are currently supported.

With the exception of unique network monitoring tools for each, the administrative and end user interaction is unchanged from the base Scyld ClusterWare system.

4.5 Remote Administration and Monitoring

Scyld ClusterWare provides a variety of tools for remotely monitoring and administering clusters. These include traditional shell and X window based tools, along with web based tools. Some utilities are available for users to monitor the system, while others are for administrators to configure the cluster.

4.5.1 Command Line Tools

The RHEL CentOS base distribution includes `openssh`. This tool allows you to securely `ssh` into your master node and manually edit `/etc/beowulf/config`, and modify `/etc/beowulf/init.d/` scripts, `/etc/beowulf/conf.d/` configuration files, and base distribution configuration files on the master node. For more information on the configuration files and command line utilities, see *Configuring the Cluster Manually*.

4.5.2 X Forwarding

SSH can also be configured to do X forwarding, which allows the GUI applications to be run on a remote machine. This allows you to use the full functionality of the convenient graphics tools, but can be slow, especially if the connection to the cluster is not via a local area network. In order to activate X forwarding, you may need to use the -X option to ssh from your client. Once the X forwarding is setup, you can use any of the GUI tools described throughout this manual.

4.6 Managing Users on the Cluster

In order for someone to gain access to a cluster, s/he must first be given a user account. The cluster administrator can manage user accounts with the same tools that are available with most Linux distributions. User access to cluster resources can also be controlled by the cluster administrator.

This chapter discusses the tools and commands for managing user accounts and controlling access to cluster resources.

4.6.1 Managing User Accounts

Adding New Users

The `useradd` command enables you to add a new user to the system. This command takes a single argument, which is the new user's login name:

```
[root@cluster ~] # useradd <username>
```

This command also creates a home directory named `/home/<username>`.

After you add the user, give them a default password using the `passwd` command so that they will be able to log in. This command takes a single argument, which is the username:

```
[root@cluster ~] # passwd <username>
```

Tip

It is good practice to give each user their own unique home directory.

Removing Users

To remove a user from your cluster, use the `userdel` command. This command takes a single argument, which is the username:

```
[root@cluster ~] # userdel <username>
```

By default, `userdel` does not remove the user's home directory. To remove the home directory, include the `-r` option in the command:

```
[root@cluster ~] # userdel -r <username>
```

Tip

The `userdel` command will never remove any files that are not in the user's home directory. To fully remove all of a user's files, remove the user's mail file from `/var/spool/mail/`, as well as any files the user may have in `/tmp/`, `/var/tmp/`, and any other directories to which the user had write permissions.

4.6.2 Managing User Groups

In addition to user accounts, you can also create user groups. Groups can be very powerful, as they allow you to assign resources to an arbitrary set of users. Groups are typically used for file permissions. However, you can also utilize groups to assign nodes to a specific set of users, thereby limiting which users have access to certain nodes. This section covers creating and modifying groups.

Creating a Group

Before you can add users to a group, you must first create the group. Groups can be created with the `groupadd` command. This command takes a single argument, which represents the name of the group:

```
[root@cluster ~] # groupadd <groupname>
```

Adding a User to a Group

Use the `usermod` command To add a user to a group. This command requires you to list all the groups the user should be a member of. To avoid accidentally removing any of the user's groups, first use the `groups` command to get a list of the user's current groups. The following example shows how to find the groups for a user named Smith:

```
[root@cluster ~] # groups smith
smith : smith src
```

After getting a list of the user's current groups, you can then add them to new groups, for example:

```
[root@cluster ~] # usermod -G smith,src,<newgroup> smith
```

Removing a Group

To remove a group, run the `groupdel` command with the groupname as an argument:

```
[root@cluster ~] # groupdel <groupname>
```

4.6.3 Controlling Access to Cluster Resources

By default, anyone who can log into the master node of the cluster can send a job to any compute node. This is not always desirable. You can use *node ownership* and *mode* to restrict the use of each node to a certain user or group, including restricting compute node access to the master node.

What Node Ownership Means

Each node (including the master node) has *user*, *group* and *mode* bits assigned to it; these indicate who is allowed to run jobs on that node. The *user* and *group* bits can be set to any user ID or group ID on your system. In addition, the use of a node can be unrestricted by setting the *user* and *group* to "root".

For the `BProc` unified process space, the node permissions "root" and "any" are equivalent. Node user access follows the normal Linux convention, i.e., the most restrictive access rule is the one used. Some examples:

- user "root", group "test", mode 101 (u=1, g=0, o=1) — Users in the group "test" will not be able to access the node.
- user "tester", group "root", and mode 011 (u=0, g=1, o=1) — The user "tester" will not be able to access the node.
- user "tester", group "test", and mode 110 (u=0, g=1, o=1) — The user "tester" and users in the group "test" are the only non-root users able to access the node.

  Tip

  In Linux systems, "other" is defined as anyone not listed in the user or group.

Checking Node Ownership

Display the current node access state by running the `bpstat` command:

```
[root@cluster ~] # bpstat -M
Node(s)   Status   Mode        User         Group
16-31     down     ---------- root         root
-1        up       ---x--x--x root         root
0-15      up       ---x--x--x root         root
```

The "User" column shows the user for each node and the "Group" column shows the group for each node. This display shows a cluster with default access permissions.

Setting Node Ownership

You can set node ownership with the `bpctl` command. Use the `-S` option to specify which node to change. Use either the `-u` option to change the user, `-g` option to change the group, or `-m` to change the mode. The only bit utilized for the mode is the *execute* bit. Following are some examples.

- The following sets the user for node 5 to *root*:

```
     [root@cluster ~] # bpctl -S 5 -u root
```

- The following sets all the compute nodes to be in the group *beousers*:

```
     [root@cluster ~] # bpctl -S all -g beousers
```

- The following allows only the group *beousers* to access the compute nodes:

```
     [root@cluster ~] # bpctl -S all -m 010 -g beousers
```

- The following disallows non-root users to execute on the master:

```
     [root@cluster ~] # bpctl -M -m 0110
```

For example:

```
[root@cluster ~] # bpctl -M -m 0110
[root@cluster ~] # bpctl -S 0-3 -g physics
[root@cluster ~] # bpstat -M
Node(s)   Status   Mode        User        Group
16-31     down     ---------- root        root
-1        up       ---x--x--- root        root
0-3       up       ---x--x--x root        physics
4-15      up       ---x--x--x root        root
```

See the *Reference Guide* for additional details on `bpctl`.

Using `bpctl` does not permanently change the node ownership settings. Whenever the master node reboots or `service restart beowulf` reboots the cluster, the node ownership settings revert to the default of full, unrestricted access, or to the optional override settings specified by the *nodeaccess* directive(s) in the `/etc/beowulf/config` file. To make permanent changes to these settings, you must edit this file. For example, to make the above setting persistent, add the *nodeaccess* entries:

```
nodeaccess -M -m 0110
nodeaccess -S 0-3 -g physics
```

The *Reference Guide* and `man beowulf-config` provides details for the `/etc/beowulf/config` file.

4.7 Job Batching

For Scyld ClusterWare, the default installation includes both the TORQUE resource manager and the Slurm workload manager, each providing users with an intuitive interface for remotely initiating and managing batch jobs on distributed compute nodes.

ClusterWare TORQUE is a customized redistribution of Open Source software that derives from ‘Adaptive Computing Enterprises, Inc. https://www.adaptivecomputing.com/products/opensource/torque. TORQUE is an Open Source tool based on standard OpenPBS. ClusterWare Slurm is a redistribution of Open Source software that derives from https://slurm.schedmd.com, and the associated Munge package derives from http://dun.github.io/munge/.

Both TORQUE and Slurm are installed by default, although only one job manager can be enabled at any one time. See *Enabling TORQUE or Slurm* below, for details. See the *User's Guide* for general information about using TORQUE or Slurm. See *Managing Multiple Master Nodes* for details about how to configure TORQUE for high availability using multiple master nodes.

Scyld also redistributes the Scyld Maui job scheduler, also derived from Adaptive Computing, that functions in conjunction with the TORQUE job manager. The alternative Moab job scheduler is also available from Adaptive Computing with a separate license, giving customers additional job scheduling, reporting, and monitoring capabilities.

In addition, Scyld provides support for most popular Open Source and commercial schedulers and resource managers, including SGE, LSF, and PBSPro. For the latest information, see the Penguin Computing Support Portal at https://www.penguincomputing.com/support.

4.7.1 Enabling TORQUE or Slurm

To enable TORQUE: after all compute nodes are up and running, then disable Slurm (if it is currently enabled), then enable and configure TORQUE, then reboot all the compute nodes:

```
service slurm-scyld cluster-stop
chkconfig slurm-scyld off
beochkconfig 98slurm off
chkconfig torque on
beochkconfig 98torque on
```

```
service torque reconfigure
service torque start
bpctl -S all -R
```

and then after the compute nodes have rebooted, restart TORQUE cluster-wide:

```
service torque cluster-restart
```

To enable Slurm: after all compute nodes are up and running, you disable TORQUE (if it is currently enabled), then enable and configure Slurm, then reboot all the compute nodes:

```
service torque cluster-stop
chkconfig torque off
beochkconfig 98torque off
chkconfig slurm-scyld on
beochkconfig 98slurm on
```

Next, configure Slurm by generating `/etc/slurm/slurm.conf` and `/etc/slurm/slurmdbd.conf` from Scyld-provided templates:

```
service slurm-scyld reconfigure
```

Finally, start Slurm on the master node and reboot all compute nodes:

```
service slurm-scyld start
bpctl -S all -R
```

and then after the compute nodes have rebooted, restart Slurm cluster-wide:

```
service slurm-scyld cluster-restart
```

Finally, start Slurm (and Munge and mysql) on the master node and reboot all compute nodes:

```
service slurm-scyld start
bpctl -S all -R
```

and then after the compute nodes have rebooted, restart Slurm cluster-wide:

```
service slurm-scyld cluster-restart
```

Note: slurmdbd uses mysql to create a database defined by `/etc/slurm/slurmdbd.conf`, and expects mysql to be configured with no password.

Each Slurm user must setup the PATH and LD_LIBRARY_PATH environment variables to properly access the Slurm commands. This is done automatically for users who login when the *slurm* service is running and the *pbs_server* is not running, via the `/etc/profile.d/scyld.slurm.sh` script. Alternatively, each Slurm user can manually execute `module load slurm` or can add that command line to (for example) the user's `.bash_profile`.

4.8 Managing Non-Scyld Nodes

A ClusterWare cluster typically consists of a Scyld master node and one or more Scyld compute nodes, integrated and communicating across the private cluster network interface. However, ClusterWare also supports additional devices and nodes that may reside on that private cluster network. This section describes how these Scyld and non-Scyld nodes are configured using entries in the `/etc/beowulf/config` file.

4.8.1 DHCP IP address assignment to devices

The private cluster network may have one or more devices attached to it that issue a DHCP request to obtain a dynamic IP address, vs. the device being configured with a static IP address. Typically, only the master node (or nodes - see *Managing Multiple Master Nodes*) owns a static IP address.

> **Caution**
>
> Care must be taken with static IP addresses to guarantee there are no address collisions.

Examples of such devices are managed switches and storage servers. The `beoserv` DHCP service for such devices is configured using the *host* directive, together with an associated *hostname* directive. For example,

```
nodes 32
iprange 10.20.30.100 10.20.30.131   # IPaddr range of compute nodes
...
hostrange 10.20.30.4  10.20.30.9    # IPaddr range of devices for DHCP
hostrange 10.20.30.90 10.20.30.99   # IPaddr range of PDUs for DHCP
...
host 00:A0:D1:E9:87:CA 10.20.30.5 smartswitch
host 00:A0:D1:E3:FC:E2 10.20.30.90 pdu1
host 00:A0:D1:E3:FD:4A 10.20.30.91 pdu2
```

The *host* keyword affects both the beoserv DHCP server and how the ClusterWare NSS responds to hostname lookups. The *host* keyword associates a non-cluster entity, identified by its MAC address, to an IP address that should be delivered to that client entity, if and when it makes a DHCP request to the master node, together with one or more optional hostnames to be associated with this IP address.

If the hostname is provided, then normal NSS functionality is available. Using the above example, then:

```
[user1@cluster ~] $ getent hosts smartswitch
```

returns:

```
10.20.30.5 smartswitch
```

and

```
[user1@cluster ~] $ getent ethers 00:A0:D1:E9:87:CA
```

returns:

```
00:a0:d1:e9:87:ca smartswitch
```

Each *host* IP address must fall within a defined *hostrange* range of IP addresses. Moreover, each of the potentially multiple *hostrange* ranges must not overlap any other range, must not overlap the cluster compute nodes range that is defined by the *iprange* directive, and must not collide with IP address(es) of master node(s) on the private network.

4.8.2 Simple provisioning using PXE

A default *node* entry, such as:

```
node 00:A0:D1:E5:C4:6E 00:A0:D1:E5:C4:6F
```

or an explicitly numbered *node* entry, such as one for node15:

```
node 15 00:A0:D1:E5:C4:6E 00:A0:D1:E5:C4:6F
```

is assumed to be a Scyld node, and a PXE request from one of these MAC addresses results in `beoserv` provisioning the node with the kernel image, initrd image, and kernel command-line arguments that are specified in `/etc/beowulf/config` file entries, e.g.:

```
kernelimage /boot/vmlinuz-2.6.18-164.2.1.el5.540g0000
initrdimage /var/beowulf/boot/computenode.initrd
kernelcommandline rw root=/dev/ram0 image=/var/beowulf/boot/computenode.rootfs
```

ClusterWare automatically maintains the `config` file's default *kernelimage* to specify the same kernel that currently executes on the master node. A Scyld node integrates into the `BProc` unified process space.

Enhanced syntax allows for custom booting of different kernel and initrd images. For example, specific nodes can boot a standalone RAM memory test in lieu of booting a full Linux kernel:

```
kernelimage 15 /var/beowulf/boot/memtest86+-4.00.bin
initrdimage 15 none
kernelcommandline 15 none
```

Thus when node15 makes a PXE request, it gets provisioned with the specified binary image that performs a memory test. In the above example, the *initrdimage* of *none* means that no initrd image is provisioned to the node because that particular memory test binary doesn't need an initrd. Moreover, the node number specifier of *15* can be a range of node numbers, each of which would be provisioned with the same memory test.

4.8.3 Simple provisioning using the *class* directive

An optional `config` file *class* directive assigns a name to a set of image and kernel command-line arguments. The previous example can be alternatively accomplished with:

```
class memtest kernelimage /var/beowulf/boot/memtest86+-4.00.bin
class memtest initrdimage none
class memtest kernelcommandline none
...
node 15 memtest 00:A0:D1:E5:C4:6E 00:A0:D1:E5:C4:6F
```

which results in the same memory test provisioning of node15 as seen earlier.

Similarly, the default Scyld node provisioning can be expressed as:

```
class scyld kernelimage /boot/vmlinuz-2.6.18-164.2.1.el5.540g0000
class scyld initrdimage /var/beowulf/boot/computenode.initrd
class scyld kernelcommandline rw root=/dev/ram0 image=/var/beowulf/boot/computenode.rootfs
...
node scyld pxe pxe 00:A0:D1:E5:C4:6E 00:A0:D1:E5:C4:6F
```

The first *pxe* is termed the `boot-sequence`, and the second *pxe* is termed the `boot-stage`. The `boot-stage` describes how `beoserv` should respond to a node's PXE request. In the example above, the `boot-stage` of *pxe* instructs `beoserv` to respond to the node's first PXE request with the kernel image, initrd image, and kernel command-line specified in the class *scyld*.

4.8.4 Booting a node from the local harddrive

The *node* entry's `boot-sequence` and `boot-stage` have more powerful capabilities. For example, suppose node15 is installed with a full distribution of CentOS 4.8 on a local harddrive, and suppose the master node's `config` file contains entries:

```
class genericboot kernelimage none
class genericboot initrdimage none
class genericboot kernelcommandline none
...
node 15 genericboot pxe+local local 00:A0:D1:E5:C4:6E 00:A0:D1:E5:C4:6F
```

When node15 boots, it first makes a DHCP request to join the private cluster network, then it attempts to boot, abiding by the specific sequence of boot devices named in its BIOS. ClusterWare expects that the first boot device is PXE over Ethernet, and the second boot device is a local harddrive. When node15 initiates its PXE request to the master node, `beoserv` sees the `boot-stage` of *local* and thus directs node15 to "boot next", i.e., to boot from the local harddrive.

4.8.5 Provisioning a non-Scyld node

In the previous example, we assumed that node15 already had a functioning, bootable operating system already installed on the node. Having a preexisting installation is not a requirement. Suppose the `config` file contains entries:

```
class centos5u4 kernelimage /var/beowulf/boot/vmlinuz-centos5u4_amd64
class centos5u4 initrdimage /var/beowulf/boot/initrd-centos5u4_amd64.img
class centos5u4 kernelcommandline initrd=initrd-centos5u4_amd64.img
                  ks=nfs:10.1.1.1:/home/os/kickstarts/n5-ks.cfg ksdevice=eth0
...
node 15 centos5u4 pxe+local pxe 00:A0:D1:E5:C4:6E 00:A0:D1:E5:C4:6F
```

(where the *kernelcommandline* has been broken into two lines for readability, although in reality it must be a single line in the `config` file). This time node15's PXE request arrives, and the `boot-stage` of *pxe* directs `beoserv` to respond with the *class centos5u4* kernel image, initrd image, and kernel command-line arguments. The latter's *ks* arguments informs node15's kernel to initiate a `kickstart` operation, which is a Red Hat functionality that provisions the requester with rpms and other configuration settings as specified in the `/home/os/kickstarts/n5-ks.cfg` kickstart configuration file found on the master node. It is the responsibility of the cluster administrator to create this kickstart file. See *Special Directories, Configuration Files, and Scripts* for a sample configuration file.

After this initial PXE response (i.e., the *pxe* step of the *pxe+local* `boot-sequence`), `beoserv` rewrites the *node* entry to change the `boot-stage` to the *local* second step of the *pxe+local* `boot-sequence`. For example,

```
node 15 centos5u4 pxe+local pxe 00:A0:D1:E5:C4:6E 00:A0:D1:E5:C4:6F
```

gets automatically changed to:

```
node 15 centos5u4 pxe+local local 00:A0:D1:E5:C4:6E 00:A0:D1:E5:C4:6F
```

What this accomplishes is: the first PXE request is met with a directive to boot a kernel on node15 that initiates the `kickstart` provisioning, and then any subsequent PXE request from node15 (presumably from a now-fully provisioned node) results in a `beoserv` directive to node15 to "boot next", i.e., to boot from the local harddrive.

If the cluster administrator wishes to reprovision the node and start fresh, then simply change the `boot-stage` from *local* back to *pxe*, and execute `service beowulf reload` to instruct `beoserv` to re-read the config file to see your manual changes.

If you want the node to `kickstart` reprovision on every boot (albeit an unlikely scenario, but presented here for completeness), then you would configure this using:

```
node 15 centos5u4 pxe pxe 00:A0:D1:E5:C4:6E 00:A0:D1:E5:C4:6F
```

4.8.6 Integrating a non-Scyld node into the cluster

A non-Scyld node that locally boots a full distribution operating system environment may have an assigned IP address in the private cluster network *iprange*, but it is initially invisible to the master node's monitoring tools and job manager. The `bpstat` tool only knows about Scyld nodes, and the more general `beostatus` is ignorant of the non-Scyld node's presence in the cluster. The non-Scyld node is itself ignorant about the names and IP addresses of other nodes in the cluster, whether they be Scyld or non-Scyld nodes, until and unless the cluster administrator adds each and every node into the non-Scyld node's local `/etc/hosts` file.

This shortcoming can be remedied by installing two special ClusterWare packages onto the non-Scyld node: `beostat-sendstats` and `beonss-kickbackclient`. These packages contain the client-side pieces of `beostat` and `beonss`. They are available in the standard ClusterWare yum repository and are compatible with non-Scyld RHEL and CentOS distributions - and perhaps with other distributions. One way to judge compatibility is to determine what libraries the ClusterWare daemons need to find on the non-Scyld compute node. (The daemons are known to execute in recent RHEL and CentOS environments.) Examine the daemons that were installed on the master node when ClusterWare was installed:

```
ldd /usr/sbin/sendstats
ldd /usr/sbin/kickbackproxy
```

and then determine if the libraries that these binaries employ are present on the target non-Scyld node. If the libraries do so exist, then the special ClusterWare packages can be downloaded and installed on a non-Scyld node.

First, you should download the packages from the ClusterWare yum repo. A useful downloader is the `/usr/bin/yumdownloader` utility, which can be installed from the CentOS *extras* yum repository if it is not already installed on your master node:

```
[root@cluster ~] # yum install yum-utils
```

Then use the utility to download the special Penguin ClusterWare rpms:

```
[root@cluster ~] # yumdownloader --destdir=<localdir> beostat-sendstats beonss-kickbackclient
```

retrieves the rpms and stores them into the directory <localdir>, e.g., `/var/www/html` or `/etc/beowulf/nonscyld`.

These special packages can be installed manually on the non-Scyld node, or can be installed as part of the kickstart procedure (see *Provisioning a non-Scyld node*). Each package includes a /etc/init.d/ script that must be edited by the cluster administrator. Examine /etc/init.d/beostat-sendstats and /etc/init.d/beonss-kickbackclient, which contain comments that instruct the administrator about how to configure each script. Additionally, the non-Scyld node's /etc/nsswitch.conf must be configured to invoke the *kickback* service for the databases that the administrator wishes to involve *beonss* and the master node. See the master node's /etc/beowulf/nsswitch.conf for a guide to which databases are supported, e.g., *hosts*, *passwd*, *shadow*, and *group*. Finally, on the non-Scyld node, enable the scripts to start at node startup:

```
[root@cluster ~] # chkconfig beostat-sendstats on
[root@cluster ~] # chkconfig beonss-kickbackclient on
```

4.9 Managing Multiple Master Nodes

ClusterWare supports up to four master nodes on the same private cluster network. Every master node of a given cluster typically references a common **/etc/beowulf/config** file, which means all master nodes share a common understanding of all compute nodes that are attached to the private cluster network. That is, each master node knows a given physical node (denoted by its MAC addresses) by a common IP address and hostname. The **config** file's *masterorder* directive configures which master node controls which compute nodes. Additionally, every master node should share a common understanding of userID (**/etc/passwd**) and groupID (**/etc/group**) values.

4.9.1 Active-Passive Masters

In a simple **active-passive** configuration, all compute nodes are "owned" by one and only one master node at any one time, and the secondary master node (or nodes) comes into play only if and when the primary master fails. A compute node's self-reassignment of ownership is called "cold re-parenting", as it only occurs when a node reboots.

For example, for a cluster with two master nodes and 32 compute nodes, the **/etc/beowulf/config** file on each master node contains the entry:

```
masterorder 0-31 10.1.1.1 10.1.1.2
```

or alternatively, an entry that uses a hyphen to avoid using explicit node numbers:

```
masterorder - 10.1.1.1 10.1.1.2
```

where the IP addresses are the static addresses assigned to the two masters. When a compute node boots, each master node interprets the same *masterorder* directive and knows that master 10.1.1.1 is the primary master and nominally "owns" all the nodes, and 10.1.1.2 is the secondary master which only steps in if the primary master is unresponsive.

4.9.2 Active-Active Masters

Many labs and workgroups today have several compute clusters, where each one is dedicated to a different research team or engineering group, or is used to run different applications. When an unusually large job needs to execute, it may be useful to combine most or all of the nodes into a single larger cluster, and then afterwards split up the cluster when the job is completed. Also, the overall demand for particular applications may change over time, requiring changes in the allocation of nodes to applications.

The downside to this approach of using multiple discrete clusters, each with their separate private cluster network, is that the compute node reconfiguration requires physically rewiring the network cabling, or requires reprogramming a smart switch to move nodes from one discrete network to another.

However, with an **active-active** configuration, the cluster's master nodes and compute nodes reside on the same common private cluster network. The nodes are divided into subsets, and each subset is actively "owned" by a different master node and perhaps dedicated to separate users and applications. Additionally, each subset is passively associated with other master nodes.

For example, suppose each master node's **/etc/beowulf/config** contains:

```
masterorder  0-15 10.1.1.1 10.1.1.2 10.1.1.3
masterorder 16-31 10.1.1.2 10.1.1.1 10.1.1.3
```

which divides the 32 compute nodes into two subsets of 16, with one subset owned by master 10.1.1.1 and the other subset owned by 10.1.1.2. To add complexity to this example, we introduce a passive third master node, 10.1.1.3, which becomes active only if both master nodes fail. This configuration provides for several advantages over two discrete 16-node clusters. One advantage is the same as provided by an **active-passive** configuration: in the event of a failure of one master node, that master's compute nodes automatically reboot and "cold re-parent" to another master node, which now becomes the active "owner" of all 32 compute nodes.

Another advantage is that the cluster administrator can easily respond to changing demands for computing resources through a controlled and methodical migration of nodes between masters. For example, the administrator can shift eight nodes, n16 to n23, from one master to the other by changing the *masterorder* entries to be:

```
masterorder  0-23 10.1.1.1 10.1.1.2 10.1.1.3
masterorder 24-31 10.1.1.2 10.1.1.1 10.1.1.3
```

and replicating this same change to all other master nodes. Then the administrator executes on every master node the command **service beowulf reload**, which instructs **beoserv** and **bpmaster** daemons to re-read the changed **/etc/beowulf/config**. Finally, on the currently "owning" master the administrator executes the command **bpctl -S 16-23 -R**, which reboots those shifted eight nodes and thereby causes them to cold re-parent to a different master node.

Reversing this reconfiguration, or performing any other reconfiguration, is equally simple:

1. Edit **/etc/beowulf/config** on one master to change the *masterorder* entries,
2. Replicate these same changes (or copy the same **config** file) to every affected master node,

3. Execute **service beowulf reload** on each master node to re-read the **config** file, and

4. Execute **bpctl -S <noderange> -R** on the current “owning” master node, where <*noderange*> is the range of affected nodes, which tells the affected node(s) to reboot and re-parent to their new active master.

4.10 Managing Node Failures

Node failures are an unfortunate reality of any computer system, and failures in a Scyld ClusterWare cluster are inevitable and hopefully rare. Various strategies and techniques are available to lessen the impact of node failures.

4.10.1 Protecting an Application from Node Failure

There is only one good solution for protecting your application from node failure, and that is checkpointing. Checkpointing is where at regular intervals your application writes to disk what it has done so far, and at startup checks the file on disk so that it can start off where it was when it last wrote the file.

The way to checkpoint that gives you the highest chance of recovering is to send the data back to the master node and have it checkpoint there, and also make regular backups of your files on the master node.

When setting up checkpointing, it is important to think carefully about how often you want to checkpoint. Some jobs that don’t have much data that needs to be saved can checkpoint as often as every 5 minutes, whereas if you have a large data set, it might be smarter to checkpoint every hour, day, week, or longer. It depends a lot on your application. If you have a lot of data to checkpoint, you don’t want to do it often as that will drastically increase your run time. However, you also want to make sure that if you only checkpoint once every two days, that you can live with losing two days worth of work if there is ever a problem.

4.10.2 Compute Node Failure

A compute node can fail for any of a variety of reasons, e.g., broken node hardware, a broken network, software bugs, or inadequate hardware resources. A common example of the latter is a condition known as *Out Of Memory*, or *OOM*, which occurs when one or more applications on the node have consumed all available RAM memory and no swap space is available. The Linux kernel detects an OOM condition, attempts to report what is happening to the cluster’s syslog server, and begins to kill processes on the node in an attempt to eliminate the process that is triggering the problem. While this kernel response may occasionally be successful, more commonly it will kill one or more processes that are important for proper node behavior (e.g., a job manager daemon, the crucial Scyld `bpslave` daemon, or even a daemon that is required for the kernel’s syslog messages to get communicated to the cluster’s syslog server). When that happens, the node may still remain *up* in a technical sense, but the node is useless and must be rebooted.

When Compute Nodes Fail

When a compute node fails, all jobs running on that node will fail. If there was an MPI job running that was using that node, the entire job will fail on all the nodes on which the MPI program was running.

Even though the running jobs running on that node failed, jobs running on other nodes that weren’t communicating with jobs on the failed node will continue to run without a problem.

If the problem with the node is easily fixed and you want to bring the node back into the cluster, then you can try to reboot it using `bpctl -S` *nodenumber* `-R`. If the compute node has failed in a more catastrophic way, then such a graceful reboot will not work, and you will need to powercycle or manually reset the hardware. When the node returns to the *up* state, new jobs can be spawned that will use it.

If you wish to switch out the node for a new physical machine, then you must replace the broken node's MAC addresses with the new machine's MAC addresses. When you boot the new machine, it either appears as a new cluster node that is appended to the end of the list of nodes (if the `config` file says *nodeassign append* and there is room for new nodes), or else the node's MAC addresses get written to the `/var/beowulf/unknown_addresses` file. Alternatively, manually edit the `config` to change the MAC addresses of the broken node to the MAC addresses of the new machine, followed by the command `service beowulf reload`. Reboot this node, or use IPMI to powercycle it, and the new machine reboots in the correct node order.

Compute Node Data

What happens to data on a compute node after the node goes down depends on how you have set up the file system on the node. If you are only using a RAMdisk on your compute nodes, then all data stored on your compute node will be lost when it goes down.

If you are using the harddrive on your compute nodes, there are a few more variables to take into account. If you have your cluster configured to run `mke2fs` on every compute node boot, then all data that was stored on `ext2` file systems on the compute nodes will be destroyed. If `mke2fs` does not execute, then `fsck` will try to recover the `ext2` file systems; however, there are no guarantees that the file system will be recoverable.

Note that even if `fsck` is able to recover the file system, there is a possibility that files you were writing to at the moment of node failure may be in a corrupt or unstable state.

4.10.3 Master Node Failure

A master node can fail for the same reasons a compute node can fail, i.e., hardware faults or software faults. An Out-Of-Memory condition is more rare on a master node because the master node is typically configured with more physical RAM, more swap space, and is less commonly a participant in user application execution than is a compute node. However, in a Scyld ClusterWare cluster the master node plays an important role in the centralized management of the cluster, so the loss of a master node for any reason has more severe consequences than the loss of a single compute node. One common strategy for reducing the impact of a master node failure is to employ multiple master nodes in the cluster. See *Managing Multiple Master Nodes* for details.

Another moderating strategy is to enable *Run-to-Completion*. If the `bpslave` daemon that runs on each compute node detects that its master node has become unresponsive, then the compute node becomes an *orphan*. What happens next depends upon whether or not the compute nodes have been configured for *Run-to-Completion*.

When Master Nodes Fail - Without Run-to-Completion

The default behavior of an orphaned `bpslave` is to initiate a reboot. All currently executing jobs on the compute node will therefore fail. The reboot generates a new DHCP request and a PXEboot. If multiple master nodes are available, then eventually one master node will respond. The compute node reconnects to this master - perhaps the same master that failed and has itself restarted, or perhaps a different master - and the compute node will be available to accept new jobs.

Currently, Scyld only offers *Cold Re-parenting* of a compute node, in which a compute node must perform a full reboot in order to "fail-over" and reconnect to a master. See *Managing Multiple Master Nodes* for details.

When Master Nodes Fail - With Run-to-Completion

You can enable *Run-to-Completion* by enabling the ClusterWare script: `beochkconfig 85run2complete on`. When enabled, if the compute node becomes orphaned because its `bpslave` daemon has lost contact with its master node's `bpmaster` daemon, then the compute node does *not* immediately reboot. Instead, the `bpslave` daemon keeps the node up and running as best it can without the cooperation of an active master node. In an ideal world, most or all jobs running on that compute node will continue to execute until they complete or until they require some external resource that causes them to hang indefinitely.

Run-to-Completion enjoys greatest success when the private cluster network uses file server(s) that require no involvement of any compute node's active master node. In particular, this means not using the master node as an NFS server, and not using a file server that is accessed using IP-forwarding through the master node. Otherwise, an unresponsive master also means an unresponsive file server, and that circumstance is often fatal to a job. Keep in mind that the default `/etc/beowulf/fstab` uses *$MASTER* as the NFS server. You should edit `/etc/beowulf/fstab` to change *$MASTER* to the IP address of the dedicated (and hopefully long-lived) non-master NFS server.

Stopping or restarting the beowulf service, or just rebooting the compute nodes doing `bpctl -S all -R`, will not put the compute nodes into an orphan state. These actions instruct each compute node to perform an immediate graceful shutdown and to restart with a PXEboot request to its active master node. Similarly, rebooting the master node will also stop the service with a `service beowulf stop` as part of the master shutdown, and the compute nodes will immediately reboot and attempt to PXEboot before the master node has fully rebooted and thus ready to service the nodes. This will be a problem unless another master node is running on the private cluster network that will respond to the PXEboot request, or unless the nodes' BIOS have been configured to perpetually retry the PXEboot, or unless you explicitly force all the compute nodes to immediately become orphans prior to rebooting the master with `bpctl -S all -O`, thereby delaying the nodes' reboots until the master has time to reboot.

Once a compute node has become orphaned, it can only rejoin the cluster by rebooting, i.e., a so-called *Cold Reparenting*. There are two modes that `bpslave` can employ:

1. No automatic reboot. The cluster administrator must reboot each orphaned node using IPMI or by manually powercycling the server(s).
2. Reboot the node after being "effectively idle" for a span of *N* seconds. This is the default mode. The default *N* is 300 seconds, and the default "effectively idle" is cpu usage below 1% of one cpu's available cpu cycles.

Edit the `85run2complete` script to change the defaults. Alternatively, the `bpctl` can set (or reset) the run-to-completion modes and values. See `man bpctl`.

The term "effectively idle" means a condition wherein the cpu usage on the compute node is so small as to be interpreted as insignificant, e.g., attributed to various daemons such as `bpslave`, `sendstats`, and `pbs_mom`, which periodically awaken, check fruitlessly for pending work, and quickly go back to sleep. An orphaned node's `bpslave` periodically computes cpu usage across short time intervals. If the cpu usage is below a threshold percentage *P* (default 1%) of one cpu's total available cpu cycles, then the node is deemed "effectively idle" across that short time interval. If and when the "effectively idle" condition persists for the full *N* seconds time span (default 300 seconds), then the node reboots. If the cpu usage exceeds that threshold percentage during any one of those short time intervals, then the time-until-reboot is reset back to the full *N* seconds.

If the cluster uses TORQUE as a job manager, Run-to-Completion works best if TORQUE is configured for High Availability.

TORQUE high availability is best achieved using multiple master nodes, a shared file server that is separate from the master nodes, ClusterWare Run-to-Completion, and a carefully applied configuration recipe. This provides an environment that supports *Failover*: where the loss of a master node allows for the probable completion of currently executing jobs, and the reconnecting of the orphaned compute nodes to a different master node with its cooperating `pbs_server`.

A critical element of the configuration is using shared storage for the TORQUE `pbs_server` daemon that executes on each master node and for the `pbs_mom` daemon that executes on each compute node. For example, on the file server we use one directory for TORQUE job data and another for TORQUE's server_priv private data:

```
mkdir -p /share/data
mkdir -p /share/torque_server_priv
```

and the `/etc/exports` contains entries to share these directories with the cluster:

```
/share/data *(rw,sync,no_root_squash)
/share/torque_server_priv *(rw,sync,no_root_squash)
```

This example shares to the world, although you may want to make your access rules more restrictive. Don't forget to reload the new exports with `exportfs -r`.

On the client side, i.e., the master nodes and compute nodes, these file server directories are mounted as `/data` and `/var/spool/torque/server_priv`. Each master node has mountpoints:

```
mkdir -p /data
mkdir -p /var/spool/torque/server_priv
```

and the master nodes' `/etc/fstab` has entries:

```
fileserver:/share/data /data  nfs  defaults 0 0
fileserver:/share/torque/server_priv /var/spool/torque/server_priv nfs defaults 0 0
```

where *fileserver* is the hostname of the file server. The mounts can now be enabled immediately using `mount -a`.

Each master node's `/etc/beowulf/fstab` has a similar entry that mounts `/data` on each compute node as it boots:

```
10.1.1.4:/share/data   /data   nfs   nolock,nonfatal  0 0
```

except here we use `10.1.1.4` as the IP address of the file server, rather than use the *fileserver* hostname, because a compute node's name service isn't available compute node boot time that would translate *fileserver* into its IP address.

On each master node, make sure the TORQUE script is enabled: `beochkconfig 90torque on`. Next, verify that all compute nodes are listed in `/var/spool/torque/server_priv/nodes`. For example, for two nodes, n0 and n1, where each node has four cores and thus you want TORQUE to schedule jobs on all cores, the file contents would be:

```
n0 np=4
n1 np=4
```

If `/var/spool/torque/server_priv/nodes` is empty and you have no queues configured, you can configure a single *batch* queue as well as the `server_priv/nodes` file by reconfiguring torque:

```
service beowulf start
# Temporarily start Beowulf services, and after all nodes are 'up':
service torque reconfigure
# For now, stop Beowulf services while we continue configuring TORQUE:
service beowulf stop
```

Next, configure the `pbs_mom` daemons on the compute nodes to use the `/bin/cp` command to send output files to `/data`. Edit the file `/var/spool/torque/mom_priv/config` to include:

```
$pbsserver      master
$usecp          *:/home /home
$usecp          *:/data /data
```

Now install the *Heartbeat* service on all master nodes, if it is not already installed, and enable it to start at master node boot time:

```
yum install heartbeat
chkconfig heartbeat on
```

and disable Beowulf and TORQUE from starting at master node boot time, since Heartbeat will manage these services for us:

```
chkconfig beowulf off
chkconfig torque off
```

On all masters, configure the Heartbeat service to manage Beowulf and TORQUE services, with the primary master named *master0*. The file `/etc/ha.d/haresources` needs to contain a line:

```
master0 beowulf torque
```

Start Beowulf and TORQUE by starting Heartbeat on the primary master node *master0*: `service heartbeat start`. The Heartbeat daemon reads the `/etc/ha.d/haresources` file and starts services in order: first *beowulf*, then *torque*. Then `service heartbeat start` on the other master nodes, who have also been configured to understand that *master0* is the Heartbeat master.

4.11 Compute Node Boot Options

One of the unique advantages of Scyld ClusterWare is the fast and flexible boot procedure for compute nodes. The Scyld `BeoBoot` system is a combination of unified booting and a carefully designed light-weight compute node environment. The `BeoBoot` system allows compute nodes to initialize with a very small boot image that may be stored on a wide range of boot media. This small boot image never has to change; however, Scyld ClusterWare‘s boot setup allows you to change the kernel the compute nodes run, the modules that are loaded, and every aspect of the application environment by changing a few files on the master node.

This chapter gives instructions for setting up different types of boot media for the compute nodes, changing various settings that control the boot process, and checking for boot error messages. A detailed description of the boot process is included in the ClusterWare technical description in *Scyld ClusterWare Design Overview*.

4.11.1 Compute Node Boot Media

There are several ways to boot a compute node with Scyld ClusterWare, as discussed in the following sections. The methods described are all interchangeable, and they work seamlessly with each other. Thus, you can have some of your compute nodes boot using one method and other nodes boot with a different method.

PXE

PXE is a protocol that defines a standard way to netboot x86-based machines. In order for PXE to work, your compute nodes must have support for it in both the network adapters as well as the BIOS. The option to PXE boot must also be turned on in the BIOS. This is the preferred method of booting nodes in a Scyld cluster.

Local Disk

You can configure a node to boot from its local harddrive. See *Managing Non-Scyld Nodes* for details.

Linux BIOS

Linux BIOS is a project to replace the BIOS of a machine with Linux. This greatly speeds up the boot process as most of the actual work done by the BIOS is designed to make things like DOS work, but which aren't really needed by Linux.

There has been work done by third parties so that it is a Scyld ClusterWare initial image that replaces the BIOS. This has the advantage that all you need for a compute node is a motherboard with ram, processor, built-in network adapter, and a power supply.

Linux BIOS is not supported by Penguin Computing, Inc., however you can see http://www.linuxbios.org/ for more information if you are interested.

Flash Disk

Although not Scyld specific, using a flash disk is mentioned as it can increase cluster reliability. A flash disk is a solid state device using an Electrical Erasable PROM (EEPROM). The devices are seen by the BIOS as an IDE or SCSI harddrive, and support all normal drive operations, including running beofdisk and installing the initial boot image. This allows a node cluster configuration with no moving parts other than cooling fans, and is an alternative to using the Linux BIOS. These devices are faster and cheaper than harddrives, and are currently limited to 4 MB to 512 MB. But, for booting, less than 2 MB would be needed.

4.11.2 Changing Boot Settings

Adding Steps to the node_up Script

If you wish to add more steps to be executed during the node_up script, you can do it without actually editing the script. Instead, you create a script in the /etc/beowulf/init.d/ directory. All scripts in this directory will be executed for each node that boots up. This script will be sourced by the node_up script when the specified node boots, therefore it must be written in standard sh. When your script is sourced, the variable $NODE will be set to the node number that is booting. See *Special Directories, Configuration Files, and Scripts* for more details.

Per-Node Parameters

Starting with Scyld Series 30, support is provided for specifying kernel image and kernel command line parameters on a per-node basis in the cluster config file /etc/beowulf/config. This enables one set of nodes to boot with a particular initrd image, while another group boots with a different one.

The utility of this feature can be illustrated by the use of the memtest86 memory testing utility. For example, if you had just expanded your cluster with 5 new nodes (nodes 16 through 20), and you wanted to test their memory before putting them into production, you could have them all boot into memtest86 rather than the usual Scyld initrd with the following entry in /etc/beowulf/config:

```
kernelimage 16-20 /var/beowulf/boot/memtest86.bin
initrdimage 16-20 none
kernelcommandline 16-20 none
```

Other Per-Node Config Options

The cluster config file /etc/beowulf/config provides per-node support for node state changes, which allows the use of other scripts or tools to control and manipulate the *wake*, *alert*, and *down* states of nodes in the cluster.

4.11.3 Error Logs

There are a number of ways to check for errors that occur during the compute node boot process, as follows:

- During the compute node boot process, any error messages are sent to the console of the compute node and forwarded to the cluster's syslog server's /var/log/messages file by the node's beoklogd daemon. By default, the syslog server is the master node. See the *syslog_server=* option in *Compute node command-line options* for details about how to direct these compute node logging messages to an alternate server. Messages can be viewed by manually editing this file read-only or by running the standard Linux System Logs tool: *Select*

System Tools -> *System Logs* from the desktop menu to open the System Logs window, then select the System Log from the list of logs in the left panel, then scroll near the end to see errors.

- During each node's boot, the `node_up` script writes node-specific output to a log file `/var/log/beowulf/node.<nodenumber>`, where `<nodenumber>` is the node number. If the compute node ends up in the *error* state, or if it remains in the *boot* state for an extended length of time, then you should examine this node log.

4.12 Disk Partitioning

Partitioning allows disk storage space to be broken up into segments that are then accessible by the operating system. This chapter discusses disk partitioning concepts, the default partitioning used by Scyld ClusterWare, and some useful partitioning scenarios.

Scyld ClusterWare creates a RAM disk on the compute node by default during the initial boot process. This RAM disk is used to hold the final boot image downloaded from the master node. If you have diskless nodes, then this chapter does not pertain to you.

4.12.1 Disk Partitioning Concepts

Disk partitioning on a cluster is essentially no different than partitioning on any stand-alone computer, with a few exceptions.

On a stand-alone computer or server, the disk drive's file system(s) divide the storage available on the disk into different sections that are configured in ways and sizes to meet your particular needs. Each partition is a segment that can be accessed independently, like a separate disk drive. The partitions are configured and determined by the partition table contained on each disk.

Each partition table entry contains information about the locations on the disk where the partition starts and ends, the state of the partition (active or not), and the partition's type. Many partition types exist, such as Linux native, AIX, DOS, etc.. The cluster administrator can determine the appropriate partition types for his/her own system.

Disk partitioning on a cluster is very much determined by the cluster system hardware and the requirements of the application(s) that will be running on the cluster, for instance:

- Some applications are very process intensive but not very data intensive. In such instances, the cluster may best utilize a RAM disk in the default partitioning scheme. The speed of the RAM will provide better performance, and not having a harddrive will provide some cost savings.
- Some applications are very data intensive but not very process intensive. In these cases, a hard disk is either required (given the size of the data set the application is working with) and/or is a very inexpensive solution over purchasing an equivalent amount of memory.

The harddrive partitioning scheme is very dependent on the application needs, the other tools that will interface with the data, and the preferences of the end-user.

4.12.2 Disk Partitioning with ClusterWare

This section briefly describes the disk partitioning process for the master node and compute nodes in a Scyld cluster.

Master Node

On the master node of a Scyld cluster, the disk partitioning administration is identical to that on any stand-alone Linux server. As part of installing Red Hat Linux, you are requested to select how you would like to partition the master node's hard disk. After installation, the disk partitioning can be modified, checked, and utilized via traditional Linux tools such as `fdisk`, `sfdisk`, `cfdisk`, `mount`, etc.

Compute Nodes

The compute nodes of a Scyld cluster are slightly different from a traditional, stand-alone Linux server. Each compute node hard disk needs to be formatted and partitioned to be useful to the applications running on the cluster. However, not too many people would enjoy partitioning 64 or more nodes manually.

To simplify this task, Scyld ClusterWare provides the `beofdisk` tool, which allows remote partitioning of the compute node hard disks. It is very similar in operation to `fdisk`, but allows many nodes to be partitioned at once. The use of `beofdisk` for compute node partitioning is covered in more detail in *Partitioning Scenarios*.

4.12.3 Default Partitioning

This section addresses the default partitioning schemes used by Scyld ClusterWare.

Master Node

The default Scyld partition table allocates 4 partitions:

- /boot partition
- /home partition
- / partition
- Swap partition = 2 times physical memory

Most administrators will want to change this to meet the requirements of their particular cluster.

Compute Nodes

The default partition table allocates three partitions for each compute node:

- BeoBoot partition = 2 MB
- Swap partition = half the compute node's physical memory or half the disk, whichever is smaller
- Single root partition = remainder of disk

For diskless operation, the default method of configuring the compute nodes at boot time is to run off a RAM disk. This "diskless" configuration is appropriate for many applications, but not all. Typical usage requires configuration and partitioning of the compute node hard disks, which is covered in the partitioning scenarios discussed in the following section.

4.12.4 Partitioning Scenarios

This section discusses how to implement two of the most common partitioning scenarios in Scyld ClusterWare:

- Apply the default partitioning to all disks in the cluster
- Specify your own manual but homogeneous partitioning to all disks in the cluster

The Scyld `beofdisk` tool can read an existing partition table on a compute node. It sequentially queries compute nodes beginning with node 0. For each new type/position/geometry it finds, it looks for an existing partition table file in `/etc/beowulf/fdisk`. If no partition table is present, a new one is generated that uses the default scheme. For each device/drive geometry it finds, `beofdisk` creates a file in `/etc/beowulf/fdisk/`. These files can then be modified by hand. Whether modified or using the default options, the files can be written back to the harddrives.

> **Caution**
>
> If you attempt to boot a node with an unpartitioned harddrive that is specified in `/etc/beowulf/fstab` (or a node-specific `fstab.N` for node *N*), then that node boots to an *error* state unless the `fstab` entry includes the "nonfatal" option. See the *Reference Guide* or `man beowulf-fstab` for details.

Applying the Default Partitioning

To apply the default disk partitioning scheme (as recommended by the Scyld `beofdisk` tool) to the compute nodes, following these steps:

Query all the harddrives on the compute nodes and write out partition table files for them that contain the suggested partitioning:

```
[root@cluster ~] # beofdisk -d
        Creating a default partition table for hda:2495:255:63
        Creating a default partition table for hda:1222:255:63
```

Read the partition table files, and partition the harddrives on the compute nodes so that they match:

```
[root@cluster ~] # beofdisk -w
```

To use the new partitions you created, modify the `/etc/beowulf/fstab` file to specify how the partitions on the compute node should be mounted. The contents of `/etc/beowulf/fstab` should be in the standard `fstab` format.

To format the disk(s) on reboot, change "mkfs never" to "mkfs always" in the cluster config file `/etc/beowulf/config`.

To try out the new partitioning, reboot the compute nodes with the following:

```
[root@cluster ~] # bpctl -S all -R

**Caution**

To prevent disks from being reformatted on subsequent reboots,
change "mkfs always" back to "mkfs never" in ``/etc/beowulf/config``
after the nodes have booted.
```

Specifying Manual Partitioning

You can manually apply your own homogeneous partitioning scheme to the partition tables, instead of taking the suggested defaults. There are two methods for doing this:

- The recommended method involves running `fdisk` on the first node (node 0) of the cluster, and then on every *first* node that has a unique type of hard disk.
- The other method is to manually edit the partition table text file retrieved by the `beofdisk` query.

For example, assume that your cluster has 6 compute nodes, and that all disks have 255 heads and 63 sectors (this is the most common). Nodes 0, 1, and 5 have a single IDE hard disk with 2500 cylinders. Nodes 2, 3, and 4 have a first

IDE disk with 2000 cylinders, and node 4 has a SCSI disk with 5000 cylinders. This cluster could be partitioned as follows:

1. Partition the disk on node 0:

```
[root@cluster ~] # bpsh 0 fdisk /dev/hda
```

   Follow the steps through the standard `fdisk` method of partitioning the disk.

2. Manually partition the disk on node 2 with `fdisk`:

```
[root@cluster ~] # bpsh 2 fdisk /dev/hda
```

   Again, follow the steps through the standard `fdisk` method of partitioning the disk.

3. Manually partition the SCSI disk on node 4 with `fdisk`:

```
[root@cluster ~] # bpsh 4 fdisk /dev/sda
```

   Again, follow the steps through the standard `fdisk` method of partitioning the disk.

4. Next, query the compute nodes to get all the partition table files written for their harddrives by using the command ‘‘beofdisk -q ‘‘.

   At this point, the 3 partition tables will be translated into text descriptions, and 3 files will be put in the directory `/etc/beowulf/fdisk`. The file names will be `hda:2500:255:63`, `hda:2000:255:63`, and `sda:5000:255:63`. These file names represent the way the compute node harddrives are currently partitioned.

   You have the option to skip the `fdisk` command and just edit these files manually. The danger is that there are lots of rules about what combinations of values are allowed, so it is easy to make an invalid partition table. Most of these rules are explained as comments at the top of the file.

5. Now write out the partitioning scheme using the command `beofdisk -w`.

   When specifying unique partitioning for certain nodes, you must also specify a unique `fstab` for each node that has a unique partition table. To do this, create the file `/etc/beowulf/fstab.<nodenumber>`. If this file exists, the `node_up` script will use that as the `fstab` for the compute node; otherwise, it will default to `/etc/beowulf/fstab`. Each instance of `/etc/beowulf/fstab.<nodenumber>` should be in the same format as `/etc/beowulf/fstab`.

6. To format the disk(s) on reboot, change “mkfs never” to “mkfs always” in the cluster config file `/etc/beowulf/config`.

7. To try out the new partitioning, reboot the compute nodes with the following:

```
[root@cluster ~] # bpctl -S all -R
```

   Caution

   To prevent disks from being reformatted on subsequent reboots, change the “mkfs always” back to “mkfs never” in `/etc/beowulf/config` after the nodes have booted.

4.13 File Systems

4.13.1 File Systems on a Cluster

File systems on a cluster consist of two types of file systems, local file systems and network file systems. The file `/etc/fstab` describes the filesystems mounted on the master node, and the file `/etc/beowulf/fstab` describes the filesystems mounted on each compute node. You may also create node-specific `/etc/beowulf/fstab.N` files, where *N* is a node number.

Local File Systems

Local file systems are the file systems that exist locally on each machine. In the Scyld ClusterWare setup, the master node has a local file system, typically ext3, and each node also has a local file system. The local file systems are used for storing data that is local to the machines.

Network/Cluster File Systems

Network file systems are used so that files can be shared across the cluster and every node in the cluster can see the exact same set of files. The default network file system for Scyld ClusterWare is NFS. NFS allows the contents of a directory on the server (by default the master node) to be accessed by the clients (the compute nodes). The default Scyld ClusterWare setup has the `/home` directory exported through NFS so that all the user home directories can be accessed on the compute nodes. Additionally, various other directories are mounted by default, as specified by `/etc/beowulf/fstab` or by a node-specific `fstab.N`.

Note that root's home directory is not in `/home`, and thus cannot access its home directory on the compute nodes. This should not be a problem, as normal compute jobs should not be run as "root".

4.13.2 NFS

NFS is the standard way to have files stored on one machine, yet be able to access them from other machines on the network as if they were stored locally.

NFS on Clusters

NFS in clusters is typically used so that if all the nodes need the same file, or set of files, they can access the file(s) through NFS. This way, if one changes the file, every node sees the change, and there is only one copy of the file that needs to be backed up.

Configuration of NFS

The Network File System (NFS) is what Scyld ClusterWare uses to allow users to access their home directories and other remote directories from compute nodes. (The *User's Guide* has a small discussion on good and bad ways to use NFS.) Two files control what directories are NFS mounted on the compute nodes. The first is `/etc/exports`. This tells the nfs daemon on the master node what directories it should allow to be mounted and who can access them. Scyld ClusterWare adds various commonly useful entries to `/etc/exports`. For example:

```
/home  @cluster(rw)
```

The */home* says that `/home` can be nfs mounted, and *@cluster(rw)* says who can mount it and what forms of access are allowed. *@cluster* is a netgroup. It uses one word to represent several machines. In this case, it represents all your compute nodes. *cluster* is a special netgroup that is setup by `beonss` that automatically maps to all of your compute nodes. This makes it easy to specify something can be mounted by your compute nodes. The *(rw)* part specifies what permissions the compute node has when it mounts `/home`. In this case, all user processes on the compute nodes have read-write access to `/home`. There are more options that can go here, and you can find them detailed in `man exports`.

The second file is `/etc/beowulf/fstab`. (Note that it is possible to set up an individual `fstab.`*N* for a node. For this discussion, we will assume that you are using a global `fstab` for all nodes.) For example, one line in the default `/etc/beowulf/fstab` is the following:

```
$MASTER:/home  /home  nfs  nolock,nonfatal  0 0
```

This is the line that tells the compute nodes to try to mount `/home` when they boot:

- The *$MASTER* is a variable that will automatically be expanded to the IP of the master node.
- The first */home* is the directory location on the master node.
- The second */home* is where it should be mounted on the compute node.
- The *nfs* specifies that this is an nfs file system.
- The *nolock* specifies that locking should be turned off with this nfs mount. We turn off locking so that we don't have to run daemons on the compute nodes. (If you need locking, see *File Locking Over NFS* for details.)
- The *nonfatal* tells ClusterWare's `/usr/lib/beoboot/bin/setup_fs` script to treat a mount failure as a nonfatal problem. Without this *nonfatal* option, any mount failure leaves the compute node in an *error* state, thus making it unavailable to users.
- The two 0's on the end are there to make the `fstab` like the standard `fstab` in `/etc`.

To add an nfs mount of `/foo` to all your compute nodes, first add the following line to the end of the `/etc/exports` file:

```
/foo  @cluster(rw)
```

Then execute `exportfs -a` as root. For the mount to take place the next time your compute nodes reboot, you must add the following line to the end of `/etc/beowulf/fstab`:

```
$MASTER:/foo  /foo  nfs  nolock  0 0
```

You can then reboot all your nodes to make the nfs mount happen. If you wish to mount the new exported filesystem without rebooting the compute nodes, you can issue the following two commands:

```
[root @cluster ~] # bpsh -a mkdir -p /foo
[root @cluster ~] # bpsh -a mount -t nfs -o nolock master:/foo /foo
```

Note that `/foo` will need to be adjusted for the directory you actually want.

If you wish to stop mounting a certain directory on the compute nodes, you can either remove the line from `/etc/beowulf/fstab` or just comment it out by inserting a '#' at the beginning of the line. You can leave untouched the entry referring to the filesystem in `/etc/exports`, or you can delete the reference, whichever you feel more comfortable with.

If you wish to unmount that directory on all the compute nodes without rebooting them, you can then run the following:

```
[root @cluster ~] # bpsh -a umount /foo
```

where `/foo` is the directory you no longer wish to have NFS mounted.

Caution

On compute nodes, NFS directories must be mounted using either a specific IP address or the *$MASTER* keyword; the hostname cannot be used. This is because `fstab` is evaluated before node name resolution is available.

File Locking Over NFS

By default, the compute nodes mount NFSv3 filesystems with locking turned off. If you have a program that requires locking, first ensure that the *nfslock* service is enabled on the master node and is executing:

```
[root @cluster ~] # chkconfig nfslock on
[root @cluster ~] # service nfslock start
```

Next, edit `/etc/beowulf/fstab` to remove the *nolock* keyword from the NFS mount entries.

Finally, reboot the cluster nodes to effect the NFS remounting with locking enabled.

NFSD Configuration

By default, when the master node reboots, the `/etc/init.d/nfs` script launches 8 NFS daemon threads to service client NFS requests. For large clusters this count may be insufficient. One symptom of an insufficiency is a syslog message, most commonly seen when you boot all the cluster nodes:

```
nfsd: too many open TCP sockets, consider increasing the number of nfsd threads
```

To increase the thread count (e.g., to 16):

```
[root @cluster ~] # echo 16 > /proc/fs/nfsd/threads
```

Ideally, the chosen thread count should be sufficient to eliminate the syslog complaints, but not significantly higher, as that would unnecessarily consume system resources. To make the new value persistent across master node reboots, create the file `/etc/sysconfig/nfs`, if it does not already exist, and add to it an entry of the form:

```
RPCNFSDCOUNT=16
```

A value of 1.5x to 2x the number of nodes is probably adequate, although perhaps excessive.

A more refined analysis starts with examining NFSD statistics:

```
[root @cluster ~] # grep th /proc/net/rpc/nfsd
```

which outputs thread statistics of the form:

```
th 16 10 26.774 5.801 0.035 0.000 0.019 0.008 0.003 0.011 0.000 0.040
```

From left to right, the *16* is the current number of NFSD threads, and the *10* is the number of times that all threads have been simultaneously busy. (Not all circumstances of all threads being busy results in that syslog message, but a high all-busy count does suggest that adding more threads may be beneficial.)

The remaining 10 numbers are histogram buckets that show how many accumulated seconds a percentage of the total number of threads have been simultaneously busy. In this example, 0-10% of the threads were busy *26.744* seconds, 10-20% of the threads were busy *5.801* seconds, and 90-100% of the threads were busy *0.040* seconds. High numbers at the end indicate that most or all of the threads are simultaneously busy for significant periods of time, which suggests that adding more threads may be beneficial.

4.13.3 ROMIO

ROMIO is a high-performance, portable implementation of MPI-IO, the I/O chapter in MPI-2: Extensions to the Message Passing Interface, and is included in the Scyld ClusterWare distribution. ROMIO is optimized for noncontiguous access patterns, which are common in parallel applications. It has an optimized implementation of collective I/O, an important optimization in parallel I/O.

Reasons to Use ROMIO

ROMIO gives you an abstraction layer on top of high performance input/output. The details for the file system may be implemented in various ways, but ROMIO prevents you from caring. Your binary code will run on an NFS file system here and a different file system there, without changing a line or recompiling. Although POSIX open(), read(), ... calls already do this, the virtual file system code to handle this abstraction is deep in the kernel.

You may need to use ROMIO to take advantage of new special and experimental file systems. It is easier and more portable to implement a ROMIO module for a new file system than a Linux-specific VFS kernel layer.

Since ROMIO is an abstraction layer, it has the freedom to be implemented arbitrarily. For example, it could be implemented on top of the POSIX Asynchronous and List I/O calls for real-time performance reasons. The end-user application is shielded from caring, and benefits from careful optimization of the I/O details by experts.

Installation and Configuration of ROMIO

ROMIO Over NFS

To use ROMIO on NFS, file locking with `fcntl` must work correctly on the NFS installation. First, since file locking is turned off by default, you need to turn on NFSv3 locking. See *File Locking Over NFS*. Now, to get the fcntl locks to work, you must mount the NFS file system with the noac option (no attribute caching). This is done by modifying the line for mounting /home in /etc/beowulf/fstab to look like the following:

```
$MASTER:/home  /home  nfs  noac,nonfatal  0 0
```

Turning off attribute caching may reduce performance, but it is necessary for correct behavior.

4.13.4 Other Cluster File Systems

There are variety of network file systems that can be used on a cluster. If you have questions regarding the use of any particular cluster file system with Scyld ClusterWare, contact Scyld Customer Support for assistance.

4.14 Load Balancing

You have made some rather significant investment in your cluster. It is also evident that it depreciates at a rather frightening rate. Given these two facts it should be obvious you want your cluster busy 100% of the time if possible.

However, timely results of output are also important. If the memory requirements of programs running on the cluster exceed the available physical memory, swap memory (hard disk) will be used severely reducing performance. Even if the memory requirements of many processes still fit within the physical memory, results of any one of the programs may take significantly longer to achieve if many jobs are running on the same nodes simultaneously.

Thus we come to concept of the “load balancing”, which maintain a delicate balance between overburdened and idle. Load balancing is when multiple servers can perform the same task, and which server performs the task is based on which server is currently doing the least amount of work. This helps to spread a heavy work load across several machines, and does it intelligently; if one machine is more heavily loaded than the others, new requests will not be sent to it. By doing this, a job is always run on a machine that has the most resources to devote to it, and therefore gets finished sooner.

Generally, it is believed that a constant load of one 100% CPU bound process per CPU is ideal. However, not all processes are CPU bound; many are I/O bound on either the harddrive or the network. The act of load balancing is often described as “scheduling”.

Optimal load balancing is almost never achieved; hence, it is a subject of study for many researchers. The optimal algorithm for scheduling the programs running on your cluster is probably not the same as it might be for others, so you may want to spend time on your own load balancing scheme.

4.14.1 Load Balancing in a Scyld Cluster

Scyld ClusterWare supplies a general load balancing and job scheduling scheme via the `beomap` subsystem in conjunction with job queuing utilities. Mapping is the assignment of processes to nodes based on current CPU load. Queuing is the holding of jobs until the cluster is idle enough to let the jobs run. Both of these are covered in detail in other sections of this guide and in the *User's Guide*. In this section, we'll just discuss the scheduling policy that is used.

Mapping Policy

The current default mapping policy consists of the following steps:

- Run on nodes that are idle
- Run on CPUs that are idle
- Minimize the load per CPU

Each proceeding step is only performed if the number of desired processes (NP) is not yet satisfied. The information required to perform these steps comes from the `BeoStat` sub-system of daemons and libbeostat library.

Queuing Policy

The current default queuing policy is to attempt to determine the desired number of processes (NP) and other mapping parameters from the job script. Next, the `beomap` command is run to determine which nodes would be used if it ran immediately. If every node in the returned map is below 0.8 CPU usage the job is released for execution.

4.14.2 Implementing a Scheduling Policy

The queuing portion of the schedule policy depends on which scheduling and resource management tool you are using. The mapping portions, however, are already modularized. There are a number of ways to override the default, including

- Substitute a different program for the `beomap` command and use `mpirun` to start jobs (which uses beomap).
- Create a shared library that defines the function get_beowulf_job_map() and use the environment variable LD_PRELOAD to force the pre-loading of this shared library.
- Create the shared library and replace the default `/usr/liblibbeomap.so` file.

These methods are in order of complexity. We can't actually highly recommend the first method as your mileage may vary. The second method is the most recommended followed by the third method of replacing the Scyld source code when you're happy that your scheduler is better.

It is highly recommended that you get the source code for the `beomap` package. It will give you a head start on writing your own mappers. For more information on developing your own mapper, see the *Programmer's Guide*.

4.15 IPMI

Included in the RHEL/CentOS base distribution are tools that may be of interest to users, including the `ipmitool` command for monitoring and managing compute node hardware.

4.15.1 IPMITool

`ipmitool` is a hardware management utility that supports the Intelligent Platform Management Interface (IPMI) specification v1.5 and v2.0.

IPMI is an open standard that defines the structures and interfaces used for remote monitoring and management of a computer motherboard (baseboard). IPMI defines a micro-controller, called the "baseboard management controller" (BMC), which is accessed locally through the managed computer's bus or through an out-of-band network interface connection (NIC).

Scyld ClusterWare supports `ipmitool` as the primary way to monitor and manage compute node hardware. The Scyld ClusterWare distribution includes `/etc/beowulf/init.d/20ipmi`, a script that executes at compute node boot time that enables IPMI on a compute node.

The *root* can use `ipmitool` for a variety of tasks, such as:

- Inventory a node's baseboards to determine what sensors are present
- Monitor sensors (fan status, temperature, power supply voltages, etc.)
- Read and display values from the Sensor Data Repository (SDR)
- Read and set the BMC's LAN configuration
- Remotely control chassis power
- Display the contents of the System Event Log (SEL), which records events detected by the BMC as well as events explicitly logged by the operating system
- Print Field Replaceable Unit (FRU) information, such as vendor ID, manufacturer, etc.
- Configure and emulate a serial port to the baseboard using the out-of-band network connection known as serial over LAN (SOL)

Several dozen companies support IPMI, including many leading manufacturers of computer hardware. You can learn more about OpenIPMI from the OpenIPMI project page at http://openipmi.sourceforge.net, which includes links to documentation and downloads.

4.16 Updating Software On Your Cluster

From time to time, Scyld may release updates and add-ons to Scyld ClusterWare. Customers on active support plans for Scyld software products can access these updates on the Penguin Computing website. Visit https://www.penguincomputing.com/support for details. This site offers answers to common technical questions and provides access to application notes, software updates, product documentation, and *Release Notes*.

The *Release Notes* for each software update will include instructions for installation, along with information on why the update was released and what bug(s) it fixes. Be sure to thoroughly read the *Release Notes*, as they may discuss specific requirements and potential conflicts with other software.

4.16.1 What Can't Be Updated

Some packages provided with Scyld ClusterWare, such as Ganglia, are specifically optimized to take advantage of the BProc unified process space, which is added to the standard Linux distributions that Scyld supports. Other packages, such as MPICH2, MVAPICH2, MPICH3, and OpenMPI, take advantage of features of the Scyld ClusterWare TORQUE distribution. Although there are generally available versions of these packages that you can download from other sources, you should use the versions provided by Scyld for best performance with BProc and ClusterWare. Contact Scyld Customer Support if you have questions about specific packages that you would like to use with Scyld ClusterWare.

Users may also choose to use commercially available MPIs, such as Intel, HP, Scali, or Verari. These require specific configuration on Scyld ClusterWare. See the Penguin Computing Support Portal at https://www.penguincomputing.com/support, or contact Scyld Customer Support.

4.17 Special Directories, Configuration Files, and Scripts

Scyld ClusterWare adds some special files and directories on top of the standard Linux install that help control the behavior of the cluster. This appendix contains a summary of those files and directories, and what is in them.

4.17.1 What Resides on the Master Node

/etc/beowulf/ directory

All the config files for controlling how `BProc` and `Beoboot` behave are stored here.

/etc/beowulf/config

This file contains the settings that control the `bpmaster` daemon for `BProc`, and the `beoserv` daemon that is part of beoboot. It also contains part of the configuration for how to make beoboot boot images.

/etc/beowulf/fdisk/

This directory is used by `beofdisk` to store files detailing the partitioning of the compute nodes' harddrives, and is also read from when it rewrites the partition tables on the compute nodes. See ?

/etc/beowulf/fstab

Refer to *Disk Partitioning* for details on using node-specific fstab.N files.

/etc/beowulf/backups/ directory

Contains time-stamped backups of older versions of various configuration files, e.g., `/etc/beowulf/config` and `/etc/beowulf/fstab`, to assist in the recovery of a working configuration after an invalid edit.

/etc/beowulf/init.d/ directory

Contains various scripts that are executed on the master node by the `node_up` script when booting a compute node.

/etc/beowulf/conf.d/ directory

Contains various configuration files that are needed when booting a compute node.

/usr/lib/beoboot directory

This directory contains files that are used by beoboot for booting compute nodes.

/usr/lib/beoboot/bin

This directory contains the `node_up` script and several smaller scripts that it calls.

/var/beowulf directory

This directory contains compute node boot files and static information, as well as the list of unknown MAC addresses. It includes three subdirectories.

/var/beowulf/boot

This is the default location for files essential to booting compute nodes. Once a system is up and running, you will typically find three files in this directory:

- `computenode` — the boot sector used for bootstrapping the kernel on the compute node.
- `computenode.initrd` — the kernel image and initial ramdisk used to boot the compute node.
- `computenode.rootfs` — the root file system for the compute node.

/var/beowulf/statistics

This directory contains a cached copy of static information from the compute nodes. At a minimum, it includes a copy of `/proc/cpuinfo`.

/var/beowulf/unknown_addresses

This file contains a list of Ethernet hardware (MAC) addresses for nodes considered *unknown* by the cluster. See *Compute Node Categories* for more information.

/var/log/beowulf directory

This directory contains the boot logs from compute nodes. These logs are the output of what happens when the `node_up` script runs. The files are named `node.`, where <number> is the actual node number.

4.17.2 What Gets Put on the Compute Nodes at Boot Time

- Generally speaking, the /dev directory contains a subset of devices present in the /dev directory on the master node. The /usr/lib/beoboot/bin/mknoderootfs script creates most of the /dev/ entries (e.g., zero, null, and random). /etc/beowulf/init.d/20ipmi creates ipmi0. /usr/lib/beoboot/bin/setup_fs creates shm and pts (as directed by /etc/beowulf/fstab). The harddrive devices (e.g., sda) are created at compute node bootup time, if local drives are discovered. If Infiniband hardware is present on the compute node, /etc/beowulf/init.d/15openib creates various device entries in /dev/infiniband/.
- The /etc directory contains the ld.so.cache, localtime, mtab, and nsswitch.conf files. The node_up script creates a simple hosts file.
- The /home directory exists as a read-write NFS mount of the /home directory from the master node. Thus, all the home directories can be accessed by jobs running on the compute nodes.
- Additionally, other read-only NFS mounts exist by default, to better assist out-of-the-box application and script execution: /bin, /usr/bin, /opt, /usr/lib64/python2.3, /usr/lib/perl5, and /usr/lib64/perl5.
- The node_up script mounts pseudo-filesystems as directed by /etc/beowulf/fstab: /proc, /sys, and /bpfs.
- mknoderootfs creates /var and several of its subdirectories.
- The /tmp directory is world-writeable and can be used as temporary space for compute jobs.
- /etc/beowulf/config names various *libraries* directories that are managed by the compute node's library cache. Run beoconfig libraries to see the current list of library directories. Caching shared libraries, done automatically as needed on a compute node, speeds up the transfer process when you are trying to run jobs, eliminates the need to NFS-mount the various common directories that contain libraries, and minimizes the space consumed by libraries in the compute node's RAM filesystem.
- Typically, when the loader starts up an application, it opens the needed shared libraries. Each open() causes the compute node to pull the shared library from the master node and save it in the library cache, which typically resides in the node's RAM filesystem. However, some applications and scripts reference a shared library or other file that, although it resides in one of those *libraries* directories, the reference does not use open() to access the file, and so the file does not get automatically pulled into the library cache. For example, an application or script might first use stat() to determine if a specific file exists, and then use open() if the stat() is successful, otherwise continue on to stat() an alternative file. The stat() on the compute node will fail until an open() pulls the file from the master. The application or script thus fails to execute, and the missing library or file name is typically displayed as an error.

  To remedy this type of failure, you should use a *prestage* directive in /etc/beowulf/config to explicitly name files that should be pulled to each compute node at node startup time. Run beoconfig prestage for the current list of prestaged files.

4.17.3 /usr/lib/locale/locale-archive Internationalization

Glibc applications silently open the file /usr/lib/locale/locale-archive, which means it gets downloaded by each compute node early in a node's startup sequence via the BProc filecache functionality. The default locale-archive is 95 MBytes in RHEL6 and over 100 MBytes in RHEL7. This download consumes significant network bandwidth and thus causes serialization delays if numerous compute nodes attempt to concurrently boot, and thereafter this large file consumes significant RAM filesystem space on each node. It is likely that a cluster's users and applications do not require all the international locale data that is present in the default file. With care, the cluster administrator may choose to rebuild locale-archive with a greatly reduced set of locales and thus create a significantly smaller file that is less impactful on cluster performance.

Rebuilding and replacing `locale-archive` should be done on a quiescent master node, as the file typically is mmap'ed by a process (e.g., `crond`, `bash`), and the appearance of a replacement version may perturb shells and other programs, such as aborting the shell that executes the rebuild or having that shell issue an immediate warning message about an undefined environment variable. In the event that a problem does appear, you should reboot the master node. Otherwise, newly executing programs on the master node will use the updated `locale-archive`, and compute nodes will employ the new file only after the node reboots.

In a `RHEL5` environment, the *glibc-common* RPM installs the `/usr/lib/locale/` directory containing the full set of locale definition files and a full `locale-archive` binary file. The `build-locale-archive` command rebuilds the `locale-archive` with every individual locale data file that is found in that directory. Thus, to reduce the size of `locale-archive`, you must first reduce the number of locale data files in that directory - but only after saving the default locale data files in a safe place, so you can later rebuild the `locale-archive` with a different set of locale data files as the cluster's needs change. Beginning with the default `/usr/lib/locale/` directory with its full set of locale data files:

```
[root@cluster ~] # cd /usr/lib
[root@cluster ~] # cp -a locale locale.default
[root@cluster ~] # (cd locale ; rm -fr *_*)
```

saves all the locale data files in a new directory and produces a stripped-down `/usr/lib/locale/`, leaving only the `locale-archive` file. Now reintroduce a smaller set of locale data files. For example, to include the U.S.-English and U.S.-Great Britain locale files:

```
[root@cluster ~] # cp -a locale.default/en_US* locale
[root@cluster ~] # cp -a locale.default/en_GB* locale
```

When `/usr/lib/locale/` contains the desired locale data files, perform the rebuild:

```
[root@cluster ~] # build-locale-archive
```

and reboot the master node and/or the compute nodes as needed.

In a `RHEL6` environment, the *glibc-common* RPM installs just the full default `locale-archive` binary file. The default `/usr/lib/locale/` directory contains no locale data files. Scyld ClusterWare has saved the default `locale-archive` as `locale-archive.default` and has created `locale-archive.default.list` as a text file containing a list of all the locales in that default file. To generate a smaller file, you start with the full default `locale-archive`, then eliminate locales from the full list using `localedef --delete-from-archive`, then execute `build-locale-archive` to finalize the new `locale-archive` file. To assist in this procedure, Scyld ClusterWare installs helper scripts and some sample locale lists. For example, to rebuild with just the U.S.-English locales:

```
[root@cluster ~] # cd /usr/lib/locale
[root@cluster ~] # ./rebuild-archive.sh locales.English_US
```

Or to include all the English language locales:

```
[root@cluster ~] # cd /usr/lib/locale
[root@cluster ~] # ./rebuild-archive.sh locales.English
```

When executing `rebuild-archive.sh`, this helper script prints details of what is being requested and asks for permission to proceed.

Several other sample `locales.*` files have been provided. The local cluster administrator can use one of these files, or can create a new custom file, as desired. Each such `locales.*` file should contain a list of one or more specific locales (e.g., *en_US.uts8*), or contain patterns that match a locale or locales (e.g., *en_US*), one per line. For example, the `locales.English` file contains:

```
# All English language locales
en_
```

which is a pattern that matches every en_* locale.

Additionally, Scyld ClusterWare provides reset-archive.sh, which is a script that returns locale-archive to its original default state.

> **Caution**
>
> Note that for both RHEL6 and RHEL7, we recommend always including *en_US** locales, just to be safe, as the default RHEL/CentOS distributions reference the LANG=en_US.uts8 locale in several /etc/ configuration files. Each Scyld ClusterWare 6-supplied locales.* file contains the suggested *en_US* locale pattern.

4.17.4 Site-Local Startup Scripts

Local, homegrown scripts to be executed at node boot time can be placed in /etc/beowulf/init.d/. The conventions for this are as follows:

- Scripts should live in /etc/beowulf/init.d/
- Scripts should be numbered in the order in which they are to be executed (e.g., 20raid, 30startsan, 45mycustom_hw)
- Any scripts going into /etc/beowulf/init.d/ should be cluster aware. That is, they should contain the appropriate bpsh and/or bpcp commands to make the script work on the compute node rather than on the master node. Examine the Scyld ClusterWare distributed scripts for examples.

Any local modifications to Scyld ClusterWare distributed scripts in /etc/beowulf/init.d will be lost across subsequent Scyld ClusterWare updates. If a local sysadmin believes a local modification is necessary, we suggest:

1. Copy the to-be-edited original script to a file with a unique name, e.g.:

```
cd /etc/beowulf/init.d
cp 37some_script 37some_script_local
```

2. Remove the executable state of the original:

```
beochkconfig 37some_script off
```

3. Edit 37some_script_local as desired.
4. Thereafter, subsequent ClusterWare updates may install a new 37some_script, but the update will not re-enable the non-executable state of that script. The local 37some_script_local remains untouched. However, keep in mind that the newer ClusterWare version of 37some_script may contain fixes or other changes that need to be reflected in 37some_script_local because that edited file was based upon an older ClusterWare version.

4.17.5 Sample Kickstart Script

Non-Scyld nodes can be provisioned using the Red Hat kickstart utility. The following is a sample kickstart configuration script, which should be edited as appropriate for your local cluster:

```
# centos 5u3  (amd64) hybrid example kickstart

install
reboot
# point to NFS server that exports a directory containing the iso images of centOS 5.3
nfs --server=192.168.5.30 --dir=/eng_local/nfs-install/centos5u3_amd64
lang en_US.UTF-8
keyboard us
```

```
xconfig --startxonboot
network --device eth0 --bootproto dhcp --onboot yes
#network --device eth1 --onboot no --bootproto dhcp
rootpw --iscrypted $1$DC2r9BD4$Y1QsTSuL6K9ESdVk18eJT0
firewall --disabled
selinux --disabled
authconfig --enableshadow --enablemd5
timezone --utc America/Los_Angeles
bootloader --location=mbr
key --skip

# The following is commented-out so nobody uses this by accident and
# overwrites their local harddisks on a compute node.
#
# In order to enable using this kickstart script to install an operating system
# on /dev/sda of your compute node and thereby erasing all prior content,
# remove the comment character in front of the next 4 lines:

# clearpart --linux --drives=sda
# part /boot --fstype ext3 --size=100 --ondisk=sda
# part swap --fstype swap --size=2040 --ondisk=sda
# part / --fstype ext3 --size=1024 --grow

#############################################################################
%packages
@ ruby
@ system-tools
@ MySQL Database
@ Editors
@ System Tools
@ Text-based Internet
@ Legacy Network Server
@ DNS Name Server
@ FTP Server
@ Network Servers
@ Web Server
@ Server Configuration Tools
@ Sound and Video
@ Administration Tools
@ Graphical Internet
@ Engineering and Scientific
@ Development Libraries
@ GNOME Software Development
@ X Software Development
@ Authoring and Publishing
@ Legacy Software Development
@ Emacs
@ Legacy Software Support
@ Ruby
@ KDE Software Development
#@ Horde
@ PostgreSQL Database
@ Development Tools
#@ Yum Utilities
#@ FreeNX and NX
kernel-devel
OpenIPMI-tools
openmpi-devel
```

```
sg3_utils

#############################################################################
%pre

# any thing you want to happen before the install process starts

#############################################################################
%post
#!/bin/bash
# anything you want to happen after the install process finishes

masterip=10.56.10.1
wget http://$masterip/sendstats
chmod +x sendstats
mv sendstats /usr/local/sbin/
echo "/usr/local/sbin/sendstats" >> /etc/rc.local

# If you get the blinking cursor of death and no OS post, then uncomment this.
#grub-install --root-directory=/boot hd0
#grub-install --root-directory=/boot hd1
#grub-install --root-directory=/boot hd2

# Removes rhgb and quiet from grub.conf
sed -i /boot/grub/grub.conf -e 's/rhgb//g;s/quiet//g'

# Sets up the serial console in grub.conf
# TODO

# turns off cpuspeed
chkconfig cpuspeed --level 123456 off

# changes xorg.conf from mga to vesa
sed -i /etc/X11/xorg.conf -e 's/mga/vesa/'

# turns on ipmi
chkconfig ipmi on
chkconfig sshd on
wget http://10.56.10.1/done
```

CHAPTER

FIVE

USER'S GUIDE

5.1 Preface

Welcome to the Scyld ClusterWare User's Guide. This manual is for those who will use ClusterWare to run applications, so it presents the basics of ClusterWare parallel computing — what ClusterWare is, what you can do with it, and how you can use it. The manual covers the ClusterWare architecture and discusses the unique features of Scyld ClusterWare. It will show you how to navigate the ClusterWare environment, how to run programs, and how to monitor their performance.

Because this manual is for the user accessing a ClusterWare system that has already been configured, it does *not* cover how to install, configure, or administer your Scyld cluster. You should refer to other parts of the Scyld documentation set for additional information, specifically:

- Visit the Penguin Computing Support Portal at https://www.penguincomputing.com/support/documentation to find the latest documentation.
- If you have not yet built your cluster or installed Scyld ClusterWare, refer to the latest *Release Notes* and the *Installation Guide*.
- If you are looking for information on how to administer your cluster, refer to the *Administrator's Guide*.
- If you plan to write programs to use on your Scyld cluster, refer to the *Programmer's Guide*.

Also not covered is use of the Linux operating system, on which Scyld ClusterWare is based. Some of the basics are presented here, but if you have not used Linux or Unix before, a book or online resource will be helpful. Books by O'Reilly and Associates are good sources of information.

This manual will provide you with information about the basic functionality of the utilities needed to start being productive with Scyld ClusterWare.

5.2 Scyld ClusterWare Overview

Scyld ClusterWare is a Linux-based high-performance computing system. It solves many of the problems long associated with Linux Beowulf-class cluster computing, while simultaneously reducing the costs of system installation, administration, and maintenance. With Scyld ClusterWare, the cluster is presented to the user as a single, large-scale parallel computer.

This chapter presents a high-level overview of Scyld ClusterWare. It begins with a brief history of Beowulf clusters, and discusses the differences between the first-generation Beowulf clusters and a Scyld cluster. A high-level technical summary of Scyld ClusterWare is then presented, covering the top-level features and major software components of Scyld. Finally, typical applications of Scyld ClusterWare are discussed.

Additional details are provided throughout the Scyld ClusterWare documentation set.

5.3 What Is a Beowulf Cluster?

The term “Beowulf” refers to a multi-computer architecture designed for executing parallel computations. A “Beowulf cluster” is a parallel computer system conforming to the Beowulf architecture, which consists of a collection of commodity off-the-shelf computers (*COTS*) (referred to as “nodes”), connected via a private network running an open-source operating system. Each node, typically running Linux, has its own processor(s), memory storage, and I/O interfaces. The nodes communicate with each other through a private network, such as Ethernet or Infiniband, using standard network adapters. The nodes usually do not contain any custom hardware components, and are trivially reproducible.

One of these nodes, designated as the “master node”, is usually attached to both the private and public networks, and is the cluster’s administration console. The remaining nodes are commonly referred to as “compute nodes”. The master node is responsible for controlling the entire cluster and for serving parallel jobs and their required files to the compute nodes. In most cases, the compute nodes are configured and controlled by the master node. Typically, the compute nodes require neither keyboards nor monitors; they are accessed solely through the master node. From the viewpoint of the master node, the compute nodes are simply additional processor and memory resources.

In conclusion, Beowulf is a technology of networking Linux computers together to create a parallel, virtual supercomputer. The collection as a whole is known as a “Beowulf cluster”. While early Linux-based Beowulf clusters provided a cost-effective hardware alternative to the supercomputers of the day, allowing users to execute high-performance computing applications, the original software implementations were not without their problems. Scyld ClusterWare addresses — and solves — many of these problems.

5.3.1 A Brief History of the Beowulf

Cluster computer architectures have a long history. The early network-of-workstations (*NOW*) architecture used a group of standalone processors connected through a typical office network, their idle cycles harnessed by a small piece of special software, as shown below.

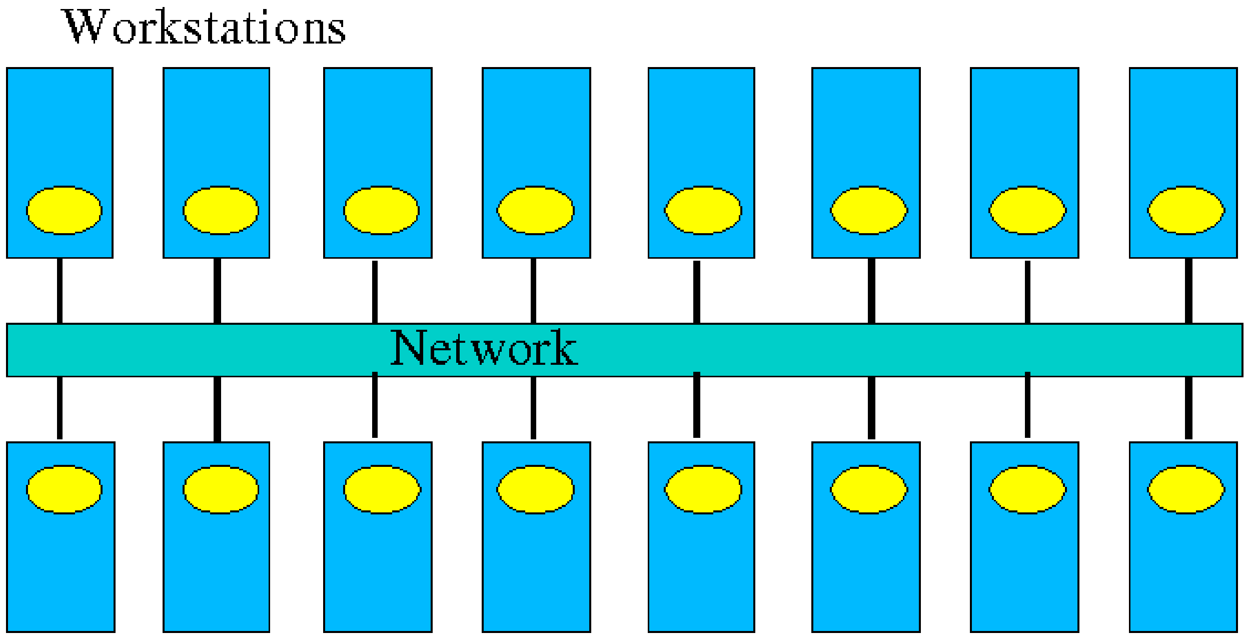


Figure 1. Network-of-Workstations Architecture

The *NOW* concept evolved to the Pile-of-PCs architecture, with one master PC connected to the public network, and the remaining PCs in the cluster connected to each other and to the master through a private network as shown in the following figure. Over time, this concept solidified into the Beowulf architecture.

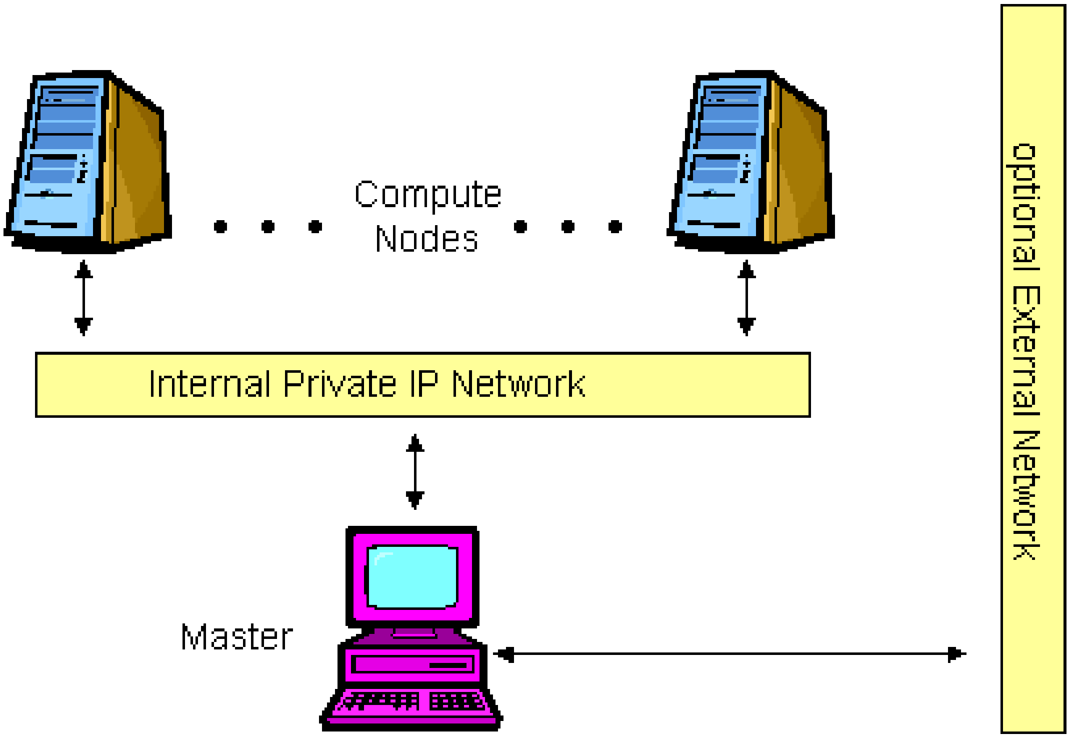


Figure 2. A Basic Beowulf Cluster

For a cluster to be properly termed a "Beowulf", it must adhere to the "Beowulf philosophy", which requires:

- Scalable performance
- The use of commodity off-the-shelf (*COTS*) hardware
- The use of an open-source operating system, typically Linux

Use of commodity hardware allows Beowulf clusters to take advantage of the economies of scale in the larger computing markets. In this way, Beowulf clusters can always take advantage of the fastest processors developed for high-end workstations, the fastest networks developed for backbone network providers, and so on. The progress of Beowulf clustering technology is not governed by any one company's development decisions, resources, or schedule.

5.3.2 First-Generation Beowulf Clusters

The original Beowulf software environments were implemented as downloadable add-ons to commercially-available Linux distributions. These distributions included all of the software needed for a networked workstation: the kernel, various utilities, and many add-on packages. The downloadable Beowulf add-ons included several programming environments and development libraries as individually-installable packages.

With this first-generation Beowulf scheme, every node in the cluster required a full Linux installation and was responsible for running its own copy of the kernel. This requirement created many administrative headaches for the maintainers of Beowulf-class clusters. For this reason, early Beowulf systems tended to be deployed by the software application developers themselves (and required detailed knowledge to install and use). Scyld ClusterWare reduces and/or eliminates these and other problems associated with the original Beowulf-class clusters.

5.3.3 Scyld ClusterWare: A New Generation of Beowulf

Scyld ClusterWare streamlines the process of configuring, administering, running, and maintaining a Beowulf-class cluster computer. It was developed with the goal of providing the software infrastructure for commercial production cluster solutions.

Scyld ClusterWare was designed with the differences between master and compute nodes in mind; it runs only the appropriate software components on each compute node. Instead of having a collection of computers each running its own fully-installed operating system, Scyld creates one large distributed computer. The user of a Scyld cluster will never log into one of the compute nodes nor worry about which compute node is which. To the user, the master node *is* the computer, and the compute nodes appear merely as attached processors capable of providing computing resources.

With Scyld ClusterWare, the cluster appears to the user as a single computer. Specifically,

- The compute nodes appear as attached processor and memory resources
- All jobs start on the master node, and are migrated to the compute nodes at runtime
- All compute nodes are managed and administered collectively via the master node

The Scyld ClusterWare architecture simplifies cluster setup and node integration, requires minimal system administration, provides tools for easy administration where necessary, and increases cluster reliability through seamless scalability. In addition to its technical advances, Scyld ClusterWare provides a standard, stable, commercially-supported platform for deploying advanced clustering systems. See the next section for a technical summary of Scyld ClusterWare.

5.4 Scyld ClusterWare Technical Summary

Scyld ClusterWare presents a more uniform system view of the entire cluster to both users and applications through extensions to the kernel. A guiding principle of these extensions is to have little increase in both kernel size and complexity and, more importantly, negligible impact on individual processor performance.

In addition to its enhanced Linux kernel, Scyld ClusterWare includes libraries and utilities specifically improved for high-performance computing applications. For information on the Scyld libraries, see the *Reference Guide*. Information on using the Scyld utilities to run and monitor jobs is provided in *Interacting With the System* and *Running Programs*. If you need to use the Scyld utilities to configure and administer your cluster, see the *Administrator's Guide*.

5.4.1 Top-Level Features of Scyld ClusterWare

The following list summarizes the top-level features of Scyld ClusterWare.

Security and Authentication. With Scyld ClusterWare, the master node is a single point of security administration and authentication. The authentication envelope is drawn around the entire cluster and its private network. This obviates the need to manage copies or caches of credentials on compute nodes or to add the overhead of networked authentication. Scyld ClusterWare provides simple permissions on compute nodes, similar to Unix file permissions, allowing their use to be administered without additional overhead.

Easy Installation. Scyld ClusterWare is designed to augment a full Linux distribution, such as Red Hat Enterprise Linux (RHEL) or CentOS. The installer used to initiate the installation on the master node is provided on an auto-run CD-ROM. You can install from scratch and have a running Linux HPC cluster in less than an hour. See the *Installation Guide* for full details.

Install Once, Execute Everywhere. A full installation of Scyld ClusterWare is required only on the master node. Compute nodes are provisioned from the master node during their boot process, and they dynamically cache any additional parts of the system during process migration or at first reference.

Single System Image. Scyld ClusterWare makes a cluster appear as a multi-processor parallel computer. The master node maintains (and presents to the user) a single process space for the entire cluster, known as the *BProc* Distributed Process Space. *BProc* is described briefly later in this chapter, and more details are provided in the *Administrator's Guide*.

Execution Time Process Migration. Scyld ClusterWare stores applications on the master node. At execution time, *BProc* migrates processes from the master to the compute nodes. This approach virtually eliminates both the risk of version skew and the need for hard disks on the compute nodes. More information is provided in the section on process space migration later in this chapter. Also refer to the *BProc* discussion in the *Administrator's Guide*.

Seamless Cluster Scalability. Scyld ClusterWare seamlessly supports the dynamic addition and deletion of compute nodes without modification to existing source code or configuration files.

Administration Tools. Scyld ClusterWare includes simplified tools for performing cluster administration and maintenance. Both graphical user interface (GUI) and command line interface (CLI) tools are supplied. See the *Administrator's Guide* for more information.

Web-Based Administration Tools. Scyld ClusterWare includes web-based tools for remote administration, job execution, and monitoring of the cluster. See the *Administrator's Guide* for more information.

Additional Features. Additional features of Scyld ClusterWare include support for cluster power management (IPMI and Wake-on-LAN, easily extensible to other out-of-band management protocols); runtime and development support for MPI and PVM; and support for the LFS and NFS3 file systems.

Fully-Supported. Scyld ClusterWare is fully-supported by Penguin Computing, Inc.

5.4.2 Process Space Migration Technology

Scyld ClusterWare is able to provide a single system image through its use of the *BProc* Distributed Process Space, the Beowulf process space management kernel enhancement. *BProc* enables the processes running on compute nodes to be visible and managed on the master node. All processes appear in the master node's process table, from which they are migrated to the appropriate compute node by *BProc*. Both process parent-child relationships and Unix job-control information are maintained with the migrated jobs. The `stdout` and `stderr` streams are redirected to the user's `ssh` or terminal session on the master node across the network.

The *BPorc* mechanism is one of the primary features that makes Scyld ClusterWare different from traditional Beowulf clusters. For more information, see the system design description in the *Administrator's Guide*.

5.4.3 Compute Node Provisioning

Scyld ClusterWare utilizes light-weight provisioning of compute nodes from the master node's kernel and Linux distribution. For Scyld Series 30 and Scyld ClusterWare, PXE is the supported method for booting nodes into the cluster; the 2-phase boot sequence of earlier Scyld distributions is no longer used.

The master node is the DHCP server serving the cluster private network. PXE booting across the private network ensures that the compute node boot package is version-synchronized for all nodes within the cluster. This boot package consists of the kernel, `initrd`, and `rootfs`. If desired, the boot package can be customized per node in the Beowulf configuration file `/etc/beowulf/config`, which also includes the kernel command line parameters for the boot package.

For a detailed description of the compute node boot procedure, see the system design description in the *Administrator's Guide*. Also refer to the chapter on compute node boot options in that document.

5.4.4 Compute Node Categories

Compute nodes seen by the master over the private network are classified into one of three categories by the master node, as follows:

- *Unknown* — A node not formally recognized by the cluster as being either a *Configured* or *Ignored* node. When bringing a new compute node online, or after replacing an existing node's network interface card, the node will be classified as *unknown*.
- *Ignored* — Nodes which, for one reason or another, you'd like the master node to ignore. These are not considered part of the cluster, nor will they receive a response from the master node during their boot process.
- *Configured* — Those nodes listed in the cluster configuration file using the "node" tag. These are formally part of the cluster, recognized as such by the master node, and used as computational resources by the cluster.

For more information on compute node categories, see the system design description in the *Administrator's Guide*.

5.4.5 Compute Node States

BProc maintains the current condition or "node state" of each configured compute node in the cluster. The compute node states are defined as follows:

- *down* — Not communicating with the master, and its previous state was either *down*, *up*, *error*, *unavailable*, or *boot*.
- *unavailable* — Node has been marked *unavailable* or "off-line" by the cluster administrator; typically used when performing maintenance activities. The node is useable only by the user *root*.
- *error* — Node encountered an error during its initialization; this state may also be set manually by the cluster administrator. The node is useable only by the user *root*.
- *up* — Node completed its initialization without error; node is online and operating normally. This is the only state in which non-*root* users may access the node.
- *reboot* — Node has been commanded to reboot itself; node will remain in this state until it reaches the *boot* state, as described below.
- *halt* — Node has been commanded to halt itself; node will remain in this state until it is reset (or powered back on) and reaches the *boot* state, as described below.
- *pwroff* — Node has been commanded to power itself off; node will remain in this state until it is powered back on and reaches the *boot* state, as described below.
- *boot* — Node has completed its *stage 2* boot but is still initializing. After the node finishes booting, its next state will be either *up* or *error*.

For more information on compute node states, see the system design description in the *Administrator's Guide*.

5.4.6 Major Software Components

The following is a list of the major software components included with Scyld ClusterWare. For more information, see the relevant sections of the Scyld ClusterWare documentation set, including the *Installation Guide*, *Administrator's Guide*, *User's Guide*, *Reference Guide*, and *Programmer's Guide*.

- `BProc` — The process migration technology; an integral part of Scyld ClusterWare.
- `BeoSetup` — A GUI for configuring the cluster.
- `BeoStatus` — A GUI for monitoring cluster status.
- `beostat` — A text-based tool for monitoring cluster status.

- `beoboot` — A set of utilities for booting the compute nodes.
- `beofdisk` — A utility for remote partitioning of hard disks on the compute nodes.
- `beoserv` — The cluster's DHCP, PXE and dynamic provisioning server; it responds to compute nodes and serves the boot image.
- `BPmaster` — The `BProc` master daemon; it runs on the master node.
- `BPslave` — The `BProc` compute daemon; it runs on each of the compute nodes.
- `bpstat` — A `BProc` utility that reports status information for all nodes in the cluster.
- `bpctl` — A `BProc` command line interface for controlling the nodes.
- `bpsh` — A `BProc` utility intended as a replacement for `rsh` (remote shell).
- `bpcp` — A `BProc` utility for copying files between nodes, similar to `rcp` (remote copy).
- `MPI` — The Message Passing Interface, optimized for use with Scyld ClusterWare.
- `PVM` — The Parallel Virtual Machine, optimized for use with Scyld ClusterWare.
- `mpprun` — A parallel job-creation package for Scyld ClusterWare.

5.5 Typical Applications of Scyld ClusterWare

Scyld clustering provides a facile solution for anyone executing jobs that involve either a large number of computations or large amounts of data (or both). It is ideal for both large, monolithic, parallel jobs and for many normal-sized jobs run many times (such as Monte Carlo type analysis).

The increased computational resource needs of modern applications are frequently being met by Scyld clusters in a number of domains, including:

- *Computationally-Intensive Activities* — Optimization problems, stock trend analysis, financial analysis, complex pattern matching, medical research, genetics research, image rendering
- *Scientific Computing / Research* — Engineering simulations, 3D-modeling, finite element analysis, computational fluid dynamics, computational drug development, seismic data analysis, PCB / ASIC routing
- *Large-Scale Data Processing* — Data mining, complex data searches and results generation, manipulating large amounts of data, data archival and sorting
- *Web / Internet Uses* — Web farms, application serving, transaction serving, data serving

These types of jobs can be performed many times faster on a Scyld cluster than on a single computer. Increased speed depends on the application code, the number of nodes in the cluster, and the type of equipment used in the cluster. All of these can be easily tailored and optimized to suit the needs of your applications.

5.6 Interacting With the System

This chapter discusses how to verify the availability of the nodes in your cluster, how to monitor node status, how to issue commands and copy data to the compute nodes, and how to monitor and control processes. For information on running programs across the cluster, see *Running Programs*.

5.6.1 Verifying the Availability of Nodes

In order to use a Scyld cluster for computation, at least one node must be available or *up*. Thus, the first priority when interacting with a cluster is ascertaining the availability of nodes. Unlike traditional Beowulf clusters, Scyld ClusterWare provides rich reporting about the availability of the nodes.

You can use either the `BeoStatus` GUI tool or the `bpstat` command to determine the availability of nodes in your cluster. These tools, which can also be used to monitor node status, are described in the next section.

If fewer nodes are *up* than you think should be, or some nodes report an error, check with your Cluster Administrator.

5.6.2 Monitoring Node Status

You can monitor the status of nodes in your cluster with the `BeoStatus` GUI tool or with either of two command line tools, `bpstat` and `beostat`. These tools are described in the sections that follow. Also see the *Reference Guide* for information on the various options and flags supported for these tools.

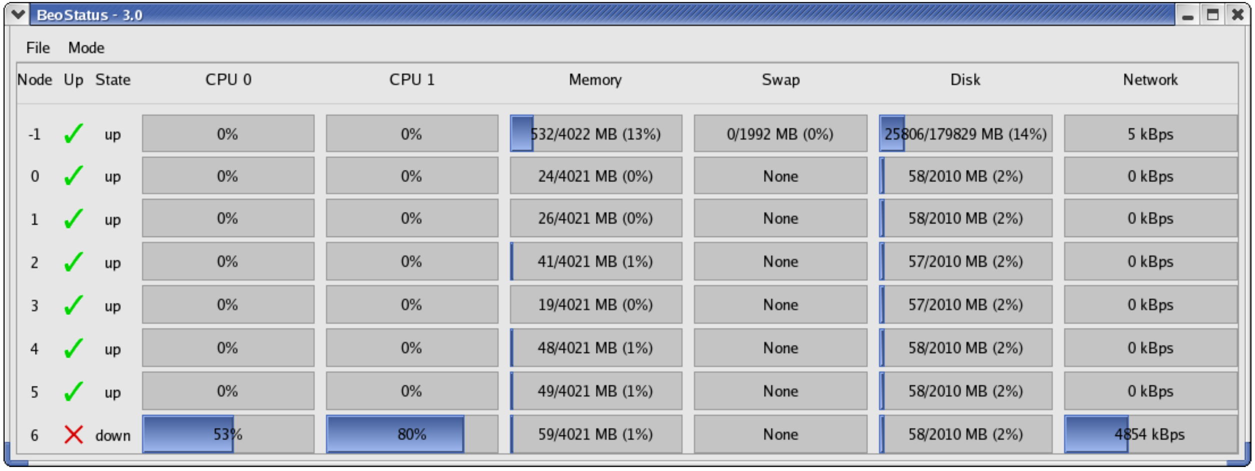
The BeoStatus GUI Tool

The `BeoStatus` graphical user interface (GUI) tool is the best way to check the status of the cluster, including which nodes are available or *up*. There are two ways to open the `BeoStatus` GUI as a Gnome X window, as follows.

Click the `BeoStatus` icon in the tool tray or in the applications pulldown.

Alternatively, type the command `beostatus` in a terminal window on the master node; you do not need to be a privileged user to use this command.

The default `BeoStatus` GUI mode is a tabular format known as the "Classic" display (shown in the following figure). You can select different display options from the Mode menu.



Node	Up	State	CPU 0	CPU 1	Memory	Swap	Disk	Network
-1	✓	up	0%	0%	532/4022 MB (13%)	0/1992 MB (0%)	25806/179829 MB (14%)	5 kBps
0	✓	up	0%	0%	24/4021 MB (0%)	None	58/2010 MB (2%)	0 kBps
1	✓	up	0%	0%	26/4021 MB (0%)	None	58/2010 MB (2%)	0 kBps
2	✓	up	0%	0%	41/4021 MB (1%)	None	57/2010 MB (2%)	0 kBps
3	✓	up	0%	0%	19/4021 MB (0%)	None	57/2010 MB (2%)	0 kBps
4	✓	up	0%	0%	48/4021 MB (1%)	None	58/2010 MB (2%)	0 kBps
5	✓	up	0%	0%	49/4021 MB (1%)	None	58/2010 MB (2%)	0 kBps
6	✗	down	53%	80%	59/4021 MB (1%)	None	58/2010 MB (2%)	4854 kBps

Figure 1. BeoStatus in the "Classic" Display Mode

BeoStatus Node Information

Each row in the `BeoStatus` display reports information for a single node, including the following:

- *Node* — The node's assigned node number, starting at zero. Node -1, if shown, is the master node. The total number of node entries shown is set by the "iprange" or "nodes" keywords in the file `/etc/beowulf/config`, rather than the number of detected nodes. The entry for an inactive node displays the last reported data in a grayed-out row.
- *Up* — A graphical representation of the node's status. A green checkmark is shown if the node is up and available. Otherwise, a red "X" is shown.
- *State* — The node's last known state. This should agree with the state reported by both the `bpstat` command and in the `BeoSetup` window.
- *CPU "X"* — The CPU loads for the node's processors; at minimum, this indicates the CPU load for the first processor in each node. Since it is possible to mix uni-processor and multi-processor machines in a Scyld cluster, the number of CPU load columns is equal to the maximum number of processors for any node in your cluster. The label "N/A" will be shown for nodes with less than the maximum number of processors.
- *Memory* — The node's current memory usage.
- *Swap* — The node's current swap space (virtual memory) usage.
- *Disk* — The node's hard disk usage. If a RAM disk is used, the maximum value shown is one-half the amount of physical memory. As the RAM disk competes with the kernel and application processes for memory, not all the RAM may be available.
- *Network* — The node's network bandwidth usage. The total amount of bandwidth available is the sum of all network interfaces for that node.

BeoStatus Update Intervals

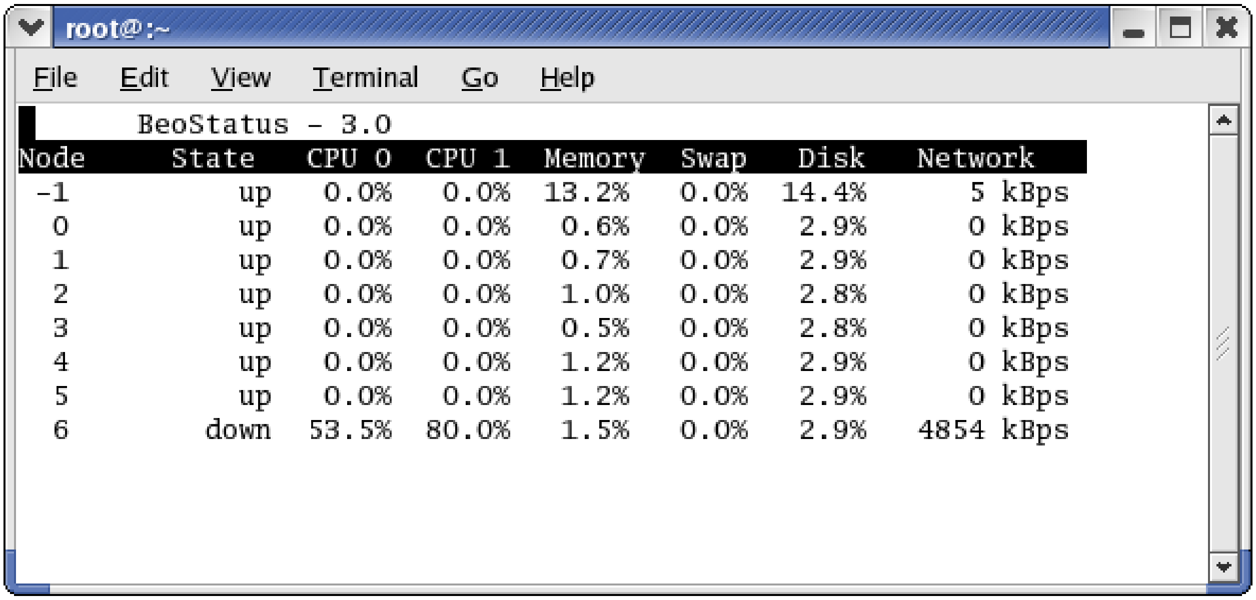
Once running, `BeoStatus` is non-interactive; the user simply monitors the reported information. The display is updated at 4-second intervals by default. You can modify this default using the command `beostatus -u secs` (where secs is the number of seconds) in a terminal window or an `ssh` session to the master node with X-forwarding enabled.

> **Tip**
>
> Each update places load on the master and compute nodes, as well as the interconnection network. Too-frequent updates can degrade the overall system performance.

BeoStatus in Text Mode

In environments where use of the Gnome X window system is undesirable or impractical, such as when accessing the master node through a slow remote network connection, you can view the status of the cluster as curses text output (shown in the following figure). Do do this, enter the command `beostatus -c` in a terminal window on the master node or an `ssh` session to the master node.

`BeoStatus` in text mode reports the same node information as reported by the "Classic" display, except for the graphical indicator of node *up* (green checkmark) or node *down* (red X). The data in the text display is updated at 4-second intervals by default.



```
         BeoStatus - 3.0
Node       State   CPU 0   CPU 1   Memory   Swap    Disk     Network
 -1           up    0.0%    0.0%    13.2%    0.0%   14.4%       5 kBps
  0           up    0.0%    0.0%     0.6%    0.0%    2.9%       0 kBps
  1           up    0.0%    0.0%     0.7%    0.0%    2.9%       0 kBps
  2           up    0.0%    0.0%     1.0%    0.0%    2.8%       0 kBps
  3           up    0.0%    0.0%     0.5%    0.0%    2.8%       0 kBps
  4           up    0.0%    0.0%     1.2%    0.0%    2.9%       0 kBps
  5           up    0.0%    0.0%     1.2%    0.0%    2.9%       0 kBps
  6         down   53.5%   80.0%     1.5%    0.0%    2.9%    4854 kBps
```

Figure 2. BeoStatus in Text Mode

The bpstat Command Line Tool

You can also check node status with the bpstat command. When run at a shell prompt on the master node without options, bpstat prints out a listing of all nodes in the cluster and their current status. You do not need to be a privileged user to use this command.

Following is an example of the outputs from bpstat for a cluster with 10 compute nodes.

```
[user@cluster user] $ bpstat
  Node(s)      Status        Mode        User       Group
    5-9          down          ---------- root        root
    4            up            ---x--x--x any         any
    0-3          up            ---x--x--x root        root
```

bpstat will show one of the following indicators in the "Status" column:

- A node marked *up* is available to run jobs. This status is the equivalent of the green checkmark in the BeoStatus GUI.
- Nodes that have not yet been configured are marked as *down*. This status is the equivalent of the red X in the BeoStatus GUI.
- Nodes currently booting are temporarily shown with a status of *boot*. Wait 10-15 seconds and try again.
- The "error" status indicates a node initialization problem. Check with your Cluster Administrator.

For additional information on bpstat, see the section on monitoring and controlling processes later in this chapter. Also see the *Reference Guide* for details on using bpstat and its command line options.

The beostat Command Line Tool

You can use the beostat command to display raw status data for cluster nodes. When run at a shell prompt on the master node without options, beostat prints out a listing of stats for all nodes in the cluster, including the master node. You do not need to be a privileged user to use this command.

The following example shows the beostat output for the master node and one compute node:

```
[user@cluster user] $ beostat
model           : 5
model name      : AMD Opteron(tm) Processor 248
stepping        : 10
cpu MHz         : 2211.352
cache size      : 1024 KB
fdiv_bug        : no
hlt_bug         : no
sep_bug         : no
f00f_bug        : no
coma_bug        : no
fpu             : yes
fpu_exception   : yes
cpuid level     : 1
wp              : yes
bogomips        : 4422.05

 *** /proc/meminfo *** Sun Sep 17 10:46:33 2006
        total:    used:    free:  shared: buffers:  cached:
Mem:  4217454592 318734336 3898720256        0 60628992        0
Swap: 2089209856        0 2089209856
MemTotal:   4118608 kB
MemFree:    3807344 kB
MemShared:        0 kB
Buffers:      59208 kB
Cached:           0 kB
SwapTotal:  2040244 kB
SwapFree:   2040244 kB

 *** /proc/loadavg *** Sun Sep 17 10:46:33 2006
3.00 2.28 1.09 178/178 0

 *** /proc/net/dev *** Sun Sep 17 10:46:33 2006
Inter-|   Receive                                                |  Transmit
 face |bytes    packets errs drop fifo frame compressed multicast|bytes    packets errs drop fifo col
  eth0:85209660   615362        0        0        0     0          0         0 703311290  559376
  eth1:4576500575 13507271        0        0        0     0          0         0 9430333982 13220730
  sit0:       0        0        0        0        0     0          0         0       0       0

 *** /proc/stat ***
cpu0 15040 0 466102 25629625            Sun Sep 17 10:46:33 2006
cpu1 17404 0 1328475 24751544           Sun Sep 17 10:46:33 2006

 *** statfs ("/") *** Sun Sep 17 10:46:33 2006
path:           /
f_type:         0xef53
f_bsize:        4096
f_blocks:       48500104
f_bfree:        41439879
f_bavail:       38976212
f_files:        24641536
f_ffree:        24191647
f_fsid:         000000 000000
f_namelen:      255


============== Node: .0 (index 0) ==================
 *** /proc/cpuinfo *** Sun Sep 17 10:46:34 2006
num processors  : 2
vendor_id       : AuthenticAMD
cpu family      : 15
model           : 5
model name      : AMD Opteron(tm) Processor 248
stepping        : 10
cpu MHz         : 2211.386
cache size      : 1024 KB
fdiv_bug        : no
hlt_bug         : no
sep_bug         : no
f00f_bug        : no
coma_bug        : no
fpu             : yes
fpu_exception   : yes
cpuid level     : 1
wp              : yes
bogomips        : 4422.04

 *** /proc/meminfo *** Sun Sep 17 10:46:34 2006
        total:    used:    free:  shared: buffers:  cached:
Mem:  4216762368 99139584 4117622784        0        0        0
Swap:        0        0        0
MemTotal:   4117932 kB
MemFree:    4021116 kB
MemShared:        0 kB
Buffers:          0 kB
Cached:           0 kB
SwapTotal:        0 kB
SwapFree:         0 kB

 *** /proc/loadavg *** Sun Sep 17 10:46:34 2006
0.99 0.75 0.54 36/36 0

 *** /proc/net/dev *** Sun Sep 17 10:46:34 2006
Inter-|   Receive                                                |  Transmit
 face |bytes    packets errs drop fifo frame compressed multicast|bytes    packets errs drop fifo col
  eth0:312353878   430256        0        0        0     0          0         0 246128779  541105
  eth1:       0        0        0        0        0     0          0         0       0       0

 *** /proc/stat ***
cpu0 29984 0 1629 15340009              Sun Sep 17 10:46:34 2006
cpu1 189495 0 11131 15170565            Sun Sep 17 10:46:34 2006

 *** statfs ("/") *** Sun Sep 17 10:46:34 2006
path:           /
f_type:         0x1021994
f_bsize:        4096
f_blocks:       514741
f_bfree:        492803
f_bavail:       492803
f_files:        514741
f_ffree:        514588
f_fsid:         000000 000000
f_namelen:      255
```

The *Reference Guide* provides details for using `beostat` and its command line options.

5.6.3 Issuing Commands

Commands on the Master Node

When you log into the cluster, you are actually logging into the master node, and the commands you enter on the command line will execute on the master node. The only exception is when you use special commands for interacting with the compute nodes, as described in the next section.

Commands on the Compute Node

Scyld ClusterWare provides the `bpsh` command for running jobs on the compute nodes. `bpsh` is a replacement for the traditional Unix utility `rsh`, used to run a job on a remote computer. Like `rsh`, the `bpsh` arguments are the node on which to run the command and the command. `bpsh` allows you to run a command on more than one node without having to type the command once for each node, but it doesn't provide an interactive shell on the remote node like `rsh` does.

`bpsh` is primarily intended for running utilities and maintenance tasks on a single node or a range of nodes, rather than for running parallel programs. For information on running parallel programs with Scyld ClusterWare, see *Running Programs*.

`bpsh` provides a convenient yet powerful interface for manipulating all (or a subset of) the cluster's nodes simultaneously. `bpsh` provides you the flexibility to access a compute node individually, but removes the requirement to access each node individually when a collective operation is desired. A number of examples and options are discussed in the sections that follow. For a complete reference to all the options available for `bpsh`, see the *Reference Guide*.

Examples for Using bpsh

Example 1. Checking for a File

You can use `bpsh` to check for specific files on a compute node. For example, to check for a file named `output` in the `/tmp` directory of node 3, you would run the following command on the master node:

```
[user@cluster user] $ bpsh 3 ls /tmp/output
```

The command output would appear on the master node terminal where you issued the command.

Example 2. Running a Command on a Range of Nodes

You can run the same command on a range of nodes using `bpsh`. For example, to check for a file named `output` in the `/tmp` directory of nodes 3 through 5, you would run the following command on the master node:

```
[user@cluster user] $ bpsh 3,4,5 ls /tmp/output
```

Example 3. Running a Command on All Available Nodes

Use the `-a` flag to indicate to `bpsh` that you wish to run a command on all available nodes. For example, to check for a file named `output` in the `/tmp` directory of all nodes currently active in your cluster, you would run the following command on the master node:

```
[user@cluster user] $ bpsh -a ls /tmp/output
```

Note that when using the -a flag, the results are sorted by the response speed of the compute nodes, and are returned without node identifiers. Because this command will produce output for every currently active node, the output may be hard to read if you have a large cluster. For example, if you ran the above command on a 64-node cluster in which half of the nodes have the file being requested, the results returned would be 32 lines of /tmp/output and another 32 lines of ls: /tmp/output: no such file or directory. Without node identifiers, it is impossible to ascertain the existence of the target file on a particular node.

See the next section for bpsh options that enable you to format the results for easier reading.

Formatting bpsh Output

The bpsh command has a number of options for formatting its output to make it more useful for the user, including the following:

- The -L option makes bpsh wait for a full line from a compute node before it prints out the line. Without this option, the output from your command could include half a line from node 0 with a line from node 1 tacked onto the end, then followed by the rest of the line from node 0.
- The -p option prefixes each line of output with the node number of the compute node that produced it. This option causes the functionality for -L to be used, even if not explicitly specified.
- The -s option forces the output of each compute node to be printed in sorted numerical order, rather than by the response speed of the compute nodes. With this option, all the output for node 0 will appear before any of the output for node 1. To add a divider between the output from each node, use the -d option.
- Using -d generates a divider between the output from each node. This option causes the functionality for -s to be used, even if not explicitly specified.

For example, if you run the command bpsh -a -d -p ls /tmp/output on an 8-node cluster, the output would make it clear which nodes do and do not have the file output in the /tmp directory, for example:

```
0  ---------------------------------------------------------------------
    /tmp/output
1  ---------------------------------------------------------------------
    1: ls: /tmp/output: No such file or directory
2  ---------------------------------------------------------------------
    2: ls: /tmp/output: No such file or directory
3  ---------------------------------------------------------------------
    3: /tmp/output
4  ---------------------------------------------------------------------
    4: /tmp/output
5  ---------------------------------------------------------------------
    5: /tmp/output
6  ---------------------------------------------------------------------
    6: ls: /tmp/output: No such file or directory
7  ---------------------------------------------------------------------
    7: ls: /tmp/output: No such file or directory
```

bpsh and Shell Interaction

Special shell features, such as piping and input/output redirection, are available to advanced users. This section provides several examples of shell interaction, using the following conventions:

- The command running will be cmda.
- If it is piped to anything, it will be piped to cmdb.
- If an input file is used, it will be /tmp/input.

- If an output file is used, it will be `/tmp/output`.
- The node used will always be node 0.

Example 4. Command on Compute Node, Output on Master Node

The easiest case is running a command on a compute node and doing something with its output on the master node, or giving it input from the master. Following are a few examples:

```
[user@cluster user] $ bpsh 0 cmda | cmdb
[user@cluster user] $ bpsh 0 cmda > /tmp/output
[user@cluster user] $ bpsh 0 cmda < /tmp/input
```

Example 5. Command on Compute Node, Output on Compute Node

A bit more complex situation is to run the command on the compute node and do something with its input (or output) on that same compute node. There are two ways to accomplish this.

The first solution requires that all the programs you run be on the compute node. For this to work, you must first copy the `cmda` and `cmdb` executable binaries to the compute node. Then you would use the following commands:

```
[user@cluster user] $ bpsh 0 sh -c "cmda | cmdb"
[user@cluster user] $ bpsh 0 sh -c "cmda > /tmp/output"
[user@cluster user] $ bpsh 0 sh -c "cmda < /tmp/input"
```

The second solution doesn't require any of the programs to be on the compute node. However, it uses a lot of network bandwidth as it takes the output and sends it to the master node, then sends it right back to the compute node. The appropriate commands are as follows:

```
[user@cluster user] $ cmda | bpsh 0 cmdb
[user@cluster user] $ cmda | bpsh 0 dd of=/tmp/output
[user@cluster user] $ bpsh 0 cat /tmp/input | cmda
```

Example 6. Command on Master Node, Output on Compute Node

You can also run a command on the master node and do something with its input or output on the compute nodes. The appropriate commands are as follows:

```
[user@cluster user] $ cmda | bpsh 0 cmdb
[user@cluster user] $ cmda | bpsh 0 dd of=/tmp/output
[user@cluster user] $ bpsh 0 cat /tmp/input | cmda
```

5.6.4 Copying Data to the Compute Nodes

There are several ways to get data from the master node to the compute nodes. This section describes using NFS to share data, using the Scyld ClusterWare command `bpcp` to copy data, and using programmatic methods for data transfer.

Sharing Data via NFS

The easiest way to transfer data to the compute nodes is via NFS. All files in your /home directory are shared by default to all compute nodes via NFS. Opening an NFS-shared file on a compute node will, in fact, open the file on the master node; no actual copying takes place.

Copying Data via bpcp

To copy a file, rather than changing the original across the network, you can use the bpcp command. This works much like the standard Unix file-copying command cp, in that you pass it a file to copy as one argument and the destination as the next argument. Like the Unix scp, the file paths may be qualified by a computer host name.

With bpcp, you can indicate the node number for the source file, destination file, or both. To do this, prepend the node number with a colon before the file name, to specify that the file is on that node or should be copied to that node. For example, to copy the file /tmp/foo to the same location on node 1, you would use the following command:

```
[user@cluster user] $ bpcp /tmp/foo 1:/tmp/foo
```

Programmatic Data Transfer

The third method for transferring data is to do it programmatically. This is a bit more complex than the methods described in the previous section, and will only be described here only conceptually.

If you are using an MPI job, you can have your Rank 0 process on the master node read in the data, then use MPI's message passing capabilities to send the data over to a compute node.

If you are writing a program that uses BProc functions directly, you can have the process first read the data while it is on the master node. When the process is moved over to the compute node, it should still be able to access the data read in while on the master node.

Data Transfer by Migration

Another programmatic method for file transfer is to read a file into memory prior to calling BProc to migrate the process to another node. This technique is especially useful for parameter and configuration files, or files containing the intermediate state of a computation. See the *Reference Guide* for a description of the BProc system calls.

5.6.5 Monitoring and Controlling Processes

One of the features of Scyld ClusterWare that isn't provided in traditional Beowulf clusters is the *BProc* Distributed Process Space. *BProc* presents a single unified process space for the entire cluster, run from the master node, where you can see and control jobs running on the compute nodes. This process space allows you to use standard Unix tools, such as top, ps, and kill. See the *Administrator's Guide* for more details on BProc.

Scyld ClusterWare also includes a tool called bpstat that can be used to determine which node is running a process. Using the command option bpstat -p will list all processes currently running by processID (PID), with the number of the node running each process. The following output is an example:

```
[user@cluster user] $ bpstat -p
  PID     Node
   6301    0
   6302    1
   6303    0
   6304    2
   6305    1
   6313    2
   6314    3
   6321    3
```

Using the command option `bpstat -P` (with an uppercase "P" instead of a lowercase "p") tells `bpstat` to take the output of the `ps` and reformat it, pre-pending a column showing the node number. The following two examples show the difference in the outputs from `ps` and from `bpstat -P`.

Example output from `ps`:

```
[user@cluster user] $ ps xf
 PID  TTY      STAT   TIME COMMAND
 6503 pts/2    S      0:00 bash
 6665 pts/2    R      0:00 ps xf
 6471 pts/3    S      0:00 bash
 6538 pts/3    S      0:00 /bin/sh /usr/bin/linpack
 6553 pts/3    S      0:00  \_ /bin/sh /usr/bin/mpirun -np 5 /tmp/xhpl
 6654 pts/3    R      0:03      \_ /tmp/xhpl -p4pg /tmp/PI6553 -p4wd /tmp
 6655 pts/3    S      0:00          \_ /tmp/xhpl -p4pg /tmp/PI6553 -p4wd /tmp
 6656 pts/3    RW     0:01          \_ [xhpl]
 6658 pts/3    SW     0:00          |   \_ [xhpl]
 6657 pts/3    RW     0:01          \_ [xhpl]
 6660 pts/3    SW     0:00          |   \_ [xhpl]
 6659 pts/3    RW     0:01          \_ [xhpl]
 6662 pts/3    SW     0:00          |   \_ [xhpl]
 6661 pts/3    SW     0:00          \_ [xhpl]
 6663 pts/3    SW     0:00              \_ [xhpl]
```

Example of the same `ps` output when run through `bpstat -P` instead:

```
[user@cluster user] $ ps xf | bpstat -P
NODE     PID  TTY      STAT   TIME COMMAND
         6503 pts/2    S      0:00 bash
         6666 pts/2    R      0:00 ps xf
         6667 pts/2    R      0:00 bpstat -P
         6471 pts/3    S      0:00 bash
         6538 pts/3    S      0:00 /bin/sh /usr/bin/linpack
         6553 pts/3    S      0:00  \_ /bin/sh /usr/bin/mpirun -np 5 /tmp/xhpl
         6654 pts/3    R      0:06      \_ /tmp/xhpl -p4pg /tmp/PI6553 -p4wd /tmp
         6655 pts/3    S      0:00          \_ /tmp/xhpl -p4pg /tmp/PI6553 -p4wd /tmp
0        6656 pts/3    RW     0:06          \_ [xhpl]
0        6658 pts/3    SW     0:00          |   \_ [xhpl]
1        6657 pts/3    RW     0:06          \_ [xhpl]
1        6660 pts/3    SW     0:00          |   \_ [xhpl]
2        6659 pts/3    RW     0:06          \_ [xhpl]
2        6662 pts/3    SW     0:00          |   \_ [xhpl]
3        6661 pts/3    SW     0:00          \_ [xhpl]
3        6663 pts/3    SW     0:00              \_ [xhpl]
```

For additional information on `bpstat`, see the section on monitoring node status earlier in this chapter. For information on the `bpstat` command line options, see the *Reference Guide*.

5.7 Running Programs

This chapter describes how to run both serial and parallel jobs with Scyld ClusterWare, and how to monitor the status of the cluster once your applications are running. It begins with a brief discussion of program execution concepts, including some examples. The discussion then covers running programs that aren't parallelized, running parallel programs (including MPI-aware and PVM-aware programs), running serial programs in parallel, job batching, and file systems.

5.7.1 Program Execution Concepts

This section compares program execution on a stand-alone computer and a Scyld cluster. It also discusses the differences between running programs on a traditional Beowulf cluster and a Scyld cluster. Finally, it provides some examples of program execution on a Scyld cluster.

Stand-Alone Computer vs. Scyld Cluster

On a stand-alone computer running Linux, Unix, and most other operating systems, executing a program is a very simple process. For example, to generate a list of the files in the current working directory, you open a terminal window and type the command `ls` followed by the `[return]` key. Typing the `[return]` key causes the command shell — a program that listens to and interprets commands entered in the terminal window — to start the `ls` program (stored at `/bin/ls`). The output is captured and directed to the standard output stream, which also appears in the same window where you typed the command.

A Scyld cluster isn't simply a group of networked stand-alone computers. Only the master node resembles the computing system with which you are familiar. The compute nodes have only the minimal software components necessary to support an application initiated from the master node. So for instance, running the `ls` command on the master node causes the same series of actions as described above for a stand-alone computer, and the output is for the master node only.

However, running `ls` on a compute node involves a very different series of actions. Remember that a Scyld cluster has no resident applications on the compute nodes; applications reside only on the master node. So for instance, to run the `ls` command on compute node 1, you would enter the command `bpsh 1 ls` on the master node. This command sends `ls` to compute node 1 via Scyld's `BProc` software, and the output stream is directed to the terminal window on the master node, where you typed the command.

Some brief examples of program execution are provided in the last section of this chapter. Both `BProc` and `bpsh` are covered in more detail in the *Administrator's Guide*.

Traditional Beowulf Cluster vs. Scyld Cluster

A job on a Beowulf cluster is actually a collection of processes running on the compute nodes. In traditional clusters of computers, and even on earlier Beowulf clusters, getting these processes started and running together was a complicated task. Typically, the cluster administrator would need to do all of the following:

- Ensure that the user had an account on all the target nodes, either manually or via a script.
- Ensure that the user could spawn jobs on all the target nodes. This typically entailed configuring a `hosts.allow` file on each machine, creating a specialized PAM module (a Linux authentication mechanism), or creating a server daemon on each node to spawn jobs on the user's behalf.
- Copy the program binary to each node, either manually, with a script, or through a network file system.
- Ensure that each node had available identical copies of all the dependencies (such as libraries) needed to run the program.
- Provide knowledge of the state of the system to the application manually, through a configuration file, or through some add-on scheduling software.

With Scyld ClusterWare, most of these steps are removed. Jobs are started on the master node and are migrated out to the compute nodes via `BProc`. A cluster architecture where jobs may be initiated only from the master node via `BProc` provides the following advantages:

- Users no longer need accounts on remote nodes.
- Users no longer need authorization to spawn jobs on remote nodes.
- Neither binaries nor libraries need to be available on the remote nodes.
- The `BProc` system provides a consistent view of all jobs running on the system.

With all these complications removed, program execution on the compute nodes becomes a simple matter of letting `BProc` know about your job when you start it. The method for doing so depends on whether you are launching a parallel program (for example, an MPI job or PVM job) or any other kind of program. See the sections on running parallel programs and running non-parallelized programs later in this chapter.

Program Execution Examples

This section provides a few examples of program execution with Scyld ClusterWare. Additional examples are provided in the sections on running parallel programs and running non-parallelized programs later in this chapter.

Example 1. Directed Execution with bpsh

In the directed execution mode, the user explicitly defines which node (or nodes) will run a particular job. This mode is invoked using the `bpsh` command, the ClusterWare shell command analogous in functionality to both the `rsh` (remote shell) and `ssh` (secure shell) commands. Following are two examples of using `bpsh`.

The first example runs `hostname` on compute node 0 and writes the output back from the node to the user's screen:

```
[user@cluster user] $ bpsh 0 /bin/hostname
  n0
```

If `/bin` is in the user's $PATH, then the `bpsh` does not need the full pathname:

```
[user@cluster user] $ bpsh 0 hostname
  n0
```

The second example runs the `/usr/bin/uptime` utility on node 1. Assuming `/usr/bin` is in the user's $PATH:

```
[user@cluster user] $ bpsh 1 uptime
  12:56:44 up  4:57,  5 users,  load average: 0.06, 0.09, 0.03
```

Example 2. Dynamic Execution with beorun and mpprun

In the dynamic execution mode, Scyld decides which node is the most capable of executing the job at that moment in time. Scyld includes two parallel execution tools that dynamically select nodes: `beorun` and `mpprun`. They differ only in that `beorun` runs the job concurrently on the selected nodes, while `mpprun` runs the job sequentially on one node at a time.

The following example shows the difference in the elapsed time to run a command with `beorun` vs. `mpprun`:

```
[user@cluster user] $ date;beorun -np 8 sleep 1;date
  Fri Aug 18 11:48:30 PDT 2006
  Fri Aug 18 11:48:31 PDT 2006
```

```
[user@cluster user] $ date;mpprun -np 8 sleep 1;date
  Fri Aug 18 11:48:46 PDT 2006
  Fri Aug 18 11:48:54 PDT 2006
```

Example 3. Binary Pre-Staged on Compute Node

A needed binary can be "pre-staged" by copying it to a compute node prior to execution of a shell script. In the following example, the shell script is in a file called `test.sh`:

```
######
#! /bin/bash
hostname.local
#######

[user@cluster user] $ bpsh 1 mkdir -p /usr/local/bin
[user@cluster user] $ bpcp /bin/hostname 1:/usr/local/bin/hostname.local
[user@cluster user] $ bpsh 1 ./test.sh
  n1
```

This makes the `hostname` binary available on compute node 1 as `/usr/local/bin/hostname.local` before the script is executed. The shell's $PATH contains `/usr/local/bin`, so the compute node searches locally for `hostname.local` in $PATH, finds it, and executes it.

Note that copying files to a compute node generally puts the files into the RAM filesystem on the node, thus reducing main memory that might otherwise be available for programs, libraries, and data on the node.

Example 4. Binary Migrated to Compute Node

If a binary is not "pre-staged" on a compute node, the full path to the binary must be included in the script in order to execute properly. In the following example, the master node starts the process (in this case, a shell) and moves it to node 1, then continues execution of the script. However, when it comes to the `hostname.local2` command, the process fails:

```
######
#! /bin/bash
hostname.local2
#######

[user@cluster user] $ bpsh 1 ./test.sh
  ./test.sh:  line 2:  hostname.local2:  command not found
```

Since the compute node does not have `hostname.local2` locally, the shell attempts to resolve the binary by asking for the binary from the master. The problem is that the master has no idea which binary to give back to the node, hence the failure.

Because there is no way for `Bproc` to know which binaries may be needed by the shell, `hostname.local2` is not migrated along with the shell during the initial startup. Therefore, it is important to provide the compute node with a full path to the binary:

```
######
#! /bin/bash
/tmp/hostname.local2
#######

[user@cluster user] $ cp /bin/hostname /tmp/hostname.local2
[user@cluster user] $ bpsh 1 ./test.sh
  n1
```

With a full path to the binary, the compute node can construct a proper request for the master, and the master knows which exact binary to return to the compute node for proper execution.

Example 5. Process Data Files

Files that are opened by a process (including files on disk, sockets, or named pipes) are not automatically migrated to compute nodes. Suppose the application BOB needs the data file `1.dat`:

```
er@cluster user] $ bpsh 1 /usr/local/BOB/bin/BOB 1.dat
```

`1.dat` must be either pre-staged to the compute node, e.g., using `bpcp` to copy it there; or else the data files must be accessible on an NFS-mounted file system. The file `/etc/beowulf/fstab` (or a node-specific `fstab.`*nodeNumber*) specifies which filesystems are NFS-mounted on each compute node by default.

Example 6. Installing Commercial Applications

Through the course of its execution, the application BOB in the example above does some work with the data file `1.dat`, and then later attempts to call `/usr/local/BOB/bin/BOB.helper.bin` and `/usr/local/BOB/bin/BOB.cleanup.bin`.

If these binaries are not in the memory space of the process during migration, the calls to these binaries will fail. Therefore, `/usr/local/BOB` should be NFS-mounted to all of the compute nodes, or the binaries should be pre-staged using `bpcp` to copy them by hand to the compute nodes. The binaries will stay on each compute node until that node is rebooted.

Generally for commercial applications, the administrator should have `$APP_HOME` NFS-mounted on the compute nodes that will be involved in execution. A general best practice is to mount a general directory such as `/opt`, and install all of the applications into `/opt`.

5.7.2 Environment Modules

The RHEL/CentOS environment-modules package provides for the dynamic modification of a user's environment via modulefiles. Each modulefile contains the information needed to configure the shell for an application, allowing a user to easily switch between applications with a simple `module switch` command that resets environment variables like PATH and LD_LIBRARY_PATH. A number of modules are already installed that configure application builds and execution with OpenMPI, MPICH2, and MVAPICH2. Execute the command `module avail` to see a list of available modules. See specific sections, below, for examples of how to use modules.

For more information about creating your own modules, see http://modules.sourceforge.net, or view the manpages `man module` and `man modulefile`.

5.7.3 Running Programs That Are Not Parallelized

Starting and Migrating Programs to Compute Nodes (bpsh)

There are no executable programs (binaries) on the file system of the compute nodes. This means that there is no `getty`, no `login`, nor any shells on the compute nodes.

Instead of the remote shell (`rsh`) and secure shell (`ssh`) commands that are available on networked stand-alone computers (each of which has its own collection of binaries), Scyld ClusterWare has the `bpsh` command. The following example shows the standard `ls` command running on node 2 using `bpsh`:

```
[user@cluster user] $ bpsh 2 ls -FC /
  bin/   dev/  home/  lib64/  proc/  sys/  usr/
  bpfs/  etc/  lib/   opt/    sbin/  tmp/  var/
```

At startup time, by default Scyld ClusterWare exports various directories, e.g., /bin and /usr/bin, on the master node, and those directories are NFS-mounted by compute nodes.

However, an NFS-accessible /bin/ls is not a requirement for bpsh 2 ls to work. Note that the /sbin directory also exists on the compute node. It is not exported by the master node by default, and thus it exists locally on a compute node in the RAM-based filesystem. bpsh 2 ls /sbin usually shows an empty directory. Nonetheless, bpsh 2 modprobe bproc executes successfully, even though which modprobe shows the command resides in /sbin/modprobe and bpsh 2 which modprobe fails to find the command on the compute node because its /sbin does not contain modprobe.

bpsh 2 modprobe bproc works because the bpsh initiates a modprobe process on the master node, then forms a process memory image that includes the command's binary and references to all its dynamically linked libraries. This process memory image is then copied (migrated) to the compute node, and there the references to dynamic libraries are remapped in the process address space. Only then does the modprobe command begin real execution.

bpsh is not a special version of sh, but a special way of handling execution. This process works with any program. Be aware of the following:

- All three standard I/O streams — stdin, stdout, and stderr — are forwarded to the master node. Since some programs need to read standard input and will stop working if they're run in the background, be sure to close standard input at invocation by using use the bpsh -n flag when you run a program in the background on a compute node.
- Because shell scripts expect executables to be present, and because compute nodes don't meet this requirement, shell scripts should be modified to include the bpsh commands required to affect the compute nodes and run on the master node.
- The dynamic libraries are cached separately from the process memory image, and are copied to the compute node only if they are not already there. This saves time and network bandwidth. After the process completes, the dynamic libraries are unloaded from memory, but they remain in the local cache on the compute node, so they won't need to be copied if needed again.

For additional information on the BProc Distributed Process Space and how processes are migrated to compute nodes, see the *Administrator's Guide*.

Copying Information to Compute Nodes (bpcp)

Just as traditional Unix has copy (cp), remote copy (rcp), and secure copy (scp) to move files to and from networked machines, Scyld ClusterWare has the bpcp command.

Although the default sharing of the master node's home directories via NFS is useful for sharing small files, it is not a good solution for large data files. Having the compute nodes read large data files served via NFS from the master node will result in major network congestion, or even an overload and shutdown of the NFS server. In these cases, staging data files on compute nodes using the bpcp command is an alternate solution. Other solutions include using dedicated NFS servers or NAS appliances, and using cluster file systems.

Following are some examples of using bpcp.

This example shows the use of bpcp to copy a data file named foo2.dat from the current directory to the /tmp directory on node 6:

```
[user@cluster user] $ bpcp foo2.dat 6:/tmp
```

The default directory on the compute node is the current directory on the master node. The current directory on the compute node may already be NFS-mounted from the master node, but it may not exist. The example above works, since /tmp exists on the compute node, but will fail if the destination does not exist. To avoid this problem, you can create the necessary destination directory on the compute node before copying the file, as shown in the next example.

In this example, we change to the /tmp/foo directory on the master, use bpsh to create the same directory on the node 6, then copy foo2.dat to the node:

```
[user@cluster user] $ cd /tmp/foo
[user@cluster user] $ bpsh 6 mkdir /tmp/foo
[user@cluster user] $ bpcp foo2.dat 6:
```

This example copies foo2.dat from node 2 to node 3 directly, without the data being stored on the master node. As in the first example, this works because /tmp exists:

```
[user@cluster user] $ bpcp 2:/tmp/foo2.dat 3:/tmp
```

5.7.4 Running Parallel Programs

An Introduction to Parallel Programming APIs

Programmers are generally familiar with serial, or sequential, programs. Simple programs — like “Hello World” and the basic suite of searching and sorting programs — are typical of sequential programs. They have a beginning, an execution sequence, and an end; at any time during the run, the program is executing only at a single point.

A thread is similar to a sequential program, in that it also has a beginning, an execution sequence, and an end. At any time while a thread is running, there is a single point of execution. A thread differs in that it isn’t a stand-alone program; it runs within a program. The concept of threads becomes important when a program has multiple threads running at the same time and performing different tasks.

To run in parallel means that more than one thread of execution is running at the same time, often on different processors of one computer; in the case of a cluster, the threads are running on different computers. A few things are required to make parallelism work and be useful: The program must migrate to another computer or computers and get started; at some point, the data upon which the program is working must be exchanged between the processes.

The simplest case is when the same single-process program is run with different input parameters on all the nodes, and the results are gathered at the end of the run. Using a cluster to get faster results of the same non-parallel program with different inputs is called *parametric* execution.

A much more complicated example is a simulation, where each process represents some number of elements in the system. Every few time steps, all the elements need to exchange data across boundaries to synchronize the simulation. This situation requires a *message passing interface* or MPI.

To solve these two problems — program startup and message passing — you can develop your own code using POSIX interfaces. Alternatively, you could utilize an existing parallel application programming interface (API), such as the Message Passing Interface (MPI) or the Parallel Virtual Machine (PVM). These are discussed in the sections that follow.

MPI

The Message Passing Interface (MPI) application programming interface is currently the most popular choice for writing parallel programs. The MPI standard leaves implementation details to the system vendors (like Scyld). This is useful because they can make appropriate implementation choices without adversely affecting the output of the program.

A program that uses MPI is automatically started a number of times and is allowed to ask two questions: How many of us (size) are there, and which one am I (rank)? Then a number of conditionals are evaluated to determine the actions of each process. Messages may be sent and received between processes.

The advantages of MPI are that the programmer:

- Doesn’t have to worry about how the program gets started on all the machines

- Has a simplified interface for inter-process messages
- Doesn't have to worry about mapping processes to nodes
- Abstracts the network details, resulting in more portable hardware-agnostic software

Also see the section on running MPI-aware programs later in this chapter. Scyld ClusterWare includes several implementations of MPI:

MPICH. Scyld ClusterWare 6 (and earlier releases) includes MPICH, a freely-available implementations of the MPI standard, and a project that is managed by Argonne National Laboratory. NOTE: MPICH is deprecated and removed from ClusterWare 7 and later releases, and supplanted by MPICH2 and beyond. Visit https://www.mpich.org for more information. Scyld MPICH is modified to use `BProc` and Scyld job mapping support; see the section on job mapping later in this chapter.

MVAPICH. MVAPICH is an implementation of MPICH for Infiniband interconnects. NOTE: MVAPICH is deprecated and removed from ClusterWare 7 and later releases, and supplanted by MVAPICH2 and beyond. Visit http://mvapich.cse.ohio-state.edu/ for more information. Scyld MVAPICH is modified to use `BProc` and Scyld job mapping support; see the section on job mapping later in this chapter.

MPICH2. Scyld ClusterWare includes MPICH2, a second generation MPICH. Visit https://www.mpich.org for more information. Scyld MPICH2 is customized to use environment modules. See *MPICH2 Release Information* for details.

MVAPICH2. MVAPICH2 is second generation MVAPICH. Visit http://mvapich.cse.ohio-state.edu/ for more information. Scyld MVAPICH2 is customized to use environment modules. See *MVAPICH2 Release Information* for details.

OpenMPI. OpenMPI is an open-source implementation of the Message Passing Interface 2 (MPI-2) specification. The OpenMPI implementation is an optimized combination of several other MPI implementations. Visit https://www.open-mpi.org for more information. Also see *OpenMPI Release Information* for details.

Other MPI Implementations. Various commercial MPI implementations run on Scyld ClusterWare. Visit the Penguin Computing Support Portal at https://www.penguincomputing.com/support for more information. You can also download and build your own version of MPI, and configure it to run on Scyld ClusterWare.

PVM

Parallel Virtual Machine (PVM) was an earlier parallel programming interface. Unlike MPI, it is not a specification but a single set of source code distributed on the Internet. PVM reveals much more about the details of starting your job on remote nodes. However, it fails to abstract implementation details as well as MPI does.

PVM is deprecated, but is still in use by legacy code. We generally advise against writing new programs in PVM, but some of the unique features of PVM may suggest its use.

Also see the section on running PVM-aware programs later in this chapter.

Custom APIs

As mentioned earlier, you can develop you own parallel API by using various Unix and TCP/IP standards. In terms of starting a remote program, there are programs written:

- Using the `rexec` function call
- To use the `rexec` or `rsh` program to invoke a sub-program
- To use Remote Procedure Call (RPC)
- To invoke another sub-program using the `inetd` super server

These solutions come with their own problems, particularly in the implementation details. What are the network addresses? What is the path to the program? What is the account name on each of the computers? How is one going to load-balance the cluster?

Scyld ClusterWare, which doesn't have binaries installed on the cluster nodes, may not lend itself to these techniques. We recommend you write your parallel code in MPI. That having been said, we can say that Scyld has some experience with getting `rexec()` calls to work, and that one can simply substitute calls to `rsh` with the more cluster-friendly `bpsh`.

Mapping Jobs to Compute Nodes

Running programs specifically designed to execute in parallel across a cluster requires at least the knowledge of the number of processes to be used. Scyld ClusterWare uses the `NP` environment variable to determine this. The following example will use 4 processes to run an MPI-aware program called `a.out`, which is located in the current directory.

```
[user@cluster user] $ NP=4 ./a.out
```

Note that each kind of shell has its own syntax for setting environment variables; the example above uses the syntax of the Bourne shell (`/bin/sh` or `/bin/bash`).

What the example above does not specify is which specific nodes will execute the processes; this is the job of the *mapper*. Mapping determines which node will execute each process. While this seems simple, it can get complex as various requirements are added. The mapper scans available resources at the time of job submission to decide which processors to use.

Scyld ClusterWare includes `beomap`, a mapping API (documented in the *Programmer's Guide* with details for writing your own mapper). The mapper's default behavior is controlled by the following environment variables:

- *NP* — The number of processes requested, but not the number of processors. As in the example earlier in this section, `NP=4 ./a.out` will run the MPI program `a.out` with 4 processes.
- *ALL_CPUS* — Set the number of processes to the number of CPUs available to the current user. Similar to the example above, `--all-cpus=1 ./a.out` would run the MPI program `a.out` on all available CPUs.
- *ALL_NODES* — Set the number of processes to the number of nodes available to the current user. Similar to the `ALL_CPUS` variable, but you get a maximum of one CPU per node. This is useful for running a job per node instead of per CPU.
- *ALL_LOCAL* — Run every process on the master node; used for debugging purposes.
- *NO_LOCAL* — Don't run any processes on the master node.
- *EXCLUDE* — A colon-delimited list of nodes to be avoided during node assignment.
- *BEOWULF_JOB_MAP* — A colon-delimited list of nodes. The first node listed will be the first process (MPI Rank 0) and so on.

You can use the `beomap` program to display the current mapping for the current user in the current environment with the current resources at the current time. See the *Reference Guide* for a detailed description of `beomap` and its options, as well as examples for using it.

Running MPICH and MVAPICH Programs

NOTE: MPICH and MVAPICH (version 1) are deprecated and removed from Scyld ClusterWare

MPI-aware programs are those written to the MPI specification and linked with Scyld MPI libraries. NOTE: MPICH and MVAPICH are deprecated and have been supplanted by MPICH2 and MVAPICH2 (and newer versions of those packages). Applications that use MPICH (Ethernet "p4") or MVAPICH (Infiniband "vapi") are compiled and linked with common MPICH/MVAPICH implementation libraries, plus specific compiler family (e.g., gnu, Intel, PGI) libraries. The same application binary can execute either in an Ethernet interconnection environment or an Infiniband interconnection environment that is specified at run time. This section discusses how to run these programs and how to set mapping parameters from within such programs.

For information on building MPICH/MVAPICH programs, see the *Programmer's Guide*.

mpirun

Almost all implementations of MPI have an `mpirun` program, which shares the syntax of `mpprun`, but which boasts of additional features for MPI-aware programs.

In the Scyld implementation of `mpirun`, all of the options available via environment variables or flags through directed execution are available as flags to `mpirun`, and can be used with properly compiled MPI jobs. For example, the command for running a hypothetical program named `my-mpi-prog` with 16 processes:

```
[user@cluster user] $ mpirun -np 16 my-mpi-prog arg1 arg2
```

is equivalent to running the following commands in the Bourne shell:

```
[user@cluster user] $ export NP=16
[user@cluster user] $ my-mpi-prog arg1 arg2
```

Setting Mapping Parameters from Within a Program

A program can be designed to set all the required parameters itself. This makes it possible to create programs in which the parallel execution is completely transparent. However, it should be noted that this will work only with Scyld ClusterWare, while the rest of your MPI program should work on any MPI platform.

Use of this feature differs from the command line approach, in that all options that need to be set on the command line can be set from within the program. This feature may be used only with programs specifically designed to take advantage of it, rather than any arbitrary MPI program. However, this option makes it possible to produce turn-key application and parallel library functions in which the parallelism is completely hidden.

Following is a brief example of the necessary source code to invoke `mpirun` with the `-np 16` option from within a program, to run the program with 16 processes:

```
/* Standard MPI include file */
# include <mpi.h>

main(int argc, char **argv) {
        setenv("NP","16",1); // set up mpirun env vars
        MPI_Init(&argc,&argv);
        MPI_Finalize();
}
```

More details for setting mapping parameters within a program are provided in the *Programmer's Guide*.

Examples

The examples in this section illustrate certain aspects of running a hypothetical MPI-aware program named `my-mpi-prog`.

Example 7. Specifying the Number of Processes

This example shows a cluster execution of a hypothetical program named `my-mpi-prog` run with 4 processes:

```
[user@cluster user] $ NP=4 ./my-mpi-prog
```

An alternative syntax is as follows:

```
[user@cluster user] $ NP=4
[user@cluster user] $ export NP
[user@cluster user] $ ./my-mpi-prog
```

Note that the user specified neither the nodes to be used nor a mechanism for migrating the program to the nodes. The mapper does these tasks, and jobs are run on the nodes with the lowest CPU utilization.

In addition to specifying the number of processes to create, you can also exclude specific nodes as computing resources. In this example, we run `my-mpi-prog` again, but this time we not only specify the number of processes to be used (NP=6), but we also exclude of the master node (NO_LOCAL=1) and some cluster nodes (EXCLUDE=2:4:5) as computing resources.

```
[user@cluster user] $ NP=6 NO_LOCAL=1 EXCLUDE=2:4:5 ./my-mpi-prog
```

Running OpenMPI Programs

OpenMPI programs are those written to the MPI-2 specification. This section provides information needed to use programs with OpenMPI as implemented in Scyld ClusterWare.

Pre-Requisites to Running OpenMPI

A number of commands, such as `mpirun`, are duplicated between OpenMPI and other MPI implementations. The environment-modules package gives users a convenient way to switch between the various implementations. Each module bundles together various compiler-specific environment variables to configure your shell for building and running your application, and for accessing compiler-specific manpages. Be sure that you are loading the proper module to match the compiler that built the application you wish to run. For example, to load the OpenMPI module for use with the Intel compiler, do the following:

```
[user@cluster user] $ module load openmpi/intel
```

Currently, there are modules for the GNU, Intel, and PGI compilers. To see a list of all of the available modules:

```
[user@cluster user] $ module avail openmpi
------------------------------- /opt/modulefiles -------------------------------
openmpi/gnu/1.5.3   openmpi/intel/1.5.3 openmpi/pgi/1.5.3
```

For more information about creating your own modules, see http://modules.sourceforge.net and the manpages `man module` and `man modulefile`.

Using OpenMPI

OpenMPI does not honor the Scyld ClusterWare job mapping environment variables. You must either specify the list of hosts on the command line or inside a hostfile. To specify the list of hosts on the command line, use the -H option. The argument following -H is a comma separated list of hostnames, not node numbers. For example, to run a two process job, with one process running on node 0 and one on node 1:

```
[user@cluster user] $ mpirun -H n0,n1 -np 2 ./mpiprog
```

Support for running jobs over Infiniband using the OpenIB transport is included with OpenMPI distributed with Scyld ClusterWare. Much like running a job with MPICH over Infiniband, one must specifically request the use of OpenIB. For example:

```
[user@cluster user] $ mpirun --mca btl openib,sm,self -H n0,n1 -np 2 ./myprog
```

Read the OpenMPI `mpirun` man page for more information about, using a hostfile, and using other tunable options available through `mpirun`.

Running MPICH2 and MVAPICH2 Programs

MPICH2 and MVAPICH2 programs are those written to the MPI-2 specification. This section provides information needed to use programs with MPICH2 or MVAPICH2 as implemented in Scyld ClusterWare.

Pre-Requisites to Running MPICH2/MVAPICH2

As with Scyld OpenMPI, the Scyld MPICH2 and MVAPICH2 distributions are repackaged Open Source MPICH2 and MVAPICH2 that utilize environment modules to build and to execute applications. Each module bundles together various compiler-specific environment variables to configure your shell for building and running your application, and for accessing implementation- and compiler-specific manpages. You must use the same module to both build the application and to execute it. For example, to load the MPICH2 module for use with the Intel compiler, do the following:

```
[user@cluster user] $ module load mpich2/intel
```

Currently, there are modules for the GNU, Intel, and PGI compilers. To see a list of all of the available modules:

```
[user@cluster user] $ module avail mpich2 mvapich2
------------------------------- /opt/modulefiles -------------------------------
mpich2/gnu/1.3.2   mpich2/intel/1.3.2 mpich2/pgi/1.3.2

------------------------------- /opt/modulefiles -------------------------------
mvapich2/gnu/1.6   mvapich2/intel/1.6 mvapich2/pgi/1.6
```

For more information about creating your own modules, see http://modules.sourceforge.net and the manpages `man module` and `man modulefile`.

Using MPICH2

Unlike the Scyld ClusterWare MPICH implementation, MPICH2 does not honor the Scyld ClusterWare job mapping environment variables. Use `mpiexec` to execute MPICH2 applications. After loading an mpich2 module, see the `man mpiexec` manpage for specifics, and visit https://www.mpich.org for full documentation.

Using MVAPICH2

MVAPICH2 does not honor the Scyld ClusterWare job mapping environment variables. Use `mpirun_rsh` to execute MVAPICH2 applications. After loading an mvapich2 module, use `mpirun_rsh --help` to see specifics, and visit http://mvapich.cse.ohio-state.edu/ for full documentation.

Running PVM-Aware Programs

Parallel Virtual Machine (PVM) is an application programming interface for writing parallel applications, enabling a collection of heterogeneous computers to be used as a coherent and flexible concurrent computational resource. Scyld has developed the Scyld PVM library, specifically tailored to allow PVM to take advantage of the technologies used in Scyld ClusterWare. A PVM-aware program is one that has been written to the PVM specification and linked against the Scyld PVM library.

A complete discussion of cluster configuration for PVM is beyond the scope of this document. However, a brief introduction is provided here, with the assumption that the reader has some background knowledge on using PVM.

You can start the master PVM daemon on the master node using the PVM console, `pvm`. To add a compute node to the virtual machine, issue an `add  .` command, where # is replaced by a node's assigned number in the cluster.

> **Tip**
>
> You can generate a list of node numbers using `bpstat` command.

Alternately, you can start the PVM console with a hostfile filename on the command line. The hostfile should contain a .# for each compute node you want as part of the virtual machine. As with standard PVM, this method automatically spawns PVM slave daemons to the specified compute nodes in the cluster. From within the PVM console, use the `conf` command to list your virtual machine's configuration; the output will include a separate line for each node being used. Once your virtual machine has been configured, you can run your PVM applications as you normally would.

Porting Other Parallelized Programs

Programs written for use on other types of clusters may require various levels of change to function with Scyld ClusterWare. For instance:

- Scripts or programs that invoke `rsh` can instead call `bpsh`.
- Scripts or programs that invoke `rcp` can instead call `bpcp`.
- `beomap` can be used with any script to load balance programs that are to be dispatched to the compute nodes.

For more information on porting applications, see the *Programmer's Guide*.

5.7.5 Running Serial Programs in Parallel

For jobs that are not "MPI-aware" or "PVM-aware", but need to be started in parallel, Scyld ClusterWare provides the parallel execution utilities `mpprun` and `beorun`. These utilities are more sophisticated than `bpsh`, in that they can automatically select ranges of nodes on which to start your program, run tasks on the master node, determine the number of CPUs on a node, and start a copy on each CPU. Thus, `mpprun` and `beorun` provide you with true "dynamic execution" capabilities, whereas `bpsh` provides "directed execution" only.

`mpprun` and `beorun` are very similar, and have similar parameters. They differ only in that `mpprun` runs jobs sequentially on the selected processors, while `beorun` runs jobs concurrently on the selected processors.

mpprun

`mpprun` is intended for applications rather than utilities, and runs them sequentially on the selected nodes. The basic syntax of `mpprun` is as follows:

```
[user@cluster user] $ mpprun [options]  app arg1 arg2...
```

where app is the application program you wish to run; it need not be a parallel program. The arg arguments are the values passed to each copy of the program being run.

Options

`mpprun` includes options for controlling various aspects of the job, including the ability to:

- Specify the number of processors on which to start copies of the program
- Start one copy on each node in the cluster
- Start one copy on each CPU in the cluster
- Force all jobs to run on the master node
- Prevent any jobs from running on the master node

The most interesting of the options is the `--map` option, which lets the user specify which nodes will run copies of a program; an example is provided in the next section. This argument, if specified, overrides the mapper's selection of resources that it would otherwise use.

See the *Reference Guide* for a complete list of options for `mpprun`.

Examples

Run 16 tasks of program *app*:

```
[user@cluster user] $ mpprun -np 16  app infile outfile
```

Run 16 tasks of program *app* on any available nodes except nodes 2 and 3:

```
[user@cluster user] $ mpprun -np 16 --exclude 2:3 app infile outfile
```

Run 4 tasks of program *app* with task 0 on node 4, task 1 on node 2, task 2 on node 1, and task 3 on node 5:

```
[user@cluster user] $ mpprun --map 4:2:1:5 app infile outfile
```

beorun

`beorun` is intended for applications rather than utilities, and runs them concurrently on the selected nodes. The basic syntax of `beorun` is as follows:

```
[user@cluster user] $ beorun [options]  app arg1 arg2...
```

where app is the application program you wish to run; it need not be a parallel program. The arg arguments are the values passed to each copy of the program being run.

Options

`beorun` includes options for controlling various aspects of the job, including the ability to:

- Specify the number of processors on which to start copies of the program
- Start one copy on each node in the cluster
- Start one copy on each CPU in the cluster
- Force all jobs to run on the master node

- Prevent any jobs from running on the master node

The most interesting of the options is the `--map` option, which lets the user specify which nodes will run copies of a program; an example is provided in the next section. This argument, if specified, overrides the mapper's selection of resources that it would otherwise use.

See the *Reference Guide* for a complete list of options for `beorun`.

Examples

Run 16 tasks of program *app*:

```
[user@cluster user] $ beorun -np 16 app infile outfile
```

Run 16 tasks of program *app* on any available nodes except nodes 2 and 3:

```
[user@cluster user] $ beorun -np 16 --exclude 2:3 app infile outfile
```

Run 4 tasks of program *app* with task 0 on node 4, task 1 on node 2, task 2 on node 1, and task 3 on node 5:

```
[user@cluster user] $ beorun --map 4:2:1:5 app infile outfile
```

5.7.6 Job Batching

Job Batching Options for ClusterWare

For Scyld ClusterWare, the default installation includes both the TORQUE resource manager and the Slurm workoad manager, each providing users an intuitive interface for for remotely initiating and managing batch jobs on distributed compute nodes. TORQUE is an Open Source tool based on standard OpenPBS. Slurm is another Open Source tool, employing the Open Source `Munge` for authentication and `mysql` (for ClusterWare 6) or `mariadb` (for ClusterWare 7 and beyond) for managing a database. Basic instructions for using TORQUE are provided in the next section. For more general product information, see http://www.adaptivecomputing.com/ for Adaptive Computing's TORQUE information and https://slurm.schedmd.com for Slurm information.

Only one job manager can be enabled at any one time. See the Scyld ClusterWare *Administrator's Guide* for details about how to enable either TORQUE or Slurm. If Slurm is the chosen job manager, then users must setup the PATH and LD_LIBRARY_PATH environment variables to properly access the Slurm commands. This is done automatically for users who login when the *slurm* service is running and the *pbs_server* is not running, via the `/etc/profile.d/scyld.slurm.sh` script. Alternatively, each Slurm user can manually execute `module load slurm` or can add that command line to (for example) the user's `.bash_profile`.

The https://slurm.schedmd.com Slurm website also provides an optional TORQUE wrapper to minimize the syntactic differences between TORQUE and Slurm commands and scripts. See https://slurm.schedmd.com/rosetta.pdf for a discussion of the differences between TORQUE and Slurm, and https://slurm.schedmd.com/faq.html#torque provides useful information about how to switch from PBS or TORQUE to Slurm.

Scyld also redistributes the Scyld Maui job scheduler, also derived from Adaptive Computing, that functions in conjunction with the TORQUE job manager. The alternative Moab job scheduler is also available from Adaptive Computing with a separate license, giving customers additional job scheduling, reporting, and monitoring capabilities.

In addition, Scyld provides support for most popular open source and commercial schedulers and resource managers, including SGE, LSF, and PBSPro. For the latest information, visit the Penguin Computing Support Portal at https://www.penguincomputing.com/support.

Job Batching with TORQUE

The default installation is configured as a simple job serializer with a single queue named batch.

You can use the TORQUE resource manager to run jobs, check job status, find out which nodes are running your job, and find job output.

Running a Job

To run a job with TORQUE, you can put the commands you would normally use into a job script, and then submit the job script to the cluster using `qsub`. The `qsub` program has a number of options that may be supplied on the command line or as special directives inside the job script. For the most part, these options should behave exactly the same in a job script or via the command line, but job scripts make it easier to manage your actions and their results.

Example 9. Starting a Job with a Job Script Using One Node

Following are some examples of running a job using `qsub`. For more detailed information on `qsub`, see the `qsub` man page.

The following script declares a job with the name "myjob", to be run using one node. The script uses the PBS -N directive, launches the job, and finally sends the current date and working directory to standard output.

```
#!/bin/sh

## Set the job name
#PBS -N myjob
#PBS -l nodes=1

# Run my job
/path/to/myjob

echo Date: $
echo Dir:  $PWD
```

You would submit "myjob" as follows:

```
[bjosh@iceberg]$ qsub -l nodes=1 myjob
15.iceberg
```

Example 10. Starting a Job from the Command Line

This example provides the command line equivalent of the job run in the example above. We enter all of the `qsub` options on the initial command line. Then `qsub` reads the job commands line-by-line until we type ^D, the end-of-file character. At that point, `qsub` queues the job and returns the Job ID.

```
[bjosh@iceberg]$ qsub -N myjob -l nodes=1:ppn=1 -j oe
cd $PBS_O_WORKDIR
echo Date: $
echo Dir:  $PWD
^D
16.iceberg
```

Example 11. Starting an MPI Job with a Job Script

The following script declares an MPI job named “mpijob”. The script uses the PBS -N directive, prints out the nodes that will run the job, launches the job using mpirun, and finally prints out the current date and working directory. When submitting MPI jobs using TORQUE, it is recommended to simply call mpirun without any arguments. mpirun will detect that it is being launched from within TORQUE and assure that the job will be properly started on the nodes TORQUE has assigned to the job. In this case, TORQUE will properly manage and track resources used by the job.

```
## Set the job name
#PBS -N mpijob

# RUN my job
mpirun /path/to/mpijob

echo Date: $
echo Dir:  $PWD
```

To request 8 total processors to run “mpijob”, you would submit the job as follows:

```
[bjosh@iceberg]$ qsub -l nodes=8 mpijob
17.iceberg
```

To request 8 total processors, using 4 nodes, each with 2 processors per node, you would submit the job as follows:

```
[bjosh@iceberg]$ qsub -l nodes=4:ppn=2 mpijob
18.iceberg
```

Checking Job Status

You can check the status of your job using qstat. The command line option qstat -n will display the status of queued jobs. To watch the progression of events, use the watch command to execute qstat -n every 2 seconds by default; type [CTRL]-C to interrupt watch when needed.

Example 12. Checking Job Status

This example shows how to check the status of the job named “myjob”, which we ran on 1 node in the first example above, using the option to watch the progression of events.

```
[bjosh@iceberg]$ qsub myjob && watch qstat -n
iceberg:

JobID        Username        Queue    Jobname SessID   NDS  TSK    ReqdMemory  ReqdTime  S  ElapTime
15.iceberg   bjosh    default myjob    --       1        --   --     00:01    Q    --
```

Table 1. Useful Job Status Commands

Command	Purpose
ps -ef | bpstat -P	Display all running jobs, with node number for each
qstat -Q	Display status of all queues
qstat -n	Display status of queued jobs
qstat -f JOBID	Display very detailed information about Job ID
pbsnodes -a	Display status of all nodes

Finding Out Which Nodes Are Running a Job

To find out which nodes are running your job, use the following commands:

- To find your Job Ids: `qstat -an`
- To find the Process IDs of your jobs: “qstat -f ‘‘
- To find the number of the node running your job: “ps -ef | bpstat -P | grep ‘‘

  The number of the node running your job will be displayed in the first column of output.

Finding Job Output

When your job terminates, TORQUE will store its output and error streams in files in the script’s working directory.

- Default output file: `.o`

  You can override the default using `qsub` with the “-o ‘‘ option on the command line, or use the “#PBS -o ‘‘ directive in your job script.

- Default error file: `.e`

  You can override the default using `qsub` with the “-e ‘‘ option on the command line, or use the “#PBS -e ‘‘ directive in your job script.

- To join the output and error streams into a single file, use `qsub` with the `-j oe` option on the command line, or use the `#PBS -j oe` directive in your job script.

Job Batching with POD Tools

`POD Tools` is a collection of tools for submitting TORQUE jobs to a remote cluster and for monitoring them. POD Tools is useful for, but not limited to, submitting and monitoring jobs to a remote Penguin On Demand cluster. POD Tools executes on both Scyld and non-Scyld client machines, and the Tools communicate with the `beoweb` service that must be executing on the target cluster.

The primary tool in POD Tools is `POD Shell (podsh)`, which is a command-line interface that allows for remote job submission and monitoring. POD Shell is largely self-documented. Enter `podsh --help` for a list of possible commands and their formats.

The general usage is `podsh [OPTIONS] [FILE/ID]`. The action specifies what type of action to perform, such as *submit* (for submitting a new job) or *status* (for collecting status on all jobs or a specific job).

POD Shell can upload a TORQUE job script to the target cluster, where it will be added to the job queue. Additionally, POD Shell can be used to stage data in and out of the target cluster. Staging data in (i.e. copying data to the cluster) is performed across an unencrypted TCP socket. Staging data out (i.e. from the cluster back to the client machine) is performed using `scp` from the cluster to the client. In order for this transfer to be successful, password-less authentication must be in place using SSH keys between the cluster’s master node and the client.

POD Shell uses a configuration file that supports both site-wide and user-local values. Site-wide values are stored in entries in `/etc/podtools.conf`. These settings can be overridden by values in a user’s `~/.podtools/podtools.conf` file. These values can again be overridden by command-line arguments passed to `podsh`. The template for `podtools.conf` is found at `/opt/scyld/podtools/podtools.conf.template`.

5.7.7 Using Singularity

Scyld ClusterWare 6 distributes Singularity, a powerful Linux container platform designed by Lawrence Berkeley National Laboratory.

Singularity enables users to have full control of their environment, allowing a non-privileged user to "swap out" the operating system on the host by executing a lightweight Singularity container environment and an application that executes within that environment. For example, Singularity can provide a user with the ability to create an Ubuntu image of their application, and run the containerized application on a RHEL6 or CentOS6 ClusterWare system in its native Ubuntu environment.

Refer to the Singularity documentation at https://www.sylabs.io/docs/ for instructions on how to create and use Singularity containers.

When running MPI-enabled applications with Singularity on Scyld ClusterWare, follow these additional instructions:

- Always compile MPI applications inside a container image with the same MPI implementation and version you plan to use on your Scyld ClusterWare system. Refer to the Singularity documentation for currently supported MPI implementations.
- Be aware of the MPI transports which are compatible with your containerized binary, and ensure that you use the same MPI transport when executing MPI applications through Singularity. For example, Scyld ClusterWare's OpenMPI packages support TCP, Verbs, PSM and PSM2 MPI transports, but not all operating systems will support this gamut of options. Adjust your `mpirun` accordingly on Scyld ClusterWare to use the MPI transport supported by your containerized application.

For example, after building a container image and an OpenMPI executable binary that was built for that image:

```
module load singularity
module load openmpi/gnu/2.0.2
mpirun -np 4 -H n0,n1,n2,n3 singularity exec <container.img> <container mpi binary>
```

5.7.8 File Systems

Data files used by the applications processed on the cluster may be stored in a variety of locations, including:

- On the local disk of each node
- On the master node's disk, shared with the nodes through a network file system
- On disks on multiple nodes, shared with all nodes through the use of a parallel file system

The simplest approach is to store all files on the master node, as with the standard Network File System. Any files in your `/home` directory are shared via NFS with all the nodes in your cluster. This makes management of the files very simple, but in larger clusters the performance of NFS on the master node can become a bottleneck for I/O-intensive applications. If you are planning a large cluster, you should include disk drives that are separate from the system disk to contain your shared files; for example, place `/home` on a separate pair of RAID1 disks in the master node. A more scalable solution is to utilize a dedicated NFS server with a properly configured storage system for all shared files and programs, or a high performance NAS appliance.

Storing files on the local disk of each node removes the performance problem, but makes it difficult to share data between tasks on different nodes. Input files for programs must be distributed manually to each of the nodes, and output files from the nodes must be manually collected back on the master node. This mode of operation can still be useful for temporary files created by a process and then later reused on that same node.

5.8 Glossary of Parallel Computing Terms

Bandwidth. A measure of the total amount of information delivered by a network. This metric is typically expressed in millions of bits per second (Mbps) for data rate on the physical communication media or megabytes per second (MBps) for the performance seen by the application.

Backplane Bandwidth. The total amount of data that a switch can move through it in a given time, typically much higher than the bandwidth delivered to a single node.

Bisection Bandwidth. The amount of data that can be delivered from one half of a network to the other half in a given time, through the least favorable halving of the network fabric.

Boot Image. The file system and kernel seen by a compute node at boot time; contains enough drivers and information to get the system up and running on the network.

Cluster. A collection of nodes, usually dedicated to a single purpose.

Compute Node. Nodes attached to the master through an interconnection network, used as dedicated attached processors. With Scyld, users never need to directly log into compute nodes.

Data Parallel. A style of programming in which multiple copies of a single program run on each node, performing the same instructions while operating on different data.

Efficiency. The ratio of a program's actual speed-up to its theoretical maximum.

FLOPS. Floating-point operations per second, a key measure of performance for many scientific and numerical applications.

Grain Size, Granularity. A measure of the amount of computation a node can perform in a given problem between communications with other nodes, typically defined as "coarse" (large amount of computation) or "fine" (small amount of computation). Granularity is a key in determining the performance of a particular process on a particular cluster.

High Availability. Refers to level of reliability; usually implies some level of fault tolerance (ability to operate in the presence of a hardware failure).

Hub. A device for connecting the NICs in an interconnection network. Only one pair of ports (a bus) can be active at any time. Modern interconnections utilize switches, not hubs.

Isoefficiency. The ability of a process to maintain a constant efficiency if the size of the process scales with the size of the machine.

Jobs. In traditional computing, a job is a single task. A parallel job can be a collection of tasks, all working on the same problem but running on different nodes.

Kernel. The core of the operating system, the kernel is responsible for processing all system calls and managing the system's physical resources.

Latency. The length of time from when a bit is sent across the network until the same bit is received. Can be measured for just the network hardware (wire latency) or application-to-application (includes software overhead).

Local Area Network (LAN). An interconnection scheme designed for short physical distances and high bandwidth, usually self-contained behind a single router.

MAC Address. On an Ethernet NIC, the hardware address of the card. MAC addresses are unique to the specific NIC, and are useful for identifying specific nodes.

Master Node. Node responsible for interacting with users, connected to both the public network and interconnection network. The master node controls the compute nodes.

Message Passing. Exchanging information between processes, frequently on separate nodes.

Middleware. A layer of software between the user's application and the operating system.

MPI. The Message Passing Interface, the standard for producing message passing libraries.

MPICH. A commonly used MPI implementation, built on the chameleon communications layer.

Network Interface Card (NIC). The device through which a node connects to the interconnection network. The performance of the NIC and the network it attaches to limit the amount of communication that can be done by a parallel program.

Node. A single computer system (motherboard, one or more processors, memory, possibly a disk, network interface).

Parallel Programming. The art of writing programs that are capable of being executed on many processors simultaneously.

Process. An instance of a running program.

Process Migration. Moving a process from one computer to another after the process begins execution.

PVM. The Parallel Virtual Machine, a common message passing library that predates MPI.

Scalability. The ability of a process to maintain efficiency as the number of processors in the parallel machine increases.

Single System Image. All nodes in the system see identical system files, including the same kernel, libraries, header files, etc. This guarantees that a program that will run on one node will run on all nodes.

Socket. A low-level construct for creating a connection between processes on a remote system.

Speedup. A measure of the improvement in the execution time of a program on a parallel computer vs. a serial computer.

Switch. A device for connecting the NICs in an interconnection network so that all pairs of ports can communicate simultaneously.

Version Skew. The problem of having more than one version of software or files (kernel, tools, shared libraries, header files) on different nodes.

5.9 TORQUE and Maui Release Information

TORQUE software downloads from Adaptive Computing: https://www.adaptivecomputing.com/products/opensource/torque

Maui software downloads from http://www.adaptivecomputing.com/support/download-center/maui-cluster-scheduler/ and documention is found at: http://docs.adaptivecomputing.com/maui/index.php

Adaptive Computing's TORQUE release notes are found at https://www.adaptivecomputing.com/support/documentation-index/torque-resource-manager-documentation

5.10 OpenMPI Release Information

The following is reproduced essentially verbatim from files contained within the OpenMPI tarball downloaded from https://www.open-mpi.org.

```
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```

```
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As more fully described in the "Software Version Number" section in
the README file, Open MPI typically releases two separate version
series simultaneously.  Since these series have different goals and
are semi-independent of each other, a single NEWS-worthy item may be
introduced into different series at different times.  For example,
feature F was introduced in the vA.B series at version vA.B.C, and was
later introduced into the vX.Y series at vX.Y.Z.

The first time feature F is released, the item will be listed in the
vA.B.C section, denoted as:

   (** also to appear: X.Y.Z) -- indicating that this item is also
                                 likely to be included in future release
                                 version vX.Y.Z.

When vX.Y.Z is later released, the same NEWS-worthy item will also be
included in the vX.Y.Z section and be denoted as:

   (** also appeared: A.B.C)  -- indicating that this item was previously
                                 included in release version vA.B.C.

4.0.1 -- March, 2019
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- Update embedded PMIx to 3.1.2.
- Fix an issue with Vader (shared-memory) transport on OS-X. Thanks
  to Daniel Vollmer for reporting.
- Fix a problem with the usNIC BTL Makefile.  Thanks to George Marselis
  for reporting.
- Fix an issue when using --enable-visibility configure option
  and older versions of hwloc.  Thanks to Ben Menadue for reporting
  and providing a fix.
- Fix an issue with MPI_WIN_CREATE_DYNAMIC and MPI_GET from self.
  thanks to Bart Janssens for reporting.
- Fix an issue of excessive compiler warning messages from mpi.h
  when using newer C++ compilers.  Thanks to @Shadow-fax for
  reporting.
- Fix a problem when building Open MPI using clang 5.0.
- Fix a problem with MPI_WIN_CREATE when using UCX.  Thanks
```

```
  to Adam Simpson for reporting.
- Fix a memory leak encountered for certain MPI datatype
  destructor operations.  Thanks to Axel Huebl for reporting.
- Fix several problems with MPI RMA accumulate operations.
  Thanks to Jeff Hammond for reporting.
- Fix possible race condition in closing some file descriptors
  during job launch using mpirun.  Thanks to Jason Williams
  for reporting and providing a fix.
- Fix a problem in OMPIO for large individual write operations.
  Thanks to Axel Huebl for reporting.
- Fix a problem with parsing of map-by ppr options to mpirun.
  Thanks to David Rich for reporting.
- Fix a problem observed when using the mpool hugepage component.  Thanks
  to Hunter Easterday for reporting and fixing.
- Fix valgrind warning generated when invoking certain MPI Fortran
  data type creation functions.  Thanks to @rtoijala for reporting.
- Fix a problem when trying to build with a PMIX 3.1 or newer
  release.  Thanks to Alastair McKinstry for reporting.
- Fix a problem encountered with building MPI F08 module files.
  Thanks to Igor Andriyash and Axel Huebl for reporting.
- Fix two memory leaks encountered for certain MPI-RMA usage patterns.
  Thanks to Joseph Schuchart for reporting and fixing.
- Fix a problem with the ORTE rmaps_base_oversubscribe MCA paramater.
  Thanks to @iassiour for reporting.
- Fix a problem with UCX PML default error handler for MPI communicators.
  Thanks to Marcin Krotkiewski for reporting.
- Fix various issues with OMPIO uncovered by the testmpio test suite.

4.0.0 -- September, 2018
------------------------

- OSHMEM updated to the OpenSHMEM 1.4 API.
- Do not build OpenSHMEM layer when there are no SPMLs available.
  Currently, this means the OpenSHMEM layer will only build if
  a MXM or UCX library is found.
- A UCX BTL was added for enhanced MPI RMA support using UCX
- With this release,  OpenIB BTL now only supports iWarp and RoCE by default.
- Updated internal HWLOC to 2.0.2
- Updated internal PMIx to 3.0.2
- Change the priority for selecting external verses internal HWLOC
  and PMIx packages to build.  Starting with this release, configure
  by default selects available external HWLOC and PMIx packages over
  the internal ones.
- Updated internal ROMIO to 3.2.1.
- Removed support for the MXM MTL.
- Removed support for SCIF.
- Improved CUDA support when using UCX.
- Enable use of CUDA allocated buffers for OMPIO.
- Improved support for two phase MPI I/O operations when using OMPIO.
- Added support for Software-based Performance Counters, see
  https://github.com/davideberius/ompi/wiki/
          How-to-Use-Software-Based-Performance-Counters-(SPCs)-in-Open-MPI
- Change MTL OFI from opting-IN on "psm,psm2,gni" to opting-OUT on
  "shm,sockets,tcp,udp,rstream"
- Various improvements to MPI RMA performance when using RDMA
  capable interconnects.
- Update memkind component to use the memkind 1.6 public API.
- Fix a problem with javadoc builds using OpenJDK 11.  Thanks to
```

```
  Siegmar Gross for reporting.
- Fix a memory leak using UCX.  Thanks to Charles Taylor for reporting.
- Fix hangs in MPI_FINALIZE when using UCX.
- Fix a problem with building Open MPI using an external PMIx 2.1.2
  library.  Thanks to Marcin Krotkiewski for reporting.
- Fix race conditions in Vader (shared memory) transport.
- Fix problems with use of newer map-by mpirun options.  Thanks to
  Tony Reina for reporting.
- Fix rank-by algorithms to properly rank by object and span
- Allow for running as root of two environment variables are set.
  Requested by Axel Huebl.
- Fix a problem with building the Java bindings when using Java 10.
  Thanks to Bryce Glover for reporting.
- Fix a problem with ORTE not reporting error messages if an application
  terminated normally but exited with non-zero error code.  Thanks to
  Emre Brookes for reporting.

3.1.3 -- October, 2018
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- Fix race condition in MPI_THREAD_MULTIPLE support of non-blocking
  send/receive path.
- Fix error handling SIGCHLD forwarding.
- Add support for CHARACTER and LOGICAL Fortran datatypes for MPI_SIZEOF.
- Fix compile error when using OpenJDK 11 to compile the Java bindings.
- Fix crash when using a hostfile with a 'user@host' line.
- Numerous Fortran '08 interface fixes.
- TCP BTL error message fixes.
- OFI MTL now will use any provider other than shm, sockets, tcp, udp, or
  rstream, rather than only supporting gni, psm, and psm2.
- Disable async receive of CUDA buffers by default, fixing a hang
  on large transfers.
- Support the BCM57XXX and BCM58XXX Broadcomm adapters.
- Fix minmax datatype support in ROMIO.
- Bug fixes in vader shared memory transport.
- Support very large buffers with MPI_TYPE_VECTOR.
- Fix hang when launching with mpirun on Cray systems.

3.1.2 -- August, 2018
---------------------

- A subtle race condition bug was discovered in the "vader" BTL
  (shared memory communications) that, in rare instances, can cause
  MPI processes to crash or incorrectly classify (or effectively drop)
  an MPI message sent via shared memory.  If you are using the "ob1"
  PML with "vader" for shared memory communication (note that vader is
  the default for shared memory communication with ob1), you need to
  upgrade to v3.1.2 or later to fix this issue.  You may also upgrade
  to the following versions to fix this issue:
  - Open MPI v2.1.5 (expected end of August, 2018) or later in the
    v2.1.x series
  - Open MPI v3.0.1 (released March, 2018) or later in the v3.0.x
    series
- Assorted Portals 4.0 bug fixes.
- Fix for possible data corruption in MPI_BSEND.
- Move shared memory file for vader btl into /dev/shm on Linux.
- Fix for MPI_ISCATTER/MPI_ISCATTERV Fortran interfaces with MPI_IN_PLACE.
- Upgrade PMIx to v2.1.3.
- Numerous One-sided bug fixes.
- Fix for race condition in uGNI BTL.
- Improve handling of large number of interfaces with TCP BTL.
- Numerous UCX bug fixes.

3.1.1 -- June, 2018
-------------------

- Fix potential hang in UCX PML during MPI_FINALIZE
- Update internal PMIx to v2.1.2rc2 to fix forward version compatibility.
- Add new MCA parameter osc_sm_backing_store to allow users to specify
  where in the filesystem the backing file for the shared memory
  one-sided component should live.  Defaults to /dev/shm on Linux.
- Fix potential hang on non-x86 platforms when using builds with
  optimization flags turned off.
- Disable osc/pt2pt when using MPI_THREAD_MULTIPLE due to numerous
  race conditions in the component.
- Fix dummy variable names for the mpi and mpi_f08 Fortran bindings to
  match the MPI standard.  This may break applications which use
  name-based parameters in Fortran which used our internal names
  rather than those documented in the MPI standard.
- Revamp Java detection to properly handle new Java versions which do
  not provide a javah wrapper.
- Fix RMA function signatures for use-mpi-f08 bindings to have the
  asynchonous property on all buffers.
- Improved configure logic for finding the UCX library.

3.1.0 -- May, 2018
------------------

- Various OpenSHMEM bug fixes.
- Properly handle array_of_commands argument to Fortran version of
  MPI_COMM_SPAWN_MULTIPLE.
- Fix bug with MODE_SEQUENTIAL and the sharedfp MPI-IO component.
- Use "javac -h" instead of "javah" when building the Java bindings
  with a recent version of Java.
- Fix mis-handling of jostepid under SLURM that could cause problems
  with PathScale/OmniPath NICs.
- Disable the POWER 7/BE block in configure.  Note that POWER 7/BE is
  still not a supported platform, but it is no longer automatically
  disabled.  See
  https://github.com/open-mpi/ompi/issues/4349#issuecomment-374970982
  for more information.
- The output-filename option for mpirun is now converted to an
  absolute path before being passed to other nodes.
- Add monitoring component for PML, OSC, and COLL to track data
  movement of MPI applications.  See
  ompi/mca/commmon/monitoring/HowTo_pml_monitoring.tex for more
  information about the monitoring framework.
- Add support for communicator assertions: mpi_assert_no_any_tag,
  mpi_assert_no_any_source, mpi_assert_exact_length, and
  mpi_assert_allow_overtaking.
- Update PMIx to version 2.1.1.
- Update hwloc to 1.11.7.
- Many one-sided behavior fixes.
- Improved performance for Reduce and Allreduce using Rabenseifner's algorithm.
- Revamped mpirun --help output to make it a bit more manageable.
- Portals4 MTL improvements: Fix race condition in rendezvous protocol and
```

```
  retry logic.
- UCX OSC: initial implementation.
- UCX PML improvements: add multi-threading support.
- Yalla PML improvements: Fix error with irregular contiguous datatypes.
- Openib BTL: disable XRC support by default.
- TCP BTL: Add check to detect and ignore connections from processes
  that aren't MPI (such as IDS probes) and verify that source and
  destination are using the same version of Open MPI, fix issue with very
  large message transfer.
- ompi_info parsable output now escapes double quotes in values, and
  also quotes values can contains colons.  Thanks to Lev Givon for the
  suggestion.
- CUDA-aware support can now handle GPUs within a node that do not
  support CUDA IPC.  Earlier versions would get error and abort.
- Add a mca parameter ras_base_launch_orted_on_hn to allow for launching
  MPI processes on the same node where mpirun is executing using a separate
  orte daemon, rather than the mpirun process.   This may be useful to set to
  true when using SLURM, as it improves interoperability with SLURM's signal
  propagation tools.  By default it is set to false, except for Cray XC systems.
- Remove LoadLeveler RAS support.
- Remove IB XRC support from the OpenIB BTL due to lack of support.
- Add functionality for IBM s390 platforms.  Note that regular
  regression testing does not occur on the s390 and it is not
  considered a supported platform.
- Remove support for big endian PowerPC.
- Remove support for XL compilers older than v13.1.
- Remove support for atomic operations using MacOS atomics library.

3.0.2 -- June, 2018
-------------------

- Disable osc/pt2pt when using MPI_THREAD_MULTIPLE due to numerous
  race conditions in the component.
- Fix dummy variable names for the mpi and mpi_f08 Fortran bindings to
  match the MPI standard.  This may break applications which use
  name-based parameters in Fortran which used our internal names
  rather than those documented in the MPI standard.
- Fixed MPI_SIZEOF in the "mpi" Fortran module for the NAG compiler.
- Fix RMA function signatures for use-mpi-f08 bindings to have the
  asynchonous property on all buffers.
- Fix Fortran MPI_COMM_SPAWN_MULTIPLE to properly follow the count
  length argument when parsing the array_of_commands variable.
- Revamp Java detection to properly handle new Java versions which do
  not provide a javah wrapper.
- Improved configure logic for finding the UCX library.
- Add support for HDR InfiniBand link speeds.
- Disable the POWER 7/BE block in configure.  Note that POWER 7/BE is
  still not a supported platform, but it is no longer automatically
  disabled.  See
  https://github.com/open-mpi/ompi/issues/4349#issuecomment-374970982
  for more information.

3.0.1 -- March, 2018
--------------------

- Fix ability to attach parallel debuggers to MPI processes.
- Fix a number of issues in MPI I/O found by the HDF5 test suite.
- Fix (extremely) large message transfers with shared memory.
- Fix out of sequence bug in multi-NIC configurations.
- Fix stdin redirection bug that could result in lost input.
- Disable the LSF launcher if CSM is detected.
- Plug a memory leak in MPI_Mem_free().  Thanks to Philip Blakely for reporting.
- Fix the tree spawn operation when the number of nodes is larger than the radix.
  Thanks to Carlos Eduardo de Andrade for reporting.
- Fix Fortran 2008 macro in MPI extensions.  Thanks to Nathan T. Weeks for
  reporting.
- Add UCX to list of interfaces that OpenSHMEM will use by default.
- Add --{enable|disable}-show-load-errors-by-default to control
  default behavior of the load errors option.
- OFI MTL improvements: handle empty completion queues properly, fix
  incorrect error message around fi_getinfo(), use default progress
  option for provider by default, Add support for reading multiple
  CQ events in ofi_progress.
- PSM2 MTL improvements: Allow use of GPU buffers, thread fixes.
- Numerous corrections to memchecker behavior.
- Add a mca parameter ras_base_launch_orted_on_hn to allow for launching
  MPI processes on the same node where mpirun is executing using a separate
  orte daemon, rather than the mpirun process.   This may be useful to set to
  true when using SLURM, as it improves interoperability with SLURM's signal
  propagation tools.  By default it is set to false, except for Cray XC systems.
- Fix a problem reported on the mailing separately by Kevin McGrattan and Stephen
  Guzik about consistency issues on NFS file systems when using OMPIO. This fix
  also introduces a new mca parameter fs_ufs_lock_algorithm which allows to
  control the locking algorithm used by ompio for read/write operations. By
  default, ompio does not perfom locking on local UNIX file systems, locks the
  entire file per operation on NFS file systems, and selective byte-range
  locking on other distributed file systems.
- Add an mca parameter pmix_server_usock_connections to allow mpirun to
  support applications statically built against the Open MPI v2.x release,
  or installed in a container along with the Open MPI v2.x libraries. It is
  set to false by default.

3.0.0 -- September, 2017
------------------------

Major new features:

- Use UCX allocator for OSHMEM symmetric heap allocations to optimize intra-node
  data transfers.  UCX SPML only.
- Use UCX multi-threaded API in the UCX PML.  Requires UCX 1.0 or later.
- Added support for Flux PMI
- Update embedded PMIx to version 2.1.0
- Update embedded hwloc to version 1.11.7

Changes in behavior compared to prior versions:

- Per Open MPI's versioning scheme (see the README), increasing the
  major version number to 3 indicates that this version is not
  ABI-compatible with prior versions of Open MPI. In addition, there may
  be differences in MCA parameter names and defaults from previous releases.
  Command line options for mpirun and other commands may also differ from
  previous versions. You will need to recompile MPI and OpenSHMEM applications
  to work with this version of Open MPI.
- With this release, Open MPI supports MPI_THREAD_MULTIPLE by default.
- New configure options have been added to specify the locations of libnl
  and zlib.
```

```
- A new configure option has been added to request Flux PMI support.
- The help menu for mpirun and related commands is now context based.
  "mpirun --help compatibility" generates the help menu in the same format
  as previous releases.

Removed legacy support:
- AIX is no longer supported.
- Loadlever is no longer supported.
- OpenSHMEM currently supports the UCX and MXM transports via the ucx and ikrit
  SPMLs respectively.
- Remove IB XRC support from the OpenIB BTL due to lack of support.
- Remove support for big endian PowerPC.
- Remove support for XL compilers older than v13.1

Known issues:

- MPI_Connect/accept between applications started by different mpirun
  commands will fail, even if ompi-server is running.

2.1.5 -- August 2018
--------------------

- A subtle race condition bug was discovered in the "vader" BTL
  (shared memory communications) that, in rare instances, can cause
  MPI processes to crash or incorrectly classify (or effectively drop)
  an MPI message sent via shared memory.  If you are using the "ob1"
  PML with "vader" for shared memory communication (note that vader is
  the default for shared memory communication with ob1), you need to
  upgrade to v2.1.5 to fix this issue.  You may also upgrade to the
  following versions to fix this issue:
  - Open MPI v3.0.1 (released March, 2018) or later in the v3.0.x
    series
  - Open MPI v3.1.2 (expected end of August, 2018) or later
- A link issue was fixed when the UCX library was not located in the
  linker-default search paths.

2.1.4 -- August, 2018
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Bug fixes/minor improvements:
- Disable the POWER 7/BE block in configure.  Note that POWER 7/BE is
  still not a supported platform, but it is no longer automatically
  disabled.  See
  https://github.com/open-mpi/ompi/issues/4349#issuecomment-374970982
  for more information.
- Fix bug with request-based one-sided MPI operations when using the
  "rdma" component.
- Fix issue with large data structure in the TCP BTL causing problems
  in some environments.  Thanks to @lgarithm for reporting the issue.
- Minor Cygwin build fixes.
- Minor fixes for the openib BTL:
  - Support for the QLogic RoCE HCA
  - Support for the Boradcom Cumulus RoCE HCA
  - Enable support for HDR link speeds
- Fix MPI_FINALIZED hang if invoked from an attribute destructor
  during the MPI_COMM_SELF destruction in MPI_FINALIZE.  Thanks to
  @AndrewGaspar for reporting the issue.
- Java fixes:
  - Modernize Java framework detection, especially on OS X/MacOS.
    Thanks to Bryce Glover for reporting and submitting the fixes.
  - Prefer "javac -h" to "javah" to support newer Java frameworks.
- Fortran fixes:
  - Use conformant dummy parameter names for Fortran bindings.  Thanks
    to Themos Tsikas for reporting and submitting the fixes.
  - Build the MPI_SIZEOF() interfaces in the "TKR"-style "mpi" module
    whenever possible.  Thanks to Themos Tsikas for reporting the
    issue.
  - Fix array of argv handling for the Fortran bindings of
    MPI_COMM_SPAWN_MULTIPLE (and its associated man page).
  - Make NAG Fortran compiler support more robust in configure.
- Disable the "pt2pt" one-sided MPI component when MPI_THREAD_MULTIPLE
  is used.  This component is simply not safe in MPI_THREAD_MULTIPLE
  scenarios, and will not be fixed in the v2.1.x series.
- Make the "external" hwloc component fail gracefully if it is tries
  to use an hwloc v2.x.y installation.  hwloc v2.x.y will not be
  supported in the Open MPI v2.1.x series.
- Fix "vader" shared memory support for messages larger than 2GB.
  Thanks to Heiko Bauke for the bug report.
- Configure fixes for external PMI directory detection.  Thanks to
  Davide Vanzo for the report.

2.1.3 -- March, 2018
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Bug fixes/minor improvements:
- Update internal PMIx version to 1.2.5.
- Fix a problem with ompi_info reporting using param option.
  Thanks to Alexander Pozdneev for reporting.
- Correct PMPI_Aint_{add|diff} to be functions (not subroutines)
  in the Fortran mpi_f08 module.
- Fix a problem when doing MPI I/O using data types with large
  extents in conjunction with MPI_TYPE_CREATE_SUBARRAY.  Thanks to
  Christopher Brady for reporting.
- Fix a problem when opening many files using MPI_FILE_OPEN.
  Thanks to William Dawson for reporting.
- Fix a problem with debuggers failing to attach to a running job.
  Thanks to Dirk Schubert for reporting.
- Fix a problem when using madvise and the OpenIB BTL.  Thanks to
  Timo Bingmann for reporting.
- Fix a problem in the Vader BTL that resulted in failures of
  IMB under certain circumstances.  Thanks to Nicolas Morey-
  Chaisemartin for reporting.
- Fix a problem preventing Open MPI from working under Cygwin.
  Thanks to Marco Atzeri for reporting.
- Reduce some verbosity being emitted by the USNIC BTL under certain
  circumstances.  Thanks to Peter Forai for reporting.
- Fix a problem with misdirection of SIGKILL.  Thanks to Michael Fern
  for reporting.
- Replace use of posix_memalign with malloc for small allocations.  Thanks
  to Ben Menaude for reporting.
- Fix a problem with Open MPI's out of band TCP network for file descriptors
  greater than 32767.  Thanks to Wojtek Wasko for reporting and fixing.
- Plug a memory leak in MPI_Mem_free().  Thanks to Philip Blakely for reporting.

2.1.2 -- September, 2017
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```

```
Bug fixes/minor improvements:
- Update internal PMIx version to 1.2.3.
- Fix some problems when using the NAG Fortran compiler to build Open MPI
  and when using the compiler wrappers.  Thanks to Neil Carlson for reporting.
- Fix a compilation problem with the SM BTL.  Thanks to Paul Hargrove for
  reporting.
- Fix a problem with MPI_IALLTOALLW when using zero-length messages.
  Thanks to Dahai Guo for reporting.
- Fix a problem with C11 generic type interface for SHMEM_G.  Thanks
  to Nick Park for reporting.
- Switch to using the lustreapi.h include file when building Open MPI
  with Lustre support.
- Fix a problem in the OB1 PML that led to hangs with OSU collective tests.
- Fix a progression issue with MPI_WIN_FLUSH_LOCAL.  Thanks to
  Joseph Schuchart for reporting.
- Fix an issue with recent versions of PBSPro requiring libcrypto.
  Thanks to Petr Hanousek for reporting.
- Fix a problem when using MPI_ANY_SOURCE with MPI_SENDRECV.
- Fix an issue that prevented signals from being propagated to ORTE
  daemons.
- Ensure that signals are forwarded from ORTE daemons to all processes
  in the process group created by the daemons.  Thanks to Ted Sussman
  for reporting.
- Fix a problem with launching a job under a debugger. Thanks to
  Greg Lee for reporting.
- Fix a problem with Open MPI native I/O MPI_FILE_OPEN when using
  a communicator having an associated topology.  Thanks to
  Wei-keng Liao for reporting.
- Fix an issue when using MPI_ACCUMULATE with derived datatypes.
- Fix a problem with Fortran bindings that led to compilation errors
  for user defined reduction operations.  Thanks to Nathan Weeks for
  reporting.
- Fix ROMIO issues with large writes/reads when using NFS file systems.
- Fix definition of Fortran MPI_ARGV_NULL and MPI_ARGVS_NULL.
- Enable use of the head node of a SLURM allocation on Cray XC systems.
- Fix a problem with synchronous sends when using the UCX PML.
- Use default socket buffer size to improve TCP BTL performance.
- Add a mca parameter ras_base_launch_orted_on_hn to allow for launching
  MPI processes on the same node where mpirun is executing using a separate
  orte daemon, rather than the mpirun process.   This may be useful to set to
  true when using SLURM, as it improves interoperability with SLURM's signal
  propagation tools.  By default it is set to false, except for Cray XC systems.
- Fix --without-lsf when lsf is installed in the default search path.
- Remove support for big endian PowerPC.
- Remove support for XL compilers older than v13.1
- Remove IB XRC support from the OpenIB BTL due to loss of maintainer.

2.1.1 -- April, 2017
--------------------

Bug fixes/minor improvements:

- Fix a problem with one of Open MPI's fifo data structures which led to
  hangs in a make check test.  Thanks to Nicolas Morey-Chaisemartin for
  reporting.
- Add missing MPI_AINT_ADD/MPI_AINT_DIFF function definitions to mpif.h.
  Thanks to Aboorva Devarajan for reporting.
- Fix the error return from MPI_WIN_LOCK when rank argument is invalid.
```

```
  Thanks to Jeff Hammond for reporting and fixing this issue.
- Fix a problem with mpirun/orterun when started under a debugger. Thanks
  to Gregory Leff for reporting.
- Add configury option to disable use of CMA by the vader BTL.  Thanks
  to Sascha Hunold for reporting.
- Add configury check for MPI_DOUBLE_COMPLEX datatype support.
  Thanks to Alexander Klein for reporting.
- Fix memory allocated by MPI_WIN_ALLOCATE_SHARED to
  be 64 bit aligned.  Thanks to Joseph Schuchart for
  reporting.
- Update MPI_WTICK man page to reflect possibly higher
  resolution than 10e-6.  Thanks to Mark Dixon for
  reporting
- Add missing MPI_T_PVAR_SESSION_NULL definition to mpi.h
  include file.  Thanks to Omri Mor for this contribution.
- Enhance the Open MPI spec file to install modulefile in /opt
  if installed in a non-default location.  Thanks to Kevin
  Buckley for reporting and supplying a fix.
- Fix a problem with conflicting PMI symbols when linking statically.
  Thanks to Kilian Cavalotti for reporting.

Known issues (to be addressed in v2.1.2):

- See the list of fixes slated for v2.1.2 here:
  https://github.com/open-mpi/ompi/milestone/28

2.1.0 -- March, 2017
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Major new features:

- The main focus of the Open MPI v2.1.0 release was to update to PMIx
  v1.2.1.  When using PMIx (e.g., via mpirun-based launches, or via
  direct launches with recent versions of popular resource managers),
  launch time scalability is improved, and the run time memory
  footprint is greatly decreased when launching large numbers of MPI /
  OpenSHMEM processes.
- Update OpenSHMEM API conformance to v1.3.
- The usnic BTL now supports MPI_THREAD_MULTIPLE.
- General/overall performance improvements to MPI_THREAD_MULTIPLE.
- Add a summary message at the bottom of configure that tells you many
  of the configuration options specified and/or discovered by Open
  MPI.

Changes in behavior compared to prior versions:

- None.

Removed legacy support:

- The ptmalloc2 hooks have been removed from the Open MPI code base.
  This is not really a user-noticable change; it is only mentioned
  here because there was much rejoycing in the Open MPI developer
  community.

Bug fixes/minor improvements:

- New MCA parameters:
  - iof_base_redirect_app_stderr_to_stdout: as its name implies, it
    combines MPI / OpenSHMEM applications' stderr into its stdout
    stream.
  - opal_event_include: allow the user to specify which FD selection
    mechanism is used by the underlying event engine.
  - opal_stacktrace_output: indicate where stacktraces should be sent
    upon MPI / OpenSHMEM process crashes ("none", "stdout", "stderr",
    "file:filename").
  - orte_timeout_for_stack_trace: number of seconds to wait for stack
    traces to be reported (or <=0 to wait forever).
  - mtl_ofi_control_prog_type/mtl_ofi_data_prog_type: specify libfabric
    progress model to be used for control and data.
- Fix MPI_WTICK regression where the time reported may be inaccurate
  on systems with processor frequency scalaing enabled.
- Fix regression that lowered the memory maximum message bandwidth for
  large messages on some BTL network transports, such as openib, sm,
  and vader.
- Fix a name collision in the shared file pointer MPI IO file locking
  scheme.  Thanks to Nicolas Joly for reporting the issue.
- Fix datatype extent/offset errors in MPI_PUT and MPI_RACCUMULATE
  when using the Portals 4 one-sided component.
- Add support for non-contiguous datatypes to the Portals 4 one-sided
  component.
- Various updates for the UCX PML.
- Updates to the following man pages:
  - mpirun(1)
  - MPI_COMM_CONNECT(3)
  - MPI_WIN_GET_NAME(3). Thanks to Nicolas Joly for reporting the
    typo.
  - MPI_INFO_GET_[NKEYS|NTHKEY](3). Thanks to Nicolas Joly for
    reporting the typo.
- Fixed a problem in the TCP BTL when using MPI_THREAD_MULTIPLE.
  Thanks to Evgueni Petrov for reporting.
- Fixed external32 representation in the romio314 module.  Note that
  for now, external32 representation is not correctly supported by the
  ompio module.  Thanks to Thomas Gastine for bringing this to our
  attention.
- Add note how to disable a warning message about when a high-speed
  MPI transport is not found.  Thanks to Susan Schwarz for reporting
  the issue.
- Ensure that sending SIGINT when using the rsh/ssh launcher does not
  orphan children nodes in the launch tree.
- Fix the help message when showing deprecated MCA param names to show
  the correct (i.e., deprecated) name.
- Enable support for the openib BTL to use multiple different
  InfiniBand subnets.
- Fix a minor error in MPI_AINT_DIFF.
- Fix bugs with MPI_IN_PLACE handling in:
  - MPI_ALLGATHER[V]
  - MPI_[I][GATHER|SCATTER][V]
  - MPI_IREDUCE[_SCATTER]
  - Thanks to all the users who helped diagnose these issues.
- Allow qrsh to tree spawn (if the back-end system supports it).
- Fix MPI_T_PVAR_GET_INDEX to return the correct index.
- Correctly position the shared file pointer in append mode in the
  OMPIO component.
- Add some deprecated names into shmem.h for backwards compatibility
  with legacy codes.
```

```
- Fix MPI_MODE_NOCHECK support.
- Fix a regression in PowerPC atomics support.  Thanks to Orion
  Poplawski for reporting the issue.
- Fixes for assembly code with aggressively-optimized compilers on
  x86_64/AMD64 platforms.
- Fix one more place where configure was mangling custom CFLAGS.
  Thanks to Phil Tooley (@Telemin) for reporting the issue.
- Better handle builds with external installations of hwloc.
- Fixed a hang with MPI_PUT and MPI_WIN_LOCK_ALL.
- Fixed a bug when using MPI_GET on non-contiguous datatypes and
  MPI_LOCK/MPI_UNLOCK.
- Fixed a bug when using POST/START/COMPLETE/WAIT after a fence.
- Fix configure portability by cleaning up a few uses of "==" with
  "test".  Thanks to Kevin Buckley for pointing out the issue.
- Fix bug when using darrays with lib and extent of darray datatypes.
- Updates to make Open MPI binary builds more bit-for-bit
  reproducable.  Thanks to Alastair McKinstry for the suggestion.
- Fix issues regarding persistent request handling.
- Ensure that shmemx.h is a standalone OpenSHMEM header file.  Thanks
  to Nick Park (@nspark) for the report.
- Ensure that we always send SIGTERM prior to SIGKILL.  Thanks to Noel
  Rycroft for the report.
- Added ConnectX-5 and Chelsio T6 device defaults for the openib BTL.
- OpenSHMEM no longer supports MXM less than v2.0.
- Plug a memory leak in ompi_osc_sm_free.  Thanks to Joseph Schuchart
  for the report.
- The "self" BTL now uses less memory.
- The vader BTL is now more efficient in terms of memory usage when
  using XPMEM.
- Removed the --enable-openib-failover configure option.  This is not
  considered backwards-incompatible because this option was stale and
  had long-since stopped working, anyway.
- Allow jobs launched under Cray aprun to use hyperthreads if
  opal_hwloc_base_hwthreads_as_cpus MCA parameter is set.
- Add support for 32-bit and floating point Cray Aries atomic
  operations.
- Add support for network AMOs for MPI_ACCUMULATE, MPI_FETCH_AND_OP,
  and MPI_COMPARE_AND_SWAP if the "ompi_single_intrinsic" info key is
  set on the window or the "acc_single_intrinsic" MCA param is set.
- Automatically disqualify RDMA CM support in the openib BTL if
  MPI_THREAD_MULTIPLE is used.
- Make configure smarter/better about auto-detecting Linux CMA
  support.
- Improve the scalability of MPI_COMM_SPLIT_TYPE.
- Fix the mixing of C99 and C++ header files with the MPI C++
  bindings.  Thanks to Alastair McKinstry for the bug report.
- Add support for ARM v8.
- Several MCA parameters now directly support MPI_T enumerator
  semantics (i.e., they accept a limited set of values -- e.g., MCA
  parameters that accept boolean values).
- Added --with-libmpi-name=STRING configure option for vendor releases
  of Open MPI.  See the README for more detail.
- Fix a problem with Open MPI's internal memory checker.  Thanks to Yvan
  Fournier for reporting.
- Fix a multi-threaded issue with MPI_WAIT.  Thanks to Pascal Deveze for
  reporting.

Known issues (to be addressed in v2.1.1):
```

```
- See the list of fixes slated for v2.1.1 here:
  https://github.com/open-mpi/ompi/milestone/26

2.0.4 -- November, 2017
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Bug fixes/minor improvements:
- Fix an issue with visibility of functions defined in the built-in PMIx.
  Thanks to Siegmar Gross for reporting this issue.
- Add configure check to prevent trying to build this release of
  Open MPI with an external hwloc 2.0 or newer release.
- Add ability to specify layered providers for OFI MTL.
- Fix a correctness issue with Open MPI's memory manager code
  that could result in corrupted message data.  Thanks to
  Valentin Petrov for reporting.
- Fix issues encountered when using newer versions of PBS Pro.
  Thanks to Petr Hanousek for reporting.
- Fix a problem with MPI_GET when using the vader BTL.  Thanks
  to Dahai Guo for reporting.
- Fix a problem when using MPI_ANY_SOURCE with MPI_SENDRECV_REPLACE.
  Thanks to Dahai Guo for reporting.
- Fix a problem using MPI_FILE_OPEN with a communicator with an
  attached cartesian topology.  Thanks to Wei-keng Liao for reporting.
- Remove IB XRC support from the OpenIB BTL due to lack of support.
- Remove support for big endian PowerPC.
- Remove support for XL compilers older than v13.1

2.0.3 -- June 2017
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Bug fixes/minor improvements:

 - Fix a problem with MPI_IALLTOALLW when zero size messages are present.
   Thanks to @mathbird for reporting.
 - Add missing MPI_USER_FUNCTION definition to the mpi_f08 module.
   Thanks to Nathan Weeks for reporting this issue.
 - Fix a problem with MPI_WIN_LOCK not returning an error code when
   a negative rank is supplied.  Thanks to Jeff Hammond for reporting and
   providing a fix.
 - Fix a problem with make check that could lead to hangs.  Thanks to
   Nicolas Morey-Chaisemartin for reporting.
 - Resolve a symbol conflict problem with PMI-1 and PMI-2 PMIx components.
   Thanks to Kilian Cavalotti for reporting this issue.
 - Insure that memory allocations returned from MPI_WIN_ALLOCATE_SHARED are
   64 byte aligned.  Thanks to Joseph Schuchart for reporting this issue.
 - Make use of DOUBLE_COMPLEX, if available, for Fortran bindings.  Thanks
   to Alexander Klein for reporting this issue.
 - Add missing MPI_T_PVAR_SESSION_NULL definition to Open MPI mpi.h include
   file.  Thanks to Omri Mor for reporting and fixing.
 - Fix a problem with use of MPI shared file pointers when accessing
   a file from independent jobs.  Thanks to Nicolas Joly for reporting
   this issue.
 - Optimize zero size MPI_IALLTOALL{V,W} with MPI_IN_PLACE.  Thanks to
   Lisandro Dalcin for the report.
 - Fix a ROMIO buffer overflow problem for large transfers when using NFS
   filesystems.
 - Fix type of MPI_ARGV[S]_NULL which prevented it from being used
   properly with MPI_COMM_SPAWN[_MULTIPLE] in the mpi_f08 module.
 - Ensure to add proper linker flags to the wrapper compilers for
   dynamic libraries on platforms that need it (e.g., RHEL 7.3 and
   later).
 - Get better performance on TCP-based networks 10Gbps and higher by
   using OS defaults for buffer sizing.
 - Fix a bug with MPI_[R][GET_]ACCUMULATE when using DARRAY datatypes.
 - Fix handling of --with-lustre configure command line argument.
   Thanks to Prentice Bisbal and Tim Mattox for reporting the issue.
 - Added MPI_AINT_ADD and MPI_AINT_DIFF declarations to mpif.h.  Thanks
   to Aboorva Devarajan (@AboorvaDevarajan) for the bug report.
 - Fix a problem in the TCP BTL when Open MPI is initialized with
   MPI_THREAD_MULTIPLE support.  Thanks to Evgueni Petro for analyzing and
   reporting this issue.
 - Fix yalla PML to properly handle underflow errors, and fixed a
   memory leak with blocking non-contiguous sends.
 - Restored ability to run autogen.pl on official distribution tarballs
   (although this is still not recommended for most users!).
 - Fix accuracy problems with MPI_WTIME on some systems by always using
   either clock_gettime(3) or gettimeofday(3).
 - Fix a problem where MPI_WTICK was not returning a higher time resolution
   when available.  Thanks to Mark Dixon for reporting this issue.
 - Restore SGE functionality.  Thanks to Kevin Buckley for the initial
   report.
 - Fix external hwloc compilation issues, and extend support to allow
   using external hwloc installations as far back as v1.5.0.  Thanks to
   Orion Poplawski for raising the issue.
 - Added latest Mellanox Connect-X and Chelsio T-6 adapter part IDs to
   the openib list of default values.
 - Do a better job of cleaning up session directories (e.g., in /tmp).
 - Update a help message to indicate how to suppress a warning about
   no high performance networks being detected by Open MPI.  Thanks to
   Susan Schwarz for reporting this issue.
 - Fix a problem with mangling of custom CFLAGS when configuring Open MPI.
   Thanks to Phil Tooley for reporting.
 - Fix some minor memory leaks and remove some unused variables.
   Thanks to Joshua Gerrard for reporting.
 - Fix MPI_ALLGATHERV bug with MPI_IN_PLACE.

Known issues (to be addressed in v2.0.4):

- See the list of fixes slated for v2.0.4 here:
  https://github.com/open-mpi/ompi/milestone/29

2.0.2 -- 26 January 2017
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Bug fixes/minor improvements:

- Fix a problem with MPI_FILE_WRITE_SHARED when using MPI_MODE_APPEND and
  Open MPI's native MPI-IO implementation.  Thanks to Nicolas Joly for
  reporting.
- Fix a typo in the MPI_WIN_GET_NAME man page.  Thanks to Nicolas Joly
  for reporting.
- Fix a race condition with ORTE's session directory setup.  Thanks to
  @tbj900 for reporting this issue.
- Fix a deadlock issue arising from Open MPI's approach to catching calls to
  munmap. Thanks to Paul Hargrove for reporting and helping to analyze this
  problem.
```

```
- Fix a problem with PPC atomics which caused make check to fail unless builtin
  atomics configure option was enabled.  Thanks to Orion Poplawski for reporting.
- Fix a problem with use of x86_64 cpuid instruction which led to segmentation
  faults when Open MPI was configured with -O3 optimization.  Thanks to Mark
  Santcroos for reporting this problem.
- Fix a problem when using built in atomics configure options on PPC platforms
  when building 32 bit applications.  Thanks to Paul Hargrove for reporting.
- Fix a problem with building Open MPI against an external hwloc installation.
  Thanks to Orion Poplawski for reporting this issue.
- Remove use of DATE in the message queue version string reported to debuggers to
  insure bit-wise reproducibility of binaries.  Thanks to Alastair McKinstry
  for help in fixing this problem.
- Fix a problem with early exit of a MPI process without calling MPI_FINALIZE
  or MPI_ABORT that could lead to job hangs.  Thanks to Christof Koehler for
  reporting.
- Fix a problem with forwarding of SIGTERM signal from mpirun to MPI processes
  in a job.  Thanks to Noel Rycroft for reporting this problem
- Plug some memory leaks in MPI_WIN_FREE discovered using Valgrind.  Thanks
  to Joseph Schuchart for reporting.
- Fix a problems  MPI_NEIGHOR_ALLTOALL when using a communicator with an empty topology
  graph.  Thanks to Daniel Ibanez for reporting.
- Fix a typo in a PMIx component help file.  Thanks to @njoly for reporting this.
- Fix a problem with Valgrind false positives when using Open MPI's internal memchecker.
  Thanks to Yvan Fournier for reporting.
- Fix a problem with MPI_FILE_DELETE returning MPI_SUCCESS when
  deleting a non-existent file. Thanks to Wei-keng Liao for reporting.
- Fix a problem with MPI_IMPROBE that could lead to hangs in subsequent MPI
  point to point or collective calls.  Thanks to Chris Pattison for reporting.
- Fix a problem when configure Open MPI for powerpc with --enable-mpi-cxx
  enabled.  Thanks to Alastair McKinstry for reporting.
- Fix a problem using MPI_IALLTOALL with MPI_IN_PLACE argument.  Thanks to
  Chris Ward for reporting.
- Fix a problem using MPI_RACCUMULATE with the Portals4 transport.  Thanks to
  @PDeveze for reporting.
- Fix an issue with static linking and duplicate symbols arising from PMIx
  Slurm components.  Thanks to Limin Gu for reporting.
- Fix a problem when using MPI dynamic memory windows.  Thanks to
  Christoph Niethammer for reporting.
- Fix a problem with Open MPI's pkgconfig files.  Thanks to Alastair McKinstry
  for reporting.
- Fix a problem with MPI_IREDUCE when the same buffer is supplied for the
  send and recv buffer arguments.  Thanks to Valentin Petrov for reporting.
- Fix a problem with atomic operations on PowerPC.  Thanks to Paul
  Hargrove for reporting.

Known issues (to be addressed in v2.0.3):

- See the list of fixes slated for v2.0.3 here:
  https://github.com/open-mpi/ompi/milestone/23

2.0.1 -- 2 September 2016
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Bug fixes/minor improvements:

- Short message latency and message rate performance improvements for
  all transports.
- Fix shared memory performance when using RDMA-capable networks.
```

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  Thanks to Tetsuya Mishima and Christoph Niethammer for reporting.
- Fix bandwith performance degredation in the yalla (MXM) PML.  Thanks
  to Andreas Kempf for reporting the issue.
- Fix OpenSHMEM crash when running on non-Mellanox MXM-based networks.
  Thanks to Debendra Das for reporting the issue.
- Fix a crash occuring after repeated calls to MPI_FILE_SET_VIEW with
  predefined datatypes.  Thanks to Eric Chamberland and Matthew
  Knepley for reporting and helping chase down this issue.
- Fix stdin propagation to MPI processes.  Thanks to Jingchao Zhang
  for reporting the issue.
- Fix various runtime and portability issues by updating the PMIx
  internal component to v1.1.5.
- Fix process startup failures on Intel MIC platforms due to very
  large entries in /proc/mounts.
- Fix a problem with use of relative path for specifing executables to
  mpirun/oshrun.  Thanks to David Schneider for reporting.
- Various improvements when running over portals-based networks.
- Fix thread-based race conditions with GNI-based networks.
- Fix a problem with MPI_FILE_CLOSE and MPI_FILE_SET_SIZE.  Thanks
  to Cihan Altinay for reporting.
- Remove all use of rand(3) from within Open MPI so as not to perturb
  applications use of it.  Thanks to Matias Cabral and Noel Rycroft
  for reporting.
- Fix crash in MPI_COMM_SPAWN.
- Fix types for MPI_UNWEIGHTED and MPI_WEIGHTS_EMPTY.  Thanks to
  Lisandro Dalcin for reporting.
- Correctly report the name of MPI_INTEGER16.
- Add some missing MPI constants to the Fortran bindings.
- Fixed compile error when configuring Open MPI with --enable-timing.
- Correctly set the shared library version of libompitrace.so.  Thanks
  to Alastair McKinstry for reporting.
- Fix errors in the MPI_RPUT, MPI_RGET, MPI_RACCUMULATE, and
  MPI_RGET_ACCUMULATE Fortran bindings.  Thanks to Alfio Lazzaro and
  Joost VandeVondele for tracking this down.
- Fix problems with use of derived datatypes in non-blocking
  collectives.  Thanks to Yuki Matsumoto for reporting.
- Fix problems with OpenSHMEM header files when using CMake.  Thanks to
  Paul Kapinos for reporting the issue.
- Fix problem with use use of non-zero lower bound datatypes in
  collectives.  Thanks to Hristo Iliev for reporting.
- Fix a problem with memory allocation within MPI_GROUP_INTERSECTION.
  Thanks to Lisandro Dalcin for reporting.
- Fix an issue with MPI_ALLGATHER for communicators that don't consist
  of two ranks.  Thanks to David Love for reporting.
- Various fixes for collectives when used with esoteric MPI datatypes.
- Fixed corner cases of handling DARRAY and HINDEXED_BLOCK datatypes.
- Fix a problem with filesystem type check for OpenBSD.
  Thanks to Paul Hargrove for reporting.
- Fix some debug input within Open MPI internal functions.  Thanks to
  Durga Choudhury for reporting.
- Fix a typo in a configury help message.  Thanks to Paul Hargrove for
  reporting.
- Correctly support MPI_IN_PLACE in MPI_[I]ALLTOALL[V|W] and
  MPI_[I]EXSCAN.
- Fix alignment issues on SPARC platforms.

Known issues (to be addressed in v2.0.2):
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```
- See the list of fixes slated for v2.0.2 here:
  https://github.com/open-mpi/ompi/milestone/20, and
  https://github.com/open-mpi/ompi-release/milestone/19
  (note that the "ompi-release" Github repo will be folded/absorbed
  into the "ompi" Github repo at some point in the future)

2.0.0 -- 12 July 2016
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 **********************************************************************
 *  Open MPI is now fully MPI-3.1 compliant
 **********************************************************************

Major new features:

- Many enhancements to MPI RMA.  Open MPI now maps MPI RMA operations
  on to native RMA operations for those networks which support this
  capability.
- Greatly improved support for MPI_THREAD_MULTIPLE (when configured
  with --enable-mpi-thread-multiple).
- Enhancements to reduce the memory footprint for jobs at scale.  A
  new MCA parameter, "mpi_add_procs_cutoff", is available to set the
  threshold for using this feature.
- Completely revamped support for memory registration hooks when using
  OS-bypass network transports.
- Significant OMPIO performance improvements and many bug fixes.
- Add support for PMIx - Process Management Interface for Exascale.
  Version 1.1.2 of PMIx is included internally in this release.
- Add support for PLFS file systems in Open MPI I/O.
- Add support for UCX transport.
- Simplify build process for Cray XC systems.  Add support for
  using native SLURM.
- Add a --tune mpirun command line option to simplify setting many
  environment variables and MCA parameters.
- Add a new MCA parameter "orte_default_dash_host" to offer an analogue
  to the existing "orte_default_hostfile" MCA parameter.
- Add the ability to specify the number of desired slots in the mpirun
  --host option.

Changes in behavior compared to prior versions:

- In environments where mpirun cannot automatically determine the
  number of slots available (e.g., when using a hostfile that does not
  specify "slots", or when using --host without specifying a ":N"
  suffix to hostnames), mpirun now requires the use of "-np N" to
  specify how many MPI processes to launch.
- The MPI C++ bindings -- which were removed from the MPI standard in
  v3.0 -- are no longer built by default and will be removed in some
  future version of Open MPI.  Use the --enable-mpi-cxx-bindings
  configure option to build the deprecated/removed MPI C++ bindings.
- ompi_info now shows all components, even if they do not have MCA
  parameters.  The prettyprint output now separates groups with a
  dashed line.
- OMPIO is now the default implementation of parallel I/O, with the
  exception for Lustre parallel filesystems (where ROMIO is still the
  default).  The default selection of OMPI vs. ROMIO can be controlled
  via the "--mca io ompi|romio" command line switch to mpirun.
- Per Open MPI's versioning scheme (see the README), increasing the
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  major version number to 2 indicates that this version is not
  ABI-compatible with prior versions of Open MPI.  You will need to
  recompile MPI and OpenSHMEM applications to work with this version
  of Open MPI.
- Removed checkpoint/restart code due to loss of maintainer. :-(
- Change the behavior for handling certain signals when using PSM and
  PSM2 libraries.  Previously, the PSM and PSM2 libraries would trap
  certain signals in order to generate tracebacks.  The mechanism was
  found to cause issues with Open MPI's own error reporting mechanism.
  If not already set, Open MPI now sets the IPATH_NO_BACKTRACE and
  HFI_NO_BACKTRACE environment variables to disable PSM/PSM2's
  handling these signals.

Removed legacy support:

- Removed support for OS X Leopard.
- Removed support for Cray XT systems.
- Removed VampirTrace.
- Removed support for Myrinet/MX.
- Removed legacy collective module:ML.
- Removed support for Alpha processors.
- Removed --enable-mpi-profiling configure option.

Known issues (to be addressed in v2.0.1):

- See the list of fixes slated for v2.0.1 here:
  https://github.com/open-mpi/ompi/milestone/16, and
  https://github.com/open-mpi/ompi-release/milestone/16
  (note that the "ompi-release" Github repo will be folded/absorbed
  into the "ompi" Github repo at some point in the future)

- ompi-release#986: Fix data size counter for large ops with fcoll/static
- ompi-release#987: Fix OMPIO performance on Lustre
- ompi-release#1013: Fix potential inconsistency in btl/openib default settings
- ompi-release#1014: Do not return MPI_ERR_PENDING from collectives
- ompi-release#1056: Remove dead profile code from oshmem
- ompi-release#1081: Fix MPI_IN_PLACE checking for IALLTOALL{V|W}
- ompi-release#1081: Fix memchecker in MPI_IALLTOALLW
- ompi-release#1081: Support MPI_IN_PLACE in MPI_(I)ALLTOALLW and MPI_(I)EXSCAN
- ompi-release#1107: Allow future PMIx support for RM spawn limits
- ompi-release#1108: Fix sparse group process reference counting
- ompi-release#1109: If specified to be oversubcribed, disable binding
- ompi-release#1122: Allow NULL arrays for empty datatypes
- ompi-release#1123: Fix signed vs. unsigned compiler warnings
- ompi-release#1123: Make max hostname length uniform across code base
- ompi-release#1127: Fix MPI_Compare_and_swap
- ompi-release#1127: Fix MPI_Win_lock when used with MPI_Win_fence
- ompi-release#1132: Fix typo in help message for --enable-mca-no-build
- ompi-release#1154: Ensure pairwise coll algorithms disqualify themselves properly
- ompi-release#1165: Fix typos in debugging/verbose message output
- ompi-release#1178: Fix ROMIO filesystem check on OpenBSD 5.7
- ompi-release#1197: Fix Fortran pthread configure check
- ompi-release#1205: Allow using external PMIx 1.1.4 and 2.0
- ompi-release#1215: Fix configure to support the NAG Fortran compiler
- ompi-release#1220: Fix combiner args for MPI_HINDEXED_BLOCK
- ompi-release#1225: Fix combiner args for MPI_DARRAY
- ompi-release#1226: Disable old memory hooks with recent gcc versions
- ompi-release#1231: Fix new "patcher" support for some XLC platforms
- ompi-release#1244: Fix Java error handling
- ompi-release#1250: Ensure TCP is not selected for RDMA operations
- ompi-release#1252: Fix verbose output in coll selection
- ompi-release#1253: Set a default name for user-defined MPI_Op
- ompi-release#1254: Add count==0 checks in some non-blocking colls
- ompi-release#1258: Fix "make distclean" when using external pmix/hwloc/libevent
- ompi-release#1260: Clean up/uniform mca/coll/base memory management
- ompi-release#1261: Remove "patcher" warning message for static builds
- ompi-release#1263: Fix IO MPI_Request for 0-size read/write
- ompi-release#1264: Add blocking fence for SLURM operations

Bug fixes / minor enhancements:

- Updated internal/embedded copies of third-party software:
  - Update the internal copy of ROMIO to that which shipped in MPICH
    3.1.4.
  - Update internal copy of libevent to v2.0.22.
  - Update internal copy of hwloc to v1.11.2.
- Notable new MCA parameters:
  - opal_progress_lp_call_ration: Control how often low-priority
    callbacks are made during Open MPI's main progress loop.
  - opal_common_verbs_want_fork_support: This replaces the
    btl_openib_want_fork_support parameter.
- Add --with-platform-patches-dir configure option.
- Add --with-pmi-libdir configure option for environments that install
  PMI libs in a non-default location.
- Various configure-related compatibility updates for newer versions
  of libibverbs and OFED.
- Numerous fixes/improvements to orte-dvm.  Special thanks to Mark
  Santcroos for his help.
- Fix a problem with timer code on ia32 platforms.  Thanks to
  Paul Hargrove for reporting this and providing a patch.
- Fix a problem with use of a 64 bit atomic counter.  Thanks to
  Paul Hargrove for reporting.
- Fix a problem with singleton job launching.  Thanks to Lisandro
  Dalcin for reporting.
- Fix a problem with use of MPI_UNDEFINED with MPI_COMM_SPLIT_TYPE.
  Thanks to Lisandro Dalcin for reporting.
- Silence a compiler warning in PSM MTL.  Thanks to Adrian Reber for
  reporting this.
- Properly detect Intel TrueScale and OmniPath devices in the ACTIVE
  state.  Thanks to Durga Choudhury for reporting the issue.
- Fix detection and use of Solaris Studio 12.5 (beta) compilers.
  Thanks to Paul Hargrove for reporting and debugging.
- Fix various small memory leaks.
- Allow NULL arrays when creating empty MPI datatypes.
- Replace use of alloca with malloc for certain datatype creation
  functions.  Thanks to Bogdan Sataric for reporting this.
- Fix use of MPI_LB and MPI_UB in creation of of certain MPI datatypes.
  Thanks to Gus Correa for helping to fix this.
- Implement a workaround for a GNU Libtool problem.  Thanks to Eric
  Schnetter for reporting and fixing.
- Improve hcoll library detection in configure.  Thanks to David
  Shrader and Ake Sandgren for reporting this.
- Miscellaneous minor bug fixes in the hcoll component.
- Miscellaneous minor bug fixes in the ugni component.
- Fix problems with XRC detection in OFED 3.12 and older releases.
  Thanks to Paul Hargrove for his analysis of this problem.
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- Update (non-standard/experimental) Java MPI interfaces to support
  MPI-3.1 functionality.
- Fix an issue with MCA parameters for Java bindings.  Thanks to
  Takahiro Kawashima and Siegmar Gross for reporting this issue.
- Fix a problem when using persistent requests in the Java bindings.
  Thanks to Nate Chambers for reporting.
- Fix problem with Java bindings on OX X 10.11.  Thanks to Alexander
  Daryin for reporting this issue.
- Fix a performance problem for large messages for Cray XC systems.
  Thanks to Jerome Vienne for reporting this.
- Fix an issue with MPI_WIN_LOCK_ALL.  Thanks to Thomas Jahns for
  reporting.
- Fix an issue with passing a parameter to configure multiple times.
  Thanks to QuesarVII for reporting and supplying a fix.
- Add support for ALPS resource allocation system on Cray CLE 5.2 and
  later.  Thanks to Mark Santcroos.
- Corrections to the HACKING file.  Thanks to Maximilien Levesque.
- Fix an issue with user supplied reduction operator functions.
  Thanks to Rupert Nash for reporting this.
- Fix an issue with an internal list management function.  Thanks to
  Adrian Reber for reporting this.
- Fix a problem with MPI-RMA PSCW epochs.  Thanks to Berk Hess for
  reporting this.
- Fix a problem in neighborhood collectives.  Thanks to Lisandro
  Dalcin for reporting.
- Fix MPI_IREDUCE_SCATTER_BLOCK for a one-process communicator. Thanks
  to Lisandro Dalcin for reporting.
- Add (Open MPI-specific) additional flavors to MPI_COMM_SPLIT_TYPE.
  See MPI_Comm_split_type(3) for details.  Thanks to Nick Andersen for
  supplying this enhancement.
- Improve closing of file descriptors during the job launch phase.
  Thanks to Piotr Lesnicki for reporting and providing this
  enhancement.
- Fix a problem in MPI_GET_ACCUMULATE and MPI_RGET_ACCUMULATE when
  using Portals4.  Thanks to Nicolas Chevalier for reporting.
- Use correct include file for lstat prototype in ROMIO. Thanks to
  William Throwe for finding and providing a fix.
- Add missing Fortran bindings for MPI_WIN_ALLOCATE.  Thanks to Christoph
  Niethammer for reporting and fixing.
- Fortran related fixes to handle Intel 2016 compiler.  Thanks to
  Fabrice Roy for reporting this.
- Fix a Fortran linkage issue.  Thanks to Macro Atzeri for finding and
  suggesting a fix.
- Fix problem with using BIND(C) for Fortran bindings with logical
  parameters.  Thanks to Paul Romano for reporting.
- Fix an issue with use of DL-related macros in opal library.  Thanks to
  Scott Atchley for finding this.
- Fix an issue with parsing mpirun command line options which contain
  colons.  Thanks to Lev Given for reporting.
- Fix a problem with Open MPI's package configury files.  Thanks to
  Christoph Junghans for reporting.
- Fix a typo in the MPI_INTERCOMM_MERGE man page.  Thanks To Harald
  Servat for reporting and correcting.
- Update man pages for non-blocking sends per MPI 3.1 standard.
  Thanks to Alexander Pozdneev for reporting.
- Fix problem when compiling against PVFS2.  Thanks to Dave Love for
  reporting.
- Fix problems with MPI_NEIGHBOR_ALLTOALL{V,W}.  Thanks to Willem
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  Vermin for reporting this issue.
- Fix various compilation problems on Cygwin.  Thanks to Marco Atzeri
  for supplying these fixes.
- Fix problem with resizing of subarray and darray data types.  Thanks
  to Keith Bennett and Dan Garmann for reporting.
- Fix a problem with MPI_COMBINER_RESIZED.  Thanks to James Ramsey for
  the report.
- Fix an hwloc binding issue.  Thanks to Ben Menadue for reporting.
- Fix a problem with the shared memory (sm) BTL.  Thanks to Peter Wind
  for the report.
- Fixes for heterogeneous support. Thanks to Siegmar Gross for reporting.
- Fix a problem with memchecker.  Thanks to Clinton Simpson for reporting.
- Fix a problem with MPI_UNWEIGHTED in topology functions.  Thanks to
  Jun Kudo for reporting.
- Fix problem with a MCA parameter base filesystem types.  Thanks to
  Siegmar Gross for reporting.
- Fix a problem with some windows info argument types.  Thanks to
  Alastair McKinstry for reporting.

1.10.7 -- 16 May 2017
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- Fix bug in TCP BTL that impacted performance on 10GbE (and faster)
  networks by not adjusting the TCP send/recv buffer sizes and using
  system default values
- Add missing MPI_AINT_ADD and MPI_AINT_DIFF function delcarations in
  mpif.h
- Fixed time reported by MPI_WTIME; it was previously reported as
  dependent upon the CPU frequency.
- Fix platform detection on FreeBSD
- Fix a bug in the handling of MPI_TYPE_CREATE_DARRAY in
  MPI_(R)(GET_)ACCUMULATE
- Fix openib memory registration limit calculation
- Add missing MPI_T_PVAR_SESSION_NULL in mpi.h
- Fix "make distcheck" when using external hwloc and/or libevent packages
- Add latest ConnectX-5 vendor part id to OpenIB device params
- Fix race condition in the UCX PML
- Fix signal handling for rsh launcher
- Fix Fortran compilation errors by removing MPI_SIZEOF in the Fortran
  interfaces when the compiler does not support it
- Fixes for the pre-ignore-TKR "mpi" Fortran module implementation
  (i.e., for older Fortran compilers -- these problems did not exist
  in the "mpi" module implementation for modern Fortran compilers):
  - Add PMPI_* interfaces
  - Fix typo in MPI_FILE_WRITE_AT_ALL_BEGIN interface name
  - Fix typo in MPI_FILE_READ_ORDERED_BEGIN interface name
- Fixed the type of MPI_DISPLACEMENT_CURRENT in all Fortran interfaces
  to be an INTEGER(KIND=MPI_OFFSET_KIND).
- Fixed typos in MPI_INFO_GET_* man pages.  Thanks to Nicolas Joly for
  the patch
- Fix typo bugs in wrapper compiler script

1.10.6 -- 17 Feb 2017
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- Fix bug in timer code that caused problems at optimization settings
  greater than 2
- OSHMEM: make mmap allocator the default instead of sysv or verbs
- Support MPI_Dims_create with dimension zero
- Update USNIC support
- Prevent 64-bit overflow on timer counter
- Add support for forwarding signals
- Fix bug that caused truncated messages on large sends over TCP BTL
- Fix potential infinite loop when printing a stacktrace

1.10.5 -- 19 Dec 2016
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- Update UCX APIs
- Fix bug in darray that caused MPI/IO failures
- Use a MPI_Get_library_version() like string to tag the debugger DLL.
  Thanks to Alastair McKinstry for the report
- Fix multi-threaded race condition in coll/libnbc
- Several fixes to OSHMEM
- Fix bug in UCX support due to uninitialized field
- Fix MPI_Ialltoallv with MPI_IN_PLACE and without MPI param check
- Correctly reset receive request type before init. Thanks Chris Pattison
  for the report and test case.
- Fix bug in iallgather[v]
- Fix concurrency issue with MPI_Comm_accept. Thanks to Pieter Noordhuis
  for the patch
- Fix ompi_coll_base_{gather,scatter}_intra_binomial
- Fixed an issue with MPI_Type_get_extent returning the wrong extent
  for distributed array datatypes.
- Re-enable use of rtdtsc instruction as a monotonic clock source if
  the processor has a core-invariant tsc. This is a partial fix for a
  performance regression introduced in Open MPI v1.10.3.


1.10.4 -- 01 Sept 2016
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- Fix assembler support for MIPS
- Improve memory handling for temp buffers in collectives
- Fix [all]reduce with non-zero lower bound datatypes
  Thanks Hristo Iliev for the report
- Fix non-standard ddt handling. Thanks Yuki Matsumoto for the report
- Various libnbc fixes. Thanks Yuki Matsumoto for the report
- Fix typos in request RMA bindings for Fortran. Thanks to @alazzaro
  and @vondele for the assist
- Various bug fixes and enhancements to collective support
- Fix predefined types mapping in hcoll
- Revive the coll/sync component to resolve unexpected message issues
  during tight loops across collectives
- Fix typo in wrapper compiler for Fortran static builds


1.10.3 -- 15 June 2016
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- Fix zero-length datatypes.  Thanks to Wei-keng Liao for reporting
  the issue.
- Minor manpage cleanups
- Implement atomic support in OSHMEM/UCX
- Fix support of MPI_COMBINER_RESIZED. Thanks to James Ramsey
  for the report
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- Fix computation of #cpus when --use-hwthread-cpus is used
- Add entry points for Allgatherv, iAllgatherv, Reduce, and iReduce
  for the HCOLL library
- Fix an HCOLL integration bug that could signal completion of request
  while still being worked
- Fix computation of cores when SMT is enabled. Thanks to Ben Menadue
  for the report
- Various USNIC fixes
- Create a datafile in the per-proc directory in order to make it
  unique per communicator. Thanks to Peter Wind for the report
- Fix zero-size malloc in one-sided pt-to-pt code. Thanks to Lisandro
  Dalcin for the report
- Fix MPI_Get_address when passed MPI_BOTTOM to not return an error.
  Thanks to Lisandro Dalcin for the report
- Fix MPI_TYPE_SET_ATTR with NULL value. Thanks to Lisandro Dalcin for
  the report
- Fix various Fortran08 binding issues
- Fix memchecker no-data case. Thanks to Clinton Stimpson for the report
- Fix CUDA support under OS-X
- Fix various OFI/MTL integration issues
- Add MPI_T man pages
- Fix one-sided pt-to-pt issue by preventing communication from happening
  before a target enters a fence, even in the no-precede case
- Fix a bug that disabled Totalview for MPMD use-case
- Correctly support MPI_UNWEIGHTED in topo-graph-neighbors. Thanks to
  Jun Kudo for the report
- Fix singleton operations under SLURM when PMI2 is enabled
- Do not use MPI_IN_PLACE in neighborhood collectives for non-blocking
  collectives (libnbc). Thanks to Jun Kudo for the report
- Silence autogen deprecation warnings for newer versions of Perl
- Do not return MPI_ERR_PENDING from collectives
- Use type int* for MPI_WIN_DISP_UNIT, MPI_WIN_CREATE_FLAVOR, and MPI_WIN_MODEL.
  Thanks to Alastair McKinstry for the report
- Fix register_datarep stub function in IO/OMPIO. Thanks to Eric
  Chamberland for the report
- Fix a bus error on MPI_WIN_[POST,START] in the shared memory one-sided component
- Add several missing MPI_WIN_FLAVOR constants to the Fortran support
- Enable connecting processes from different subnets using the openib BTL
- Fix bug in basic/barrier algorithm in OSHMEM
- Correct process binding for the --map-by node case
- Include support for subnet-to-subnet routing over InfiniBand networks
- Fix usnic resource check
- AUTHORS: Fix an errant reference to Subversion IDs
- Fix affinity for MPMD jobs running under LSF
- Fix many Fortran binding bugs
- Fix `MPI_IN_PLACE`-related bugs
- Fix PSM/PSM2 support for singleton operations
- Ensure MPI transports continue to progress during RTE barriers
- Update HWLOC to 1.9.1 end-of-series
- Fix a bug in the Java command line parser when the
  -Djava.library.path options was given by the user
- Update the MTL/OFI provider selection behavior
- Add support for clock_gettime on Linux.
- Correctly detect and configure for Solaris Studio 12.5
  beta compilers
- Correctly compute #slots when -host is used for MPMD case
- Fix a bug in the hcoll collectives due to an uninitialized field
- Do not set a binding policy when oversubscribing a node
- Fix hang in intercommunicator operations when oversubscribed
- Speed up process termination during MPI_Abort
- Disable backtrace support by default in the PSM/PSM2 libraries to
  prevent unintentional conflicting behavior.


1.10.2 -- 26 Jan 2016
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 **********************************************************************
 *  OSHMEM is now 1.2 compliant
 **********************************************************************

- Fix NBC_Copy for legitimate zero-size messages
- Fix multiple bugs in OSHMEM
- Correctly handle mpirun --host <user>@<ip-address>
- Centralize two MCA params to avoid duplication between OMPI and
  OSHMEM layers: opal_abort_delay and opal_abort_print_stack
- Add support for Fujitsu compilers
- Add UCX support for OMPI and OSHMEM
- Correctly handle oversubscription when not given directives
  to permit it. Thanks to @ammore1 for reporting it
- Fix rpm spec file to not include the /usr directory
- Add Intel HFI1 default parameters for the openib BTL
- Resolve symbol conflicts in the PSM2 library
- Add ability to empty the rgpusm cache when full if requested
- Fix another libtool bug when -L requires a space between it
  and the path. Thanks to Eric Schnetter for the patch.
- Add support for OSHMEM v1.2 APIs
- Improve efficiency of oshmem_preconnect_all algorithm
- Fix bug in buffered sends support
- Fix double free in edge case of mpirun. Thanks to @jsharpe for
  the patch
- Multiple one-sided support fixes
- Fix integer overflow in the tuned "reduce" collective when
  using buffers larger than INT_MAX in size
- Fix parse of user environment variables in mpirun. Thanks to
  Stefano Garzarella for the patch
- Performance improvements in PSM2 support
- Fix NBS iBarrier for inter-communicators
- Fix bug in vader BTL during finalize
- Improved configure support for Fortran compilers
- Fix rank_file mapper to support default --slot-set. Thanks
  to Matt Thompson for reporting it
- Update MPI_Testsome man page. Thanks to Eric Schnetter for
  the suggestion
- Fix missing resize of the returned type for subarray and
  darray types. Thanks to Keith Bennett and Dan Garmann for
  reporting it
- Fix Java support on OSX 10.11. Thanks to Alexander Daryin
  for reporting the problem
- Fix some compilation issues on Solaris 11.2. Thanks to
  Paul Hargrove for his continued help in such areas


1.10.1 -- 4 Nov 2015
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- Workaround an optimization problem with gcc compilers >= 4.9.2 that
  causes problems with memory registration, and forced
  mpi_leave_pinned to default to 0 (i.e., off).  Thanks to @oere for
  the fix.
- Fix use of MPI_LB and MPI_UB in subarray and darray datatypes.
  Thanks to Gus Correa and Dimitar Pashov for pointing out the issue.
- Minor updates to mpi_show_mpi_alloc_mem_leaks and
  ompi_debug_show_handle_leaks functionality.
- Fix segv when invoking non-blocking reductions with a user-defined
  operation.  Thanks to Rupert Nash and Georg Geiser for identifying
  the issue.
- No longer probe for PCI topology on Solaris (unless running as root).
- Fix for Intel Parallel Studio 2016 ifort partial support of the
  !GCC$ pragma.  Thanks to Fabrice Roy for reporting the problem.
- Bunches of Coverity / static analysis fixes.
- Fixed ROMIO to look for lstat in <sys/stat.h>.  Thanks to William
  Throwe for submitting the patch both upstream and to Open MPI.
- Fixed minor memory leak when attempting to open plugins.
- Fixed type in MPI_IBARRIER C prototype.  Thanks to Harald Servat for
  reporting the issue.
- Add missing man pages for MPI_WIN_CREATE_DYNAMIC, MPI_WIN_ATTACH,
  MPI_WIN_DETACH, MPI_WIN_ALLOCATE, MPI_WIN_ALLOCATE_SHARED.
- When mpirun-launching new applications, only close file descriptors
  that are actually open (resulting in a faster launch in some
  environments).
- Fix "test ==" issues in Open MPI's configure script.  Thank to Kevin
  Buckley for pointing out the issue.
- Fix performance issue in usnic BTL: ensure progress thread is
  throttled back to not aggressively steal CPU cycles.
- Fix cache line size detection on POWER architectures.
- Add missing #include in a few places.  Thanks to Orion Poplawski for
  supplying the patch.
- When OpenSHMEM building is disabled, no longer install its header
  files, help files, or man pages.  Add man pages for oshrun, oshcc,
  and oshfort.
- Fix mpi_f08 implementations of MPI_COMM_SET_INFO, and profiling
  versions of MPI_BUFFER_DETACH, MPI_WIN_ALLOCATE,
  MPI_WIN_ALLOCATE_SHARED, MPI_WTICK, and MPI_WTIME.
- Add orte_rmaps_dist_device MCA param, allowing users to map near a
  specific device.
- Various updates/fixes to the openib BTL.
- Add missing defaults for the Mellanox ConnectX 3 card to the openib BTL.
- Minor bug fixes in the OFI MTL.
- Various updates to Mellanox's MXM, hcoll, and FCA components.
- Add OpenSHMEM man pages.  Thanks to Tony Curtis for sharing the man
  pages files from openshmem.org.
- Add missing "const" attributes to MPI_COMPARE_AND_SWAP,
  MPI_FETCH_AND_OP, MPI_RACCUMULATE, and MPI_WIN_DETACH prototypes.
  Thanks to Michael Knobloch and Takahiro Kawashima for bringing this
  to our attention.
- Fix linking issues on some platforms (e.g., SLES 12).
- Fix hang on some corner cases when MPI applications abort.
- Add missing options to mpirun man page. Thanks to Daniel Letai
  for bringing this to our attention.
- Add new --with-platform-patches-dir configure option
- Adjust relative selection priorities to ensure that MTL
  support is favored over BTL support when both are available
- Use CUDA IPC for all sized messages for performance
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1.10.0 -- 25 Aug 2015
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** NOTE: The v1.10.0 release marks the transition to Open MPI's new
** version numbering scheme.  The v1.10.x release series is based on
** the v1.8.x series, but with a few new features.  v2.x will be the
** next series after the v1.10.x series, and complete the transition
** to the new version numbering scheme.  See README for more details
** on the new versioning scheme.
**
** NOTE: In accordance with OMPI version numbering, the v1.10 is *not*
** API compatible with the v1.8 release series.

- Added libfabric support (see README for more details):
  - usNIC BTL updated to use libfabric.
  - Added OFI MTL (usable with PSM in libfabric v1.1.0).
- Added Intel Omni-Path support via new PSM2 MTL.
- Added "yalla" PML for faster MXM support.
- Removed support for MX
- Added persistent distributed virtual machine (pDVM) support for fast
  workflow executions.
- Fixed typo in GCC inline assembly introduced in Open MPI v1.8.8.
  Thanks to Paul Hargrove for pointing out the issue.
- Add missing man pages for MPI_Win_get|set_info(3).
- Ensure that session directories are cleaned up at the end of a run.
- Fixed linking issues on some OSs where symbols of dependent
  libraries are not automatically publicly available.
- Improve hcoll and fca configury library detection.  Thanks to David
  Shrader for helping track down the issue.
- Removed the LAMA mapper (for use in setting affinity).  Its
  functionality has been largely superseded by other mpirun CLI
  options.
- CUDA: Made the asynchronous copy mode be the default.
- Fix a malloc(0) warning in MPI_IREDUCE_SCATTER_BLOCK.  Thanks to
  Lisandro Dalcin for reporting the issue.
- Fix typo in MPI_Scatter(3) man page.  Thanks to Akshay Venkatesh for
  noticing the mistake.
- Add rudimentary protection from TCP port scanners.
- Fix typo in Open MPI error handling.  Thanks to Ake Sandgren for
  pointing out the error.
- Increased the performance of the CM PML (i.e., the Portals, PSM,
  PSM2, MXM, and OFI transports).
- Restored visibility of blocking send requests in message queue
  debuggers (e.g., TotalView, DDT).
- Fixed obscure IPv6-related bug in the TCP BTL.
- Add support for the "no_locks" MPI_Info key for one-sided
  functionality.
- Fixed ibv_fork support for verbs-based networks.
- Fixed a variety of small bugs in OpenSHMEM.
- Fixed MXM configure with additional CPPFLAGS and LDFLAGS.  Thanks to
  David Shrader for the patch.
- Fixed incorrect memalign threshhold in the openib BTL.  Thanks to
  Xavier Besseron for pointing out the issue.


1.8.8 -- 5 Aug 2015
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- Fix a segfault in MPI_FINALIZE with the PSM MTL.
- Fix mpi_f08 sentinels (e.g., MPI_STATUS_IGNORE) handling.
- Set some additional MXM default values for OSHMEM.
- Fix an invalid memory access in MPI_MRECV and MPI_IMRECV.
- Include two fixes that were mistakenly left out of the official
  v1.8.7 tarball:
  - Fixed MPI_WIN_POST and MPI_WIN_START for zero-size messages
  - Protect the OOB TCP ports from segfaulting when accessed by port
    scanners


1.8.7 -- 15 Jul 2015
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** NOTE: v1.8.7 technically breaks ABI with prior versions
** in the 1.8 series because it repairs two incorrect API
** signatures. However, users will only need to recompile
** if they were using those functions - which they couldn't
** have been, because the signatures were wrong :-)

- Plugged a memory leak that impacted blocking sends
- Fixed incorrect declaration for MPI_T_pvar_get_index and added
  missing return code MPI_T_INVALID_NAME.
- Fixed an uninitialized variable in PMI2 support
- Added new vendor part id for Mellanox ConnectX4-LX
- Fixed NBC_Copy for legitimate zero-size messages
- Fixed MPI_Win_post and MPI_Win_start for zero-size messages
- Protect the OOB ports from segfaulting when accessed by port scanners
- Fixed several Fortran typos
- Fixed configure detection of XRC support
- Fixed support for highly heterogeneous systems to avoid
  memory corruption when printing out the bindings

1.8.6 -- 17 Jun 2015
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- Fixed memory leak on Mac OS-X exposed by TCP keepalive
- Fixed keepalive support to ensure that daemon/node failure
  results in complete job cleanup
- Update Java binding support
- Fixed MPI_THREAD_MULTIPLE bug in vader shared memory BTL
- Fixed issue during shutdown when CUDA initialization wasn't complete
- Fixed orted environment when no prefix given
- Fixed trivial typo in MPI_Neighbor_allgather manpage
- Fixed tree-spawn support for sh and ksh shells
- Several data type fixes
- Fixed IPv6 support bug
- Cleaned up an unlikely build issue
- Fixed PMI2 process map parsing for cyclic mappings
- Fixed memalign threshold in openib BTL
- Fixed debugger access to message queues for blocking send/recv


1.8.5 -- 5 May 2015
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- Fixed configure problems in some cases when using an external hwloc
  installation.  Thanks to Erick Schnetter for reporting the error and
  helping track down the source of the problem.
- Fixed linker error on OS X when using the clang compiler.  Thanks to
  Erick Schnetter for reporting the error and helping track down the
  source of the problem.
- Fixed MPI_THREAD_MULTIPLE deadlock error in the vader BTL.  Thanks
  to Thomas Klimpel for reporting the issue.
- Fixed several Valgrind warnings.  Thanks for Lisandro Dalcin for
  contributing a patch fixing some one-sided code paths.
- Fixed version compatibility test in OOB that broke ABI within the
  1.8 series. NOTE: this will not resolve the problem between pre-1.8.5
  versions, but will fix it going forward.
- Fix some issues related to running on Intel Xeon Phi coprocessors.
- Opportunistically switch away from using GNU Libtool's libltdl
  library when possible (by default).
- Fix some VampirTrace errors.  Thanks to Paul Hargrove for reporting
  the issues.
- Correct default binding patterns when --use-hwthread-cpus was
  specified and nprocs <= 2.
- Fix warnings about -finline-functions when compiling with clang.
- Updated the embedded hwloc with several bug fixes, including the
  "duplicate Lhwloc1 symbol" that multiple users reported on some
  platforms.
- Do not error when mpirun is invoked with with default bindings
  (i.e., no binding was specified), and one or more nodes do not
  support bindings.  Thanks to Annu Desari for pointing out the
  problem.
- Let root invoke "mpirun --version" to check the version without
  printing the "Don't run as root!" warnings.  Thanks to Robert McLay
  for the suggestion.
- Fixed several bugs in OpenSHMEM support.
- Extended vader shared memory support to 32-bit architectures.
- Fix handling of very large datatypes.  Thanks to Bogdan Sataric for
  the bug report.
- Fixed a bug in handling subarray MPI datatypes, and a bug when using
  MPI_LB and MPI_UB.  Thanks to Gus Correa for pointing out the issue.
- Restore user-settable bandwidth and latency PML MCA variables.
- Multiple bug fixes for cleanup during MPI_FINALIZE in unusual
  situations.
- Added support for TCP keepalive signals to ensure timely termination
  when sockets between daemons cannot be created (e.g., due to a
  firewall).
- Added MCA parameter to allow full use of a SLURM allocation when
  started from a tool (supports LLNL debugger).
- Fixed several bugs in the configure logic for PMI and hwloc.
- Fixed incorrect interface index in TCP communications setup.  Thanks
  to Mark Kettenis for spotting the problem and providing a patch.
- Fixed MPI_IREDUCE_SCATTER with single-process communicators when
  MPI_IN_PLACE was not used.
- Added XRC support for OFED v3.12 and higher.
- Various updates and bug fixes to the Mellanox hcoll collective
  support.
- Fix problems with Fortran compilers that did not support
  REAL*16/COMPLEX*32 types.  Thanks to Orion Poplawski for identifying
  the issue.
- Fixed problem with rpath/runpath support in pkg-config files.
  Thanks to Christoph Junghans for notifying us of the issue.
- Man page fixes:
  - Removed erroneous "color" discussion from MPI_COMM_SPLIT_TYPE.
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    Thanks to Erick Schnetter for spotting the outdated text.
  - Fixed prototypes for MPI_IBARRIER.  Thanks to Maximilian for
    finding the issue.
  - Updated docs about buffer usage in non-blocking communications.
    Thanks to Alexander Pozdneev for citing the outdated text.
  - Added documentation about the 'ompi_unique' MPI_Info key with
    MPI_PUBLISH_NAME.
  - Fixed typo in MPI_INTERCOMM_MERGE.  Thanks to Harald Servat for
    noticing and sending a patch.
  - Updated configure paths in HACKING.  Thanks to Maximilien Levesque
    for the fix.
  - Fixed Fortran typo in MPI_WIN_LOCK_ALL.  Thanks to Thomas Jahns
    for pointing out the issue.
- Fixed a number of MPI one-sided bugs.
- Fixed MPI_COMM_SPAWN when invoked from a singleton job.
- Fixed a number of minor issues with CUDA support, including
  registering of shared memory and supporting reduction support for
  GPU buffers.
- Improved support for building OMPI on Cray platforms.
- Fixed performance regression introduced by the inadvertent default
  enabling of MPI_THREAD_MULTIPLE support.


1.8.4 -- 19 Dec 2014
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- Fix MPI_SIZEOF; now available in mpif.h for modern Fortran compilers
  (see README for more details).  Also fixed various compiler/linker
  errors.
- Fixed inadvertant Fortran ABI break between v1.8.1 and v1.8.2 in the
  mpi interface module when compiled with gfortran >= v4.9.
- Fix various MPI_THREAD_MULTIPLE issues in the TCP BTL.
- mpirun no longer requires the --hetero-nodes switch; it will
  automatically detect when running in heterogeneous scenarios.
- Update LSF support, to include revamped affinity functionality.
- Update embedded hwloc to v1.9.1.
- Fixed max registerable memory computation in the openib BTL.
- Updated error message when debuggers are unable to find various
  symbols/types to be more clear.  Thanks to Dave Love for raising the
  issue.
- Added proper support for LSF and PBS/Torque libraries in static builds.
- Rankfiles now support physical processor IDs.
- Fixed potential hang in MPI_ABORT.
- Fixed problems with the PSM MTL and "re-connect" scenarios, such as
  MPI_INTERCOMM_CREATE.
- Fix MPI_IREDUCE_SCATTER with a single process.
- Fix (rare) race condition in stdout/stderr funneling to mpirun where
  some trailing output could get lost when a process terminated.
- Removed inadvertent change that set --enable-mpi-thread-multiple "on"
  by default, thus impacting performance for non-threaded apps.
- Significantly reduced startup time by optimizing internal hash table
  implementation.
- Fixed OS X linking with the Fortran mpi module when used with
  gfortran >= 4.9.  Thanks to Github user yafshar for raising the
  issue.
- Fixed memory leak on Cygwin platforms.  Thanks for Marco Atzeri for
  reporting the issue.
- Fixed seg fault in neighborhood collectives when the degree of the
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  topology is higher than the communicator size.  Thanks to Lisandro
  Dalcin for reporting the issue.
- Fixed segfault in neighborhood collectives under certain use-cases.
- Fixed various issues regarding Solaris support.  Thanks to Siegmar
  Gross for patiently identifying all the issues.
- Fixed PMI configure tests for certain Slurm installation patterns.
- Fixed param registration issue in Java bindings.  Thanks to Takahiro
  Kawashima and Siegmar Gross for identifying the issue.
- Several man page fixes.
- Silence several warnings and close some memory leaks (more remain,
  but it's better than it was).
- Re-enabled the use of CMA and knem in the shared memory BTL.
- Updated mpirun manpage to correctly explain new map/rank/binding options.
- Fixed MPI_IALLGATHER problem with intercommunicators.  Thanks for
  Takahiro Kawashima for the patch.
- Numerous updates and performance improvements to OpenSHMEM.
- Turned off message coalescing in the openib BTL until a proper fix
  for that capability can be provided (tentatively expected for 1.8.5)
- Fix a bug in iof output that dates back to the dinosaurs which would
  output extra bytes if the system was very heavily loaded
- Fix a bug where specifying mca_component_show_load_errors=0 could
  cause ompi_info to segfault
- Updated valgrind suppression file


1.8.3 -- 26 Sep 2014
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- Fixed application abort bug to ensure that MPI_Abort exits appropriately
  and returns the provided exit status
- Fixed some alignment (not all) issues identified by Clang
- Allow CUDA-aware to work with nonblocking collectives. Forces packing to
  happen when using GPU buffers.
- Fixed configure test issue with Intel 2015 Fortran compiler
- Fixed some PGI-related errors
- Provide better help message when encountering a firewall
- Fixed MCA parameter quoting to protect multi-word params and params
  that contain special characters
- Improved the bind-to help message to clarify the defaults
- Add new MPI-3.1 tools interface
- Several performance optimizations and memory leak cleanups
- Turn off the coll/ml plugin unless specifically requested as it
  remains in an experimental state
- Fix LSF support by adding required libraries for the latest LSF
  releases.  Thanks to Joshua Randal for supplying the initial
  patches.


1.8.2 -- 25 Aug 2014
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- Fix auto-wireup of OOB, allowing ORTE to automatically
  test all available NICs
- "Un-deprecate" pernode, npernode, and npersocket options
  by popular demand
- Add missing Fortran bindings for MPI_WIN_LOCK_ALL,
  MPI_WIN_UNLOCK_ALL, and MPI_WIN_SYNC.
- Fix cascading/over-quoting in some cases with the rsh/ssh-based
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  launcher.  Thanks to multiple users for raising the issue.
- Properly add support for gfortran 4.9 ignore TKR pragma (it was
  erroneously only partially added in v1.7.5).  Thanks to Marcus
  Daniels for raising the issue.
- Update/improve help messages in the usnic BTL.
- Resolve a race condition in MPI_Abort.
- Fix obscure cases where static linking from wrapper compilers would
  fail.
- Clarify the configure --help message about when OpenSHMEM is
  enabled/disabled by default.  Thanks to Paul Hargrove for the
  suggestion.
- Align pages properly where relevant.  Thanks to Paul Hargrove for
  identifying the issue.
- Various compiler warning and minor fixes for OpenBSD, FreeBSD, and
  Solaris/SPARC.  Thanks to Paul Hargrove for the patches.
- Properly pass function pointers from Fortran to C in the mpi_f08
  module, thereby now supporting gfortran 4.9.  Thanks to Tobias
  Burnus for assistance and testing with this issue.
- Improve support for Cray CLE 5.
- Fix mpirun regression: ensure exit status is non-zero if mpirun is
  terminated due to signal.
- Improved CUDA efficiency of asynchronous copies.
- Fix to parameter type in MPI_Type_indexed.3.  Thanks to Bastian
  Beischer for reporting the mistake.
- Fix NUMA distance calculations in the openib BTL.
- Decrease time required to shut down mpirun at the end of a job.
- More RMA fixes.
- More hostfile fixes from Tetsuya Mishima.
- Fix darray issue where UB was not computed correctly.
- Fix mpi_f08 parameter name for MPI_GET_LIBRARY_VERSION.  Thanks to
  Junchao Zhang for pointing out the issue.
- Ensure mpirun aborts properly when unable to map processes in
  scheduled environments.
- Ensure that MPI RMA error codes show up properly.  Thanks to
  Lisandro Dalcin for reporting the issue.
- Minor bug fixes and improvements to the bash and zsh mpirun
  autocompletion scripts.
- Fix sequential mpirun process mapper.  Thanks to Bill Chen for
  reporting the issue.
- Correct SLURM stdout/stderr redirection.
- Added missing portals 4 files.
- Performance improvements for blocking sends and receives.
- Lots of cleanup to the ml collective component
- Added new Java methods to provide full MPI coverage
- Many OSHMEM cleanups
- Prevent comm_spawn from automatically launching a VM across
  all available nodes
- Close many memory leaks to achieve valgrind-clean operation
- Better handling of TCP connection discovery for mismatched networks
  where we don't have a direct 1:1 subnet match between nodes
- Prevent segfault when OMPI info tools are used in pipes and user
  exits one step of that pipe before completing output


1.8.1 -- 23 Apr 2014
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- Fix for critical bug: mpirun removed files (but not directories)
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  from / when run as root.  Thanks to Jay Fenlason and Orion Poplawski
  for bringing the issue to our attention and helping identify the
  fix.


1.8 -- 31 Mar 2014
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- Commit upstream ROMIO fix for mixed NFS+local filesystem environments.
- Several fixes for MPI-3 one-sided support.  For example,
  arbitrary-length datatypes are now supported.
- Add config support for the Mellanox ConnectX 4 card.
- Add missing MPI_COMM_GET|SET_INFO functions, and missing
  MPI_WEIGHTS_EMPTY and MPI_ERR_RMA_SHARED constants.  Thanks to
  Lisandro Dalcin for pointing out the issue.
- Update some help messages in OSHMEM, the usnic BTL, the TCP BTL, and
  ORTE, and update documentation about ompi_info's --level option.
- Fix some compiler warnings.
- Ensure that ORTE daemons are not bound to a single processor
  if TaskAffinity is set on by default in Slurm. Thanks to Artem Polyakov
  for identifying the problem and providing a patch


1.7.5 -- 20 Mar 2014
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 **********************************************************************
 *  Open MPI is now fully MPI-3.0 compliant
 **********************************************************************

- Add Linux OpenSHMEM support built on top of Open MPI's MPI
  layer. Thanks to Mellanox for contributing this new feature.
- Allow restricting ORTE daemons to specific cores using the
  orte_daemon_cores MCA param.
- Ensure to properly set "locality" flags for processes launched via
  MPI dynamic functions such as MPI_COMM_SPAWN.
- Fix MPI_GRAPH_CREATE when nnodes is smaller than the size of the old
  communicator.
- usnic BTL now supports underlying UDP transport.
- usnic BTL now checks for common connectivty errors at first send to
  a remote server.
- Minor scalability improvements in the usnic BTL.
- ompi_info now lists whether the Java MPI bindings are available or not.
- MPI-3: mpi.h and the Fortran interfaces now report MPI_VERSION==3
  and MPI_SUBVERSION==0.
- MPI-3: Added support for new RMA functions and functionality.
- Fix MPI_Info "const buglet.  Thanks to Orion Poplawski for
  identifying the issue.
- Multiple fixes to mapping/binding options. Thanks to Tetsuya Mishima
  for his assistance.
- Multiple fixes for normal and abnormal process termination,
  including singleton MPI_Abort and ensuring to kill entire process
  groups when abnormally terminating a job.
- Fix DESTDIR install for javadocs.  Thanks to Orion Poplawski for
  pointing out the issue.
- Various performance improvements for the MPI Java bindings.
- OMPI now uses its own internal random number generator and will not
  perturb srand() and friends.
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- Some cleanups for Cygwin builds.  Thanks to Marco Atzeri for the
  patches.
- Add a new collective component (coll/ml) that provides substantially
  improved performance.  It is still experimental, and requires
  setting coll_ml_priority > 0 to become active.
- Add version check during startup to ensure you are using the same
  version of Open MPI on all nodes in a job.
- Significantly improved the performance of MPI_DIMS_CREATE for large
  values.  Thanks to Andreas Schafer for the contribution.
- Removed ASYNCHRONOUS keyword from the "ignore TKR" mpi_f08 module.
- Deprecated the following mpirun options:
  --bynode, --bycore, --byslot: replaced with --map-by node|core|slot.
  --npernode, --npersocket: replaced with --map-by ppr:N:node and
       --map-by ppr:N:socket, respectively
- Pick NFS "infinitely stale" fix from ROMIO upstream.
- Various PMI2 fixes and extension to support broader range of mappings.
- Improve launch performance at large scale.
- Add support for PBS/Torque environments that set environment
  variables to indicate the number of slots available on each nodes.
  Set the ras_tm_smp MCA parameter to "1" to enable this mode.
- Add new, more scalable endpoint exchange (commonly called "modex")
  method that only exchanges endpoint data on a per-peer basis
  on first message. Not all transports have been updated to use
  this feature. Set the rte_orte_direct_modex parameter to "1"
  to enable this mode.

1.7.4 -- 5 Feb 2014
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 **********************************************************************
 *      CRITICAL CHANGE
 *
 * As of release 1.7.4, OpenMPI's default mapping, ranking, and binding
 * settings have changed:
 *
 * Mapping:
 *   if #procs <= 2, default to map-by core
 *   if #procs > 2, default to map-by socket
 * Ranking:
 *   if default mapping is used, then default to rank-by slot
 *   if map-by <obj> is given, then default to rank-by <obj>,
 *      where <obj> is whatever object we mapped against
 * Binding:
 *   default to bind-to core
 *
 * Users can override any of these settings individually using the
 * corresponding MCA parameter. Note that multi-threaded applications
 * in particular may want to override at least the binding default
 * to allow threads to use multiple cores.
 **********************************************************************

- Restore version number output in "ompi_info --all".
- Various bug fixes for the mpi_f08 Fortran bindings.
- Fix ROMIO compile error with Lustre 2.4.  Thanks to Adam Moody for
  reporting the issue.
- Various fixes for 32 bit platforms.
- Add ability to selectively disable building the mpi or mpi_f08
  module.  See the README file for details.
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- Fix MX MTL finalization issue.
- Fix ROMIO issue when opening a file with MPI_MODE_EXCL.
- Fix PowerPC and MIPS assembly issues.
- Various fixes to the hcoll and FCA collective offload modules.
- Prevent integer overflow when creating datatypes.  Thanks to
  original patch from Gilles Gouaillardet.
- Port some upstream hwloc fixes to Open MPI's embedded copy for
  working around buggy NUMA node cpusets and including mising header
  files.  Thanks to Jeff Becker and Paul Hargrove for reporting the
  issues.
- Fix recursive invocation issues in the MXM MTL.
- Various bug fixes to the new MCA parameter back-end system.
- Have the posix fbtl module link against -laio on NetBSD platforms.
  Thanks to Paul Hargrove for noticing the issue.
- Various updates and fixes to network filesystem detection to support
  more operating systems.
- Add gfortran v4.9 "ignore TKR" syntax to the mpi Fortran module.
- Various compiler fixes for several BSD-based platforms.  Thanks to
  Paul Hargrove for reporting the issues.
- Fix when MPI_COMM_SPAWN[_MULTIPLE] is used on oversubscribed
  systems.
- Change the output from --report bindings to simply state that a
  process is not bound, instead of reporting that it is bound to all
  processors.
- Per MPI-3.0 guidance, remove support for all MPI subroutines with
  choice buffers from the TKR-based mpi Fortran module.  Thanks to Jed
  Brown for raising the issue.
- Only allow the usnic BTL to build on 64 bit platforms.
- Various bug fixes to SLURM support, to include ensuring proper
  exiting on abnormal termination.
- Ensure that MPI_COMM_SPAWN[_MULTIPLE] jobs get the same mapping
  directives that were used with mpirun.
- Fixed the application of TCP_NODELAY.
- Change the TCP BTL to not warn if a non-existent interface is
  ignored.
- Restored the "--bycore" mpirun option for backwards compatibility.
- Fixed debugger attach functionality.  Thanks to Ashley Pittman for
  reporting the issue and suggesting the fix.
- Fixed faulty MPI_IBCAST when invoked on a communicator with only
  one process.
- Add new Mellanox device IDs to the openib BTL.
- Progress towards cleaning up various internal memory leaks as
  reported by Valgrind.
- Fixed some annoying flex-generated warnings that have been there for
  years.  Thanks to Tom Fogal for the initial patch.
- Support user-provided environment variables via the "env" info key
  to MPI_COMM_SPAWN[_MULTIPLE].  Thanks to Tom Fogal for the feature
  request.
- Fix uninitialized variable in MPI_DIST_GRAPH_CREATE.
- Fix a variety of memory errors on SPARC platforms.  Thanks to
  Siegmar Gross for reporting and testing all the issues.
- Remove Solaris threads support.  When building on Solaris, pthreads
  will be used.
- Correctly handle the convertor internal stack for persistent
  receives.  Thanks to Guillaume Gouaillardet for identifying the
  problem.
- Add support for using an external libevent via --with-libevent.  See
  the README for more details.
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- Various OMPIO updates and fixes.
- Add support for the MPIEXEC_TIMEOUT environment variable.  If set,
  mpirun will terminate the job after this many seconds.
- Update the internal copy of ROMIO to that which shipped in MPICH
  3.0.4.
- Various performance tweaks and improvements in the usnic BTL,
  including now reporting MPI_T performance variables for each usnic
  device.
- Fix to not access send datatypes for non-root processes with
  MPI_ISCATTER[V] and MPI_IGATHER[V].  Thanks to Pierre Jolivet for
  supplying the initial patch.
- Update VampirTrace to 5.14.4.9.
- Fix ptmalloc2 hook disable when used with ummunotify.
- Change the default connection manager for the openib BTL to be based
  on UD verbs data exchanges instead of ORTE OOB data exchanges.
- Fix Fortran compile error when compiling with 8-byte INTEGERs and
  4-byte ints.
- Fix C++11 issue identified by Jeremiah Willcock.
- Many changes, updates, and bug fixes to the ORTE run-time layer.
- Correctly handle MPI_REDUCE_SCATTER with recvcounts of 0.
- Update man pages for MPI-3, and add some missing man pages for
  MPI-2.x functions.
- Updated mpi_f08 module in accordance with post-MPI-3.0 errata which
  basically removed BIND(C) from all interfaces.
- Fixed MPI_IN_PLACE detection for MPI_SCATTER[V] in Fortran
  routines.  Thanks to Charles Gerlach for identifying the issue.
- Added support for routable RoCE to the openib BTL.
- Update embedded hwloc to v1.7.2.
- ErrMgr framework redesigned to better support fault tolerance development
  activities. See the following RFC for details:
  http://www.open-mpi.org/community/lists/devel/2010/03/7589.php
- Added database framework to OPAL and changed all modex operations
  to flow thru it, also included additional system info in the
  available data
- Added staged state machine to support sequential work flows
- Added distributed file system support for accessing files across
  nodes that do not have networked file systems
- Extended filem framework to support scalable pre-positioning of
  files for use by applications, adding new "raw" component that
  transmits files across the daemon network
- Native Windows support has been removed. A cygwin package is
  available from that group for Windows-based use.
- Added new MPI Java bindings.  See the Javadocs for more details on
  the API.
- Wrapper compilers now add rpath support by default to generated
  executables on systems that support it.  This behavior can be
  disabled via --disable-wrapper-rpath.  See note in README about ABI
  issues when using rpath in MPI applications.
- Added a new parallel I/O component and multiple new frameworks to
  support parallel I/O operations.
- Fixed MPI_STATUS_SIZE Fortran issue when used with 8-byte Fortran
  INTEGERs and 4-byte C ints.  Since this issue affects ABI, it is
  only enabled if Open MPI is configured with
  --enable-abi-breaking-fortran-status-i8-fix.  Thanks to Jim Parker
  for supplying the initial patch.
- Add support for Intel Phi SCIF transport.
- For CUDA-aware MPI configured with CUDA 6.0, use new pointer
  attribute to avoid extra synchronization in stream 0 when using
  CUDA IPC between GPUs on the same node.
- For CUDA-aware MPI configured with CUDA 6.0, compile in support
  of GPU Direct RDMA in openib BTL to improve small message latency.
- Updated ROMIO from MPICH v3.0.4.
- MPI-3: Added support for remaining non-blocking collectives.
- MPI-3: Added support for neighborhood collectives.
- MPI-3: Updated C bindings with consistent use of [].
- MPI-3: Added the const keyword to read-only buffers.
- MPI-3: Added support for non-blocking communicator duplication.
- MPI-3: Added support for non-collective communicator creation.

1.7.3 -- 17 Oct 2013
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- Make CUDA-aware support dynamically load libcuda.so so CUDA-aware
  MPI library can run on systems without CUDA software.
- Fix various issues with dynamic processes and intercommunicator
  operations under Torque.  Thanks to Suraj Prabhakaran for reporting
  the problem.
- Enable support for the Mellanox MXM2 library by default.
- Improve support for Portals 4.
- Various Solaris fixes.  Many thanks to Siegmar Gross for his
  incredible patience in reporting all the issues.
- MPI-2.2: Add reduction support for MPI_C_*COMPLEX and MPI::*COMPLEX.
- Fixed internal accounting when openpty() fails.  Thanks to Michal
  Peclo for reporting the issue and providing a patch.
- Fixed too-large memory consumption in XRC mode of the openib BTL.
  Thanks to Alexey Ryzhikh for the patch.
- Add bozo check for negative np values to mpirun to prevent a
  deadlock.  Thanks to Upinder Malhi for identifying the issue.
- Fixed MPI_IS_THREAD_MAIN behavior.  Thanks to Lisandro Dalcin for
  pointing out the problem.
- Various rankfile fixes.
- Fix functionality over iWARP devices.
- Various memory and performance optimizations and tweaks.
- Fix MPI_Cancel issue identified by Fujitsu.
- Add missing support for MPI_Get_address in the "use mpi" TKR
  implementation.  Thanks to Hugo Gagnon for identifying the issue.
- MPI-3: Add support for MPI_Count.
- MPI-2.2: Add missing MPI_IN_PLACE support for MPI_ALLTOALL.
- Added new usnic BTL to support the Cisco usNIC device.
- Minor VampirTrace update to 5.14.4.4.
- Removed support for ancient OS X systems (i.e., prior to 10.5).
- Fixed obscure packing/unpacking datatype bug.  Thanks to Takahiro
  Kawashima for identifying the issue.
- Add run-time support for PMI2 environments.
- Update openib BTL default parameters to include support for Mellanox
  ConnectX3-Pro devices.
- Update libevent to v2.0.21.
- "ompi_info --param TYPE PLUGIN" now only shows a small number of MCA
  parameters by default.  Add "--level 9" or "--all" to see *all* MCA
  parameters.  See README for more details.
- Add support for asynchronous CUDA-aware copies.
- Add support for Mellanox MPI collective operation offload via the
  "hcoll" library.
- MPI-3: Add support for the MPI_T interface.  Open MPI's MCA
  parameters are now accessible via the MPI_T control variable
  interface.  Support has been added for a small number of MPI_T
  performance variables.
- Add Gentoo memory hooks override.  Thanks to Justin Bronder for the
  patch.
- Added new "mindist" process mapper, allowing placement of processes
  via PCI locality information reported by the BIOS.
- MPI-2.2: Add support for MPI_Dist_graph functionality.
- Enable generic, client-side support for PMI2 implementations. Can
  be leveraged by any resource manager that implements PMI2; e.g. SLURM,
  versions 2.6 and higher.


1.7.2: 26 Jun 2013
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- Major VampirTrace update to 5.14.4.2.
  (** also appeared: 1.6.5)
- Fix to set flag==1 when MPI_IPROBE is called with MPI_PROC_NULL.
  (** also appeared: 1.6.5)
- Set the Intel Phi device to be ignored by default by the openib BTL.
  (** also appeared: 1.6.5)
- Decrease the internal memory storage used by intrinsic MPI datatypes
  for Fortran types.  Thanks to Takahiro Kawashima for the initial
  patch.
  (** also appeared: 1.6.5)
- Fix total registered memory calculation for Mellanox ConnectIB and
  OFED 2.0.
  (** also appeared: 1.6.5)
- Fix possible data corruption in the MXM MTL component.
  (** also appeared: 1.6.5)
- Remove extraneous -L from hwloc's embedding.  Thanks to Stefan
  Friedel for reporting the issue.
  (** also appeared: 1.6.5)
- Fix contiguous datatype memory check.  Thanks to Eric Chamberland
  for reporting the issue.
  (** also appeared: 1.6.5)
- Make the openib BTL more friendly to ignoring verbs devices that are
  not RC-capable.
  (** also appeared: 1.6.5)
- Fix some MPI datatype engine issues.  Thanks to Thomas Jahns for
  reporting the issue.
  (** also appeared: 1.6.5)
- Add INI information for Chelsio T5 device.
  (** also appeared: 1.6.5)
- Integrate MXM STREAM support for MPI_ISEND and MPI_IRECV, and other
  minor MXM fixes.
  (** also appeared: 1.6.5)
- Fix to not show amorphous "MPI was already finalized" error when
  failing to MPI_File_close an open file.  Thanks to Brian Smith for
  reporting the issue.
  (** also appeared: 1.6.5)
- Add a distance-based mapping component to find the socket "closest"
  to the PCI bus.
- Fix an error that caused epoll to automatically be disabled
  in libevent.
- Upgrade hwloc to 1.5.2.
- *Really* fixed XRC compile issue in Open Fabrics support.
- Fix MXM connection establishment flow.
- Fixed parallel debugger ability to attach to MPI jobs.
- Fixed some minor memory leaks.
- Fixed datatype corruption issue when combining datatypes of specific
  formats.
- Added Location Aware Mapping Algorithm (LAMA) mapping component.
- Fixes for MPI_STATUS handling in corner cases.
- Add a distance-based mapping component to find the socket "closest"
  to the PCI bus.


1.7.1: 16 Apr 2013
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- Fixed compile error when --without-memory-manager was specified
  on Linux
- Fixed XRC compile issue in Open Fabrics support.


1.7: 1 Apr 2013
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- Added MPI-3 functionality:
    - MPI_GET_LIBRARY_VERSION
    - Matched probe
    - MPI_TYPE_CREATE_HINDEXED_BLOCK
    - Non-blocking collectives
    - MPI_INFO_ENV support
    - Fortran '08 bindings (see below)
- Dropped support for checkpoint/restart due to loss of maintainer :-(
- Enabled compile-time warning of deprecated MPI functions by default
  (in supported compilers).
- Revamped Fortran MPI bindings (see the README for details):
  - "mpifort" is now the preferred wrapper compiler for Fortran
  - Added "use mpi_f08" bindings (for compilers that support it)
  - Added better "use mpi" support (for compilers that support it)
  - Removed incorrect MPI_SCATTERV interface from "mpi" module that
    was added in the 1.5.x series for ABI reasons.
- Lots of VampirTrace upgrades and fixes; upgrade to v5.14.3.
- Modified process affinity system to provide warning when bindings
  result in being "bound to all", which is equivalent to not being
  bound.
- Removed maffinity, paffinity, and carto frameworks (and associated
  MCA params).
- Upgraded to hwloc v1.5.1.
- Added performance improvements to the OpenIB (OpenFabrics) BTL.
- Made malloc hooks more friendly to IO interprosers.  Thanks to the
  bug report and suggested fix from Darshan maintainer Phil Carns.
- Added support for the DMTCP checkpoint/restart system.
- Added support for the Cray uGNI interconnect.
- Fixed header file problems on OpenBSD.
- Fixed issue with MPI_TYPE_CREATE_F90_REAL.
- Wrapper compilers now explicitly list/link all Open MPI libraries if
  they detect static linking CLI arguments.
- Open MPI now requires a C99 compiler to build.  Please upgrade your
  C compiler if you do not have a C99-compliant compiler.
- Fix MPI_GET_PROCESSOR_NAME Fortran binding to set ierr properly.
  Thanks to LANL for spotting the error.
- Many MXM and FCA updates.
- Fixed erroneous free of putenv'ed string that showed up in Valgrind
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  reports.
- Fixed MPI_IN_PLACE case for MPI_ALLGATHER.
- Fixed a bug that prevented MCA params from being forwarded to
  daemons upon launch.
- Fixed issues with VT and CUDA --with-cuda[-libdir] configuration CLI
  parameters.
- Entirely new implementation of many MPI collective routines focused
  on better performance.
- Revamped autogen / build system.
- Add new sensor framework to ORTE that includes modules for detecting
  stalled applications and processes that consume too much memory.
- Added new state machine framework to ORTE that converts ORTE into an
  event-driven state machine using the event library.
- Added a new MCA parameter (ess_base_stream_buffering) that allows the user
  to override the system default for buffering of stdout/stderr streams
  (via setvbuf). Parameter is not visible via ompi_info.
- Revamped the launch system to allow consideration of node hardware
  in assigning process locations and bindings.
- Added the -novm option to preserve the prior launch behavior.
- Revamped the process mapping system to utilize node hardware by adding
  new map-by, rank-by, and bind-to cmd line options.
- Added new MCA parameter to provide protection against IO forwarding
  backlog.
- Dropped support for native Windows due to loss of maintainers. :-(
- Added a new parallel I/O component and multiple new frameworks to
  support parallel I/O operations.
- Fix typo in orte_setup_hadoop.m4. Thanks to Aleksej Saushev for
  reporting it
- Fix a very old error in opal_path_access(). Thanks to Marco Atzeri
  for chasing it down.


1.6.6: Not released
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- Prevent integer overflow in datatype creation.  Thanks to Gilles
  Gouaillardet for identifying the problem and providing a preliminary
  version of the patch.
- Ensure help-opal-hwloc-base.txt is included in distribution
  tarballs.  Thanks to Gilles Gouaillardet for supplying the patch.
- Correctly handle the invalid status for NULL and inactive requests.
  Thanks to KAWASHIMA Takahiro for submitting the initial patch.
- Fixed MPI_STATUS_SIZE Fortran issue when used with 8-byte Fortran
  INTEGERs and 4-byte C ints.  Since this issue affects ABI, it is
  only enabled if Open MPI is configured with
  --enable-abi-breaking-fortran-status-i8-fix.  Thanks to Jim Parker
  for supplying the initial patch.
- Fix datatype issue for sending from the middle of non-contiguous
  data.
- Fixed failure error with pty support.  Thanks to Michal Pecio for
  the patch.
- Fixed debugger support for direct-launched jobs.
- Fix MPI_IS_THREAD_MAIN to return the correct value.  Thanks to
  Lisandro Dalcin for pointing out the issue.
- Update VT to 5.14.4.4:
  - Fix C++-11 issue.
  - Fix support for building RPMs on Fedora with CUDA libraries.
- Add openib part number for ConnectX3-Pro HCA.
- Ensure to check that all resolved IP addresses are local.
- Fix MPI_COMM_SPAWN via rsh when mpirun is on a different server.
- Add Gentoo "sandbox" memory hooks override.


1.6.5: 26 Jun 2013
------------------

- Updated default SRQ parameters for the openib BTL.
  (** also to appear: 1.7.2)
- Major VampirTrace update to 5.14.4.2.
  (** also to appear: 1.7.2)
- Fix to set flag==1 when MPI_IPROBE is called with MPI_PROC_NULL.
  (** also to appear: 1.7.2)
- Set the Intel Phi device to be ignored by default by the openib BTL.
  (** also to appear: 1.7.2)
- Decrease the internal memory storage used by intrinsic MPI datatypes
  for Fortran types.  Thanks to Takahiro Kawashima for the initial
  patch.
  (** also to appear: 1.7.2)
- Fix total registered memory calculation for Mellanox ConnectIB and
  OFED 2.0.
  (** also to appear: 1.7.2)
- Fix possible data corruption in the MXM MTL component.
  (** also to appear: 1.7.2)
- Remove extraneous -L from hwloc's embedding.  Thanks to Stefan
  Friedel for reporting the issue.
  (** also to appear: 1.7.2)
- Fix contiguous datatype memory check.  Thanks to Eric Chamberland
  for reporting the issue.
  (** also to appear: 1.7.2)
- Make the openib BTL more friendly to ignoring verbs devices that are
  not RC-capable.
  (** also to appear: 1.7.2)
- Fix some MPI datatype engine issues.  Thanks to Thomas Jahns for
  reporting the issue.
  (** also to appear: 1.7.2)
- Add INI information for Chelsio T5 device.
  (** also to appear: 1.7.2)
- Integrate MXM STREAM support for MPI_ISEND and MPI_IRECV, and other
  minor MXM fixes.
  (** also to appear: 1.7.2)
- Improved alignment for OpenFabrics buffers.
- Fix to not show amorphous "MPI was already finalized" error when
  failing to MPI_File_close an open file.  Thanks to Brian Smith for
  reporting the issue.
  (** also to appear: 1.7.2)


1.6.4: 21 Feb 2013
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- Fix Cygwin shared memory and debugger plugin support.  Thanks to
  Marco Atzeri for reporting the issue and providing initial patches.
- Fix to obtaining the correct available nodes when a rankfile is
  providing the allocation.  Thanks to Siegmar Gross for reporting the
  problem.
- Fix process binding issue on Solaris.  Thanks to Siegmar Gross for
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  reporting the problem.
- Updates for MXM 2.0.
- Major VT update to 5.14.2.3.
- Fixed F77 constants for Cygwin/Cmake build.
- Fix a linker error when configuring --without-hwloc.
- Automatically provide compiler flags that compile properly on some
  types of ARM systems.
- Fix slot_list behavior when multiple sockets are specified.  Thanks
  to Siegmar Gross for reporting the problem.
- Fixed memory leak in one-sided operations.  Thanks to Victor
  Vysotskiy for letting us know about this one.
- Added performance improvements to the OpenIB (OpenFabrics) BTL.
- Improved error message when process affinity fails.
- Fixed MPI_MINLOC on man pages for MPI_REDUCE(_LOCAL).  Thanks to Jed
  Brown for noticing the problem and supplying a fix.
- Made malloc hooks more friendly to IO interprosers.  Thanks to the
  bug report and suggested fix from Darshan maintainer Phil Carns.
- Restored ability to direct launch under SLURM without PMI support.
- Fixed MPI datatype issues on OpenBSD.
- Major VT update to 5.14.2.3.
- Support FCA v3.0+.
- Fixed header file problems on OpenBSD.
- Fixed issue with MPI_TYPE_CREATE_F90_REAL.
- Fix an issue with using external libltdl installations.  Thanks to
  opolawski for identifying the problem.
- Fixed MPI_IN_PLACE case for MPI_ALLGATHER for FCA.
- Allow SLURM PMI support to look in lib64 directories.  Thanks to
  Guillaume Papaure for the patch.
- Restore "use mpi" ABI compatibility with the rest of the 1.5/1.6
  series (except for v1.6.3, where it was accidentally broken).
- Fix a very old error in opal_path_access(). Thanks to Marco Atzeri
  for chasing it down.


1.6.3: 30 Oct 2012
------------------

- Fix mpirun --launch-agent behavior when a prefix is specified.
  Thanks to Reuti for identifying the issue.
- Fixed memchecker configury.
- Brought over some compiler warning squashes from the development trunk.
- Fix spawning from a singleton to multiple hosts when the "add-host"
  MPI_Info key is used.  Thanks to Brian Budge for pointing out the
  problem.
- Add Mellanox ConnextIB IDs and max inline value.
- Fix rankfile when no -np is given.
- FreeBSD detection improvement.  Thanks to Brooks Davis for the
  patch.
- Removed TCP warnings on Windows.
- Improved collective algorithm selection for very large messages.
- Fix PSM MTL affinity settings.
- Fix issue with MPI_OP_COMMUTATIVE in the mpif.h bindings.  Thanks to
  Ake Sandgren for providing a patch to fix the issue.
- Fix issue with MPI_SIZEOF when using CHARACTER and LOGICAL types in
  the mpi module.  Thanks to Ake Sandgren for providing a patch to fix
  the issue.
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1.6.2: 25 Sep 2012
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- Fix issue with MX MTL.  Thanks to Doug Eadline for raising the issue.
- Fix singleton MPI_COMM_SPAWN when the result job spans multiple nodes.
- Fix MXM hang, and update for latest version of MXM.
- Update to support Mellanox FCA 2.5.
- Fix startup hang for large jobs.
- Ensure MPI_TESTANY / MPI_WAITANY properly set the empty status when
  count==0.
- Fix MPI_CART_SUB behavior of not copying periods to the new
  communicator properly.  Thanks to John Craske for the bug report.
- Add btl_openib_abort_not_enough_reg_mem MCA parameter to cause Open
  MPI to abort MPI jobs if there is not enough registered memory
  available on the system (vs. just printing a warning).  Thanks to
  Brock Palen for raising the issue.
- Minor fix to Fortran MPI_INFO_GET: only copy a value back to the
  user's buffer if the flag is .TRUE.
- Fix VampirTrace compilation issue with the PGI compiler suite.


1.6.1: 22 Aug 2012
------------------

- A bunch of changes to eliminate hangs on OpenFabrics-based networks.
  Users with Mellanox hardware are ***STRONGLY ENCOURAGED*** to check
  their registered memory kernel module settings to ensure that the OS
  will allow registering more than 8GB of memory.  See this FAQ item
  for details:

  http://www.open-mpi.org/faq/?category=openfabrics#ib-low-reg-mem

  - Fall back to send/receive semantics if registered memory is
    unavilable for RDMA.
  - Fix two fragment leaks when registered memory is exhausted.
  - Hueristically determine how much registered memory is available
    and warn if it's significantly less than all of RAM.
  - Artifically limit the amount of registered memory each MPI process
    can use to about 1/Nth to total registered memory available.
  - Improve error messages when events occur that are likely due to
    unexpected registered memory exhaustion.

- Fix double semicolon error in the C++ in <mpi.h>.  Thanks to John
  Foster for pointing out the issue.
- Allow -Xclang to be specified multiple times in CFLAGS.  Thanks to
  P. Martin for raising the issue.
- Break up a giant "print *" statement in the ABI-preserving incorrect
  MPI_SCATTER interface in the "large" Fortran "mpi" module.  Thanks
  to Juan Escobar for the initial patch.
- Switch the MPI_ALLTOALLV default algorithm to a pairwise exchange.
- Increase the openib BTL default CQ length to handle more types of
  OpenFabrics devices.
- Lots of VampirTrace fixes; upgrade to v5.13.0.4.
- Map MPI_2INTEGER to underlying MPI_INTEGERs, not MPI_INTs.
- Ensure that the OMPI version number is toleant of handling spaces.
  Thanks to dragonboy for identifying the issue.
- Fixed IN parameter marking on Fortran "mpi" module
  MPI_COMM_TEST_INTER interface.
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- Various MXM improvements.
- Make the output of "mpirun --report-bindings" much more friendly /
  human-readable.
- Properly handle MPI_COMPLEX8|16|32.
- More fixes for mpirun's processor affinity options (--bind-to-core
  and friends).
- Use aligned memory for OpenFabrics registered memory.
- Multiple fixes for parameter checking in MPI_ALLGATHERV,
  MPI_REDUCE_SCATTER, MPI_SCATTERV, and MPI_GATHERV.  Thanks to the
  mpi4py community (Bennet Fauber, Lisandro Dalcin, Jonathan Dursi).
- Fixed file positioning overflows in MPI_FILE_GET_POSITION,
  MPI_FILE_GET_POSITION_SHARED, FILE_GET_SIZE, FILE_GET_VIEW.
- Removed the broken --cpu-set mpirun option.
- Fix cleanup of MPI errorcodes.  Thanks to Alexey Bayduraev for the
  patch.
- Fix default hostfile location.  Thanks to Gotz Waschk for noticing
  the issue.
- Improve several error messages.


1.6: 14 May 2012
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- Fix some process affinity issues.  When binding a process, Open MPI
  will now bind to all available hyperthreads in a core (or socket,
  depending on the binding options specified).
  --> Note that "mpirun --bind-to-socket ..." does not work on POWER6-
      and POWER7-based systems with some Linux kernel versions.  See
      the FAQ on the Open MPI web site for more information.
- Add support for ARM5 and ARM6 (in addition to the existing ARM7
  support).  Thanks to Evan Clinton for the patch.
- Minor Mellanox MXM fixes.
- Properly detect FDR10, FDR, and EDR OpenFabrics devices.
- Minor fixes to the mpirun(1) and MPI_Comm_create(3) man pages.
- Prevent segv if COMM_SPAWN_MULTIPLE fails.  Thanks to Fujitsu for
  the patch.
- Disable interposed memory management in fakeroot environments.  This
  fixes a problem in some build environments.
- Minor hwloc updates.
- Array versions of MPI_TEST and MPI_WAIT with a count==0 will now
  return immediately with MPI_SUCCESS.  Thanks to Jeremiah Willcock
  for the suggestion.
- Update VampirTrace to v5.12.2.
- Properly handle forwarding stdin to all processes when "mpirun
  --stdin all" is used.
- Workaround XLC assembly bug.
- OS X Tiger (10.4) has not been supported for a while, so forcibly
  abort configure if we detect it.
- Fix segv in the openib BTL when running on SPARC 64 systems.
- Fix some include file ordering issues on some BSD-based platforms.
  Thanks to Paul Hargove for this (and many, many other) fixes.
- Properly handle .FALSE. return parameter value to attribute copy
  callback functions.
- Fix a bunch of minor C++ API issues; thanks to Fujitsu for the patch.
- Fixed the default hostfile MCA parameter behavior.
- Per the MPI spec, ensure not to touch the port_name parameter to
  MPI_CLOSE_PORT (it's an IN parameter).
```

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1.5.5: 27 Mar 2012
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- Many, many portability configure/build fixes courtesy of Paul
  Hargrove.  Thanks, Paul!
- Fixed shared memory fault tolerance support compiler errors.
- Removed not-production-quality rshd and tmd PLM launchers.
- Minor updates to the Open MPI SRPM spec file.
- Fixed mpirun's --bind-to-socket option.
- A few MPI_THREAD_MULTIPLE fixes in the shared memory BTL.
- Upgrade the GNU Autotools used to bootstrap the 1.5/1.6 series to
  all the latest versions at the time of this release.
- Categorically state in the README that if you're having a problem
  with Open MPI with the Linux Intel 12.1 compilers, *upgrade your
  Intel Compiler Suite to the latest patch version*, and the problems
  will go away. :-)
- Fix the --without-memory-manager configure option.
- Fixes for Totalview/DDT MPI-capable debuggers.
- Update rsh/ssh support to properly handle the Mac OS X library path
  (i.e., DYLD_LIBRARY_PATH).
- Make warning about shared memory backing files on a networked file
  system be optional (i.e., can be disabled via MCA parameter).
- Several fixes to processor and memory affinity.
- Various shared memory infrastructure improvements.
- Various checkpoint/restart fixes.
- Fix MPI_IN_PLACE (and other MPI sentinel values) on OS X.  Thanks to
  Dave Goodell for providing the magic OS X gcc linker flags necessary.
- Various man page corrections and typo fixes.  Thanks to Fujitsu for
  the patch.
- Updated wrapper compiler man pages to list the various --showme
  options that are available.
- Add PMI direct-launch support (e.g., "srun mpi_application" under
  SLURM).
- Correctly compute the aligned address when packing the
  datatype description. Thanks to Fujitsu for the patch.
- Fix MPI obscure corner case handling in packing MPI datatypes.
  Thanks to Fujitsu for providing the patch.
- Workaround an Intel compiler v12.1.0 2011.6.233 vector optimization
  bug.
- Output the MPI API in ompi_info output.
- Major VT update to 5.12.1.4.
- Upgrade embedded Hardware Locality (hwloc) v1.3.2, plus some
  post-1.3.2-release bug fixes.  All processor and memory binding is
  now done through hwloc.  Woo hoo!  Note that this fixes core binding
  on AMD Opteron 6200 and 4200 series-based systems (sometimes known
  as Interlagos, Valencia, or other Bulldozer-based chips).
- New MCA parameters to control process-wide memory binding policy:
  hwloc_base_mem_alloc_policy, hwloc_base_mem_bind_failure_action (see
  ompi_info --param hwloc base).
- Removed direct support for libnuma.  Libnuma support may now be
  picked up through hwloc.
- Added MPI_IN_PLACE support to MPI_EXSCAN.
- Various fixes for building on Windows, including MinGW support.
- Removed support for the OpenFabrics IBCM connection manager.
- Updated Chelsio T4 and Intel NE OpenFabrics default buffer settings.
- Increased the default RDMA CM timeout to 30 seconds.
- Issue a warning if both btl_tcp_if_include and btl_tcp_if_exclude
  are specified.
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- Many fixes to the Mellanox MXM transport.


1.5.4: 18 Aug 2011
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- Add support for the (as yet unreleased) Mellanox MXM transport.
- Add support for dynamic service levels (SLs) in the openib BTL.
- Fixed C++ bindings cosmetic/warnings issue with
  MPI::Comm::NULL_COPY_FN and MPI::Comm::NULL_DELETE_FN.  Thanks to
  Julio Hoffimann for identifying the issues.
- Also allow the word "slots" in rankfiles (i.e., not just "slot").
  (** also to appear in 1.4.4)
- Add Mellanox ConnectX 3 device IDs to the openib BTL defaults.
  (** also to appear in 1.4.4)
- Various FCA updates.
- Fix 32 bit SIGBUS errors on Solaris SPARC platforms.
- Add missing ARM assembly code files.
- Update to allow more than 128 entries in an appfile.
  (** also to appear in 1.4.4)
- Various VT updates and bug fixes.
- Update description of btl_openib_cq_size to be more accurate.
  (** also to appear in 1.4.4)
- Various assembly "clobber" fixes.
- Fix a hang in carto selection in obscure situations.
- Guard the inclusion of execinfo.h since not all platforms have it.  Thanks
  to Aleksej Saushev for identifying this issue.
  (** also to appear in 1.4.4)
- Support Solaris legacy munmap prototype changes.
  (** also to appear in 1.4.4)
- Updated to Automake 1.11.1 per
  http://www.open-mpi.org/community/lists/devel/2011/07/9492.php.
- Fix compilation of LSF support.
- Update MPI_Comm_spawn_multiple.3 man page to reflect what it
  actually does.
- Fix for possible corruption of the environment.  Thanks to Peter
  Thompson for the suggestion.  (** also to appear in 1.4.4)
- Enable use of PSM on direct-launch SLURM jobs.
- Update paffinity hwloc to v1.2, and to fix minor bugs affinity
  assignment bugs on PPC64/Linux platforms.
- Let the openib BTL auto-detect its bandwidth.
- Support new MPI-2.2 datatypes.
- Updates to support more datatypes in MPI one-sided communication.
- Fix recursive locking bug when MPI-IO was used with
  MPI_THREAD_MULTIPLE.  (** also to appear in 1.4.4)
- Fix mpirun handling of prefix conflicts.
- Ensure mpirun's --xterm options leaves sessions attached.
  (** also to appear in 1.4.4)
- Fixed type of sendcounts and displs in the "use mpi" F90 module.
  ABI is preserved, but applications may well be broken.  See the
  README for more details.  Thanks to Stanislav Sazykin for
  identifying the issue.  (** also to appear in 1.4.4)
- Fix indexed datatype leaks.  Thanks to Pascal Deveze for supplying
  the initial patch.  (** also to appear in 1.4.4)
- Fix debugger mapping when mpirun's -npernode option is used.
- Fixed support for configure's --disable-dlopen option when used with
  "make distclean".
- Fix segv associated with MPI_Comm_create with MPI_GROUP_EMPTY.
```

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  Thanks to Dominik Goeddeke for finding this.
  (** also to appear in 1.4.4)
- Improved LoadLeveler ORTE support.
- Add new WinVerbs BTL plugin, supporting native OpenFabrics verbs on
  Windows (the "wv" BTL).
- Add new btl_openib_gid_index MCA parameter to allow selecting which
  GID to use on an OpenFabrics device's GID table.
- Add support for PCI relaxed ordering in the OpenFabrics BTL (when
  available).
- Update rsh logic to allow correct SGE operation.
- Ensure that the mca_paffinity_alone MCA parameter only appears once
  in the ompi_info output.  Thanks to Gus Correa for identifying the
  issue.
- Fixed return codes from MPI_PROBE and MPI_IPROBE.
  (** also to appear in 1.4.4)
- Remove --enable-progress-thread configure option; it doesn't work on
  the v1.5 branch.  Rename --enable-mpi-threads to
  --enable-mpi-thread-multiple.  Add new --enable-opal-multi-threads
  option.
- Updates for Intel Fortran compiler version 12.
- Remove bproc support.  Farewell bproc!
- If something goes wrong during MPI_INIT, fix the error
  message to say that it's illegal to invoke MPI_INIT before
  MPI_INIT.


1.5.3
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- Add missing "affinity" MPI extension (i.e., the OMPI_Affinity_str()
  API) that was accidentally left out of the 1.5.2 release.


1.5.2
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- Replaced all custom topology / affinity code with initial support
  for hwloc v1.1.1 (PLPA has been removed -- long live hwloc!).  Note
  that hwloc is bundled with Open MPI, but an external hwloc can be
  used, if desired.  See README for more details.
- Many CMake updates for Windows builds.
- Updated opal_cr_thread_sleep_wait MCA param default value to make it
  less aggressive.
- Updated debugger support to allow Totalview attaching from jobs
  launched directly via srun (not mpirun).  Thanks to Nikolay Piskun
  for the patch.
- Added more FTB/CIFTS support.
- Fixed compile error with the PGI compiler.
- Portability fixes to allow the openib BTL to run on the Solaris
  verbs stack.
- Fixed multi-token command-line issues when using the mpirun
  --debug switch.  For example:
      mpirun --debug -np 2 a.out "foo bar"
  Thanks to Gabriele Fatigati for reporting the issue.
- Added ARM support.
- Added the MPI_ROOT environment variable in the Open MPI Linux SRPM
  for customers who use the BPS and LSF batch managers.
- Updated ROMIO from MPICH v1.3.1 (plus one additional patch).
- Fixed some deprecated MPI API function notification messages.
- Added new "bfo" PML that provides failover on OpenFabrics networks.
- Fixed some buffer memcheck issues in MPI_*_init.
- Added Solaris-specific chip detection and performance improvements.
- Fix some compile errors on Solaris.
- Updated the "rmcast" framework with bug fixes, new functionality.
- Updated the Voltaire FCA component with bug fixes, new
  functionality.  Support for FCA version 2.1.
- Fix gcc 4.4.x and 4.5.x over-aggressive warning notifications on
  possibly freeing stack variables.  Thanks to the Gentoo packagers
  for reporting the issue.
- Make the openib component be verbose when it disqualifies itself due
  to MPI_THREAD_MULTIPLE.
- Minor man page fixes.
- Various checkpoint / restart fixes.
- Fix race condition in the one-sided unlock code.  Thanks to
  Guillaume Thouvenin for finding the issue.
- Improve help message aggregation.
- Add OMPI_Affinity_str() optional user-level API function (i.e., the
  "affinity" MPI extension).  See README for more details.
- Added btl_tcp_if_seq MCA parameter to select a different ethernet
  interface for each MPI process on a node.  This parameter is only
  useful when used with virtual ethernet interfaces on a single
  network card (e.g., when using virtual interfaces give dedicated
  hardware resources on the NIC to each process).
- Changed behavior of mpirun to terminate if it receives 10 (or more)
  SIGPIPEs.
- Fixed oversubscription detection.
- Added new mtl_mx_board and mtl_mx_endpoint MCA parameters.
- Added ummunotify support for OpenFabrics-based transports.  See the
  README for more details.


1.5.1
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- Fixes for the Oracle Studio 12.2 Fortran compiler.
- Fix SPARC and SPARCv9 atomics.  Thanks to Nicola Stange for the
  initial patch.
- Fix Libtool issues with the IBM XL compiler in 64-bit mode.
- Restore the reset of the libevent progress counter to avoid
  over-sampling the event library.
- Update memory barrier support.
- Use memmove (instead of memcpy) when necessary (e.g., source and
  destination overlap).
- Fixed ompi-top crash.
- Fix to handle Autoconf --program-transforms properly and other
  m4/configury updates.  Thanks to the GASNet project for the
  --program transforms fix.
- Allow hostfiles to specify usernames on a per-host basis.
- Update wrapper compiler scripts to search for perl during configure,
  per request from the BSD maintainers.
- Minor man page fixes.
- Added --with-libltdl option to allow building Open MPI with an
  external installation of libltdl.
- Fixed various issues with -D_FORTIFY_SOURCE=2.
- Various VT fixes and updates.
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1.5
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- Added "knem" support: direct process-to-process copying for shared
  memory message passing.  See http://runtime.bordeaux.inria.fr/knem/
  and the README file for more details.
- Updated shared library versioning scheme and linking style of MPI
  applications.  The MPI application ABI has been broken from the
  v1.3/v1.4 series.  MPI applications compiled against any prior
  version of Open MPI will need to, at a minimum, re-link.  See the
  README file for more details.
- Added "fca" collective component, enabling MPI collective offload
  support for Voltaire switches.
- Fixed MPI one-sided operations with large target displacements.
  Thanks to Brian Price and Jed Brown for reporting the issue.
- Fixed MPI_GET_COUNT when used with large counts.  Thanks to Jed
  Brown for reporting the issue.
- Made the openib BTL safer if extremely low SRQ settings are used.
- Fixed handling of the array_of_argv parameter in the Fortran
  binding of MPI_COMM_SPAWN_MULTIPLE (** also to appear: 1.4.3).
- Fixed malloc(0) warnings in some collectives.
- Fixed a problem with the Fortran binding for
  MPI_FILE_CREATE_ERRHANDLER.  Thanks to Secretan Yves for identifying
  the issue (** also to appear: 1.4.3).
- Updates to the LSF PLM to ensure that the path is correctly passed.
  Thanks to Teng Lin for the patch (** also to appear: 1.4.3).
- Fixes for the F90 MPI_COMM_SET_ERRHANDLER and MPI_WIN_SET_ERRHANDLER
  bindings.  Thanks to Paul Kapinos for pointing out the issue
  (** also to appear: 1.4.3).
- Fixed extra_state parameter types in F90 prototypes for
  MPI_COMM_CREATE_KEYVAL, MPI_GREQUEST_START, MPI_REGISTER_DATAREP,
  MPI_TYPE_CREATE_KEYVAL, and MPI_WIN_CREATE_KEYVAL.
- Fixes for Solaris oversubscription detection.
- If the PML determines it can't reach a peer process, print a
  slightly more helpful message.  Thanks to Nick Edmonds for the
  suggestion.
- Make btl_openib_if_include/exclude function the same way
  btl_tcp_if_include/exclude works (i.e., supplying an _include list
  overrides supplying an _exclude list).
- Apply more scalable reachability algorithm on platforms with more
  than 8 TCP interfaces.
- Various assembly code updates for more modern platforms / compilers.
- Relax restrictions on using certain kinds of MPI datatypes with
  one-sided operations.  Users beware; not all MPI datatypes are valid
  for use with one-sided operations!
- Improve behavior of MPI_COMM_SPAWN with regards to --bynode.
- Various threading fixes in the openib BTL and other core pieces of
  Open MPI.
- Various help file and man pages updates.
- Various FreeBSD and NetBSD updates and fixes.  Thanks to Kevin
  Buckley and Aleksej Saushev for their work.
- Fix case where freeing communicators in MPI_FINALIZE could cause
  process failures.
- Print warnings if shared memory state files are opened on what look
  like networked filesystems.
- Update libevent to v1.4.13.
- Allow propagating signals to processes that call fork().
- Fix bug where MPI_GATHER was sometimes incorrectly examining the
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  datatype on non-root processes.  Thanks to Michael Hofmann for
  investigating the issue.
- Various Microsoft Windows fixes.
- Various Catamount fixes.
- Various checkpoint / restart fixes.
- Xgrid support has been removed until it can be fixed (patches
  would be welcome).
- Added simplistic "libompitrace" contrib package.  Using the MPI
  profiling interface, it essentially prints out to stderr when select
  MPI functions are invoked.
- Update bundled VampirTrace to v5.8.2.
- Add pkg-config(1) configuration files for ompi, ompi-c, ompi-cxx,
  ompi-f77, ompi-f90.  See the README for more details.
- Removed the libopenmpi_malloc library (added in the v1.3 series)
  since it is no longer necessary
- Add several notifier plugins (generally used when Open MPI detects
  system/network administrator-worthy problems); each have their own
  MCA parameters to govern their usage.  See "ompi_info --param
  notifier <name>" for more details.
  - command to execute arbitrary commands (e.g., run a script).
  - file to send output to a file.
  - ftb to send output to the Fault Tolerant Backplane (see
    http://wiki.mcs.anl.gov/cifts/index.php/CIFTS)
  - hnp to send the output to mpirun.
  - smtp (requires libesmtp) to send an email.


1.4.5
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- Fixed the --disable-memory-manager configure switch.
  (** also to appear in 1.5.5)
- Fix typos in code and man pages.  Thanks to Fujitsu for these fixes.
  (** also to appear in 1.5.5)
- Improve management of the registration cache; when full, try freeing
  old entries and attempt to re-register.
- Fixed a data packing pointer alignment issue.  Thanks to Fujitsu
  for the patch.
  (** also to appear in 1.5.5)
- Add ability to turn off warning about having the shared memory backing
  store over a networked filesystem.  Thanks to Chris Samuel for this
  suggestion.
  (** also to appear in 1.5.5)
- Removed an unnecessary memmove() and plugged a couple of small memory leaks
  in the openib OOB connection setup code.
- Fixed some QLogic bugs. Thanks to Mark Debbage from QLogic for the patches.
- Fixed problem with MPI_IN_PLACE and other sentinel Fortran constants
  on OS X.
  (** also to appear in 1.5.5)
- Fix SLURM cpus-per-task allocation.
  (** also to appear in 1.5.5)
- Fix the datatype engine for when data left over from the previous
  pack was larger than the allowed space in the pack buffer. Thanks to
  Yuki Matsumoto and Takahiro Kawashima for the bug report and the
  patch.
- Fix Fortran value for MPI_MAX_PORT_NAME.  Thanks to Enzo Dari for
  raising the issue.
- Workaround an Intel compiler v12.1.0 2011.6.233 vector optimization
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  bug.
- Fix issues on Solaris with the openib BTL.
- Fixes for the Oracle Studio 12.2 Fortran compiler.
- Update iWARP parameters for the Intel NICs.
  (** also to appear in 1.5.5)
- Fix obscure cases where MPI_ALLGATHER could crash.  Thanks to Andrew
  Senin for reporting the problem.
  (** also to appear in 1.5.5)


1.4.4
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- Modified a memcpy() call in the openib btl connection setup to use
  memmove() instead because of the possibility of an overlapping
  copy (as identified by valgrind).
- Changed use of sys_timer_get_cycles() to the more appropriate
  wrapper: opal_timer_base_get_cycles().  Thanks to Jani Monoses
  for this fix.
- Corrected the reported default value of btl_openib_ib_timeout
  in the "IB retries exceeded" error message.  Thanks to Kevin Buckley
  for this correction.
- Increased rdmacm address resolution timeout from 1s to 30s &
  updated Chelsio T4 openib BTL defaults.  Thanks to Steve Wise
  for these updates.
  (** also to appear in 1.5.5)
- Ensure that MPI_Accumulate error return in 1.4 is consistent with
  1.5.x and trunk.
- Allow the word "slots" in rankfiles (i.e., not just "slot").
  (** also appeared in 1.5.4)
- Add Mellanox ConnectX 3 device IDs to the openib BTL defaults.
  (** also appeared in 1.5.4)
- Update description of btl_openib_cq_size to be more accurate.
- Ensure mpirun's --xterm options leaves sessions attached.
  (** also appeared in 1.5.4)
- Update to allow more than 128 entries in an appfile.
  (** also appeared in 1.5.4)
- Update description of btl_openib_cq_size to be more accurate.
  (** also appeared in 1.5.4)
- Fix for deadlock when handling recursive attribute keyval deletions
  (e.g., when using ROMIO with MPI_THREAD_MULTIPLE).
- Fix indexed datatype leaks.  Thanks to Pascal Deveze for supplying
  the initial patch.  (** also appeared in 1.5.4)
- Fixed the F90 types of the sendcounts and displs parameters to
  MPI_SCATTERV.  Thanks to Stanislav Sazykin for identifying the issue.
  (** also appeared in 1.5.4)
- Exclude opal/libltdl from "make distclean" when --disable-dlopen is
  used.  Thanks to David Gunter for reporting the issue.
- Fixed a segv in MPI_Comm_create when called with GROUP_EMPTY.
  Thanks to Dominik Goeddeke for finding this.
  (** also appeared in 1.5.4)
- Fixed return codes from MPI_PROBE and MPI_IPROBE.
  (** also appeared in 1.5.4)
- Fixed undefined symbol error when using the vtf90 profiling tool.
- Fix for referencing an uninitialized variable in DPM ORTE.  Thanks
  to Avinash Malik for reporting the issue.
- Fix for correctly handling multi-token args when using debuggers.
- Eliminated the unneeded u_int*_t datatype definitions.
- Change in ORTE DPM to get around gcc 4.[45].x compiler wanrings
  about possibly calling free() on a non-heap variable, even though it
  will never happen because the refcount will never go to zero.
- Fixed incorrect text in MPI_File_set_view man page.
- Fix in MPI_Init_thread for checkpoint/restart.
- Fix for libtool issue when using pgcc to compile ompi in conjunction
  with the -tp option.
- Fixed a race condition in osc_rdma_sync.  Thanks to Guillaume
  Thouvenin for finding this issue.
- Clarification of MPI_Init_thread man page.
- Fixed an indexing problem in precondition_transports.
- Fixed a problem in which duplicated libs were being specified for
  linking.  Thanks to Hicham Mouline for noticing it.
- Various autogen.sh fixes.
- Fix for memchecking buffers during MPI_*INIT.
- Man page cleanups.  Thanks to Jeremiah Willcock and Jed Brown.
- Fix for VT rpmbuild on RHEL5.
- Support Solaris legacy munmap prototype changes.
  (** also appeared in 1.5.4)
- Expands app_idx to int32_t to allow more than 127 app_contexts.
- Guard the inclusion of execinfo.h since not all platforms have it.  Thanks
  to Aleksej Saushev for identifying this issue.
  (** also appeared in 1.5.4)
- Fix to avoid possible environment corruption.  Thanks to Peter Thompson
  for identifying the issue and supplying a patch.
  (** also appeared in 1.5.4)
- Fixed paffinity base MCA duplicate registrations.  Thanks to Gus
  Correa for bringing this to our attention.
- Fix recursive locking bug when MPI-IO was used with
  MPI_THREAD_MULTIPLE.  (** also appeared in 1.5.4)
- F90 MPI API fixes.
- Fixed a misleading MPI_Bcast error message.  Thanks to Jeremiah
  Willcock for reporting this.
- Added <sys/stat.h> to ptmalloc's hooks.c (it's not always included
  by default on some systems).
- Libtool patch to get around a build problem when using the IBM XL
  compilers.
- Fix to detect and avoid overlapping memcpy().  Thanks to
  Francis Pellegrini for identifying the issue.
- Fix to allow ompi to work on top of RoCE vLANs.
- Restored a missing debugger flag to support TotalView.  Thanks to
  David Turner and the TV folks for supplying the fix.
- Updated SLURM support to 1.5.1.
- Removed an extraneous #include from the TCP BTL.
- When specifying OOB ports, fix to convert the ports into network
  byte order before binding.
- Fixed use of memory barriers in the SM BTL.  This fixed segv's when
  compiling with Intel 10.0.025 or PGI 9.0-3.
- Fix to prevent the SM BTL from creating its mmap'd file in
  directories that are remotely mounted.


1.4.3
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- Fixed handling of the array_of_argv parameter in the Fortran
  binding of MPI_COMM_SPAWN_MULTIPLE (** also to appear: 1.5).
- Fixed a problem with the Fortran binding for
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  MPI_FILE_CREATE_ERRHANDLER.  Thanks to Secretan Yves for identifying
  the issue (** also to appear: 1.5).
- Updates to the LSF PLM to ensure that the path is correctly passed.
  Thanks to Teng Lin for the patch (** also to appear: 1.5).
- Fixes for the F90 MPI_COMM_SET_ERRHANDLER and MPI_WIN_SET_ERRHANDLER
  bindings.  Thanks to Paul Kapinos for pointing out the issue.
  (** also to appear: 1.5).
- Fixed various MPI_THREAD_MULTIPLE race conditions.
- Fixed an issue with an undeclared variable from ptmalloc2 munmap on
  BSD systems.
- Fixes for BSD interface detection.
- Various other BSD fixes.  Thanks to Kevin Buckley helping to track.
  all of this down.
- Fixed issues with the use of the -nper* mpirun command line arguments.
- Fixed an issue with coll tuned dynamic rules.
- Fixed an issue with the use of OPAL_DESTDIR being applied too aggressively.
- Fixed an issue with one-sided xfers when the displacement exceeds 2GBytes.
- Change to ensure TotalView works properly on Darwin.
- Added support for Visual Studio 2010.
- Fix to ensure proper placement of VampirTrace header files.
- Needed to add volatile keyword to a varialbe used in debugging
  (MPIR_being_debugged).
- Fixed a bug in inter-allgather.
- Fixed malloc(0) warnings.
- Corrected a typo the MPI_Comm_size man page (intra -> inter).  Thanks
  to Simon number.cruncher for pointing this out.
- Fixed a SegV in orted when given more than 127 app_contexts.
- Removed xgrid source code from the 1.4 branch since it is no longer
  supported in the 1.4 series.
- Removed the --enable-opal-progress-threads config option since
  opal progress thread support does not work in 1.4.x.
- Fixed a defect in VampirTrace's vtfilter.
- Fixed wrong Windows path in hnp_contact.
- Removed the requirement for a paffinity component.
- Removed a hardcoded limit of 64 interconnected jobs.
- Fix to allow singletons to use ompi-server for rendezvous.
- Fixed bug in output-filename option.
- Fix to correctly handle failures in mx_init().
- Fixed a potential Fortran memory leak.
- Fixed an incorrect branch in some ppc32 assembly code.  Thanks
  to Matthew Clark for this fix.
- Remove use of undocumented AS_VAR_GET macro during configuration.
- Fixed an issue with VampirTrace's wrapper for MPI_init_thread.
- Updated mca-btl-openib-device-params.ini file with various new vendor id's.
- Configuration fixes to ensure CPPFLAGS in handled properly if a non-standard
  valgrind location was specified.
- Various man page updates


1.4.2
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- Fixed problem when running in heterogeneous environments.  Thanks to
  Timur Magomedov for helping to track down this issue.
- Update LSF support to ensure that the path is passed correctly.
  Thanks to Teng Lin for submitting a patch.
- Fixed some miscellaneous oversubscription detection bugs.
- IBM re-licensed its LoadLeveler code to be BSD-compliant.
- Various OpenBSD and NetBSD build and run-time fixes.  Many thanks to
  the OpenBSD community for their time, expertise, and patience
  getting these fixes incorporated into Open MPI's main line.
- Various fixes for multithreading deadlocks, race conditions, and
  other nefarious things.
- Fixed ROMIO's handling of "nearly" contiguous issues (e.g., with
  non-zero true_lb).  Thanks for Pascal Deveze for the patch.
- Bunches of Windows build fixes.  Many thanks to several Windows
  users for their help in improving our support on Windows.
- Now allow the graceful failover from MTLs to BTLs if no MTLs can
  initialize successfully.
- Added "clobber" information to various atomic operations, fixing
  erroneous behavior in some newer versions of the GNU compiler suite.
- Update various iWARP and InfiniBand device specifications in the
  OpenFabrics .ini support file.
- Fix the use of hostfiles when a username is supplied.
- Various fixes for rankfile support.
- Updated the internal version of VampirTrace to 5.4.12.
- Fixed OS X TCP wireup issues having to do with IPv4/IPv6 confusion
  (see https://svn.open-mpi.org/trac/ompi/changeset/22788 for more
  details).
- Fixed some problems in processor affinity support, including when
  there are "holes" in the processor namespace (e.g., offline
  processors).
- Ensure that Open MPI's "session directory" (usually located in /tmp)
  is cleaned up after process termination.
- Fixed some problems with the collective "hierarch" implementation
  that could occur in some obscure conditions.
- Various MPI_REQUEST_NULL, API parameter checking, and attribute
  error handling fixes.  Thanks to Lisandro Dalcin for reporting the
  issues.
- Fix case where MPI_GATHER erroneously used datatypes on non-root
  nodes.  Thanks to Michael Hofmann for investigating the issue.
- Patched ROMIO support for PVFS2 > v2.7 (patch taken from MPICH2
  version of ROMIO).
- Fixed "mpirun --report-bindings" behavior when used with
  mpi_paffinity_alone=1.  Also fixed mpi_paffinity_alone=1 behavior
  with non-MPI applications.  Thanks to Brice Goglin for noticing the
  problem.
- Ensure that all OpenFabrics devices have compatible receive_queues
  specifications before allowing them to communicate.  See the lengthy
  comment in https://svn.open-mpi.org/trac/ompi/changeset/22592 for
  more details.
- Fix some issues with checkpoint/restart.
- Improve the pre-MPI_INIT/post-MPI_FINALIZE error messages.
- Ensure that loopback addresses are never advertised to peer
  processes for RDMA/OpenFabrics support.
- Fixed a CSUM PML false positive.
- Various fixes for Catamount support.
- Minor update to wrapper compilers in how user-specific argv is
  ordered on the final command line.  Thanks to Jed Brown for the
  suggestions.
- Removed flex.exe binary from Open MPI tarballs; now generate flex
  code from a newer (Windows-friendly) flex when we make official
  tarballs.


1.4.1
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- Update to PLPA v1.3.2, addressing a licensing issue identified by
  the Fedora project.  See
  https://svn.open-mpi.org/trac/plpa/changeset/262 for details.
- Add check for malformed checkpoint metadata files (Ticket #2141).
- Fix error path in ompi-checkpoint when not able to checkpoint
  (Ticket #2138).
- Cleanup component release logic when selecting checkpoint/restart
  enabled components (Ticket #2135).
- Fixed VT node name detection for Cray XT platforms, and fixed some
  broken VT documentation files.
- Fix a possible race condition in tearing down RDMA CM-based
  connections.
- Relax error checking on MPI_GRAPH_CREATE.  Thanks to David Singleton
  for pointing out the issue.
- Fix a shared memory "hang" problem that occurred on x86/x86_64
  platforms when used with the GNU >=4.4.x compiler series.
- Add fix for Libtool 2.2.6b's problems with the PGI 10.x compiler
  suite.  Inspired directly from the upstream Libtool patches that fix
  the issue (but we need something working before the next Libtool
  release).


1.4
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The *only* change in the Open MPI v1.4 release (as compared to v1.3.4)
was to update the embedded version of Libtool's libltdl to address a
potential security vulnerability.  Specifically: Open MPI v1.3.4 was
created with GNU Libtool 2.2.6a; Open MPI v1.4 was created with GNU
Libtool 2.2.6b.  There are no other changes between Open MPI v1.3.4
and v1.4.


1.3.4
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- Fix some issues in OMPI's SRPM with regard to shell_scripts_basename
  and its use with mpi-selector.  Thanks to Bill Johnstone for
  pointing out the problem.
- Added many new MPI job process affinity options to mpirun.  See the
  newly-updated mpirun(1) man page for details.
- Several updates to mpirun's XML output.
- Update to fix a few Valgrind warnings with regards to the ptmalloc2
  allocator and Open MPI's use of PLPA.
- Many updates and fixes to the (non-default) "sm" collective
  component (i.e., native shared memory MPI collective operations).
- Updates and fixes to some MPI_COMM_SPAWN_MULTIPLE corner cases.
- Fix some internal copying functions in Open MPI's use of PLPA.
- Correct some SLURM nodelist parsing logic that may have interfered
  with large jobs.  Additionally, per advice from the SLURM team,
  change the environment variable that we use for obtaining the job's
  allocation.
- Revert to an older, safer (but slower) communicator ID allocation
  algorithm.
- Fixed minimum distance finding for OpenFabrics devices in the openib
  BTL.
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- Relax the parameter checking MPI_CART_CREATE a bit.
- Fix MPI_COMM_SPAWN[_MULTIPLE] to only error-check the info arguments
  on the root process.  Thanks to Federico Golfre Andreasi for
  reporting the problem.
- Fixed some BLCR configure issues.
- Fixed a potential deadlock when the openib BTL was used with
  MPI_THREAD_MULTIPLE.
- Fixed dynamic rules selection for the "tuned" coll component.
- Added a launch progress meter to mpirun (useful for large jobs; set
  the orte_report_launch_progress MCA parameter to 1 to see it).
- Reduced the number of file descriptors consumed by each MPI process.
- Add new device IDs for Chelsio T3 RNICs to the openib BTL config file.
- Fix some CRS self component issues.
- Added some MCA parameters to the PSM MTL to tune its run-time
  behavior.
- Fix some VT issues with MPI_BOTTOM/MPI_IN_PLACE.
- Man page updates from the Debain Open MPI package maintainers.
- Add cycle counter support for the Alpha and Sparc platforms.
- Pass visibility flags to libltdl's configure script, resulting in
  those symbols being hidden.  This appears to mainly solve the
  problem of applications attempting to use different versions of
  libltdl from that used to build Open MPI.


1.3.3
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- Fix a number of issues with the openib BTL (OpenFabrics) RDMA CM,
  including a memory corruption bug, a shutdown deadlock, and a route
  timeout.  Thanks to David McMillen and Hal Rosenstock for help in
  tracking down the issues.
- Change the behavior of the EXTRA_STATE parameter that is passed to
  Fortran attribute callback functions: this value is now stored
  internally in MPI -- it no longer references the original value
  passed by MPI_*_CREATE_KEYVAL.
- Allow the overriding RFC1918 and RFC3330 for the specification of
  "private" networks, thereby influencing Open MPI's TCP
  "reachability" computations.
- Improve flow control issues in the sm btl, by both tweaking the
  shared memory progression rules and by enabling the "sync" collective
  to barrier every 1,000th collective.
- Various fixes for the IBM XL C/C++ v10.1 compiler.
- Allow explicit disabling of ptmalloc2 hooks at runtime (e.g., enable
  support for Debian's builtroot system).  Thanks to Manuel Prinz and
  the rest of the Debian crew for helping identify and fix this issue.
- Various minor fixes for the I/O forwarding subsystem.
- Big endian iWARP fixes in the Open Fabrics RDMA CM support.
- Update support for various OpenFabrics devices in the openib BTL's
  .ini file.
- Fixed undefined symbol issue with Open MPI's parallel debugger
  message queue support so it can be compiled by Sun Studio compilers.
- Update MPI_SUBVERSION to 1 in the Fortran bindings.
- Fix MPI_GRAPH_CREATE Fortran 90 binding.
- Fix MPI_GROUP_COMPARE behavior with regards to MPI_IDENT.  Thanks to
  Geoffrey Irving for identifying the problem and supplying the fix.
- Silence gcc 4.1 compiler warnings about type punning.  Thanks to
  Number Cruncher for the fix.
- Added more Valgrind and other memory-cleanup fixes.  Thanks to
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  various Open MPI users for help with these issues.
- Miscellaneous VampirTrace fixes.
- More fixes for openib credits in heavy-congestion scenarios.
- Slightly decrease the latency in the openib BTL in some conditions
  (add "send immediate" support to the openib BTL).
- Ensure to allow MPI_REQUEST_GET_STATUS to accept an
  MPI_STATUS_IGNORE parameter.  Thanks to Shaun Jackman for the bug
  report.
- Added Microsoft Windows support.  See README.WINDOWS file for
  details.


1.3.2
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- Fixed a potential infinite loop in the openib BTL that could occur
  in senders in some frequent-communication scenarios.  Thanks to Don
  Wood for reporting the problem.
- Add a new checksum PML variation on ob1 (main MPI point-to-point
  communication engine) to detect memory corruption in node-to-node
  messages
- Add a new configuration option to add padding to the openib
  header so the data is aligned
- Add a new configuration option to use an alternative checksum algo
  when using the checksum PML
- Fixed a problem reported by multiple users on the mailing list that
  the LSF support would fail to find the appropriate libraries at
  run-time.
- Allow empty shell designations from getpwuid().  Thanks to Sergey
  Koposov for the bug report.
- Ensure that mpirun exits with non-zero status when applications die
  due to user signal.  Thanks to Geoffroy Pignot for suggesting the
  fix.
- Ensure that MPI_VERSION / MPI_SUBVERSION match what is returned by
  MPI_GET_VERSION.  Thanks to Rob Egan for reporting the error.
- Updated MPI_*KEYVAL_CREATE functions to properly handle Fortran
  extra state.
- A variety of ob1 (main MPI point-to-point communication engine) bug
  fixes that could have caused hangs or seg faults.
- Do not install Open MPI's signal handlers in MPI_INIT if there are
  already signal handlers installed.  Thanks to Kees Verstoep for
  bringing the issue to our attention.
- Fix GM support to not seg fault in MPI_INIT.
- Various VampirTrace fixes.
- Various PLPA fixes.
- No longer create BTLs for invalid (TCP) devices.
- Various man page style and lint cleanups.
- Fix critical OpenFabrics-related bug noted here:
  http://www.open-mpi.org/community/lists/announce/2009/03/0029.php.
  Open MPI now uses a much more robust memory intercept scheme that is
  quite similar to what is used by MX.  The use of "-lopenmpi-malloc"
  is no longer necessary, is deprecated, and is expected to disappear
  in a future release.  -lopenmpi-malloc will continue to work for the
  duration of the Open MPI v1.3 and v1.4 series.
- Fix some OpenFabrics shutdown errors, both regarding iWARP and SRQ.
- Allow the udapl BTL to work on Solaris platforms that support
  relaxed PCI ordering.
- Fix problem where the mpirun would sometimes use rsh/ssh to launch on
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  the localhost (instead of simply forking).
- Minor SLURM stdin fixes.
- Fix to run properly under SGE jobs.
- Scalability and latency improvements for shared memory jobs: convert
  to using one message queue instead of N queues.
- Automatically size the shared-memory area (mmap file) to match
  better what is needed;  specifically, so that large-np jobs will start.
- Use fixed-length MPI predefined handles in order to provide ABI
  compatibility between Open MPI releases.
- Fix building of the posix paffinity component to properly get the
  number of processors in loosely tested environments (e.g.,
  FreeBSD).  Thanks to Steve Kargl for reporting the issue.
- Fix --with-libnuma handling in configure.  Thanks to Gus Correa for
  reporting the problem.


1.3.1
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- Added "sync" coll component to allow users to synchronize every N
  collective operations on a given communicator.
- Increased the default values of the IB and RNR timeout MCA parameters.
- Fix a compiler error noted by Mostyn Lewis with the PGI 8.0 compiler.
- Fix an error that prevented stdin from being forwarded if the
  rsh launcher was in use.  Thanks to Branden Moore for pointing out
  the problem.
- Correct a case where the added datatype is considered as contiguous but
  has gaps in the beginning.
- Fix an error that limited the number of comm_spawns that could
  simultaneously be running in some environments
- Correct a corner case in OB1's GET protocol for long messages; the
  error could sometimes cause MPI jobs using the openib BTL to hang.
- Fix a bunch of bugs in the IO forwarding (IOF) subsystem and add some
  new options to output to files and redirect output to xterm.  Thanks to
  Jody Weissmann for helping test out many of the new fixes and
  features.
- Fix SLURM race condition.
- Fix MPI_File_c2f(MPI_FILE_NULL) to return 0, not -1.  Thanks to
  Lisandro Dalcin for the bug report.
- Fix the DSO build of tm PLM.
- Various fixes for size disparity between C int's and Fortran
  INTEGER's.  Thanks to Christoph van Wullen for the bug report.
- Ensure that mpirun exits with a non-zero exit status when daemons or
  processes abort or fail to launch.
- Various fixes to work around Intel (NetEffect) RNIC behavior.
- Various fixes for mpirun's --preload-files and --preload-binary
  options.
- Fix the string name in MPI::ERRORS_THROW_EXCEPTIONS.
- Add ability to forward SIFTSTP and SIGCONT to MPI processes if you
  set the MCA parameter orte_forward_job_control to 1.
- Allow the sm BTL to allocate larger amounts of shared memory if
  desired (helpful for very large multi-core boxen).
- Fix a few places where we used PATH_MAX instead of OPAL_PATH_MAX,
  leading to compile problems on some platforms.  Thanks to Andrea Iob
  for the bug report.
- Fix mca_btl_openib_warn_no_device_params_found MCA parameter; it
  was accidentally being ignored.
- Fix some run-time issues with the sctp BTL.
- Ensure that RTLD_NEXT exists before trying to use it (e.g., it
  doesn't exist on Cygwin).  Thanks to Gustavo Seabra for reporting
  the issue.
- Various fixes to VampirTrace, including fixing compile errors on
  some platforms.
- Fixed missing MPI_Comm_accept.3 man page; fixed minor issue in
  orterun.1 man page.  Thanks to Dirk Eddelbuettel for identifying the
  problem and submitting a patch.
- Implement the XML formatted output of stdout/stderr/stddiag.
- Fixed mpirun's -wdir switch to ensure that working directories for
  multiple app contexts are properly handled.  Thanks to Geoffroy
  Pignot for reporting the problem.
- Improvements to the MPI C++ integer constants:
  - Allow MPI::SEEK_* constants to be used as constants
  - Allow other MPI C++ constants to be used as array sizes
- Fix minor problem with orte-restart's command line options.  See
  ticket #1761 for details.  Thanks to Gregor Dschung for reporting
  the problem.


1.3
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- Extended the OS X 10.5.x (Leopard) workaround for a problem when
  assembly code is compiled with -g[0-9].  Thanks to Barry Smith for
  reporting the problem.  See ticket #1701.
- Disabled MPI_REAL16 and MPI_COMPLEX32 support on platforms where the
  bit representation of REAL*16 is different than that of the C type
  of the same size (usually long double).  Thanks to Julien Devriendt
  for reporting the issue.  See ticket #1603.
- Increased the size of MPI_MAX_PORT_NAME to 1024 from 36. See ticket #1533.
- Added "notify debugger on abort" feature. See tickets #1509 and #1510.
  Thanks to Seppo Sahrakropi for the bug report.
- Upgraded Open MPI tarballs to use Autoconf 2.63, Automake 1.10.1,
  Libtool 2.2.6a.
- Added missing MPI::Comm::Call_errhandler() function.  Thanks to Dave
  Goodell for bringing this to our attention.
- Increased MPI_SUBVERSION value in mpi.h to 1 (i.e., MPI 2.1).
- Changed behavior of MPI_GRAPH_CREATE, MPI_TOPO_CREATE, and several
  other topology functions per MPI-2.1.
- Fix the type of the C++ constant MPI::IN_PLACE.
- Various enhancements to the openib BTL:
  - Added btl_openib_if_[in|ex]clude MCA parameters for
    including/excluding comma-delimited lists of HCAs and ports.
  - Added RDMA CM support, includng btl_openib_cpc_[in|ex]clude MCA
    parameters
  - Added NUMA support to only use "near" network adapters
  - Added "Bucket SRQ" (BSRQ) support to better utilize registered
    memory, including btl_openib_receive_queues MCA parameter
  - Added ConnectX XRC support (and integrated with BSRQ)
  - Added btl_openib_ib_max_inline_data MCA parameter
  - Added iWARP support
  - Revamped flow control mechansisms to be more efficient
  - "mpi_leave_pinned=1" is now the default when possible,
    automatically improving performance for large messages when
    application buffers are re-used
- Elimiated duplicated error messages when multiple MPI processes fail
  with the same error.
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- Added NUMA support to the shared memory BTL.
- Add Valgrind-based memory checking for MPI-semantic checks.
- Add support for some optional Fortran datatypes (MPI_LOGICAL1,
  MPI_LOGICAL2, MPI_LOGICAL4 and MPI_LOGICAL8).
- Remove the use of the STL from the C++ bindings.
- Added support for Platform/LSF job launchers.  Must be Platform LSF
  v7.0.2 or later.
- Updated ROMIO with the version from MPICH2 1.0.7.
- Added RDMA capable one-sided component (called rdma), which
  can be used with BTL components that expose a full one-sided
  interface.
- Added the optional datatype MPI_REAL2. As this is added to the "end of"
  predefined datatypes in the fortran header files, there will not be
  any compatibility issues.
- Added Portable Linux Processor Affinity (PLPA) for Linux.
- Addition of a finer symbols export control via the visibiliy feature
  offered by some compilers.
- Added checkpoint/restart process fault tolerance support. Initially
  support a LAM/MPI-like protocol.
- Removed "mvapi" BTL; all InfiniBand support now uses the OpenFabrics
  driver stacks ("openib" BTL).
- Added more stringent MPI API parameter checking to help user-level
  debugging.
- The ptmalloc2 memory manager component is now by default built as
  a standalone library named libopenmpi-malloc.  Users wanting to
  use leave_pinned with ptmalloc2 will now need to link the library
  into their application explicitly.  All other users will use the
  libc-provided allocator instead of Open MPI's ptmalloc2.  This change
  may be overriden with the configure option enable-ptmalloc2-internal
- The leave_pinned options will now default to using mallopt on
  Linux in the cases where ptmalloc2 was not linked in.  mallopt
  will also only be available if munmap can be intercepted (the
  default whenever Open MPI is not compiled with --without-memory-
  manager.
- Open MPI will now complain and refuse to use leave_pinned if
  no memory intercept / mallopt option is available.
- Add option of using Perl-based wrapper compilers instead of the
  C-based wrapper compilers.  The Perl-based version does not
  have the features of the C-based version, but does work better
  in cross-compile environments.


1.2.9: 14 Feb 2009
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- Fix a segfault when using one-sided communications on some forms of derived
  datatypes.  Thanks to Dorian Krause for reporting the bug. See #1715.
- Fix an alignment problem affecting one-sided communications on
  some architectures (e.g., SPARC64). See #1738.
- Fix compilation on Solaris when thread support is enabled in Open MPI
  (e.g., when using --with-threads). See #1736.
- Correctly take into account the MTU that an OpenFabrics device port
  is using. See #1722 and
  https://bugs.openfabrics.org/show_bug.cgi?id=1369.
- Fix two datatype engine bugs. See #1677.
  Thanks to Peter Kjellstrom for the bugreport.
- Fix the bml r2 help filename so the help message can be found. See #1623.
- Fix a compilation problem on RHEL4U3 with the PGI 32 bit compiler
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  caused by <infiniband/driver.h>.  See ticket #1613.
- Fix the --enable-cxx-exceptions configure option. See ticket #1607.
- Properly handle when the MX BTL cannot open an endpoint. See ticket #1621.
- Fix a double free of events on the tcp_events list. See ticket #1631.
- Fix a buffer overun in opal_free_list_grow (called by MPI_Init).
  Thanks to Patrick Farrell for the bugreport and Stephan Kramer for
  the bugfix.  See ticket #1583.
- Fix a problem setting OPAL_PREFIX for remote sh-based shells.
  See ticket #1580.


1.2.8
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- Tweaked one memory barrier in the openib component to be more conservative.
  May fix a problem observed on PPC machines.  See ticket #1532.
- Fix OpenFabrics IB partition support. See ticket #1557.
- Restore v1.1 feature that sourced .profile on remote nodes if the default
  shell will not do so (e.g. /bin/sh and /bin/ksh).  See ticket #1560.
- Fix segfault in MPI_Init_thread() if ompi_mpi_init() fails. See ticket #1562.
- Adjust SLURM support to first look for $SLURM_JOB_CPUS_PER_NODE instead of
  the deprecated $SLURM_TASKS_PER_NODE environment variable.  This change
  may be *required* when using SLURM v1.2 and above.  See ticket #1536.
- Fix the MPIR_Proctable to be in process rank order. See ticket #1529.
- Fix a regression introduced in 1.2.6 for the IBM eHCA. See ticket #1526.


1.2.7
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- Add some Sun HCA vendor IDs.  See ticket #1461.
- Fixed a memory leak in MPI_Alltoallw when called from Fortran.
  Thanks to Dave Grote for the bugreport.  See ticket #1457.
- Only link in libutil when it is needed/desired.  Thanks to
  Brian Barret for diagnosing and fixing the problem.  See ticket #1455.
- Update some QLogic HCA vendor IDs.  See ticket #1453.
- Fix F90 binding for MPI_CART_GET.  Thanks to Scott Beardsley for
  bringing it to our attention. See ticket #1429.
- Remove a spurious warning message generated in/by ROMIO. See ticket #1421.
- Fix a bug where command-line MCA parameters were not overriding
  MCA parameters set from environment variables.  See ticket #1380.
- Fix a bug in the AMD64 atomics assembly.  Thanks to Gabriele Fatigati
  for the bug report and bugfix.  See ticket #1351.
- Fix a gather and scatter bug on intercommunicators when the datatype
  being moved is 0 bytes. See ticket #1331.
- Some more man page fixes from the Debian maintainers.
  See tickets #1324 and #1329.
- Have openib BTL (OpenFabrics support) check for the presence of
  /sys/class/infiniband before allowing itself to be used.  This check
  prevents spurious "OMPI did not find RDMA hardware!" notices on
  systems that have the software drivers installed, but no
  corresponding hardware.  See tickets #1321 and #1305.
- Added vendor IDs for some ConnectX openib HCAs. See ticket #1311.
- Fix some RPM specfile inconsistencies.  See ticket #1308.
  Thanks to Jim Kusznir for noticing the problem.
- Removed an unused function prototype that caused warnings on
  some systems (e.g., OS X).  See ticket #1274.
- Fix a deadlock in inter-communicator scatter/gather operations.
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  Thanks to Martin Audet for the bug report.  See ticket #1268.


1.2.6
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- Fix a bug in the inter-allgather for asymmetric inter-communicators.
  Thanks to Martin Audet for the bug report. See ticket #1247.
- Fix a bug in the openib BTL when setting the CQ depth.  Thanks
  to Jon Mason for the bug report and fix.  See ticket #1245.
- On Mac OS X Leopard, the execinfo component will be used for
  backtraces, making for a more durable solution.  See ticket #1246.
- Added vendor IDs for some QLogic DDR openib HCAs. See ticket #1227.
- Updated the URL to get the latest config.guess and config.sub files.
  Thanks to Ralf Wildenhues for the bug report. See ticket #1226.
- Added shared contexts support to PSM MTL.  See ticket #1225.
- Added pml_ob1_use_early_completion MCA parameter to allow users
  to turn off the OB1 early completion semantic and avoid "stall"
  problems seen on InfiniBand in some cases.  See ticket #1224.
- Sanitized some #define macros used in mpi.h to avoid compiler warnings
  caused by MPI programs built with different autoconf versions.
  Thanks to Ben Allan for reporting the problem, and thanks to
  Brian Barrett for the fix. See ticket #1220.
- Some man page fixes from the Debian maintainers. See ticket #1219.
- Made the openib BTL a bit more resilient in the face of driver
  errors.  See ticket #1217.
- Fixed F90 interface for MPI_CART_CREATE.  See ticket #1208.
  Thanks to Michal Charemza for reporting the problem.
- Fixed some C++ compiler warnings. See ticket #1203.
- Fixed formatting of the orterun man page.  See ticket #1202.
  Thanks to Peter Breitenlohner for the patch.


1.2.5
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- Fixed compile issue with open() on Fedora 8 (and newer) platforms.
  Thanks to Sebastian Schmitzdorff for noticing the problem.
- Added run-time warnings during MPI_INIT when MPI_THREAD_MULTIPLE
  and/or progression threads are used (the OMPI v1.2 series does not
  support these well at all).
- Better handling of ECONNABORTED from connect on Linux.  Thanks to
  Bob Soliday for noticing the problem; thanks to Brian Barrett for
  submitting a patch.
- Reduce extraneous output from OOB when TCP connections must
  be retried.  Thanks to Brian Barrett for submitting a patch.
- Fix for ConnectX devices and OFED 1.3.  See ticket #1190.
- Fixed a configure problem for Fortran 90 on Cray systems.  Ticket #1189.
- Fix an uninitialized variable in the error case in opal_init.c.
  Thanks to Ake Sandgren for pointing out the mistake.
- Fixed a hang in configure if $USER was not defined.  Thanks to
  Darrell Kresge for noticing the problem.  See ticket #900.
- Added support for parallel debuggers even when we have an optimized build.
  See ticket #1178.
- Worked around a bus error in the Mac OS X 10.5.X (Leopard) linker when
  compiling Open MPI with -g.  See ticket #1179.
- Removed some warnings about 'rm' from Mac OS X 10.5 (Leopard) builds.
- Fix the handling of mx_finalize().  See ticket #1177.
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  Thanks to Ake Sandgren for bringing this issue to our attention.
- Fixed minor file descriptor leak in the Altix timer code.  Thanks to
  Paul Hargrove for noticing the problem and supplying the fix.
- Fix a problem when using a different compiler for C and Objective C.
  See ticket #1153.
- Fix segfault in MPI_COMM_SPAWN when the user specified a working
  directory.  Thanks to Murat Knecht for reporting this and suggesting
  a fix.
- A few manpage fixes from the Debian Open MPI maintainers.  Thanks to
  Tilman Koschnick, Sylvestre Ledru, and Dirk Eddelbuettel.
- Fixed issue with pthread detection when compilers are not all
  from the same vendor.  Thanks to Ake Sandgren for the bug
  report.  See ticket #1150.
- Fixed vector collectives in the self module.  See ticket #1166.
- Fixed some data-type engine bugs: an indexing bug, and an alignment bug.
  See ticket #1165.
- Only set the MPI_APPNUM attribute if it is defined.  See ticket
  #1164.


1.2.4
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- Really added support for TotalView/DDT parallel debugger message queue
  debugging (it was mistakenly listed as "added" in the 1.2 release).
- Fixed a build issue with GNU/kFreeBSD. Thanks to Petr Salinger for
  the patch.
- Added missing MPI_FILE_NULL constant in Fortran.  Thanks to
  Bernd Schubert for bringing this to our attention.
- Change such that the UDAPL BTL is now only built in Linux when
  explicitly specified via the --with-udapl configure command line
  switch.
- Fixed an issue with umask not being propagated when using the TM
  launcher.
- Fixed behavior if number of slots is not the same on all bproc nodes.
- Fixed a hang on systems without GPR support (ex. Cray XT3/4).
- Prevent users of 32-bit MPI apps from requesting >= 2GB of shared
  memory.
- Added a Portals MTL.
- Fix 0 sized MPI_ALLOC_MEM requests.  Thanks to Lisandro Dalcin for
  pointing out the problem.
- Fixed a segfault crash on large SMPs when doing collectives.
- A variety of fixes for Cray XT3/4 class of machines.
- Fixed which error handler is used when MPI_COMM_SELF is passed
  to MPI_COMM_FREE.  Thanks to Lisandro Dalcini for the bug report.
- Fixed compilation on platforms that don't have hton/ntoh.
- Fixed a logic problem in the fortran binding for MPI_TYPE_MATCH_SIZE.
  Thanks to Jeff Dusenberry for pointing out the problem and supplying
  the fix.
- Fixed a problem with MPI_BOTTOM in various places of the f77-interface.
  Thanks to Daniel Spangberg for bringing this up.
- Fixed problem where MPI-optional Fortran datatypes were not
  correctly initialized.
- Fixed several problems with stdin/stdout forwarding.
- Fixed overflow problems with the sm mpool MCA parameters on large SMPs.
- Added support for the DDT parallel debugger via orterun's --debug
  command line option.
- Added some sanity/error checks to the openib MCA parameter parsing
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  code.
- Updated the udapl BTL to use RDMA capabilities.
- Allow use of the BProc head node if it was allocated to the user.
  Thanks to Sean Kelly for reporting the problem and helping debug it.
- Fixed a ROMIO problem where non-blocking I/O errors were not properly
  reported to the user.
- Made remote process launch check the $SHELL environment variable if
  a valid shell was not otherwise found for the user.
  Thanks to Alf Wachsmann for the bugreport and suggested fix.
- Added/updated some vendor IDs for a few openib HCAs.
- Fixed a couple of failures that could occur when specifying devices
  for use by the OOB.
- Removed dependency on sysfsutils from the openib BTL for
  libibverbs >=v1.1 (i.e., OFED 1.2 and beyond).


1.2.3
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- Fix a regression in comm_spawn functionality that inadvertently
  caused the mapping of child processes to always start at the same
  place.  Thanks to Prakash Velayutham for helping discover the
  problem.
- Fix segfault when a user's home directory is unavailable on a remote
  node.  Thanks to Guillaume Thomas-Collignon for bringing the issue
  to our attention.
- Fix MPI_IPROBE to properly handle MPI_STATUS_IGNORE on mx and psm
  MTLs. Thanks to Sophia Corwell for finding this and supplying a
  reproducer.
- Fix some error messages in the tcp BTL.
- Use _NSGetEnviron instead of environ on Mac OS X so that there
  are no undefined symbols in the shared libraries.
- On OS X, when MACOSX_DEPLOYMENT_TARGET is 10.3 or higher, support
  building the Fortran 90 bindings as a shared library.  Thanks to
  Jack Howarth for his advice on making this work.
- No longer require extra include flag for the C++ bindings.
- Fix detection of weak symbols support with Intel compilers.
- Fix issue found by Josh England: ompi_info would not show framework
  MCA parameters set in the environment properly.
- Rename the oob_tcp_include/exclude MCA params to oob_tcp_if_include/exclude
  so that they match the naming convention of the btl_tcp_if_include/exclude
  params.  The old names are depreciated, but will still work.
- Add -wd as a synonym for the -wdir orterun/mpirun option.
- Fix the mvapi BTL to compile properly with compilers that do not support
  anonymous unions.  Thanks to Luis Kornblueh for reporting the bug.


1.2.2
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- Fix regression in 1.2.1 regarding the handling of $CC with both
  absolute and relative path names.
- Fix F90 array of status dimensions.  Thanks to Randy Bramley for
  noticing the problem.
- Add btl_openib_ib_pkey_value MCA parameter for controlling IB port selection.
- Fixed a variety of threading/locking bugs.
- Fixed some compiler warnings associated with ROMIO, OS X, and gridengine.
- If pbs-config can be found, use it to look for TM support.  Thanks
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  to Bas van der Vlies for the inspiration and preliminary work.
- Fixed a deadlock in orterun when the rsh PLS encounters some errors.


1.2.1
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- Fixed a number of connection establishment errors in the TCP out-
  of-band messaging system.
- Fixed a memory leak when using mpi_comm calls.
  Thanks to Bas van der Vlies for reporting the problem.
- Fixed various memory leaks in OPAL and ORTE.
- Improved launch times when using TM (PBS Pro, Torque, Open PBS).
- Fixed mpi_leave_pinned to work for all datatypes.
- Fix functionality allowing users to disable sbrk() (the
  mpool_base_disable_sbrk MCA parameter) on platforms that support it.
- Fixed a pair of problems with the TCP "listen_thread" mode for the
  oob_tcp_listen_mode MCA parameter that would cause failures when
  attempting to launch applications.
- Fixed a segfault if there was a failure opening a BTL MX endpoint.
- Fixed a problem with mpirun's --nolocal option introduced in 1.2.
- Re-enabled MPI_COMM_SPAWN_MULTIPLE from singletons.
- LoadLeveler and TM configure fixes, Thanks to Martin Audet for the
  bug report.
- Various C++ MPI attributes fixes.
- Fixed issues with backtrace code on 64 bit Intel & PPC OS X builds.
- Fixed issues with multi-word CC variables and libtool.
  Thanks to Bert Wesarg for the bug reports.
- Fix issue with non-uniform node naming schemes in SLURM.
- Fix file descriptor leak in the Grid Engine/N1GE support.
- Fix compile error on OS X 10.3.x introduced with Open MPI 1.1.5.
- Implement MPI_TYPE_CREATE_DARRAY function (was in 1.1.5 but not 1.2).
- Recognize zsh shell when using rsh/ssh for launching MPI jobs.
- Ability to set the OPAL_DESTDIR or OPAL_PREFIX environment
  variables to "re-root" an existing Open MPI installation.
- Always include -I for Fortran compiles, even if the prefix is
  /usr/local.
- Support for "fork()" in MPI applications that use the
  OpenFabrics stack (OFED v1.2 or later).
- Support for setting specific limits on registered memory.


1.2
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- Fixed race condition in the shared memory fifo's, which led to
  orphaned messages.
- Corrected the size of the shared memory file - subtracted out the
  space the header was occupying.
- Add support for MPI_2COMPLEX and MPI_2DOUBLE_COMPLEX.
- Always ensure to create $(includedir)/openmpi, even if the C++
  bindings are disabled so that the wrapper compilers don't point to
  a directory that doesn't exist.  Thanks to Martin Audet for
  identifying the problem.
- Fixes for endian handling in MPI process startup.
- Openib BTL initialization fixes for cases where MPI processes in the
  same job has different numbers of active ports on the same physical
  fabric.
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- Print more descriptive information when displaying backtraces on
  OS's that support this functionality, such as the hostname and PID
  of the process in question.
- Fixes to properly handle MPI exceptions in C++ on communicators,
  windows, and files.
- Much more reliable runtime support, particularly with regards to MPI
  job startup scalability, BProc support, and cleanup in failure
  scenarios (e.g., MPI_ABORT, MPI processes abnormally terminating,
  etc.).
- Significant performance improvements for MPI collectives,
  particularly on high-speed networks.
- Various fixes in the MX BTL component.
- Fix C++ typecast problems with MPI_ERRCODES_IGNORE.  Thanks to
  Satish Balay for bringing this to our attention.
- Allow run-time specification of the maximum amount of registered
  memory for OpenFabrics and GM.
- Users who utilize the wrapper compilers (e.g., mpicc and mpif77)
  will not notice, but the underlying library names for ORTE and OPAL
  have changed to libopen-rte and libopen-pal, respectively (listed
  here because there are undoubtedly some users who are not using the
  wrapper compilers).
- Many bug fixes to MPI-2 one-sided support.
- Added support for TotalView message queue debugging.
- Fixes for MPI_STATUS_SET_ELEMENTS.
- Print better error messages when mpirun's "-nolocal" is used when
  there is only one node available.
- Added man pages for several Open MPI executables and the MPI API
  functions.
- A number of fixes for Alpha platforms.
- A variety of Fortran API fixes.
- Build the Fortran MPI API as a separate library to allow these
  functions to be profiled properly.
- Add new --enable-mpirun-prefix-by-default configure option to always
  imply the --prefix option to mpirun, preventing many rsh/ssh-based
  users from needing to modify their shell startup files.
- Add a number of missing constants in the C++ bindings.
- Added tight integration with Sun N1 Grid Engine (N1GE) 6 and the
  open source Grid Engine.
- Allow building the F90 MPI bindings as shared libraries for most
  compilers / platforms.  Explicitly disallow building the F90
  bindings as shared libraries on OS X because of complicated
  situations with Fortran common blocks and lack of support for
  unresolved common symbols in shared libraries.
- Added stacktrace support for Solaris and Mac OS X.
- Update event library to libevent-1.1b.
- Fixed standards conformance issues with MPI_ERR_TRUNCATED and
  setting MPI_ERROR during MPI_TEST/MPI_WAIT.
- Addition of "cm" PML to better support library-level matching
  interconnects, with support for Myrinet/MX, and QLogic PSM-based
  networks.
- Addition of "udapl" BTL for transport across uDAPL interconnects.
- Really check that the $CXX given to configure is a C++ compiler
  (not a C compiler that "sorta works" as a C++ compiler).
- Properly check for local host only addresses properly, looking
  for 127.0.0.0/8, rather than just 127.0.0.1.


1.1.5
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- Implement MPI_TYPE_CREATE_DARRAY function.
- Fix race condition in shared memory BTL startup that could cause MPI
  applications to hang in MPI_INIT.
- Fix syntax error in a corner case of the event library.  Thanks to
  Bert Wesarg for pointing this out.
- Add new MCA parameter (mpi_preconnect_oob) for pre-connecting the
  "out of band" channels between all MPI processes.  Most helpful for
  MPI applications over InfiniBand where process A sends an initial
  message to process B, but process B does not enter the MPI library
  for a long time.
- Fix for a race condition in shared memory locking semantics.
- Add major, minor, and release version number of Open MPI to mpi.h.
  Thanks to Martin Audet for the suggestion.
- Fix the "restrict" compiler check in configure.
- Fix a problem with argument checking in MPI_TYPE_CREATE_SUBARRAY.
- Fix a problem with compiling the XGrid components with non-gcc
  compilers.


1.1.4
-----

- Fixed 64-bit alignment issues with TCP interface detection on
  intel-based OS X machines.
- Adjusted TCP interface selection to automatically ignore Linux
  channel-bonded slave interfaces.
- Fixed the type of the first parameter to the MPI F90 binding for
  MPI_INITIALIZED.  Thanks to Tim Campbell for pointing out the
  problem.
- Fix a bunch of places in the Fortran MPI bindings where (MPI_Fint*)
  was mistakenly being used instead of (MPI_Aint*).
- Fixes for fortran MPI_STARTALL, which could sometimes return
  incorrect request values.  Thanks to Tim Campbell for pointing out
  the problem.
- Include both pre- and post-MPI-2 errata bindings for
  MPI::Win::Get_attr.
- Fix math error on Intel OS X platforms that would greatly increase
  shared memory latency.
- Fix type casting issue with MPI_ERRCODES_IGNORE that would cause
  errors when using a C++ compiler.  Thanks to Barry Smith for
  bringing this to our attention.
- Fix possible segmentation fault during shutdown when using the
  MX BTL.


1.1.3
-----

- Remove the "hierarch" coll component; it was not intended to be
  included in stable releases yet.
- Fix a race condition with stdout/stderr not appearing properly from
  all processes upon termination of an MPI job.
- Fix internal accounting errors with the self BTL.
- Fix typos in the code path for when sizeof(int) != sizeof(INTEGER)
  in the MPI F77 bindings functions.  Thanks to Pierre-Matthieu
  Anglade for bringing this problem to our attention.
```

```
- Fix for a memory leak in the derived datatype function
  ompi_ddt_duplicate().  Thanks to Andreas Schafer for reporting,
  diagnosing, and patching the leak.
- Used better performing basic algorithm for MPI_ALLGATHERV.
- Added a workaround for a bug in the Intel 9.1 C++ compiler (all
  versions up to and including 20060925) in the MPI C++ bindings that
  caused run-time failures.  Thanks to Scott Weitzenkamp for reporting
  this problem.
- Fix MPI_SIZEOF implementation in the F90 bindings for COMPLEX
  variable types.
- Fixes for persistent requests involving MPI_PROC_NULL.  Thanks to
  Lisandro Dalcin for reporting the problem.
- Fixes to MPI_TEST* and MPI_WAIT* for proper MPI exception reporting.
  Thanks to Lisandro Dalcin for finding the issue.
- Various fixes for MPI generalized request handling; addition of
  missing MPI::Grequest functionality to the C++ bindings.
- Add "mpi_preconnect_all" MCA parameter to force wireup of all MPI
  connections during MPI_INIT (vs. making connections lazily whenever
  the first MPI communication occurs between a pair of peers).
- Fix a problem for when $FC and/or $F77 were specified as multiple
  tokens.  Thanks to Orion Poplawski for identifying the problem and
  to Ralf Wildenhues for suggesting the fix.
- Fix several MPI_*ERRHANDLER* functions and MPI_GROUP_TRANSLATE_RANKS
  with respect to what arguments they allowed and the behavior that
  they effected.  Thanks to Lisandro Dalcin for reporting the
  problems.


1.1.2
-----

- Really fix Fortran status handling in MPI_WAITSOME and MPI_TESTSOME.
- Various datatype fixes, reported by several users as causing
  failures in the BLACS testing suite.  Thanks to Harald Forbert, Ake
  Sandgren and, Michael Kluskens for reporting the problem.
- Correctness and performance fixes for heterogeneous environments.
- Fixed a error in command line parsing on some platforms (causing
  mpirun to crash without doing anything).
- Fix for initialization hangs on 64 bit Mac OS X PowerPC systems.
- Fixed some memory allocation problems in mpirun that could cause
  random problems if "-np" was not specified on the command line.
- Add Kerberos authentication support for XGrid.
- Added LoadLeveler support for jobs larger than 128 tasks.
- Fix for large-sized Fortran LOGICAL datatypes.
- Fix various error checking in MPI_INFO_GET_NTHKEY and
  MPI_GROUP_TRANSLATE_RANKS, and some collective operations
  (particularly with regards to MPI_IN_PLACE).  Thanks to Lisandro
  Dalcin for reporting the problems.
- Fix receiving messages to buffers allocated by MPI_ALLOC_MEM.
- Fix a number of race conditions with the MPI-2 Onesided
  interface.
- Fix the "tuned" collective componenete where some cases where
  MPI_BCAST could hang.
- Update TCP support to support non-uniform TCP environments.
- Allow the "poe" RAS component to be built on AIX or Linux.
- Only install mpif.h if the rest of the Fortran bindings are
  installed.
- Fixes for BProc node selection.
- Add some missing Fortran MPI-2 IO constants.


1.1.1
-----

- Fix for Fortran string handling in various MPI API functions.
- Fix for Fortran status handling in MPI_WAITSOME and MPI_TESTSOME.
- Various fixes for the XL compilers.
- Automatically disable using mallot() on AIX.
- Memory fixes for 64 bit platforms with registering MCA parameters in
  the self and MX BTL components.
- Fixes for BProc to support oversubscription and changes to the
  mapping algorithm so that mapping processes "by slot" works as
  expected.
- Fixes for various abort cases to not hang and clean up nicely.
- If using the Intel 9.0 v20051201 compiler on an IA64 platform, the
  ptmalloc2 memory manager component will automatically disable
  itself.  Other versions of the Intel compiler on this platform seem
  to work fine (e.g., 9.1).
- Added "host" MPI_Info key to MPI_COMM_SPAWN and
  MPI_COMM_SPAWN_MULTIPLE.
- Add missing C++ methods: MPI::Datatype::Create_indexed_block,
  MPI::Datatype::Create_resized, MPI::Datatype::Get_true_extent.
- Fix OSX linker issue with Fortran bindings.
- Fixed MPI_COMM_SPAWN to start spawning new processes in slots that
  (according to Open MPI) are not already in use.
- Added capability to "mpirun a.out" (without specifying -np) that
  will run on all currently-allocated resources (e.g., within a batch
  job such as SLURM, Torque, etc.).
- Fix a bug with one particular case of MPI_BCAST.  Thanks to Doug
  Gregor for identifying the problem.
- Ensure that the shared memory mapped file is only created when there
  is more than one process on a node.
- Fixed problems with BProc stdin forwarding.
- Fixed problem with MPI_TYPE_INDEXED datatypes.  Thanks to Yven
  Fournier for identifying this problem.
- Fix some thread safety issues in MPI attributes and the openib BTL.
- Fix the BProc allocator to not potentially use the same resources
  across multiple ORTE universes.
- Fix gm resource leak.
- More latency reduction throughout the code base.
- Make the TM PLS (PBS Pro, Torque, Open PBS) more scalable, and fix
  some latent bugs that crept in v1.1.  Thanks to the Thunderbird crew
  at Sandia National Laboratories and Martin Schaffoner for access to
  testing facilities to make this happen.
- Added new command line options to mpirun:
  --nolocal: Do not run any MPI processes on the same node as mpirun
    (compatibility with the OSC mpiexec launcher)
  --nooversubscribe: Abort if the number of processes requested would
    cause oversubscription
  --quiet / -q: do not show spurious status messages
  --version / -V: show the version of Open MPI
- Fix bus error in XGrid process starter.  Thanks to Frank from the
  Open MPI user's list for identifying the problem.
- Fix data size mismatches that caused memory errors on PPC64
  platforms during the startup of the openib BTL.
- Allow propagation of SIGUSR1 and SIGUSR2 signals from mpirun to
```

```
  back-end MPI processes.
- Add missing MPI::Is_finalized() function.


1.1
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- Various MPI datatype fixes, optimizations.
- Fixed various problems on the SPARC architecture (e.g., not
  correctly aligning addresses within structs).
- Improvements in various run-time error messages to be more clear
  about what they mean and where the errors are occurring.
- Various fixes to mpirun's handling of --prefix.
- Updates and fixes for Cray/Red Storm support.
- Major improvements to the Fortran 90 MPI bindings:
  - General improvements in compile/linking time and portability
    between different F90 compilers.
  - Addition of "trivial", "small" (the default), and "medium"
    Fortran 90 MPI module sizes (v1.0.x's F90 module was
    equivalent to "medium").  See the README file for more
    explanation.
  - Fix various MPI F90 interface functions and constant types to
    match.  Thanks to Michael Kluskens for pointing out the problems
    to us.
- Allow short messagees to use RDMA (vs. send/receive semantics) to a
  limited number peers in both the mvapi and openib BTL components.
  This reduces communication latency over IB channels.
- Numerous performance improvements throughout the entire code base.
- Many minor threading fixes.
- Add a define OMPI_SKIP_CXX to allow the user to skip the mpicxx.h from
  being included in mpi.h. It allows the user to compile C code with a CXX
  compiler without including the CXX bindings.
- PERUSE support has been added. In order to activate it add
  --enable-peruse to the configure options. All events described in
  the PERUSE 2.0 draft are supported, plus one Open MPI
  extension. PERUSE_COMM_REQ_XFER_CONTINUE allow to see how the data
  is segmented internally, using multiple interfaces or the pipeline
  engine. However, this version only support one event of each type
  simultaneously attached to a communicator.
- Add support for running jobs in heterogeneous environments.
  Currently supports environments with different endianness and
  different representations of C++ bool and Fortran LOGICAL.
  Mismatched sizes for other datatypes is not supported.
- Open MPI now includes an implementation of the MPI-2 One-Sided
  Communications specification.
- Open MPI is now configurable in cross-compilation environments.
  Several Fortran 77 and Fortran 90 tests need to be pre-seeded with
  results from a config.cache-like file.
- Add --debug option to mpirun to generically invoke a parallel debugger.


1.0.3: Not released (all fixes included in 1.1)
-----------------------------------------------

- Fix a problem noted by Chris Hennes where MPI_INFO_SET incorrectly
  disallowed long values.
- Fix a problem in the launch system that could cause inconsistent
  launch behavior, particularly when launching large jobs.
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- Require that the openib BTL find <sysfs/libsysfs.h>.  Thanks to Josh
  Aune for the suggestion.
- Include updates to support the upcoming Autoconf 2.60 and Libtool
  2.0.  Thanks to Ralf Wildenhues for all the work!
- Fix bug with infinite loop in the "round robin" process mapper.
  Thanks to Paul Donohue for reporting the problem.
- Enusre that memory hooks are removed properly during MPI_FINALIZE.
  Thanks to Neil Ludban for reporting the problem.
- Various fixes to the included support for ROMIO.
- Fix to ensure that MPI_LONG_LONG and MPI_LONG_LONG_INT are actually
  synonyms, as defined by the MPI standard.  Thanks to Martin Audet
  for reporting this.
- Fix Fortran 90 configure tests to properly utilize LDFLAGS and LIBS.
  Thanks to Terry Reeves for reporting the problem.
- Fix shared memory progression in asynchronous progress scenarios.
  Thanks to Mykael Bouquey for reporting the problem.
- Fixed back-end operations for predefined MPI_PROD for some
  datatypes.  Thanks to Bert Wesarg for reporting this.
- Adapted configure to be able to handle Torque 2.1.0p0's (and above)
  new library name.  Thanks to Brock Palen for pointing this out and
  providing access to a Torque 2.1.0p0 cluster to test with.
- Fixed situation where mpirun could set a shell pipeline's stdout
  to non-blocking, causing the shell pipeline to prematurely fail.
  Thanks to Darrell Kresge for figuring out what was happening.
- Fixed problems with leave_pinned that could cause Badness with the
  mvapi BTL.
- Fixed problems with MPI_FILE_OPEN and non-blocking MPI-2 IO access.
- Fixed various InfiniBand port matching issues during startup.
  Thanks to Scott Weitzenkamp for identifying these problems.
- Fixed various configure, build and run-time issues with ROMIO.
  Thanks to Dries Kimpe for bringing them to our attention.
- Fixed error in MPI_COMM_SPLIT when dealing with intercommunicators.
  Thanks to Bert Wesarg for identifying the problem.
- Fixed backwards handling of "high" parameter in MPI_INTERCOMM_MERGE.
  Thanks to Michael Kluskens for pointing this out to us.
- Fixed improper handling of string arguments in Fortran bindings
  for MPI-IO functionality
- Fixed segmentation fault with 64 bit applications on Solaris when
  using the shared memory transports.
- Fixed MPI_COMM_SELF attributes to free properly at the beginning of
  MPI_FINALIZE.  Thanks to Martin Audet for bringing this to our
  attention.
- Fixed alignment tests for cross-compiling to not cause errors with
  recent versions of GCC.


1.0.2
-----

- Fixed assembly race condition on AMD64 platforms.
- Fixed residual .TRUE. issue with copying MPI attributes set from
  Fortran.
- Remove unnecessary logic from Solaris pty I/O forwarding.  Thanks to
  Francoise Roch for bringing this to our attention.
- Fixed error when count = 0 was given for multiple completion MPI
  functions (MPI_TESTSOME, MPI_TESTANY, MPI_TESTALL, MPI_WAITSOME,
  MPI_WAITANY, MPI_WAITALL).
- Better handling in MPI_ABORT for when peer processes have already
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  died, especially under some resource managers.
- Random updates to README file, to include notes about the Portland
  compilers.
- Random, small threading fixes to prevent deadlock.
- Fixed a problem with handling long mpirun app files.  Thanks to Ravi
  Manumachu for identifying the problem.
- Fix handling of strings in several of the Fortran 77 bindings.
- Fix LinuxPPC assembly issues.  Thanks to Julian Seward for reporting
  the problem.
- Enable pty support for standard I/O forwarding on platforms that
  have ptys but do not have openpty().  Thanks to Pierre Valiron for
  bringing this to our attention.
- Disable inline assembly for PGI compilers to avoid compiler errors.
  Thanks to Troy Telford for bringing this to our attention.
- Added MPI_UNSIGNED_CHAR and MPI_SIGNED_CHAR to the allowed reduction
  types.
- Fix a segv in variable-length message displays on Opterons running
  Solaris.  Thanks to Pierre Valiron for reporting the issue.
- Added MPI_BOOL to the intrinsic reduction operations MPI_LAND,
  MPI_LOR, MPI_LXOR.  Thanks to Andy Selle for pointing this out to us.
- Fixed TCP BTL network matching logic during MPI_INIT; in some cases
  on multi-NIC nodes, a NIC could get paired with a NIC on another
  network (typically resulting in deadlock).  Thanks to Ken Mighell
  for pointing this out to us.
- Change the behavior of orterun (mpirun, mpirexec) to search for
  argv[0] and the cwd on the target node (i.e., the node where the
  executable will be running in all systems except BProc, where the
  searches are run on the node where orterun is invoked).
- Fix race condition in shared memory transport that could cause
  crashes on machines with weak memory consistency models (including
  POWER/PowerPC machines).
- Fix warnings about setting read-only MCA parameters on bproc systems.
- Change the exit status set by mpirun when an application process is
  killed by a signal.  The exit status is now set to signo + 128, which
  conforms with the behavior of (almost) all shells.
- Correct a datatype problem with the convertor when partially
  unpacking data. Now we can position the convertor to any position
  not only on the predefined types boundaries. Thanks to Yvan Fournier
  for reporting this to us.
- Fix a number of standard I/O forwarding issues, including the
  ability to background mpirun and a loss of data issue when
  redirecting mpirun's standard input from a file.
- Fixed bug in ompi_info where rcache and bml MCA parameters would not
  be displayed.
- Fixed umask issues in the session directory.  Thanks to Glenn Morris
  for reporting this to us.
- Fixed tcsh-based LD_LIBRARY_PATH issues with --prefix.  Thanks to
  Glen Morris for identifying the problem and suggesting the fix.
- Removed extraneous \n's when setting PATH and LD_LIBRARY_PATH in the
  rsh startup.  Thanks to Glen Morris for finding these typos.
- Fixed missing constants in MPI C++ bindings.
- Fixed some errors caused by threading issues.
- Fixed openib BTL flow control logic to not overrun the number of
  send wqes available.
- Update to match newest OpenIB user-level library API.  Thanks to
  Roland Dreier for submitting this patch.
- Report errors properly when failing to register memory in the openib
  BTL.
```

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- Reduce memory footprint of openib BTL.
- Fix parsing problem with mpirun's "-tv" switch.  Thanks to Chris
  Gottbrath for supplying the fix.
- Fix Darwin net/if.h configure warning.
- The GNU assembler unbelievably defaults to making stacks executable.
  So when using gas, add flags to explicitly tell it to not make
  stacks executable (lame but necessary).
- Add missing MPI::Request::Get_status() methods.  Thanks to Bill
  Saphir for pointing this out to us.
- Improved error messages on memory registration errors (e.g., when
  using high-speed networks).
- Open IB support now checks firmware for how many outstanding RDMA
  requests are supported.  Thanks to Mellanox for pointing this out to
  us.
- Enable printing of stack traces in MPI processes upon SIGBUS,
  SIGSEGV, and SIGFPE if the platform supports it.
- Fixed F90 compilation support for the Lahey compiler.
- Fixed issues with ROMIO shared library support.
- Fixed internal accounting problems with rsh support.
- Update to GNU Libtool 1.5.22.
- Fix error in configure script when setting CCAS to ias (the Intel
  assembler).
- Added missing MPI::Intercomm collectives.
- Fixed MPI_IN_PLACE handling for Fortran collectives.
- Fixed some more C++ const_cast<> issues.  Thanks for Martin Audet
  (again) for bringing this to our attention.
- Updated ROMIO with the version from MPICH 1.2.7p1, marked as version
  2005-06-09.
- Fixes for some cases where the use of MPI_BOTTOM could cause
  problems.
- Properly handle the case where an mVAPI does not have shared receive
  queue support (such as the one shipped by SilverStorm / Infinicon
  for OS X).


1.0.1
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- Fixed assembly on Solaris AMD platforms.  Thanks to Pierre Valiron
  for bringing this to our attention.
- Fixed long messages in the send-to-self case.
- Ensure that when the "leave_pinned" option is used, the memory hooks
  are also enabled.  Thanks to Gleb Natapov for pointing this out.
- Fixed compile errors for IRIX.
- Allow hostfiles to have integer host names (for BProc clusters).
- Fixed a problem with message matching of out-of-order fragments in
  multiple network device scenarios.
- Converted all the C++ MPI bindings to use proper const_cast<>'s
  instead of old C-style casts to get rid of const-ness.  Thanks to
  Martin Audet for raising the issue with us.
- Converted MPI_Offset to be a typedef instead of a #define because it
  causes problems for some C++ parsers.  Thanks to Martin Audet for
  bringing this to our attention.
- Improved latency of TCP BTL.
- Fixed index value in MPI_TESTANY to be MPI_UNDEFINED if some
  requests were not MPI_REQUEST_NULL, but no requests finished.
- Fixed several Fortran MPI API implementations that incorrectly used
  integers instead of logicals or address-sized integers.
```

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- Fix so that Open MPI correctly handles the Fortran value for .TRUE.,
  regardless of what the Fortran compiler's value for .TRUE. is.
- Improved scalability of MX startup.
- Fix datatype offset handling in the coll basic component's
  MPI_SCATTERV implementation.
- Fix EOF handling on stdin.
- Fix missing MPI_F_STATUS_IGNORE and MPI_F_STATUSES_IGNORE
  instanatiations.  Thanks to Anthony Chan for pointing this out.
- Add a missing value for MPI_WIN_NULL in mpif.h.
- Bring over some fixes for the sm btl that somehow didn't make it
  over from the trunk before v1.0.  Thanks to Beth Tibbitts and Bill
  Chung for helping identify this issue.
- Bring over some fixes for the iof that somehow didn't make it over
  from the trunk before v1.0.
- Fix for --with-wrapper-ldflags handling.  Thanks to Dries Kimpe for
  pointing this out to us.


1.0: 17 Nov 2005
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Initial public release.
```

5.11 MPICH2 Release Information

The following is reproduced essentially verbatim from files contained within the MPICH2 tarball downloaded from http://www.mpich.org/downloads/.

NOTE: MPICH-2 has been effectively deprecated by the Open Source Community in favor of MPICH-3, which Scyld ClusterWare distributes as a set of *mpich-scyld* RPMs. Scyld ClusterWare continues to distribute *mpich2-scyld*, although we encourage users to migrate to MPICH-3, which enjoys active support by the Community.

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===============================================================================
                               Changes in 1.5
===============================================================================

 # OVERALL: Nemesis now supports an "--enable-yield=..." configure
   option for better performance/behavior when oversubscribing
   processes to cores.  Some form of this option is enabled by default
   on Linux, Darwin, and systems that support sched_yield().

 # OVERALL: Added support for Intel Many Integrated Core (MIC)
   architecture: shared memory, TCP/IP, and SCIF based communication.

 # OVERALL: Added support for IBM BG/Q architecture.  Thanks to IBM
   for the contribution.

 # MPI-3: const support has been added to mpi.h, although it is
   disabled by default.  It can be enabled on a per-translation unit
   basis with "#define MPICH2_CONST const".

 # MPI-3: Added support for MPIX_Type_create_hindexed_block.

 # MPI-3: The new MPI-3 nonblocking collective functions are now
   available as "MPIX_" functions (e.g., "MPIX_Ibcast").
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# MPI-3: The new MPI-3 neighborhood collective routines are now available as
  "MPIX_" functions (e.g., "MPIX_Neighbor_allgather").

# MPI-3: The new MPI-3 MPI_Comm_split_type function is now available
  as an "MPIX_" function.

# MPI-3: The new MPI-3 tools interface is now available as "MPIX_T_"
  functions.  This is a beta implementation right now with several
  limitations, including no support for multithreading.  Several
  performance variables related to CH3's message matching are exposed
  through this interface.

# MPI-3: The new MPI-3 matched probe functionality is supported via
  the new routines MPIX_Mprobe, MPIX_Improbe, MPIX_Mrecv, and
  MPIX_Imrecv.

# MPI-3: The new MPI-3 nonblocking communicator duplication routine,
  MPIX_Comm_idup, is now supported.  It will only work for
  single-threaded programs at this time.

# MPI-3: MPIX_Comm_reenable_anysource support

# MPI-3: Native MPIX_Comm_create_group support (updated version of
  the prior MPIX_Group_comm_create routine).

# MPI-3: MPI_Intercomm_create's internal communication no longer interferes
  with point-to-point communication, even if point-to-point operations on the
  parent communicator use the same tag or MPI_ANY_TAG.

# MPI-3: Eliminated the possibility of interference between
  MPI_Intercomm_create and point-to-point messaging operations.

# Build system: Completely revamped build system to rely fully on
  autotools.  Parallel builds ("make -j8" and similar) are now supported.

# Build system: rename "./maint/updatefiles" --> "./autogen.sh" and
  "configure.in" --> "configure.ac"

# JUMPSHOT: Improvements to Jumpshot to handle thousands of
  timelines, including performance improvements to slog2 in such
  cases.

# JUMPSHOT: Added navigation support to locate chosen drawable's ends
  when viewport has been scrolled far from the drawable.

# PM/PMI: Added support for memory binding policies.

# PM/PMI: Various improvements to the process binding support in
  Hydra.  Several new pre-defined binding options are provided.

# PM/PMI: Upgraded to hwloc-1.5

# PM/PMI: Several improvements to PBS support to natively use the PBS
  launcher.

# Several other minor bug fixes, memory leak fixes, and code cleanup.
  A full list of changes is available using:
     svn log -r8478:HEAD https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.5

     ... or at the following link:

     https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/
       mpich2-1.5?action=follow_copy&rev=HEAD&stop_rev=8478&mode=follow_copy

===============================================================================
                               Changes in 1.4.1
===============================================================================

 # OVERALL: Several improvements to the ARMCI API implementation
   within MPICH2.

 # Build system: Added beta support for DESTDIR while installing
   MPICH2.

 # PM/PMI: Upgrade hwloc to 1.2.1rc2.

 # PM/PMI: Initial support for the PBS launcher.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.
   A full list of changes is available using:

   svn log -r8675:HEAD \
     https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.4.1

     ... or at the following link:

   https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/
     mpich2-1.4.1?action=follow_copy&rev=HEAD&stop_rev=8675&mode=follow_copy


===============================================================================
                               Changes in 1.4
===============================================================================

 # OVERALL: Improvements to fault tolerance for collective
   operations. Thanks to Rui Wang @ ICT for reporting several of these
   issues.

 # OVERALL: Improvements to the universe size detection. Thanks to
   Yauheni Zelenko for reporting this issue.

 # OVERALL: Bug fixes for Fortran attributes on some systems. Thanks
   to Nicolai Stange for reporting this issue.

 # OVERALL: Added new ARMCI API implementation (experimental).

 # OVERALL: Added new MPIX_Group_comm_create function to allow
   non-collective creation of sub-communicators.

 # FORTRAN: Bug fixes in the MPI_DIST_GRAPH_ Fortran bindings.

 # PM/PMI: Support for a manual "none" launcher in Hydra to allow for
   higher-level tools to be built on top of Hydra. Thanks to Justin
   Wozniak for reporting this issue, for providing several patches for
   the fix, and testing it.
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# PM/PMI: Bug fixes in Hydra to handle non-uniform layouts of hosts
  better. Thanks to the MVAPICH group at OSU for reporting this issue
  and testing it.

# PM/PMI: Bug fixes in Hydra to handle cases where only a subset of
  the available launchers or resource managers are compiled
  in. Thanks to Satish Balay @ Argonne for reporting this issue.

# PM/PMI: Support for a different username to be provided for each
  host; this only works for launchers that support this (such as
  SSH).

# PM/PMI: Bug fixes for using Hydra on AIX machines. Thanks to
  Kitrick Sheets @ NCSA for reporting this issue and providing the
  first draft of the patch.

# PM/PMI: Bug fixes in memory allocation/management for environment
  variables that was showing up on older platforms. Thanks to Steven
  Sutphen for reporting the issue and providing detailed analysis to
  track down the bug.

# PM/PMI: Added support for providing a configuration file to pick
  the default options for Hydra. Thanks to Saurabh T. for reporting
  the issues with the current implementation and working with us to
  improve this option.

# PM/PMI: Improvements to the error code returned by Hydra.

# PM/PMI: Bug fixes for handling "=" in environment variable values in
  hydra.

# PM/PMI: Upgrade the hwloc version to 1.2.

# COLLECTIVES: Performance and memory usage improvements for MPI_Bcast
  in certain cases.

# VALGRIND: Fix incorrect Valgrind client request usage when MPICH2 is
  built for memory debugging.

# BUILD SYSTEM: "--enable-fast" and "--disable-error-checking" are once
  again valid simultaneous options to configure.

# TEST SUITE: Several new tests for MPI RMA operations.

# Several other minor bug fixes, memory leak fixes, and code cleanup.
  A full list of changes is available using:

  svn log -r7838:HEAD \
    https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.4

  ... or at the following link:

  https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/
    mpich2-1.4?action=follow_copy&rev=HEAD&stop_rev=7838&mode=follow_copy



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            KNOWN ISSUES
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### Known runtime failures

 * MPI_Alltoall might fail in some cases because of the newly added
   fault-tolerance features. If you are seeing this error, try setting
   the environment variable MPICH_ENABLE_COLL_FT_RET=0.

### Threads

 * ch3:sock does not (and will not) support fine-grained threading.

 * MPI-IO APIs are not currently thread-safe when using fine-grained
   threading (--enable-thread-cs=per-object).

 * ch3:nemesis:tcp fine-grained threading is still experimental and may
   have correctness or performance issues.  Known correctness issues
   include dynamic process support and generalized request support.


### Lacking channel-specific features

 * ch3 does not presently support communication across heterogeneous
   platforms (e.g., a big-endian machine communicating with a
   little-endian machine).

 * ch3:nemesis:mx does not support dynamic processes at this time.

 * Support for "external32" data representation is incomplete. This
   affects the MPI_Pack_external and MPI_Unpack_external routines, as
   well the external data representation capabilities of ROMIO.

 * ch3 has known problems in some cases when threading and dynamic
   processes are used together on communicators of size greater than
   one.


### Build Platforms

 * Builds using the native "make" program on OpenSolaris fail unknown
   reasons.  A workaround is to use GNU Make instead.  See the following
   ticket for more information:

     http://trac.mcs.anl.gov/projects/mpich2/ticket/1122

 * Build fails with Intel compiler suite 13.0, because of weak symbol
   issues in the compiler.  A workaround is to disable weak symbol
   support by passing --disable-weak-symbols to configure.  See the
   following ticket for more information:

     https://trac.mcs.anl.gov/projects/mpich2/ticket/1659

 * The sctp channel is fully supported for FreeBSD and Mac OS X. As of
   the time of this release, bugs in the stack currently existed in
   the Linux kernel, and will hopefully soon be resolved. It is known
   to not work under Solaris and Windows. For Solaris, the SCTP API
   available in the kernel of standard Solaris 10 is a subset of the
   standard API used by the sctp channel. Cooperation with the Sun
   SCTP developers to support ch3:sctp under Solaris for future
   releases is currently ongoing. For Windows, no known kernel-based
   SCTP stack for Windows currently exists.

### Process Managers

 * The MPD process manager can only handle relatively small amounts of
   data on stdin and may also have problems if there is data on stdin
   that is not consumed by the program.

 * The SMPD process manager does not work reliably with threaded MPI
   processes. MPI_Comm_spawn() does not currently work for >= 256
   arguments with smpd.


### Performance issues

 * SMP-aware collectives do not perform as well, in select cases, as
   non-SMP-aware collectives, e.g. MPI_Reduce with message sizes
   larger than 64KiB. These can be disabled by the configure option
   "--disable-smpcoll".

 * MPI_Irecv operations that are not explicitly completed before
   MPI_Finalize is called may fail to complete before MPI_Finalize
   returns, and thus never complete. Furthermore, any matching send
   operations may erroneously fail. By explicitly completed, we mean
   that the request associated with the operation is completed by one
   of the MPI_Test or MPI_Wait routines.


### C++ Binding:

 * The MPI datatypes corresponding to Fortran datatypes are not
   available (e.g., no MPI::DOUBLE_PRECISION).

 * The C++ binding does not implement a separate profiling interface,
   as allowed by the MPI-2 Standard (Section 10.1.10 Profiling).

 * MPI::ERRORS_RETURN may still throw exceptions in the event of an
   error rather than silently returning.
```

5.12 MPICH-3 Release Information

The following is reproduced essentially verbatim from files contained within the MPICH-3 tarball downloaded from https://www.mpich.org. See https://www.mpich.org/documentation/guides for various user guides.

5.12.1 CHANGELOG

```
===============================================================================
                               Changes in 3.2.1
===============================================================================

 # Fixes for platforms with strict memory alignment requirements.
 # Fixes for MPI_Win info management.

 # Fixed a progress bug with MPI generalized requests.

 # Fixed multiple integer overflow bugs in CH3 and ROMIO.

 # Improved detection for Fortran 2008 binding support.

 # Enhanced support for libfabric (OFI) netmod.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.

   A full list of changes is available at the following link:

     http://git.mpich.org/mpich.git/shortlog/v3.2..v3.2.1


===============================================================================
                               Changes in 3.2
===============================================================================

 # Added support for MPI-3.1 features including nonblocking collective I/O,
   address manipulation routines, thread-safety for MPI initialization,
   pre-init functionality, and new MPI_T routines to look up variables
   by name.

 # Fortran 2008 bindings are enabled by default and fully supported.

 # Added support for the Mellanox MXM InfiniBand interface.  (thanks
   to Mellanox for the code contribution).

 # Added support for the Mellanox HCOLL interface for collectives.
   (thanks to Mellanox for the code contribution).

 # Significant stability improvements to the MPICH/portals4
   implementation.

 # Completely revamped RMA infrastructure including several
   scalability improvements, performance improvements, and bug fixes.

 # Added experimental support for Open Fabrics Interfaces (OFI) version 1.0.0.
   https://github.com/ofiwg/libfabric (thanks to Intel for code contribution)

 # The Myrinet MX network module, which had a life cyle from 1.1 till
   3.1.2, has now been deleted.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.

   A full list of changes is available at the following link:

     http://git.mpich.org/mpich.git/shortlog/v3.1.3..v3.2rc1

   A full list of bugs that have been fixed is available at the
   following link:

   https://trac.mpich.org/projects/mpich/
                 query?status=closed&group=resolution&milestone=mpich-3.2
```

```
===============================================================================
                               Changes in 3.1.4
===============================================================================

 # Bug fixes to MPI-3 shared memory functionality.

 # Fixed a bug that prevented Fortran programs from being profiled by PMPI
   libraries written in C.

 # Fixed support for building MPICH on OSX with Intel C/C++ and Fortran compilers.

 # Several bug fixes in ROMIO.

 # Enhancements to the testsuite.

 # Backports support for the Mellanox MXM InfiniBand interface.

 # Backports support for the Mellanox HCOLL interface for collectives.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.

   A full list of changes is available at the following link:

     http://git.mpich.org/mpich.git/shortlog/v3.1.3..v3.1.4


===============================================================================
                               Changes in 3.1.3
===============================================================================

 # Several enhancements to Portals4 support.

 # Several enhancements to PAMI (thanks to IBM for the code contribution).

 # Several enhancements to the CH3 RMA implementation.

 # Several enhancements to ROMIO.

 # Fixed deadlock in multi-threaded MPI_Comm_idup.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.

   A full list of changes is available at the following link:

     http://git.mpich.org/mpich.git/shortlog/v3.1.2..v3.1.3

   A full list of bugs that have been fixed is available at the
   following link:

   https://trac.mpich.org/projects/mpich/ \
             query?status=closed&group=resolution&milestone=mpich-3.1.3


===============================================================================
                               Changes in 3.1.2
===============================================================================

 # Significant enhancements to the BG/Q device, especially for RMA and
```

```
   shared memory functionality.

 # Several enhancements to ROMIO.

 # Upgraded to hwloc-1.9.

 # Added more Fortran 2008 (F08) tests and fixed a few F08 binding bugs.
   Now all MPICH F90 tests have been ported to F08.

 # Updated weak alias support to align with gcc-4.x

 # Minor enhancements to the CH3 RMA implementation.

 # Better implementation of MPI_Allreduce for intercommunicator.

 # Added environment variables to control memory tracing overhead.

 # Added flags to enable C99 mode with Solaris compilers.

 # Updated implementation of MPI-T CVARs of type MPI_CHAR, as interpreted
   in MPI-3.0 Errata.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.

   A full list of changes is available at the following link:

     http://git.mpich.org/mpich.git/shortlog/v3.1.1..v3.1.2

   A full list of bugs that have been fixed is available at the
   following link:

   https://trac.mpich.org/projects/mpich/ \
                query?status=closed&group=resolution&milestone=mpich-3.1.2


===============================================================================
                               Changes in 3.1.1
===============================================================================

 # Blue Gene/Q implementation supports MPI-3. This release contains a
   functional and compliant Blue Gene/Q implementation of the MPI-3 standard.
   Instructions to build on Blue Gene/Q are on the mpich.org wiki:
   http://wiki.mpich.org/mpich/index.php/BGQ

 # Fortran 2008 bindings (experimental). Build with --enable-fortran=all. Must have
   a Fortran 2008 + TS 29113 capable compiler.

 # Significant rework of MPICH library management and which symbols go
   into which libraries.  Also updated MPICH library names to make
   them consistent with Intel MPI, Cray MPI and IBM PE MPI.  Backward
   compatibility links are provided for older mpich-based build
   systems.

 # The ROMIO "Blue Gene" driver has seen significant rework.  We have separated
   "file system" features from "platform" features, since GPFS shows up in more
   places than just Blue Gene

 # New ROMIO options for aggregator selection and placement on Blue Gene
 # Optional new ROMIO two-phase algorithm requiring less communication for
   certain workloads

 # The old ROMIO optimization "deferred open" either stopped working or was
   disabled on several platforms.

 # Added support for powerpcle compiler. Patched libtool in MPICH to support
   little-endian powerpc linux host.

 # Fixed the prototype of the Reduce_local C++ binding.  The previous
   prototype was completely incorrect.  Thanks to Jeff Squyres for
   reporting the issue.

 # The mpd process manager, which was deprecated and unsupported for
   the past four major release series (1.3.x till 3.1), has now been
   deleted.  RIP.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.

   A full list of changes is available at the following link:

     http://git.mpich.org/mpich.git/shortlog/v3.1..v3.1.1

   A full list of bugs that have been fixed is available at the
   following link:

   https://trac.mpich.org/projects/mpich/ \
               query?status=closed&group=resolution&milestone=mpich-3.1.1


===============================================================================
                               Changes in 3.1
===============================================================================

 # Implement runtime compatibility with MPICH-derived implementations as per
   the ABI Compatibility Initiative (see http://www.mpich.org/abi for more
   information).

 # Integrated MPICH-PAMI code base for Blue Gene/Q and other IBM
   platforms.

 # Several improvements to the SCIF netmod.  (code contribution from
   Intel).

 # Major revamp of the MPI_T interface added in MPI-3.

 # Added environment variables to control a lot more capabilities for
   collectives.  See the README.envvar file for more information.

 # Allow non-blocking collectives and fault tolerance at the same
   time. The option MPIR_PARAM_ENABLE_COLL_FT_RET has been deprecated as
   it is no longer necessary.

 # Improvements to MPI_WIN_ALLOCATE to internally allocate shared
   memory between processes on the same node.

 # Performance improvements for MPI RMA operations on shared memory
   for MPI_WIN_ALLOCATE and MPI_WIN_ALLOCATE_SHARED.
 # Enable shared library builds by default.

 # Upgraded hwloc to 1.8.

 # Several improvements to the Hydra-SLURM integration.

 # Several improvements to the Hydra process binding code.  See the
   Hydra wiki page for more information:
   http://wiki.mpich.org/mpich/index.php/Using_the_Hydra_Process_Manager

 # MPICH now supports operations on very large datatypes (those that describe
   more than 32 bits of data).  This work also allows MPICH to fully support
   MPI-3's introduction of MPI_Count.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.

   A full list of changes is available at the following link:

     http://git.mpich.org/mpich.git/shortlog/v3.0.4..v3.1

   A full list of bugs that have been fixed is available at the
   following link:

   https://trac.mpich.org/projects/mpich/ \
                  query?status=closed&group=resolution&milestone=mpich-3.1


===============================================================================
                               Changes in 3.0.4
===============================================================================

 # BUILD SYSTEM: Reordered the default compiler search to prefer Intel
   and PG compilers over GNU compilers because of the performance
   difference.

   WARNING: If you do not explicitly specify the compiler you want
   through CC and friends, this might break ABI for you relative to
   the previous 3.0.x release.

 # OVERALL: Added support to manage per-communicator eager-rendezvous
   thresholds.

 # PM/PMI: Performance improvements to the Hydra process manager on
   large-scale systems by allowing for key/value caching.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.
   A full list of changes is available at the following link:

     http://git.mpich.org/mpich.git/shortlog/v3.0.3..v3.0.4


===============================================================================
                               Changes in 3.0.3
===============================================================================

 # RMA: Added a new mechanism for piggybacking RMA synchronization operations,
   which improves the performance of several synchronization operations,
   including Flush.
 # RMA: Added an optimization to utilize the MPI_MODE_NOCHECK assertion in
   passive target RMA to improve performance by eliminating a lock request
   message.

 # RMA: Added a default implementation of shared memory windows to CH3.  This
   adds support for this MPI 3.0 feature to the ch3:sock device.

 # RMA: Fix a bug that resulted in an error when RMA operation request handles
   where completed outside of a synchronization epoch.

 # PM/PMI: Upgraded to hwloc-1.6.2rc1.  This version uses libpciaccess
   instead of libpci, to workaround the GPL license used by libpci.

 # PM/PMI: Added support for the Cobalt process manager.

 # BUILD SYSTEM: allow MPI_LONG_DOUBLE_SUPPORT to be disabled with a configure
   option.

 # FORTRAN: fix MPI_WEIGHTS_EMPTY in the Fortran bindings

 # MISC: fix a bug in MPI_Get_elements where it could return incorrect values

 # Several other minor bug fixes, memory leak fixes, and code cleanup.
   A full list of changes is available at the following link:

     http://git.mpich.org/mpich.git/shortlog/v3.0.2..v3.0.3


===============================================================================
                               Changes in 3.0.2
===============================================================================

 # PM/PMI: Upgrade to hwloc-1.6.1

 # RMA: Performance enhancements for shared memory windows.

 # COMPILER INTEGRATION: minor improvements and fixes to the clang static type
   checking annotation macros.

 # MPI-IO (ROMIO): improved error checking for user errors, contributed by IBM.

 # MPI-3 TOOLS INTERFACE: new MPI_T performance variables providing information
   about nemesis communication behavior and and CH3 message matching queues.

 # TEST SUITE: "make testing" now also outputs a "summary.tap" file that can be
   interpreted with standard TAP consumer libraries and tools.  The
   "summary.xml" format remains unchanged.

 # GIT: This is the first release built from the new git repository at
   git.mpich.org.  A few build system mechanisms have changed because of this
   switch.

 # BUG FIX: resolved a compilation error related to LLONG_MAX that affected
   several users (ticket #1776).

 # BUG FIX: nonblocking collectives now properly make progress when MPICH is
   configured with the ch3:sock channel (ticket #1785).
 # Several other minor bug fixes, memory leak fixes, and code cleanup.
   A full list of changes is available at the following link:

     http://git.mpich.org/mpich.git/shortlog/v3.0.1..v3.0.2


===============================================================================
                               Changes in 3.0.1
===============================================================================

 # PM/PMI: Critical bug-fix in Hydra to work correctly in multi-node
   tests.

 # A full list of changes is available using:

   svn log -r10790:HEAD \
       https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich-3.0.1

   ... or at the following link:

   https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/ \
           mpich-3.0.1?action=follow_copy&rev=HEAD&stop_rev=10790&mode=follow_copy


===============================================================================
                               Changes in 3.0
===============================================================================

 # MPI-3: All MPI-3 features are now implemented and the MPI_VERSION
   bumped up to 3.0.

 # OVERALL: Added support for ARM-v7 native atomics

 # MPE: MPE is now separated out of MPICH and can be downloaded/used
   as a separate package.

 # PM/PMI: Upgraded to hwloc-1.6

 # Several other minor bug fixes, memory leak fixes, and code cleanup.
   A full list of changes is available using:

   svn log -r10344:HEAD \
          https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich-3.0

     ... or at the following link:

   https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/ \
         mpich-3.0?action=follow_copy&rev=HEAD&stop_rev=10344&mode=follow_copy


===============================================================================
                               Changes in 1.5
===============================================================================

 # OVERALL: Nemesis now supports an "--enable-yield=..." configure
   option for better performance/behavior when oversubscribing
   processes to cores.  Some form of this option is enabled by default
   on Linux, Darwin, and systems that support sched_yield().
```

```
# OVERALL: Added support for Intel Many Integrated Core (MIC)
  architecture: shared memory, TCP/IP, and SCIF based communication.

# OVERALL: Added support for IBM BG/Q architecture.  Thanks to IBM
  for the contribution.

# MPI-3: const support has been added to mpi.h, although it is
  disabled by default.  It can be enabled on a per-translation unit
  basis with "#define MPICH2_CONST const".

# MPI-3: Added support for MPIX_Type_create_hindexed_block.

# MPI-3: The new MPI-3 nonblocking collective functions are now
  available as "MPIX_" functions (e.g., "MPIX_Ibcast").

# MPI-3: The new MPI-3 neighborhood collective routines are now available as
  "MPIX_" functions (e.g., "MPIX_Neighbor_allgather").

# MPI-3: The new MPI-3 MPI_Comm_split_type function is now available
  as an "MPIX_" function.

# MPI-3: The new MPI-3 tools interface is now available as "MPIX_T_"
  functions.  This is a beta implementation right now with several
  limitations, including no support for multithreading.  Several
  performance variables related to CH3's message matching are exposed
  through this interface.

# MPI-3: The new MPI-3 matched probe functionality is supported via
  the new routines MPIX_Mprobe, MPIX_Improbe, MPIX_Mrecv, and
  MPIX_Imrecv.

# MPI-3: The new MPI-3 nonblocking communicator duplication routine,
  MPIX_Comm_idup, is now supported.  It will only work for
  single-threaded programs at this time.

# MPI-3: MPIX_Comm_reenable_anysource support

# MPI-3: Native MPIX_Comm_create_group support (updated version of
  the prior MPIX_Group_comm_create routine).

# MPI-3: MPI_Intercomm_create's internal communication no longer interferes
  with point-to-point communication, even if point-to-point operations on the
  parent communicator use the same tag or MPI_ANY_TAG.

# MPI-3: Eliminated the possibility of interference between
  MPI_Intercomm_create and point-to-point messaging operations.

# Build system: Completely revamped build system to rely fully on
  autotools.  Parallel builds ("make -j8" and similar) are now supported.

# Build system: rename "./maint/updatefiles" --> "./autogen.sh" and
  "configure.in" --> "configure.ac"

# JUMPSHOT: Improvements to Jumpshot to handle thousands of
  timelines, including performance improvements to slog2 in such
  cases.

# JUMPSHOT: Added navigation support to locate chosen drawable's ends
```

```
   when viewport has been scrolled far from the drawable.

 # PM/PMI: Added support for memory binding policies.

 # PM/PMI: Various improvements to the process binding support in
   Hydra.  Several new pre-defined binding options are provided.

 # PM/PMI: Upgraded to hwloc-1.5

 # PM/PMI: Several improvements to PBS support to natively use the PBS
   launcher.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.
   A full list of changes is available using:

   svn log -r8478:HEAD \
       https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.5

   ... or at the following link:

   https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/ \
         mpich2-1.5?action=follow_copy&rev=HEAD&stop_rev=8478&mode=follow_copy


===============================================================================
                               Changes in 1.4.1
===============================================================================

 # OVERALL: Several improvements to the ARMCI API implementation
   within MPICH2.

 # Build system: Added beta support for DESTDIR while installing
   MPICH2.

 # PM/PMI: Upgrade hwloc to 1.2.1rc2.

 # PM/PMI: Initial support for the PBS launcher.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.
   A full list of changes is available using:

   svn log -r8675:HEAD \
         https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.4.1

   ... or at the following link:

   https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/ \
      mpich2-1.4.1?action=follow_copy&rev=HEAD&stop_rev=8675&mode=follow_copy


===============================================================================
                               Changes in 1.4
===============================================================================

 # OVERALL: Improvements to fault tolerance for collective
   operations. Thanks to Rui Wang @ ICT for reporting several of these
   issues.
```

```
# OVERALL: Improvements to the universe size detection. Thanks to
  Yauheni Zelenko for reporting this issue.

# OVERALL: Bug fixes for Fortran attributes on some systems. Thanks
  to Nicolai Stange for reporting this issue.

# OVERALL: Added new ARMCI API implementation (experimental).

# OVERALL: Added new MPIX_Group_comm_create function to allow
  non-collective creation of sub-communicators.

# FORTRAN: Bug fixes in the MPI_DIST_GRAPH_ Fortran bindings.

# PM/PMI: Support for a manual "none" launcher in Hydra to allow for
  higher-level tools to be built on top of Hydra. Thanks to Justin
  Wozniak for reporting this issue, for providing several patches for
  the fix, and testing it.

# PM/PMI: Bug fixes in Hydra to handle non-uniform layouts of hosts
  better. Thanks to the MVAPICH group at OSU for reporting this issue
  and testing it.

# PM/PMI: Bug fixes in Hydra to handle cases where only a subset of
  the available launchers or resource managers are compiled
  in. Thanks to Satish Balay @ Argonne for reporting this issue.

# PM/PMI: Support for a different username to be provided for each
  host; this only works for launchers that support this (such as
  SSH).

# PM/PMI: Bug fixes for using Hydra on AIX machines. Thanks to
  Kitrick Sheets @ NCSA for reporting this issue and providing the
  first draft of the patch.

# PM/PMI: Bug fixes in memory allocation/management for environment
  variables that was showing up on older platforms. Thanks to Steven
  Sutphen for reporting the issue and providing detailed analysis to
  track down the bug.

# PM/PMI: Added support for providing a configuration file to pick
  the default options for Hydra. Thanks to Saurabh T. for reporting
  the issues with the current implementation and working with us to
  improve this option.

# PM/PMI: Improvements to the error code returned by Hydra.

# PM/PMI: Bug fixes for handling "=" in environment variable values in
  hydra.

# PM/PMI: Upgrade the hwloc version to 1.2.

# COLLECTIVES: Performance and memory usage improvements for MPI_Bcast
  in certain cases.

# VALGRIND: Fix incorrect Valgrind client request usage when MPICH2 is
  built for memory debugging.

# BUILD SYSTEM: "--enable-fast" and "--disable-error-checking" are once
```

```
   again valid simultaneous options to configure.

 # TEST SUITE: Several new tests for MPI RMA operations.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.
   A full list of changes is available using:

   svn log -r7838:HEAD \
      https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.4

   ... or at the following link:

   https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/ \
      mpich2-1.4?action=follow_copy&rev=HEAD&stop_rev=7838&mode=follow_copy


===============================================================================
                               Changes in 1.3.2
===============================================================================

 # OVERALL: MPICH2 now recognizes the OSX mach_absolute_time as a
   native timer type.

 # OVERALL: Performance improvements to MPI_Comm_split on large
   systems.

 # OVERALL: Several improvements to error returns capabilities in the
   presence of faults.

 # PM/PMI: Several fixes and improvements to Hydra's process binding
   capability.

 # PM/PMI: Upgrade the hwloc version to 1.1.1.

 # PM/PMI: Allow users to sort node lists allocated by resource
   managers in Hydra.

 # PM/PMI: Improvements to signal handling. Now Hydra respects Ctrl-Z
   signals and passes on the signal to the application.

 # PM/PMI: Improvements to STDOUT/STDERR handling including improved
   support for rank prepending on output. Improvements to STDIN
   handling for applications being run in the background.

 # PM/PMI: Split the bootstrap servers into "launchers" and "resource
   managers", allowing the user to pick a different resource manager
   from the launcher. For example, the user can now pick the "SLURM"
   resource manager and "SSH" as the launcher.

 # PM/PMI: The MPD process manager is deprecated.

 # PM/PMI: The PLPA process binding library support is deprecated.

 # WINDOWS: Adding support for gfortran and 64-bit gcc libs.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.
   A full list of changes is available using:
```

```
   svn log -r7457:HEAD \
       https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.3.2

   ... or at the following link:

   https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/ \
       mpich2-1.3.2?action=follow_copy&rev=HEAD&stop_rev=7457&mode=follow_copy


===============================================================================
                               Changes in 1.3.1
===============================================================================

 # OVERALL: MPICH2 is now fully compliant with the CIFTS FTB standard
   MPI events (based on the draft standard).

 # OVERALL: Major improvements to RMA performance for long lists of
   RMA operations.

 # OVERALL: Performance improvements for Group_translate_ranks.

 # COLLECTIVES: Collective algorithm selection thresholds can now be controlled
   at runtime via environment variables.

 # ROMIO: PVFS error codes are now mapped to MPI error codes.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.
   A full list of changes is available using:

   svn log -r7350:HEAD \
      https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.3.1

   ... or at the following link:

   https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/ \
         mpich2-1.3.1?action=follow_copy&rev=HEAD&stop_rev=7350&mode=follow_copy


===============================================================================
                               Changes in 1.3
===============================================================================

 # OVERALL: Initial support for fine-grained threading in
   ch3:nemesis:tcp.

 # OVERALL: Support for Asynchronous Communication Progress.

 # OVERALL: The ssm and shm channels have been removed.

 # OVERALL: Checkpoint/restart support using BLCR.

 # OVERALL: Improved tolerance to process and communication failures
   when error handler is set to MPI_ERRORS_RETURN.  If a communication
   operation fails (e.g., due to a process failure) MPICH2 will return
   an error, and further communication to that process is not
   possible.  However, communication with other processes will still
   proceed normally.  Note, however, that the behavior collective
   operations on communicators containing the failed process is
   undefined, and may give incorrect results or hang some processes.

 # OVERALL: Experimental support for inter-library dependencies.

 # PM/PMI: Hydra is now the default process management framework
   replacing MPD.

 # PM/PMI: Added dynamic process support for Hydra.

 # PM/PMI: Added support for LSF, SGE and POE in Hydra.

 # PM/PMI: Added support for CPU and memory/cache topology aware
   process-core binding.

 # DEBUGGER: Improved support and bug fixes in the Totalview support.

 # Build system: Replaced F90/F90FLAGS by FC/FCFLAGS. F90/F90FLAGS are
   not longer supported in the configure.

 # Multi-compiler support: On systems where C compiler that is used to
   build mpich2 libraries supports multiple weak symbols and multiple aliases,
   the Fortran binding built in the mpich2 libraries can handle different
   Fortran compilers (than the one used to build mpich2).  Details in README.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.
   A full list of changes is available using:

   svn log -r5762:HEAD \
       https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.3

   ... or at the following link:

   https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/ \
         mpich2-1.3?action=follow_copy&rev=HEAD&stop_rev=5762&mode=follow_copy


===============================================================================
                               Changes in 1.2.1
===============================================================================

 # OVERALL: Improved support for fine-grained multithreading.

 # OVERALL: Improved integration with Valgrind for debugging builds of MPICH2.

 # PM/PMI: Initial support for hwloc process-core binding library in
   Hydra.

 # PM/PMI: Updates to the PMI-2 code to match the PMI-2 API and
   wire-protocol draft.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.
   A full list of changes is available using:

     svn log -r5425:HEAD https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.2.1

     ... or at the following link:

     https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/mpich2-1.2.1? \
    action=follow_copy&rev=HEAD&stop_rev=5425&mode=follow_copy


===============================================================================
                               Changes in 1.2
===============================================================================

 # OVERALL: Support for MPI-2.2

 # OVERALL: Several fixes to Nemesis/MX.

 # WINDOWS: Performance improvements to Nemesis/windows.

 # PM/PMI: Scalability and performance improvements to Hydra using
   PMI-1.1 process-mapping features.

 # PM/PMI: Support for process-binding for hyperthreading enabled
   systems in Hydra.

 # PM/PMI: Initial support for PBS as a resource management kernel in
   Hydra.

 # PM/PMI: PMI2 client code is now officially included in the release.

 # TEST SUITE: Support to run the MPICH2 test suite through valgrind.

 # Several other minor bug fixes, memory leak fixes, and code cleanup.
   A full list of changes is available using:

     svn log -r5025:HEAD https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.2

     ... or at the following link:

     https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/mpich2-1.2? \
    action=follow_copy&rev=HEAD&stop_rev=5025&mode=follow_copy


===============================================================================
                               Changes in 1.1.1p1
===============================================================================

 - OVERALL: Fixed an invalid read in the dataloop code for zero count types.

 - OVERALL: Fixed several bugs in ch3:nemesis:mx (tickets #744,#760;
   also change r5126).

 - BUILD SYSTEM: Several fixes for functionality broken in 1.1.1 release,
   including MPICH2LIB_xFLAGS and extra libraries living in $LIBS instead of
   $LDFLAGS.  Also, '-lpthread' should no longer be duplicated in link lines.

 - BUILD SYSTEM: MPICH2 shared libraries are now compatible with glibc versioned
   symbols on Linux, such as those present in the MX shared libraries.

 - BUILD SYSTEM: Minor tweaks to improve compilation under the nvcc CUDA
   compiler.

 - PM/PMI: Fix mpd incompatibility with python2.3 introduced in mpich2-1.1.1.
 - PM/PMI: Several fixes to hydra, including memory leak fixes and process
   binding issues.

 - TEST SUITE: Correct invalid arguments in the coll2 and coll3 tests.

 - Several other minor bug fixes, memory leak fixes, and code cleanup.  A full
   list of changes is available using:

     svn log -r5032:HEAD https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.1.1p1

     ... or at the following link:

     https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/mpich2-1.1.1p1? \
    action=follow_copy&rev=HEAD&stop_rev=5032&mode=follow_copy


===============================================================================
                               Changes in 1.1.1
===============================================================================

 # OVERALL: Improved support for Boost MPI.

 # PM/PMI: Significantly improved time taken by MPI_Init with Nemesis and MPD on
   large numbers of processes.

 # PM/PMI: Improved support for hybrid MPI-UPC program launching with
   Hydra.

 # PM/PMI: Improved support for process-core binding with Hydra.

 # PM/PMI: Preliminary support for PMI-2. Currently supported only
   with Hydra.

 # Many other bug fixes, memory leak fixes and code cleanup. A full
   list of changes is available using:

  svn log -r4655:HEAD https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.1.1

  ... or at the following link:

  https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/mpich2-1.1.1? \
    action=follow_copy&rev=HEAD&stop_rev=4655&mode=follow_copy


===============================================================================
                               Changes in 1.1
===============================================================================

- OVERALL: Added MPI 2.1 support.

- OVERALL: Nemesis is now the default configuration channel with a
  completely new TCP communication module.

- OVERALL: Windows support for nemesis.

- OVERALL: Added a new Myrinet MX network module for nemesis.

- OVERALL: Initial support for shared-memory aware collective
```

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  communication operations.  Currently MPI_Bcast, MPI_Reduce, MPI_Allreduce,
  and MPI_Scan.

- OVERALL: Improved handling of MPI Attributes.

- OVERALL: Support for BlueGene/P through the DCMF library (thanks to
  IBM for the patch).

- OVERALL: Experimental support for fine-grained multithreading

- OVERALL: Added dynamic processes support for Nemesis.

- OVERALL: Added automatic as well as statically runtime configurable
  receive timeout variation for MPD (thanks to OSU for the patch).

- OVERALL: Improved performance for MPI_Allgatherv, MPI_Gatherv, and MPI_Alltoall.

- PM/PMI: Initial support for the new Hydra process management
  framework (current support is for ssh, rsh, fork and a preliminary
  version of slurm).

- ROMIO: Added support for MPI_Type_create_resized and
  MPI_Type_create_indexed_block datatypes in ROMIO.

- ROMIO: Optimized Lustre ADIO driver (thanks to Weikuan Yu for
  initial work and Sun for further improvements).

- Many other bug fixes, memory leak fixes and code cleanup. A full
  list of changes is available using:

  svn log -r813:HEAD https://svn.mcs.anl.gov/repos/mpi/mpich2/tags/release/mpich2-1.1

  ... or at the following link:

  https://trac.mcs.anl.gov/projects/mpich2/log/mpich2/tags/release/mpich2-1.1? \
    action=follow_copy&rev=HEAD&stop_rev=813&mode=follow_copy


===============================================================================
                               Changes in 1.0.7
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- OVERALL: Initial ROMIO device for BlueGene/P (the ADI device is also
added but is not configurable at this time).

- OVERALL: Major clean up for the propagation of user-defined and
other MPICH2 flags throughout the code.

- OVERALL: Support for STI Cell Broadband Engine.

- OVERALL: Added datatype free hooks to be used by devices
independently.

- OVERALL: Added device-specific timer support.

- OVERALL: make uninstall works cleanly now.

- ROMIO: Support to take hints from a config file
- ROMIO: more tests and bug fixes for nonblocking I/O

- PM/PMI: Added support to use PMI Clique functionality for process
managers that support it.

- PM/PMI: Added SLURM support to configure to make it transparent to
users.

- PM/PMI: SMPD Singleton Init support.

- WINDOWS: Fortran 90 support added.

- SCTP: Added MPICH_SCTP_NAGLE_ON support.

- MPE: Updated MPE logging API so that it is thread-safe (through
global mutex).

- MPE: Added infrastructure to piggyback argument data to MPI states.

- DOCS: Documentation creation now works correctly for VPATH builds.

- Many other bug fixes, memory leak fixes and code cleanup. A full
list of changes is available using:
  svn log -r100:HEAD https://svn.mcs.anl.gov/repos/mpi/mpich2/branches/release/MPICH2_1_0_7


===============================================================================
                   Changes in 1.0.6
===============================================================================

- Updates to the ch3:nemesis channel including preliminary support for
thread safety.

- Preliminary support for dynamic loading of ch3 channels (sock, ssm,
shm). See the README file for details.

- Singleton init now works with the MPD process manager.

- Fixes in MPD related to MPI-2 connect-accept.

- Improved support for MPI-2 generalized requests that allows true
nonblocking I/O in ROMIO.

- MPE changes:
  * Enabled thread-safe MPI logging through global mutex.
  * Enhanced Jumpshot to be more thread friendly
    + added simple statistics in the Legend windows.
  * Added backtrace support to MPE on Solaris and glibc based systems,
    e.g. Linux.  This improves the output error message from the
    Collective/Datatype checking library.
  * Fixed the CLOG2 format so it can be used in serial (non-MPI) logging.

- Performance improvements for derived datatypes (including packing
and communication) through in-built loop-unrolling and buffer
alignment.

- Performance improvements for MPI_Gather when non-power-of-two
processes are used, and when a non-zero ranked root is performing the
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gather.

- MPI_Comm_create works for intercommunicators.

- Enabled -O2 and equivalent compiler optimizations for supported
compilers by default (including GNU, Intel, Portland, Sun, Absoft,
IBM).

- Many other bug fixes, memory leak fixes and code cleanup. A full
list of changes is available at
www.mcs.anl.gov/mpi/mpich2/mpich2_1_0_6changes.htm.


===============================================================================
                   Changes in 1.0.5
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- An SCTP channel has been added to the CH3 device. This was
  implemented by Brad Penoff and Mike Tsai, Univ. of British Columbia.
  Their group's webpage is located at http://www.cs.ubc.ca/labs/dsg/mpi-sctp/ .

- Bugs related to dynamic processes have been fixed.

- Performance-related fixes have been added to derived datatypes and
  collective communication.

- Updates to the Nemesis channel

- Fixes to thread safety for the ch3:sock channel

- Many other bug fixes and code cleanup.  A full list of changes is available
  at www.mcs.anl.gov/mpi/mpich2/mpich2_1_0_5changes.htm .


===============================================================================
                   Changes in 1.0.4
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- For the ch3:sock channel, the default build of MPICH2 supports
  thread safety. A separate build is not needed as before. However,
  thread safety is enabled only if the user calls MPI_Init_thread with
  MPI_THREAD_MULTIPLE. If not, no thread locks are called, so there
  is no penalty.

- A new low-latency channel called Nemesis has been added. It can be
  selected by specifying the option --with-device=ch3:nemesis.
  Nemesis uses shared memory for intranode communication and various
  networks for internode communication.  Currently available networks
  are TCP, GM and MX.  Nemesis is still a work in progress.  See the
  README for more information about the channel.

- Support has been added for providing message queues to debuggers.
  Configure with --enable-debuginfo to make this information available.
  This is still a "beta" test version and has not been extensively tested.

- For systems with firewalls, the environment variable MPICH_PORT_RANGE can
  be used to restrict the range of ports used by MPICH2.  See the documentation
  for more details.
```

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- Withdrew obsolete modules, including the ib and rdma communication layers.
  For Infiniband and MPICH2, please see
  http://nowlab.cse.ohio-state.edu/projects/mpi-iba/
  For other interconnects, please contact us at mpich2-maint@mcs.anl.gov .

- Numerous bug fixes and code cleanup.  A full list of changes is available
  at www.mcs.anl.gov/mpi/mpich2/mpich2_1_0_4changes.htm .

- Numerous new tests in the MPICH2 test suite.

- For developers, the way in which information is passed between the top
  level configure and configures in the device, process management, and
  related modules has been cleaned up.  See the comments at the beginning
  of the top-level configure.in for details.  This change makes it easier
  to interface other modules to MPICH2.


===============================================================================
                   Changes in 1.0.3
===============================================================================

- There are major changes to the ch3 device implementation.  Old and
  unsupported channels (essm, rdma) have been removed.   The
  internal interface between ch3 and the channels has been improved to
  similify the process of adding a new channel (sharing existing code
  where possible) and to improve performance.  Further changes in this
  internal interface are expected.

- Numerous bug fixes and code cleanup

        Creation of intercommunicators and intracommunicators
        from the intercommunicators created with Spawn and Connect/Accept

        The computation of the alignment and padding of items within
        structures now handles additional cases, including systems
        where the alignment an padding depends on the type of the first
    item in the structure

        MPD recognizes wdir info keyword

        gforker's mpiexec supports -env and -genv arguments for controlling
        which environment variables are delivered to created processes

- While not a bug, to aid in the use of memory trace packages, MPICH2
  tries to free all allocated data no later than when MPI_Finalize
  returns.

- Support for DESTDIR in install targets

- Enhancements to SMPD

- In order to support special compiler flags for users that may be
  different from those used to build MPICH2, the environment variables
  MPI_CFLAGS, MPI_FFLAGS, MPI_CXXFLAGS, and MPI_F90FLAGS may be used
  to specify the flags used in mpicc, mpif77, mpicxx, and mpif90
  respectively.  The flags CFLAGS, FFLAGS, CXXFLAGS, and F90FLAGS are
  used in the building of MPICH2.
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- Many enhancements to MPE

- Enhanced support for features and idiosyncracies of Fortran 77 and
  Fortran 90 compilers, including gfortran, g95, and xlf

- Enhanced support for C++ compilers that do not fully support abstract
  base classes

- Additional tests in the mpich2/tests/mpi

- New FAQ included (also available at
    http://www.mcs.anl.gov/mpi/mpich2/faq.htm)

- Man pages for mpiexec and mpif90

- Enhancements for developers, including a more flexible and general
  mechanism for inserting logging and information messages, controlable
  with --mpich-dbg-xxx command line arguments or MPICH_DBG_XXX environment
  variables.

- Note to developers:
  This release contains many changes to the structure of the CH3
  device implementation (in src/mpid/ch3), including signficant
  reworking of the files (many files have been combined into fewer files
  representing logical grouping of functions).  The next release of
  MPICH2 will contain even more significant changes to the device
  structure as we introduce a new communication implementation.

===============================================================================
                   Changes in 1.0.2
===============================================================================

- Optimizations to the MPI-2 one-sided communication functions for the
  sshm (scalable shared memory) channel when window memory is
  allocated with MPI_Alloc_mem (for all three synchronization methods).

- Numerous bug fixes and code cleanup.

- Fixed memory leaks.

- Fixed shared library builds.

- Fixed performance problems with MPI_Type_create_subarray/darray

- The following changes have been made to MPE2:

  - MPE2 now builds the MPI collective and datatype checking library
    by default.

  - SLOG-2 format has been upgraded to 2.0.6 which supports event drawables
    and provides count of real drawables in preview drawables.

  - new slog2 tools, slog2filter and slog2updater, which both are logfile
    format convertors.  slog2filter removes undesirable categories of
    drawables as well as alters the slog2 file structure.  slog2updater
    is a slog2filter that reads in older logfile format, 2.0.5, and
    writes out the latest format 2.0.6.
```

```
- The following changes have been made to MPD:

  - Nearly all code has been replaced by new code that follows a more
    object-oriented approach than before.  This has not changed any
    fundamental behavior or interfaces.

  - There is info support in spawn and spawn_multiple for providing
    parts of the environment for spawned processes such as search-path
    and current working directory.  See the Standard for the required
    fields.

  - mpdcheck has been enhanced to help users debug their cluster and
    network configurations.

  - CPickle has replaced marshal as the source module for dumps and loads.

  - The mpigdb command has been replaced by mpiexec -gdb.

  - Alternate interfaces can be used.  See the Installer's Guide.


===============================================================================
                   Changes in 1.0.1
===============================================================================

- Copyright statements have been added to all code files, clearly identifying
  that all code in the distribution is covered by the extremely flexible
  copyright described in the COPYRIGHT file.

- The MPICH2 test suite (mpich2/test) can now be run against any MPI
  implementation, not just MPICH2.

- The send and receive socket buffers sizes may now be changed by setting
  MPICH_SOCKET_BUFFER_SIZE.  Note: the operating system may impose a maximum
  socket buffer size that prohibits MPICH2 from increasing the buffers to the
  desire size.  To raise the maximum allowable buffer size, please contact your
  system administrator.

- Error handling throughout the MPI routines has been improved.  The error
  handling in some internal routines has been simplified as well, making the
  routines easier to read.

- MPE (Jumpshot and CLOG logging) is now supported on Microsoft Windows.

- C applications built for Microsoft Windows may select the desired channels at
  runtime.

- A program not started with mpiexec may become an MPI program by calling
  MPI_Init.  It will have an MPI_COMM_WORLD of size one.  It may then call
  other MPI routines, including MPI_COMM_SPAWN, to become a truly parallel
  program.  At present, the use of MPI_COMM_SPAWN and MPI_COMM_SPAWN_MULTIPLE
  by such a process is only supported by the MPD process manager.

- Memory leaks in communicator allocation and the C++ binding have been fixed.

- Following GNU guidelines, the parts of the install step that checked the
  installation have been moved to an installcheck target.  Much of the
  installation now supports the DESTDIR prefix.
```

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- Microsoft Visual Studio projects have been added to make it possible to build
  x86-64 version

- Problems with compilers and linkers that do not support weak symbols, which
  are used to support the PMPI profiling interface, have been corrected.

- Handling of Fortran 77 and Fortran 90 compilers has been improved, including
  support for g95.

- The Fortran stdcall interface on Microsoft Windows now supports character*.

- A bug in the OS X implementation of poll() caused the sock channel to hang.
  A workaround has been put in place.

- Problems with installation under OS/X are now detected and corrected.
  (Install breaks libraries that are more than 10 seconds old!)

- The following changes have been made to MPD:

  - Sending a SIGINT to mpiexec/mpdrun, such as by typing control-C, now causes
    SIGINT to be sent to the processes within the job.  Previously, SIGKILL was
    sent to the processes, preventing applications from catching the signal
    and performing their own signal processing.

  - The process for merging output has been improved.

  - A new option, -ifhn, has been added to the machine file, allowing the user
    to select the destination interface to be used for TCP communication.  See
    the User's Manual for details.

  - The user may now select, via the "-s" option to mpiexec/mpdrun, which
    processes receive input through stdin.  stdin is immediately closed for all
    processes not in set receiving input.  This prevents processes not in the
    set from hanging should they attempt to read from stdin.

  - The MPICH2 Installer's Guide now contains an appendix on troubleshooting
    problems with MPD.

- The following changes have been made to SMPD:

  - On Windows machines, passwordless authentication (via SSPI) can now be used
    to start processes on machines within a domain.  This feature is a recent
    addition, and should be considered experimental.

  - On Windows machines, the -localroot option was added to mpiexec, allowing
    processes on the local machines to perform GUI operations on the local
    desktop.

  - On Windows machines, network drive mapping is now supported via the -map
    option to mpiexec.

  - Three new GUI tools have been added for Microsoft Windows.  These tools are
    wrappers to the command line tools, mpiexec.exe and smpd.exe.  wmpiexec
    allows the user to run a job much in the way they with mpiexec.  wmpiconfig
    provides a means of setting various global options to the SMPD process
    manager environment.  wmpiregister encrypts the user's credentials and
    saves them to the Windows Registry.
```

```
- The following changes have been made to MPE2:

  - MPE2 no longer attempt to compile or link code during 'make install' to
    validate the installation.  Instead, 'make installcheck' may now be used to
    verify that the MPE installation.

  - MPE2 now supports DESTDIR.

- The sock channel now has preliminary support for MPI_THREAD_SERIALIZED and
  MPI_THREAD_MULTIPLE on both UNIX and Microsoft Windows.  We have performed
  rudimentary testing; and while overall the results were very positive, known
  issues do exist.  ROMIO in particular experiences hangs in several places.
  We plan to correct that in the next release.  As always, please report any
  difficulties you encounter.

- Another channel capable of communicating with both over sockets and shared
  memory has been added.  Unlike the ssm channel which waits for new data to
  arrive by continuously polling the system in a busy loop, the essm channel
  waits by blocking on an operating system event object.  This channel is
  experimental, and is only available for Microsoft Windows.

- The topology routines have been modified to allow the device to override the
  default implementation.  This allows the device to export knowledge of the
  underlying physical topology to the MPI routines (Dims_create and the
  reorder == true cases in Cart_create and Graph_create).

- New memory allocation macros, MPIU_CHK[PL]MEM_*(), have been added to help
  prevent memory leaks.  See mpich2/src/include/mpimem.h.

- New error reporting macros, MPIU_ERR_*, have been added to simplify the error
  handling throughout the code, making the code easier to read.  See
  mpich2/src/include/mpierrs.h.

- Interprocess communication using the Sock interface (sock and ssm channels)
  may now be bound to a particular destination interface using the environment
  variable MPICH_INTERFACE_HOSTNAME.  The variable needs to be set for each
  process for which the destination interface is not the default interface.
  (Other mechanisms for destination interface selection will be provided in
  future releases.)  Both MPD and SMPD provide a more simplistic mechanism for
  specifying the interface.  See the user documentation.

- Too many bug fixes to describe.  Much thanks goes to the users who reported
  bugs.  Their patience and understanding as we attempted to recreate the
  problems and solve them is greatly appreciated.


===============================================================================
                Changes in 1.0
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- MPICH2 now works on Solaris.

- The User's Guide has been expanded considerably.  The Installation Guide has
  been expanded some as well.

- MPI_COMM_JOIN has been implemented; although like the other dynamic process
  routines, it is only supported by the Sock channel.
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- MPI_COMM_CONNECT and MPI_COMM_ACCEPT are now allowed to connect with remote
  process to which they are already connected.

- Shared libraries can now be built (and used) on IA32 Linux with the GNU
  compilers (--enable-sharedlibs=gcc), and on Solaris with the native Sun
  Workshop compilers (--enable-sharedlibs=solaris).  They may also work on
  other operating systems with GCC, but that has not been tested.  Previous
  restrictions disallowing C++ and Fortran bindings when building shared
  libraries have been removed.

- The dataloop and datatype contents code has been improved to address
  alignment issues on all platforms.

- A bug in the datatype code, which handled zero block length cases
  incorrectly, has been fixed.

- An segmentation fault in the datatype memory management, resulting from
  freeing memory twice, has been fixed.

- The following changes were made to the MPD process manager:

  - MPI_SPAWN_MULTIPLE now works with MPD.

  - The arguments to the 'mpiexec' command supplied by the MPD have changed.
    First, the -default option has been removed.  Second, more flexible ways to
    pass environment variables have been added.

  - The commands 'mpdcheck' and 'testconfig' have been to installations using
    MPD.  These commands test the setup of the machines on which you wish to
    run MPICH2 jobs.  They help to identify misconfiguration, firewall issues,
    and other communication problems.

  - Support for MPI_APPNUM and MPI_UNIVERSE_SIZE has been added to the Simple
    implementation of PMI and the MPD process manager.

  - In general, error detection and recovery in MPD has improved.

- A new process manager, gforker, is now available.  Like the forker process
  manager, gforker spawns processes using fork(), and thus is quite useful on
  SMPs machines.  However, unlike forker, gforker supports all of the features
  of a standard mpiexec, plus some.  Therefore, It should be used in place of
  the previous forker process manager, which is now deprecated.

- The following changes were made to ROMIO:

  - The amount of duplicated ROMIO code in the close, resize, preallocate,
    read, write, asynchronous I/O, and sync routines has been substantially
    reduced.

  - A bug in flattening code, triggered by nested datatypes, has been fixed.

  - Some small memory leaks have been fixed.

  - The error handling has been abstracted allowing different MPI
    implementations to handle and report error conditions in their own way.
    Using this abstraction, the error handling routines have been made
    consistent with rest of MPICH2.
  - AIO support has been cleaned up and unified.  It now works correctly on
    Linux, and is properly detected on old versions of AIX.

  - A bug in MPI_File_seek code, and underlying support code, has been fixed.

  - Support for PVFS2 has improved.

  - Several dead file systems have been removed.  Others, including HFS, SFS,
    PIOFS, and Paragon, have been deprecated.

- MPE and CLOG have been updated to version 2.1. For more details, please see
  src/mpe2/README.

- New macros for memory management were added to support function local
  allocations (alloca), to rollback pending allocations when error conditions
  are detected to avoid memory leaks, and to improve the conciseness of code
  performing memory allocations.

- New error handling macros were added to make internal error handling code
  more concise.

===============================================================================
                   Changes in 0.971
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- Code restricted by copyrights less flexible than the one described in the
  COPYRIGHT file has been removed.

- Installation and User Guides have been added.

- The SMPD PMI Wire Protocol Reference Manual has been updated.

- To eliminate portability problems, common blocks in mpif.h that spanned
  multiple lines were broken up into multiple common blocks each described on a
  single line.

- A new command, mpich2version, was added to allow the user to obtain
  information about the MPICH2 installation.  This command is currently a
  simple shell script.  We anticipate that the mpich2version command will
  eventually provide additional information such as the patches applied and the
  date of the release.

- The following changes were made to MPD2:

  - Support was added for MPI's "singleton init", in which a single
    process started in the normal way (i.e., not by mpiexec or mpirun)
    becomes an MPI process with an MPI_COMM_WORLD of size one by
    calling MPI_Init.  After this the process can call other MPI
    functions, including MPI_Comm_spawn.

  - The format for some of the arguments to mpiexec have changed,
    especially for passing environment variables to MPI processes.

  - In addition to miscellaneous hardening, better error checking and
    messages have been added.

  - The install process has been improved.  In particular, configure
    has been updated to check for a working install program and supply
    it's own installation script (install.sh) if necessary.

  - A new program, mpdcheck, has been added to help diagnose machine
    configurations that might be erroneous or at least confusing to
    mpd.

  - Runtime version checking has been added to insure that the Simple
    implementation of PMI linked into the application and the MPD
    process manager being used to run that application are compatible.

  - Minor improvements have been made to mpdboot.

  - Support for the (now deprecated) BNR interface has been added to
    allow MPICH1 programs to also be run via MPD2.

- Shared libraries are now supported on Linux systems using the GNU compilers
  with the caveat that C++ support must be disabled (--disable-cxx).

- The CH3 interface and device now provide a mechanism for using RDMA (remote
  direct memory access) to transfer data between processes.

- Logging capabilities for MPI and internal routines have been readded.  See
  the documentation in doc/logging for details.

- A "meminit" option was added to --enable-g to force all bytes associated with
  a structure or union to be initialized prior to use.  This prevents programs
  like Valgrind from complaining about uninitialized accesses.

- The dist-with-version and snap targets in the top-level Makefile.sm now
  properly produce mpich2-<ver>/maint/Version instead of mpich2-<ver>/Version.
  In addition, they now properly update the VERSION variable in Makefile.sm
  without clobbering the sed line that performs the update.

- The dist and snap targets in the top-level Makefile.sm now both use the
  dist-with-version target to avoid inconsistencies.

- The following changes were made to simplemake:

  - The environment variables DEBUG, DEBUG_DIRS, and DEBUG_CONFDIR can now be
    used to control debugging output.

  - Many fixes were made to make simplemake so that it would run cleanly with
    perl -w.

  - Installation of *all* files from a directory is now possible (example,
    installing all of the man pages).

  - The clean targets now remove the cache files produced by newer versions of
    autoconf.

  - For files that are created by configure, the determination of the
    location of that configure has been improved, so that make of those
    files (e.g., make Makefile) is more likely to work.  There is still
    more to do here.

  - Short loops over subdirectories are now unrolled.

  - The maintainerclean target has been renamed to maintainer-clean to match
```

```
    GNU guidelines.

  - The distclean and maintainer-clean targets have been improved.

  - An option was added to perform one ar command per directory instead of one
    per file when creating the profiling version of routines (needed only for
    systems that do not support weak symbols).


===============================================================================
                Changes in 0.97
===============================================================================

- MPI-2 one-sided communication has been implemented in the CH3 device.

- mpigdb works as a simple parallel debugger for MPI programs started
  with mpd.  New since MPICH1 is the ability to attach to running
  parallel programs.  See the README in mpich2/src/pm/mpd for details.

- MPI_Type_create_darray() and MPI_Type_create_subarray() implemented including
  the right contents and envelope data.

- ROMIO flattening code now supports subarray and darray combiners.

- Improve scalability and performance of some ROMIO PVFS and PVFS2 routines

- An error message string parameter was added to MPID_Abort().  If the
  parameter is non-NULL this string will be used as the message with the abort
  output.  Otherwise, the output message will be base on the error message
  associated with the mpi_errno parameter.

- MPID_Segment_init() now takes an additional boolean parameter that specifies
  if the segment processing code is to produce/consume homogeneous (FALSE) or
  heterogeneous (TRUE) data.

- The definitions of MPID_VCR and MPID_VCRT are now defined by the device.

- The semantics of MPID_Progress_{Start,Wait,End}() have changed.  A typical
  blocking progress loop now looks like the following.

  if (req->cc != 0)
  {
      MPID_Progress_state progress_state;

      MPID_Progress_start(&progress_state);
      while (req->cc != 0)
      {
          mpi_errno = MPID_Progress_wait(&progress_state);
          if (mpi_errno != MPI_SUCCESS)
          {
              /* --BEGIN ERROR HANDLING-- */
              MPID_Progress_end(&progress_state);
              goto fn_fail;
              /* --END ERROR HANDLING-- */
          }
      }
      MPID_Progress_end(&progress_state);
  }
  NOTE: each of these routines now takes a single parameter, a pointer to a
  thread local state variable.

- The CH3 device and interface have been modified to better support
  MPI_COMM_{SPAWN,SPAWN_MULTIPLE,CONNECT,ACCEPT,DISCONNECT}.  Channels
  writers will notice the following.  (This is still a work in progress.  See
  the note below.)

  - The introduction of a process group object (MPIDI_PG_t) and a new
    set of routines to manipulate that object.

  - The renaming of the MPIDI_VC object to MPIDI_VC_t to make it more
    consistent with the naming of other objects in the device.

  - The process group information in the MPIDI_VC_t moved from the channel
    specific portion to the device layer.

  - MPIDI_CH3_Connection_terminate() was added to the CH3 interface to allow
    the channel to properly shutdown a connection before the device deletes all
    associated data structures.

  - A new upcall routine, MPIDI_CH3_Handle_connection(), was added to allow the
    device to notify the device when a connection related event has completed.
    A present the only event is MPIDI_CH3_VC_EVENT_TERMINATED, which notify the
    device that the underlying connection associated with a VC has been
    properly shutdown.  For every call to MPIDI_CH3_Connection_terminate() that
    the device makes, the channel must make a corresponding upcall to
    MPIDI_CH3_Handle_connection().  MPID_Finalize() will likely hang if this
    rule is not followed.

  - MPIDI_CH3_Get_parent_port() was added to provide MPID_Init() with the port
    name of the the parent (spawner).  This port name is used by MPID_Init()
    and MPID_Comm_connect() to create an intercommunicator between the parent
    (spawner) and child (spawnee).  Eventually, MPID_Comm_spawn_multiple() will
    be update to perform the reverse logic; however, the logic is presently
    still in the sock channel.

  Note: the changes noted are relatively fresh and are the beginning to a set
  of future changes.  The goal is to minimize the amount of code required by a
  channel to support MPI dynamic process functionality.  As such, portions of
  the device will change dramatically in a future release.  A few more changes
  to the CH3 interface are also quite likely.

- MPIDI_CH3_{iRead,iWrite}() have been removed from the CH3 interface.
  MPIDI_CH3U_Handle_recv_pkt() now returns a receive request with a populated
  iovec to receive data associated with the request.
  MPIDU_CH3U_Handle_{recv,send}_req() reload the iovec in the request and
  return and set the complete argument to TRUE if more data is to read or
  written.  If data transfer for the request is complete, the complete argument
  must be set to FALSE.


===============================================================================
                               Changes in 0.96p2
===============================================================================

The shm and ssm channels have been added back into the distribution.
Officially, these channels are supported only on x86 platforms using the gcc
```

```
compiler.  The necessary assembly instructions to guarantee proper ordering of
memory operations are lacking for other platforms and compilers.  That said, we
have seen a high success rate when testing these channels on unsupported
systems.

This patch release also includes a new unsupported channel.  The scalable
shared memory, or sshm, channel is similar to the shm channel except that it
allocates shared memory communication queues only when necessary instead of
preallocating N-squared queues.


===============================================================================
                               Changes in 0.96p1
===============================================================================

This patch release fixes a problem with building MPICH2 on Microsoft Windows
platforms.  It also corrects a serious bug in the poll implementation of the
Sock interface.


===============================================================================
                                Changes in 0.96
===============================================================================

The 0.96 distribution is largely a bug fix release.  In addition to the many
bug fixes, major improvements have been made to the code that supports the
dynamic process management routines (MPI_Comm_{connect,accept,spawn,...}()).
Additional changes are still required to support MPI_Comm_disconnect().

We also added an experimental (and thus completely unsupported) rdma device.
The internal interface is similar to the CH3 interface except that it contains
a couple of extra routines to inform the device about data transfers using the
rendezvous protocol.  The channel can use this extra information to pin memory
and perform a zero-copy transfer.  If all goes well, the results will be rolled
back into the CH3 device.

Due to last minute difficulties, this release does not contain the shm or ssm
channels.  These channels will be included in a subsequent patch release.


===============================================================================
                Changes in 0.94
===============================================================================

Active target one-sided communication is now available for the ch3:sock
channel.  This new functionality has undergone some correctness testing but has
not been optimized in terms of performance.  Future release will include
performance enhancements, passive target communication, and availability in
channels other than just ch3:sock.

The shared memory channel (ch3:shm), which performs communication using shared
memory on a single machine, is now complete and has been extensively tested.
At present, this channel only supports IA32 based machines (excluding the
Pentium Pro which has a memory ordering bug).  In addition, this channel must
be compiled with gcc.  Future releases with support additional architectures
and compilers.

A new channel has been added that performs inter-node communication using
```

```
sockets (TCP/IP) and intra-node communication using shared memory.  This
channel, ch3:ssm, is ideal for clusters of SMPs.  Like the shared memory
channel (ch3:shm), this channel only supports IA32 based machines and must be
compiled with gcc.  In future releases, the ch3:ssm channel will support
additional architectures and compilers.

The two channels that perform commutation using shared memory, ch3:shm and
ch3:ssm, now support the allocation of shared memory using both the POSIX and
System V interfaces.  The POSIX interface will be used if available; otherwise,
the System V interface is used.

In the interest of increasing portability, many enhancements have been made to
both the code and the configure scripts.

And, as always, many bugs have been fixed :-).


***** INTERFACE CHANGES ****

The parameters to MPID_Abort() have changed.  MPID_Abort() now takes a pointer
to communicator object, an MPI error code, and an exit code.

MPIDI_CH3_Progress() has been split into two functions:
 MPIDI_CH3_Progress_wait() and MPIDI_CH3_Progress_test().


===============================================================================
                Changes in 0.93
===============================================================================

Version 0.93 has undergone extensive changes to provide better error reporting.
Part of these changes involved modifications to the ADI3 and CH3 interfaces.
The following routines now return MPI error codes:

MPID_Cancel_send()
MPID_Cancel_recv()
MPID_Progress_poke()
MPID_Progress_test()
MPID_Progress_wait()
MPIDI_CH3_Cancel_send()
MPIDI_CH3_Progress()
MPIDI_CH3_Progress_poke()
MPIDI_CH3_iRead()
MPIDI_CH3_iSend()
MPIDI_CH3_iSendv()
MPIDI_CH3_iStartmsg()
MPIDI_CH3_iStartmsgv()
MPIDI_CH3_iWrite()
MPIDI_CH3U_Handle_recv_pkt()
MPIDI_CH3U_Handle_recv_req()
MPIDI_CH3U_Handle_send_req()

*******************************************************************************
Of special note are MPID_Progress_test(), MPID_Progress_wait() and
MPIDI_CH3_Progress() which previously returned an integer value indicating if
one or more requests had completed.  They no longer return this value and
instead return an MPI error code (also an integer).  The implication being that
while the semantics changed, the type signatures did not.
```

```
********************************************************************************

The function used to create error codes, MPIR_Err_create_code(), has also
changed.  It now takes additional parameters, allowing it create a stack of
errors and making it possible for the reporting function to indicate in which
function and on which line the error occurred.  It also allows an error to be
designated as fatal or recoverable.  Fatal errors always result in program
termination regardless of the error handler installed by the application.

A RDMA channel has been added and includes communication methods for shared
memory and shmem.  This is recent development and the RDMA interface is still
in flux.
```

5.12.2 Release Notes

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-----------------------------------------------------------------------
                        KNOWN ISSUES
-----------------------------------------------------------------------

### Fine-grained thread safety

 * ch3:sock does not (and will not) support fine-grained threading.

 * MPI-IO APIs are not currently thread-safe when using fine-grained
   threading (--enable-thread-cs=per-object).

 * ch3:nemesis:tcp fine-grained threading is still experimental and may
   have correctness or performance issues.  Known correctness issues
   include dynamic process support and generalized request support.


### Lacking channel-specific features

 * ch3 does not presently support communication across heterogeneous
   platforms (e.g., a big-endian machine communicating with a
   little-endian machine).

 * ch3:nemesis:mx does not support dynamic processes at this time.

 * Support for "external32" data representation is incomplete. This
   affects the MPI_Pack_external and MPI_Unpack_external routines, as
   well the external data representation capabilities of ROMIO.  In
   particular: noncontiguous user buffers could consume egregious
   amounts of memory in the MPI library and any types which vary in
   width between the native representation and the external32
   representation will likely cause corruption.  The following ticket
   contains some additional information:

     http://trac.mpich.org/projects/mpich/ticket/1754

 * ch3 has known problems in some cases when threading and dynamic
   processes are used together on communicators of size greater than
   one.


### Process Managers
```

```
 * Hydra has a bug related to stdin handling:

     https://trac.mpich.org/projects/mpich/ticket/1782


### Performance issues

 * SMP-aware collectives do not perform as well, in select cases, as
   non-SMP-aware collectives, e.g. MPI_Reduce with message sizes
   larger than 64KiB. These can be disabled by the configure option
   "--disable-smpcoll".

 * MPI_Irecv operations that are not explicitly completed before
   MPI_Finalize is called may fail to complete before MPI_Finalize
   returns, and thus never complete. Furthermore, any matching send
   operations may erroneously fail. By explicitly completed, we mean
   that the request associated with the operation is completed by one
   of the MPI_Test or MPI_Wait routines.
```

5.13 MVAPICH2 Release Information

The following is reproduced essentially verbatim from files contained within the MVAPICH2 tarball downloaded from http://mvapich.cse.ohio-state.edu/

The MVAPICH2 User Guide is available at http://mvapich.cse.ohio-state.edu/support/.

MVAPICH2-2.1 introduces an algorithm to determine CPU topology on the node, and this new algorithm does not work properly for older Mellanox controllers and firmware, resulting in software threads not spreading out across a node's cores by default. This problem has been fixed in MVAPICH-2.2 and beyond.

Prior to updating to MVAPICH2-2.1, the cluster administrator should determine the potential vulnerability to this problem. For each node that contains an Infiniband controller, execute `ibstat`, and if the first output line is:

```
CA 'mthca0'
```

then that node *may* exhibit the problem. The cluster administrator has two choices: either avoid updating the `mvapich2-scyld` packages (keeping in mind that the `mvapich2-psm-scyld` packages can be updated, as those packages are only used by QLogic Infiniband controllers, which don't have the problem); or update `mvapich2-scyld`, execute tests to determine if the problem exists for those Mellanox *mthca* nodes, and if the problem does exist, then instruct users to employ explicit CPU Mapping. See http://mvapich.cse.ohio-state.edu/static/media/mvapich/mvapich2-2.1-userguide.html#x1-540006.5 fo details.

```
MVAPICH2 Changelog
------------------
This file briefly describes the changes to the MVAPICH2 software
package.  The logs are arranged in the "most recent first" order.

MVAPICH2 2.3.1 (03/01/2019)

* Features and Enhancements (since 2.3):
    - Add support for JSM and Flux resource managers
    - Architecture detection, enhanced point-to-point and collective tuning for
      AMD Epyc system
    - Enhanced point-to-point and collective tuning for IBM POWER9 and ARM
      systems
    - Add support of DDN Infinite Memory Engine (IME) to ROMIO
        - Thanks to Sylvain Didelot @DDN for the patch
    - Optimize performance of MPI_Wait operation
    - Update to hwloc 1.11.11

* Bug Fixes (since 2.3):
    - Fix autogen error with Flang compiler on ARM systems
        - Thanks to Nathan Sircombe @ARM for the patch
    - Fix issues with shmem collectives on ARM architecture
        - Thanks to Pavel Shamis @ARM for the patch
    - Fix issues with MPI-3 shared memory windows for PSM-CH3 and PSM2-CH3
      channel
        - Thanks to Adam Moody @LLNL for the report
    - Fix segfault in MPI_Reduce
        - Thanks to Samuel Khuvis @OSC for the report
    - Fix compilation issues with IBM XLC compiler
        - Thanks to Ken Raffenetti and Yanfei Guo @ANL for the patch
    - Fix issues with MPI_Mprobe/Improbe and MPI_Mrecv/Imrecv for PSM-CH3 and
      PSM2-CH3 channel
        - Thanks to Adam Moody @LLNL for the report
    - Fix compilation issues with PGI compilers for CUDA-enabled builds
    - Fix potential hangs in MPI_Finalize
    - Fix issues in handling very large messages with RGET protocol
    - Fix issues with handling GPU buffers
    - Fix issue with hardware multicast based Allreduce
    - Fix build issue with TCP/IP-CH3 channel
    - Fix memory leaks exposed by TotalView
        - Thanks to Adam Moody @LLNL for the report
    - Fix issues with cleaning up temporary files generated in CUDA builds
    - Fix compilation warnings

MVAPICH2 2.3 (07/23/2018)

* Features and Enhancements (since 2.3rc2):
    - Add point-to-point and collective tuning for IBM POWER9 CPUs
    - Enhanced collective tuning for IBM POWER8, Intel Skylake, Intel KNL, Intel
      Broadwell architectures

* Bug Fixes (since 2.3rc2):
    - Fix issues in CH3-TCP/IP channel
    - Fix build and runtime issues with CUDA support
    - Fix error when XRC and RoCE were enabled at the same time
    - Fix issue with XRC connection establishment
    - Fix for failure at finalize seen on iWARP enabled devices
    - Fix issue with MPI_IN_PLACE-based communcation in MPI_Reduce and
      MPI_Reduce_scatter
    - Fix issue with allocating large number of shared memory based MPI3-RMA
      windows
    - Fix failure in mpirun_rsh with large number of nodes
    - Fix singleton initialization issue with SLURM/PMI2 and PSM/Omni-Path
        - Thanks to Adam Moody @LLNL for the report
    - Fix build failure with when enabling GPFS support in ROMIO
        - Thanks to Doug Johnson @OHTech for the report
    - Fix issues with architecture detection in PSM-CH3 and PSM2-CH3 channels
    - Fix failures with CMA read at very large message sizes
    - Fix faiures with MV2_SHOW_HCA_BINDING on single-node jobs
    - Fix compilation warnings and memory leaks

MVAPICH2 2.3rc2 (04/30/2018)
```

```
* Features and Enhancements (since 2.3rc1):
    - Based on MPICH v3.2.1
    - Enhanced small message performance for MPI_Alltoallv
    - Improve performance for host-based transfers when CUDA is enabled
    - Add architecture detection for IBM POWER9 CPUs
    - Enhance architecture detection for Intel Skylake CPUs
    - Enhance MPI initialization to gracefully handle RDMA_CM failures
    - Improve algorithm selection of several collectives
    - Enhance detection of number and IP addresses of IB devices
    - Tested with CLANG v5.0.0

* Bug Fixes (since 2.3rc1):
    - Fix issue in autogen step with duplicate error messages
    - Fix issue with XRC connection establishment
    - Fix build issue with SLES 15 and Perl 5.26.1
        - Thanks to Matias A Cabral @Intel for the report and patch
    - Fix segfault when manually selecting collective algorithms
    - Fix cleanup of preallocated RDMA_FP regions at RDMA_CM finalize
    - Fix compilation warnings and memory leaks

MVAPICH2 2.3rc1 (02/19/2018)

* Features and Enhancements (since 2.3b):
    - Enhanced performance for Allreduce, Reduce_scatter_block, Allgather,
      Allgatherv through new algorithms
        - Thanks to Danielle Sikich and Adam Moody @ LLNL for the patch
    - Enhance support for MPI_T PVARs and CVARs
    - Improved job startup time for OFA-IB-CH3, PSM-CH3, and PSM2-CH3
    - Support to automatically detect IP address of IB/RoCE interfaces when
      RDMA_CM is enabled without relying on mv2.conf file
    - Enhance HCA detection to handle cases where node has both IB and RoCE HCAs
    - Automatically detect and use maximum supported MTU by the HCA
    - Added logic to detect heterogeneous CPU/HFI configurations in PSM-CH3 and
      PSM2-CH3 channels
        - Thanks to Matias Cabral@Intel for the report
    - Enhanced intra-node and inter-node tuning for PSM-CH3 and PSM2-CH3
      channels
    - Enhanced HFI selection logic for systems with multiple Omni-Path HFIs
    - Enhanced tuning and architecture detection for OpenPOWER, Intel Skylake
      and Cavium ARM (ThunderX) systems
    - Added 'SPREAD', 'BUNCH', and 'SCATTER' binding options for hybrid CPU
      binding policy
    - Rename MV2_THREADS_BINDING_POLICY to MV2_HYBRID_BINDING_POLICY
    - Added support for MV2_SHOW_CPU_BINDING to display number of OMP threads
    - Update to hwloc version 1.11.9

* Bug Fixes (since 2.3b):
    - Fix issue with RDMA_CM in multi-rail scenario
    - Fix issues in nullpscw RMA test.
    - Fix issue with reduce and allreduce algorithms for large message sizes
    - Fix hang issue in hydra when no SLURM environment is present
        - Thanks to Vaibhav Sundriyal for the report
    - Fix issue to test Fortran KIND with FFLAGS
        - Thanks to Rob Latham@mcs.anl.gov for the patch
    - Fix issue in parsing environment variables
    - Fix issue in displaying process to HCA binding
    - Enhance CPU binding logic to handle vendor specific core mappings
    - Fix compilation warnings and memory leaks
```

```
MVAPICH2 2.3b (08/10/2017)

* Features and Enhancements (since 2.3a):
    - Enhance performance of point-to-point operations for CH3-Gen2 (InfiniBand),
      CH3-PSM, and CH3-PSM2 (Omni-Path) channels
    - Improve performance for MPI-3 RMA operations
    - Introduce support for Cavium ARM (ThunderX) systems
    - Improve support for process to core mapping on many-core systems
        - New environment variable MV2_THREADS_BINDING_POLICY for
          multi-threaded MPI and MPI+OpenMP applications
        - Support `linear' and `compact' placement of threads
        - Warn user if oversubcription of core is detected
    - Improve launch time for large-scale jobs with mpirun_rsh
    - Add support for non-blocking Allreduce using Mellanox SHARP
    - Efficient support for different Intel Knight's Landing (KNL) models
    - Improve performance for Intra- and Inter-node communication for OpenPOWER
      architecture
    - Improve support for large processes per node and hugepages on SMP systems
    - Enhance collective tuning for Intel Knight's Landing and Intel Omni-Path
      based systems
    - Enhance collective tuning for Bebop@ANL, Bridges@PSC, and Stampede2@TACC
      systems
    - Enhance large message intra-node performance with CH3-IB-Gen2 channel on
      Intel Knight's Landing
    - Enhance support for MPI_T PVARs and CVARs
* Bug Fixes (since 2.3a):
    - Fix issue with bcast algorithm selection
    - Fix issue with large message transfers using CMA
    - Fix issue in Scatter and Gather with large messages
    - Fix tuning tables for various collectives
    - Fix issue with launching single-process MPI jobs
    - Fix compilation error in the CH3-TCP/IP channel
        - Thanks to Isaac Carroll@Lightfleet for the patch
    - Fix issue with memory barrier instructions on ARM
        - Thanks to Pavel (Pasha) Shamis@ARM for reporting the issue
    - Fix compilation warnings and memory leaks

MVAPICH2 2.3a (03/29/2017)

* Features and Enhancements (since 2.2):
    - Based on and ABI compatible with MPICH 3.2
    - Support collective offload using Mellanox's SHArP for Allreduce
        - Enhance tuning framework for Allreduce using SHArP
    - Introduce capability to run MPI jobs across multiple InfiniBand subnets
    - Introduce basic support for executing MPI jobs in Singularity
    - Enhance collective tuning for Intel Knight's Landing and Intel Omni-path
    - Enhance process mapping support for multi-threaded MPI applications
        - Introduce MV2_CPU_BINDING_POLICY=hybrid
        - Introduce MV2_THREADS_PER_PROCESS
    - On-demand connection management for PSM-CH3 and PSM2-CH3 channels
    - Enhance PSM-CH3 and PSM2-CH3 job startup to use non-blocking PMI calls
    - Enhance debugging support for PSM-CH3 and PSM2-CH3 channels
    - Improve performance of architecture detection
    - Introduce run time parameter MV2_SHOW_HCA_BINDING to show process to HCA
      bindings
    - Enhance MV2_SHOW_CPU_BINDING to enable display of CPU bindings on all
      nodes
    - Deprecate OFA-IB-Nemesis channel
    - Update to hwloc version 1.11.6
* Bug Fixes (since 2.2):
    - Fix issue with ring startup in multi-rail systems
    - Fix startup issue with SLURM and PMI-1
        - Thanks to Manuel Rodriguez for the report
    - Fix startup issue caused by fix for bash `shellshock' bug
    - Fix issue with very large messages in PSM
    - Fix issue with singleton jobs and PMI-2
        - Thanks to Adam T. Moody@LLNL for the report
    - Fix incorrect reporting of non-existing files with Luster ADIO
        - Thanks to Wei Kang@NWU for the report
    - Fix hang in MPI_Probe
        - Thanks to John Westlund@Intel for the report
    - Fix issue while setting affinity with Torque Cgroups
        - Thanks to Doug Johnson@OSC for the report
    - Fix runtime errors observed when running MVAPICH2 on aarch64 platforms
        - Thanks to Sreenidhi Bharathkar Ramesh@Broadcom for posting
          the original patch
        - Thanks to Michal Schmidt@RedHat for reposting it
    - Fix failure in mv2_show_cpu_affinity with affinity disabled
        - Thanks to Carlos Rosales-Fernandez@TACC for the report
    - Fix mpirun_rsh error when running short-lived non-MPI jobs
        - Thanks to Kevin Manalo@OSC for the report
    - Fix comment and spelling mistake
        - Thanks to Maksym Planeta for the report
    - Ignore cpusets and cgroups that may have been set by resource manager
        - Thanks to Adam T. Moody@LLNL for the report and the patch
    - Fix reduce tuning table entry for 2ppn 2node
    - Fix compilation issues due to inline keyword with GCC 5 and newer
    - Fix compilation warnings and memory leaks

MVAPICH2 2.2 (09/07/2016)

* Features and Enhancements (since 2.2rc2):
    - Single node collective tuning for Bridges@PSC, Stampede@TACC and other
      architectures
    - Enable PSM builds when both PSM and PSM2 libraries are present
        - Thanks to Adam T. Moody@LLNL for the report and patch
    - Add support for HCAs that return result of atomics in big endian notation
    - Establish loopback connections by default if HCA supports atomics
* Bug Fixes (since 2.2rc2):
    - Fix minor error in use of communicator object in collectives
    - Fix missing u_int64_t declaration with PGI compilers
        - Thanks to Adam T. Moody@LLNL for the report and patch
    - Fix memory leak in RMA rendezvous code path
        - Thanks to Min Si@ANL for the report and patch

MVAPICH2 2.2rc2 (08/08/2016)

* Features and Enhancements (since 2.2rc1):
    - Enhanced performance for MPI_Comm_split through new bitonic algorithm
        - Thanks to Adam T. Moody@LLNL for the patch
    - Enable graceful fallback to Shared Memory if LiMIC2 or CMA transfer fails
    - Enable support for multiple MPI initializations
    - Unify process affinity support in Gen2, PSM and PSM2 channels
    - Remove verbs dependency when building the PSM and PSM2 channels
    - Allow processes to request MPI_THREAD_MULTIPLE when socket or NUMA node
      level affinity is specified
    - Point-to-point and collective performance optimization for Intel Knights
      Landing
    - Automatic detection and tuning for InfiniBand EDR HCAs
    - Warn user to reconfigure library if rank type is not large enough to
      represent all ranks in job
    - Collective tuning for Opal@LLNL, Bridges@PSC, and Stampede-1.5@TACC
    - Tuning and architecture detection for Intel Broadwell processors
    - Add ability to avoid using --enable-new-dtags with ld
        - Thanks to Adam T. Moody@LLNL for the suggestion
    - Add LIBTVMPICH specific CFLAGS and LDFLAGS
        - Thanks to Adam T. Moody@LLNL for the suggestion

* Bug Fixes (since 2.2rc1):
    - Disable optimization that removes use of calloc in ptmalloc hook
      detection code
        - Thanks to Karl W. Schulz@Intel
    - Fix weak alias typos (allows successful compilation with CLANG compiler)
        - Thanks to Min Dong@Old Dominion University for the patch
    - Fix issues in PSM large message gather operations
        - Thanks to Adam T. Moody@LLNL for the report
    - Enhance error checking in collective tuning code
        - Thanks to Jan Bierbaum@Technical University of Dresden for the patch
    - Fix issues with UD based communication in RoCE mode
    - Fix issues with PMI2 support in singleton mode
    - Fix default binding bug in hydra launcher
    - Fix issues with Checkpoint Restart when launched with mpirun_rsh
    - Fix fortran binding issues with Intel 2016 compilers
    - Fix issues with socket/NUMA node level binding
    - Disable atomics when using Connect-IB with RDMA_CM
    - Fix hang in MPI_Finalize when using hybrid channel
    - Fix memory leaks

MVAPICH2 2.2rc1 (03/29/2016)

* Features and Enhancements (since 2.2b):
    - Support for OpenPower architecture
        - Optimized inter-node and intra-node communication
    - Support for Intel Omni-Path architecture
        - Thanks to Intel for contributing the patch
        - Introduction of a new PSM2 channel for Omni-Path
    - Support for RoCEv2
    - Architecture detection for PSC Bridges system with Omni-Path
    - Enhanced startup performance and reduced memory footprint for storing
      InfiniBand end-point information with SLURM
        - Support for shared memory based PMI operations
        - Availability of an updated patch from the MVAPICH project website
          with this support for SLURM installations
    - Optimized pt-to-pt and collective tuning for Chameleon InfiniBand
      systems at TACC/UoC
    - Enable affinity by default for TrueScale(PSM) and Omni-Path(PSM2)
      channels
    - Enhanced tuning for shared-memory based MPI_Bcast
    - Enhanced debugging support and error messages
    - Update to hwloc version 1.11.2

* Bug Fixes (since 2.2b):
    - Fix issue in some of the internal algorithms used for MPI_Bcast,
      MPI_Alltoall and MPI_Reduce
    - Fix hang in one of the internal algorithms used for MPI_Scatter
        - Thanks to Ivan Raikov@Stanford for reporting this issue
    - Fix issue with rdma_connect operation
    - Fix issue with Dynamic Process Management feature
    - Fix issue with de-allocating InfiniBand resources in blocking mode
    - Fix build errors caused due to improper compile time guards
        - Thanks to Adam Moody@LLNL for the report
    - Fix finalize hang when running in hybrid or UD-only mode
        - Thanks to Jerome Vienne@TACC for reporting this issue
    - Fix issue in MPI_Win_flush operation
        - Thanks to Nenad Vukicevic for reporting this issue
    - Fix out of memory issues with non-blocking collectives code
        - Thanks to Phanisri Pradeep Pratapa and Fang Liu@GaTech for
          reporting this issue
    - Fix fall-through bug in external32 pack
        - Thanks to Adam Moody@LLNL for the report and patch
    - Fix issue with on-demand connection establishment and blocking mode
        - Thanks to Maksym Planeta@TU Dresden for the report
    - Fix memory leaks in hardware multicast based broadcast code
    - Fix memory leaks in TrueScale(PSM) channel
    - Fix compilation warnings

MVAPICH2 2.2b (11/12/2015)

* Features and Enhancements (since 2.2a):
    - Enhanced performance for small messages
    - Enhanced startup performance with SLURM
        - Support for PMIX_Iallgather and PMIX_Ifence
    - Support to enable affinity with asynchronous progress thread
    - Enhanced support for MPIT based performance variables
    - Tuned VBUF size for performance
    - Improved startup performance for QLogic PSM-CH3 channel
        - Thanks to Maksym Planeta@TU Dresden for the patch

* Bug Fixes (since 2.2a):
    - Fix issue with MPI_Get_count in QLogic PSM-CH3 channel with very large
      messages (>2GB)
    - Fix issues with shared memory collectives and checkpoint-restart
    - Fix hang with checkpoint-restart
    - Fix issue with unlinking shared memory files
    - Fix memory leak with MPIT
    - Fix minor typos and usage of inline and static keywords
        - Thanks to Maksym Planeta@TU Dresden for the patch and suggestions
    - Fix missing MPIDI_FUNC_EXIT
        - Thanks to Maksym Planeta@TU Dresden for the patch
    - Remove unused code
        - Thanks to Maksym Planeta@TU Dresden for the patch
    - Continue with warning if user asks to enable XRC when the system does not
      support XRC

MVAPICH2 2.2a (08/17/2015)

* Features and Enhancements (since 2.1 GA):

  - Based on MPICH 3.1.4
  - Support for backing on-demand UD CM information with shared memory
    for minimizing memory footprint
  - Reorganized HCA-aware process mapping
  - Dynamic identification of maximum read/atomic operations supported by HCA
  - Enabling support for intra-node communications in RoCE mode without
    shared memory
  - Updated to hwloc 1.11.0
  - Updated to sm_20 kernel optimizations for MPI Datatypes
  - Automatic detection and tuning for 24-core Haswell architecture

* Bug Fixes (since 2.1 GA):

  - Fix for error with multi-vbuf design for GPU based communication
  - Fix bugs with hybrid UD/RC/XRC communications
  - Fix for MPICH putfence/getfence for large messages
  - Fix for error in collective tuning framework
  - Fix validation failure with Alltoall with IN_PLACE option
     - Thanks for Mahidhar Tatineni @SDSC for the report
  - Fix bug with MPI_Reduce with IN_PLACE option
     - Thanks to Markus Geimer for the report
  - Fix for compilation failures with multicast disabled
     - Thanks to Devesh Sharma @Emulex for the report
  - Fix bug with MPI_Bcast
  - Fix IPC selection for shared GPU mode systems
  - Fix for build time warnings and memory leaks
  - Fix issues with Dynamic Process Management
     - Thanks to Neil Spruit for the report
   - Fix bug in architecture detection code
     - Thanks to Adam Moody @LLNL for the report

MVAPICH2-2.1 (04/03/2015)

* Features and Enhancements (since 2.1rc2):
    - Tuning for EDR adapters
    - Optimization of collectives for SDSC Comet system

* Bug-Fixes (since 2.1rc2):
    - Relocate reading environment variables in PSM
        - Thanks to Adam Moody@LLNL for the suggestion
    - Fix issue with automatic process mapping
    - Fix issue with checkpoint restart when full path is not given
    - Fix issue with Dynamic Process Management
    - Fix issue in CUDA IPC code path
    - Fix corner case in CMA runtime detection

MVAPICH2-2.1rc2 (03/12/2015)

* Features and Enhancements (since 2.1rc1):
    - Based on MPICH-3.1.4
    - Enhanced startup performance with mpirun_rsh
    - Checkpoint-Restart Support with DMTCP (Distributed MultiThreaded
      CheckPointing)
        - Thanks to the DMTCP project team (http://dmtcp.sourceforge.net/)
    - Support for handling very large messages in RMA
    - Optimize size of buffer requested for control messages in large message
      transfer
    - Enhanced automatic detection of atomic support
    - Optimized collectives (bcast, reduce, and allreduce) for 4K processes
    - Introduce support to sleep for user specified period before aborting
        - Thanks to Adam Moody@LLNL for the suggestion
    - Disable PSM from setting CPU affinity
```

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        - Thanks to Adam Moody@LLNL for providing the patch
    - Install PSM error handler to print more verbose error messages
        - Thanks to Adam Moody@LLNL for providing the patch
    - Introduce retry mechanism to perform psm_ep_open in PSM channel
        - Thanks to Adam Moody@LLNL for providing the patch

* Bug-Fixes (since 2.1rc1):
    - Fix failures with shared memory collectives with checkpoint-restart
    - Fix failures with checkpoint-restart when using internal communication
      buffers of different size
    - Fix undeclared variable error when --disable-cxx is specified with
      configure
        - Thanks to Chris Green from FANL for the patch
    - Fix segfault seen during connect/accept with dynamic processes
        - Thanks to Neil Spruit for the fix
    - Fix errors with large messages pack/unpack operations in PSM channel
    - Fix for bcast collective tuning
    - Fix assertion errors in one-sided put operations in PSM channel
    - Fix issue with code getting stuck in infinite loop inside ptmalloc
        - Thanks to Adam Moody@LLNL for the suggested changes
    - Fix assertion error in shared memory large message transfers
        - Thanks to Adam Moody@LLNL for reporting the issue
    - Fix compilation warnings

MVAPICH2-2.1rc1 (12/18/2014)

* Features and Enhancements (since 2.1a):
    - Based on MPICH-3.1.3
    - Flexibility to use internal communication buffers of different size for
      improved performance and memory footprint
    - Improve communication performance by removing locks from critical path
    - Enhanced communication performance for small/medium message sizes
    - Support for linking Intel Trace Analyzer and Collector
    - Increase the number of connect retry attempts with RDMA_CM
    - Automatic detection and tuning for Haswell architecture

* Bug-Fixes (since 2.1a):
    - Fix automatic detection of support for atomics
    - Fix issue with void pointer arithmetic with PGI
    - Fix deadlock in ctxidup MPICH test in PSM channel
    - Fix compile warnings

MVAPICH2-2.1a (09/21/2014)

* Features and Enhancements (since 2.0):
    - Based on MPICH-3.1.2
    - Support for PMI-2 based startup with SLURM
    - Enhanced startup performance for Gen2/UD-Hybrid channel
    - GPU support for MPI_Scan and MPI_Exscan collective operations
    - Optimize creation of 2-level communicator
    - Collective optimization for PSM-CH3 channel
    - Tuning for IvyBridge architecture
    - Add -export-all option to mpirun_rsh
    - Support for additional MPI-T performance variables (PVARs)
      in the CH3 channel
    - Link with libstdc++ when building with GPU support
        (required by CUDA 6.5)
```

```
* Bug-Fixes (since 2.0):
    - Fix error in large message (>2GB) transfers in CMA code path
    - Fix memory leaks in OFA-IB-CH3 and OFA-IB-Nemesis channels
    - Fix issues with optimizations for broadcast and reduce collectives
    - Fix hang at finalize with Gen2-Hybrid/UD channel
    - Fix issues for collectives with non power-of-two process counts
          - Thanks to Evren Yurtesen for identifying the issue
    - Make ring startup use HCA selected by user
    - Increase counter length for shared-memory collectives

MVAPICH2-2.0 (06/20/2014)

* Features and Enhancements (since 2.0rc2):
    - Consider CMA in collective tuning framework

* Bug-Fixes (since 2.0rc2):
    - Fix bug when disabling registration cache
    - Fix shared memory window bug when shared memory collectives are disabled
    - Fix mpirun_rsh bug when running mpmd programs with no arguments

MVAPICH2-2.0rc2 (05/25/2014)

* Features and Enhancements (since 2.0rc1):
    - CMA support is now enabled by default
    - Optimization of collectives with CMA support
    - RMA optimizations for shared memory and atomic operations
    - Tuning RGET and Atomics operations
    - Tuning RDMA FP-based communication
    - MPI-T support for additional performance and control variables
    - The --enable-mpit-pvars=yes configuration option will now
      enable only MVAPICH2 specific variables
    - Large message transfer support for PSM interface
    - Optimization of collectives for PSM interface
    - Updated to hwloc v1.9

* Bug-Fixes (since 2.0rc1):
    - Fix multicast hang when there is a single process on one node
      and more than one process on other nodes
    - Fix non-power-of-two usage of scatter-doubling-allgather algorithm
    - Fix for bcastzero type hang during finalize
    - Enhanced handling of failures in RDMA_CM based
      connection establishment
    - Fix for a hang in finalize when using RDMA_CM
    - Finish receive request when RDMA READ completes in RGET protocol
    - Always use direct RDMA when flush is used
    - Fix compilation error with --enable-g=all in PSM interface
    - Fix warnings and memory leaks

MVAPICH2-2.0rc1 (03/24/2014)

* Features and Enhancements (since 2.0b):
    - Based on MPICH-3.1
    - Enhanced direct RDMA based designs for MPI_Put and MPI_Get operations in
      OFA-IB-CH3 channel
    - Optimized communication when using MPI_Win_allocate for OFA-IB-CH3
      channel
    - MPI-3 RMA support for CH3-PSM channel
    - Multi-rail support for UD-Hybrid channel
    - Optimized and tuned blocking and non-blocking collectives for OFA-IB-CH3,
      OFA-IB-Nemesis, and CH3-PSM channels
    - Improved hierarchical job startup performance
    - Optimized sub-array data-type processing for GPU-to-GPU communication
    - Tuning for Mellanox Connect-IB adapters
    - Updated hwloc to version 1.8
    - Added options to specify CUDA library paths
    - Deprecation of uDAPL-CH3 channel

* Bug-Fixes (since 2.0b):
    - Fix issues related to MPI-3 RMA locks
    - Fix an issue related to MPI-3 dynamic window
    - Fix issues related to MPI_Win_allocate backed by shared memory
    - Fix issues related to large message transfers for OFA-IB-CH3 and
      OFA-IB-Nemesis channels
    - Fix warning in job launch, when using DPM
    - Fix an issue related to MPI atomic operations on HCAs without atomics
      support
    - Fixed an issue related to selection of compiler. (We prefer the GNU,
      Intel, PGI, and Ekopath compilers in that order).
        - Thanks to Uday R Bondhugula from IISc for the report
    - Fix an issue in message coalescing
    - Prevent printing out inter-node runtime parameters for pure intra-node
      runs
        - Thanks to Jerome Vienne from TACC for the report
    - Fix an issue related to ordering of messages for GPU-to-GPU transfers
    - Fix a few memory leaks and warnings

MVAPICH2-2.0b (11/08/2013)

* Features and Enhancements (since 2.0a):
    - Based on MPICH-3.1b1
    - Multi-rail support for GPU communication
    - Non-blocking streams in asynchronous CUDA transfers for better overlap
    - Initialize GPU resources only when used by MPI transfer
    - Extended support for MPI-3 RMA in OFA-IB-CH3, OFA-IWARP-CH3, and
      OFA-RoCE-CH3
    - Additional MPIT counters and performance variables
    - Updated compiler wrappers to remove application dependency on network and
      other extra libraries
        - Thanks to Adam Moody from LLNL for the suggestion
    - Capability to checkpoint CH3 channel using the Hydra process manager
    - Optimized support for broadcast, reduce and other collectives
    - Tuning for IvyBridge architecture
    - Improved launch time for large-scale mpirun_rsh jobs
    - Introduced retry mechanism in mpirun_rsh for socket binding
    - Updated hwloc to version 1.7.2

* Bug-Fixes (since 2.0a):
    - Consider list provided by MV2_IBA_HCA when scanning device list
    - Fix issues in Nemesis interface with --with-ch3-rank-bits=32
    - Better cleanup of XRC files in corner cases
    - Initialize using better defaults for ibv_modify_qp (initial ring)
    - Add unconditional check and addition of pthread library
    - MPI_Get_library_version updated with proper MVAPICH2 branding
        - Thanks to Jerome Vienne from the TACC for the report

MVAPICH2-2.0a (08/24/2013)
```

```
* Features and Enhancements (since 1.9):
    - Based on MPICH-3.0.4
    - Dynamic CUDA initialization. Support GPU device selection after MPI_Init
    - Support for running on heterogeneous clusters with GPU and non-GPU nodes
    - Supporting MPI-3 RMA atomic operations and flush operations with CH3-Gen2
      interface
    - Exposing internal performance variables to MPI-3 Tools information
      interface (MPIT)
    - Enhanced MPI_Bcast performance
    - Enhanced performance for large message MPI_Scatter and MPI_Gather
    - Enhanced intra-node SMP performance
    - Tuned SMP eager threshold parameters
    - Reduced memory footprint
    - Improved job-startup performance
    - Warn and continue when ptmalloc fails to initialize
    - Enable hierarchical SSH-based startup with Checkpoint-Restart
    - Enable the use of Hydra launcher with Checkpoint-Restart

* Bug-Fixes (since 1.9):
    - Fix data validation issue with MPI_Bcast
        - Thanks to Claudio J. Margulis from University of Iowa for the report
    - Fix buffer alignment for large message shared memory transfers
    - Fix a bug in One-Sided shared memory backed windows
    - Fix a flow-control bug in UD transport
        - Thanks to Benjamin M. Auer from NASA for the report
    - Fix bugs with MPI-3 RMA in Nemesis IB interface
    - Fix issue with very large message (>2GB bytes) MPI_Bcast
        - Thanks to Lu Qiyue for the report
    - Handle case where $HOME is not set during search for MV2 user config file
        - Thanks to Adam Moody from LLNL for the patch
    - Fix a hang in connection setup with RDMA-CM

MVAPICH2-1.9 (05/06/2013)

* Features and Enhancements (since 1.9rc1):
    - Updated to hwloc v1.7
    - Tuned Reduce, AllReduce, Scatter, Reduce-Scatter and
        Allgatherv Collectives

* Bug-Fixes (since 1.9rc1):
    - Fix cuda context issue with async progress thread
       - Thanks to Osuna Escamilla Carlos from env.ethz.ch for the report
    - Overwrite pre-existing PSM environment variables
       - Thanks to Adam Moody from LLNL for the patch
    - Fix several warnings
       - Thanks to Adam Moody from LLNL for some of the patches

MVAPICH2-1.9RC1 (04/16/2013)

* Features and Enhancements (since 1.9b):
    - Based on MPICH-3.0.3
    - Updated SCR to version 1.1.8
    - Install utility scripts included with SCR
    - Support for automatic detection of path to utilities used by mpirun_rsh
      during configuration
        - Utilities supported: rsh, ssh, xterm, totalview
    - Support for launching jobs on heterogeneous networks with mpirun_rsh
    - Tuned Bcast, Reduce, Scatter Collectives
    - Tuned MPI performance on Kepler GPUs
    - Introduced MV2_RDMA_CM_CONF_FILE_PATH parameter which specifies path to
      mv2.conf

* Bug-Fixes (since 1.9b):
    - Fix autoconf issue with LiMIC2 source-code
        - Thanks to Doug Johnson from OH-TECH for the report
    - Fix build errors with --enable-thread-cs=per-object and
      --enable-refcount=lock-free
        - Thanks to Marcin Zalewski from Indiana University for the report
    - Fix MPI_Scatter failure with MPI_IN_PLACE
        - Thanks to Mellanox for the report
    - Fix MPI_Scatter failure with cyclic host files
    - Fix deadlocks in PSM interface for multi-threaded jobs
        - Thanks to Marcin Zalewski from Indiana University for the report
    - Fix MPI_Bcast failures in SCALAPACK
        - Thanks to Jerome Vienne from TACC for the report
    - Fix build errors with newer Ekopath compiler
    - Fix a bug with shmem collectives in PSM interface
    - Fix memory corruption when more entries specified in mv2.conf than the
      requested number of rails
        - Thanks to Akihiro Nomura from Tokyo Institute of Technology for the
          report
    - Fix memory corruption with CR configuration in Nemesis interface

MVAPICH2-1.9b (02/28/2013)

* Features and Enhancements (since 1.9a2):
    - Based on MPICH-3.0.2
        - Support for all MPI-3 features
    - Support for single copy intra-node communication using Linux supported
      CMA (Cross Memory Attach)
        - Provides flexibility for intra-node communication: shared memory,
          LiMIC2, and CMA
    - Checkpoint/Restart using LLNL's Scalable Checkpoint/Restart Library (SCR)
        - Support for application-level checkpointing
        - Support for hierarchical system-level checkpointing
    - Improved job startup time
        - Provided a new runtime variable MV2_HOMOGENEOUS_CLUSTER for optimized
          startup on homogeneous clusters
    - New version of LiMIC2 (v0.5.6)
        - Provides support for unlocked ioctl calls
    - Tuned Reduce, Allgather, Reduce_Scatter, Allgatherv collectives
    - Introduced option to export environment variables automatically with
      mpirun_rsh
    - Updated to HWLOC v1.6.1
    - Provided option to use CUDA libary call instead of CUDA driver to check
      buffer pointer type
        - Thanks to Christian Robert from Sandia for the suggestion
    - Improved debug messages and error reporting

* Bug-Fixes (since 1.9a2):
    - Fix page fault with memory access violation with LiMIC2 exposed by newer
      Linux kernels
        - Thanks to Karl Schulz from TACC for the report
    - Fix a failure when lazy memory registration is disabled and CUDA is
      enabled
        - Thanks to Jens Glaser from University of Minnesota for the report
    - Fix an issue with variable initialization related to DPM support
    - Rename a few internal variables to avoid name conflicts with external
      applications
        - Thanks to Adam Moody from LLNL for the report
    - Check for libattr during configuration when Checkpoint/Restart and
      Process Migration are requested
        - Thanks to John Gilmore from Vastech for the report
    - Fix build issue with --disable-cxx
    - Set intra-node eager threshold correctly when configured with LiMIC2
    - Fix an issue with MV2_DEFAULT_PKEY in partitioned InfiniBand network
        - Thanks to Jesper Larsen from FCOO for the report
    - Improve makefile rules to use automake macros
        - Thanks to Carmelo Ponti from CSCS for the report
    - Fix configure error with automake conditionals
        - Thanks to Evren Yurtesen from Abo Akademi for the report
    - Fix a few memory leaks and warnings
    - Properly cleanup shared memory files (used by XRC) when applications fail

MVAPICH2-1.9a2 (11/08/2012)

* Features and Enhancements (since 1.9a):
    - Based on MPICH2-1.5
    - Initial support for MPI-3:
      (Available for all interfaces: OFA-IB-CH3, OFA-IWARP-CH3, OFA-RoCE-CH3,
       uDAPL-CH3, OFA-IB-Nemesis, PSM-CH3)
        - Nonblocking collective functions available as "MPIX_" functions
          (e.g., "MPIX_Ibcast")
        - Neighborhood collective routines available as "MPIX_" functions
          (e.g., "MPIX_Neighbor_allgather")
        - MPI_Comm_split_type function available as an "MPIX_" function
        - Support for MPIX_Type_create_hindexed_block
        - Nonblocking communicator duplication routine MPIX_Comm_idup (will
          only work for single-threaded programs)
        - MPIX_Comm_create_group support
        - Support for matched probe functionality (e.g., MPIX_Mprobe,
          MPIX_Improbe, MPIX_Mrecv, and MPIX_Imrecv),
          (Not Available for PSM)
        - Support for "Const" (disabled by default)
    - Efficient vector, hindexed datatype processing on GPU buffers
    - Tuned alltoall, Scatter and Allreduce collectives
    - Support for Mellanox Connect-IB HCA
    - Adaptive number of registration cache entries based on job size
    - Revamped Build system:
        - Uses automake instead of simplemake,
        - Allows for parallel builds ("make -j8" and similar)

* Bug-Fixes (since 1.9a):
    - CPU frequency mismatch warning shown under debug
    - Fix issue with MPI_IN_PLACE buffers with CUDA
    - Fix ptmalloc initialization issue due to compiler optimization
        - Thanks to Kyle Sheumaker from ACT for the report
    - Adjustable MAX_NUM_PORTS at build time to support more than two ports
    - Fix issue with MPI_Allreduce with MPI_IN_PLACE send buffer
    - Fix memleak in MPI_Cancel with PSM interface
        - Thanks to Andrew Friedley from LLNL for the report

MVAPICH2-1.9a (09/07/2012)
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* Features and Enhancements (since 1.8):
    - Support for InfiniBand hardware UD-multicast
    - UD-multicast-based designs for collectives
      (Bcast, Allreduce and Scatter)
    - Enhanced Bcast and Reduce collectives with pt-to-pt communication
    - LiMIC-based design for Gather collective
    - Improved performance for shared-memory-aware collectives
    - Improved intra-node communication performance with GPU buffers
      using pipelined design
    - Improved inter-node communication performance with GPU buffers
      with non-blocking CUDA copies
    - Improved small message communication performance with
      GPU buffers using CUDA IPC design
    - Improved automatic GPU device selection and CUDA context management
    - Optimal communication channel selection for different
      GPU communication modes (DD, DH and HD) in different
      configurations (intra-IOH and inter-IOH)
    - Removed libibumad dependency for building the library
    - Option for selecting non-default gid-index in a loss-less
      fabric setup in RoCE mode
    - Option to disable signal handler setup
    - Tuned thresholds for various architectures
    - Set DAPL-2.0 as the default version for the uDAPL interface
    - Updated to hwloc v1.5
    - Option to use IP address as a fallback if hostname
      cannot be resolved
    - Improved error reporting

* Bug-Fixes (since 1.8):
    - Fix issue in intra-node knomial bcast
    - Handle gethostbyname return values gracefully
    - Fix corner case issue in two-level gather code path
    - Fix bug in CUDA events/streams pool management
    - Fix ptmalloc initialization issue when MALLOC_CHECK_ is
      defined in the environment
        - Thanks to Mehmet Belgin from Georgia Institute of
          Technology for the report
    - Fix memory corruption and handle heterogeneous architectures
      in gather collective
    - Fix issue in detecting the correct HCA type
    - Fix issue in ring start-up to select correct HCA when
      MV2_IBA_HCA is specified
    - Fix SEGFAULT in MPI_Finalize when IB loop-back is used
    - Fix memory corruption on nodes with 64-cores
        - Thanks to M Xie for the report
    - Fix hang in MPI_Finalize with Nemesis interface when
      ptmalloc initialization fails
        - Thanks to Carson Holt from OICR for the report
    - Fix memory corruption in shared memory communication
        - Thanks to Craig Tierney from NOAA for the report
          and testing the patch
    - Fix issue in IB ring start-up selection with mpiexec.hydra
    - Fix issue in selecting CUDA run-time variables when running
      on single node in SMP only mode
    - Fix few memory leaks and warnings

MVAPICH2-1.8 (04/30/2012)
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* Features and Enhancements (since 1.8rc1):
    - Introduced a unified run time parameter MV2_USE_ONLY_UD to enable UD only
      mode
    - Enhanced designs for Alltoall and Allgather collective communication from
      GPU device buffers
    - Tuned collective communication from GPU device buffers
    - Tuned Gather collective
    - Introduced a run time parameter MV2_SHOW_CPU_BINDING to show current CPU
      bindings
    - Updated to hwloc v1.4.1
    - Remove dependency on LEX and YACC


* Bug-Fixes (since 1.8rc1):
    - Fix hang with multiple GPU configuration
        - Thanks to Jens Glaser from University of Minnesota for the report
    - Fix buffer alignment issues to improve intra-node performance
    - Fix a DPM multispawn behavior
    - Enhanced error reporting in DPM functionality
    - Quote environment variables in job startup to protect from shell
    - Fix hang when LIMIC is enabled
    - Fix hang in environments with heterogeneous HCAs
    - Fix issue when using multiple HCA ports in RDMA_CM mode
        - Thanks to Steve Wise from Open Grid Computing for the report
    - Fix hang during MPI_Finalize in Nemesis IB netmod
    - Fix for a start-up issue in Nemesis with heterogeneous architectures
    - Fix few memory leaks and warnings

MVAPICH2-1.8rc1 (03/22/2012)

* Features & Enhancements (since 1.8a2):
    - New design for intra-node communication from GPU Device buffers using
      CUDA IPC for better performance and correctness
        - Thanks to Joel Scherpelz from NVIDIA for his suggestions
    - Enabled shared memory communication for host transfers when CUDA is
      enabled
    - Optimized and tuned collectives for GPU device buffers
    - Enhanced pipelined inter-node device transfers
    - Enhanced shared memory design for GPU device transfers for large messages
    - Enhanced support for CPU binding with socket and numanode level
      granularity
    - Support suspend/resume functionality with mpirun_rsh
    - Exporting local rank, local size, global rank and global size through
      environment variables (both mpirun_rsh and hydra)
    - Update to hwloc v1.4
    - Checkpoint-Restart support in OFA-IB-Nemesis interface
    - Enabling run-through stabilization support to handle process failures in
      OFA-IB-Nemesis interface
    - Enhancing OFA-IB-Nemesis interface to handle IB errors gracefully
    - Performance tuning on various architecture clusters
    - Support for Mellanox IB FDR adapter

* Bug-Fixes (since 1.8a2):
    - Fix a hang issue on InfiniHost SDR/DDR cards
        - Thanks to Nirmal Seenu from Fermilab for the report
    - Fix an issue with runtime parameter MV2_USE_COALESCE usage
    - Fix an issue with LiMIC2 when CUDA is enabled
    - Fix an issue with intra-node communication using datatypes and GPU device
```

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      buffers
    - Fix an issue with Dynamic Process Management when launching processes on
      multiple nodes
    -  Thanks to Rutger Hofman from VU Amsterdam for the report
    - Fix build issue in hwloc source with mcmodel=medium flags
        - Thanks to Nirmal Seenu from Fermilab for the report
    - Fix a build issue in hwloc with --disable-shared or --disabled-static
      options
    - Use portable stdout and stderr redirection
        - Thanks to Dr. Axel Philipp from *MTU* Aero Engines for the patch
    - Fix a build issue with PGI 12.2
        - Thanks to Thomas Rothrock from U.S. Army SMDC for the patch
    - Fix an issue with send message queue in OFA-IB-Nemesis interface
    - Fix a process cleanup issue in Hydra when MPI_ABORT is called (upstream
      MPICH2 patch)
    - Fix an issue with non-contiguous datatypes in MPI_Gather
    - Fix a few memory leaks and warnings

MVAPICH2-1.8a2 (02/02/2012)

* Features and Enhancements (since 1.8a1p1):
    - Support for collective communication from GPU buffers
    - Non-contiguous datatype support in point-to-point and collective
      communication from GPU buffers
    - Efficient GPU-GPU transfers within a node using CUDA IPC (for CUDA 4.1)
    - Alternate synchronization mechanism using CUDA Events for pipelined device
      data transfers
    - Exporting processes local rank in a node through environment variable
    - Adjust shared-memory communication block size at runtime
    - Enable XRC by default at configure time
    - New shared memory design for enhanced intra-node small message performance
    - Tuned inter-node and intra-node performance on different cluster
      architectures
    - Update to hwloc v1.3.1
    - Support for fallback to R3 rendezvous protocol if RGET fails
    - SLURM integration with mpiexec.mpirun_rsh to use SLURM allocated hosts
      without specifying a hostfile
    - Support added to automatically use PBS_NODEFILE in Torque and PBS
      environments
    - Enable signal-triggered (SIGUSR2) migration

* Bug Fixes (since 1.8a1p1):
    - Set process affinity independently of SMP enable/disable to control the
      affinity in loopback mode
    - Report error and exit if user requests MV2_USE_CUDA=1 in non-cuda
      configuration
    - Fix for data validation error with GPU buffers
    - Updated WRAPPER_CPPFLAGS when using --with-cuda. Users should not have to
      explicitly specify CPPFLAGS or LDFLAGS to build applications
    - Fix for several compilation warnings
    - Report an error message if user requests MV2_USE_XRC=1 in non-XRC
      configuration
    - Remove debug prints in regular code path with MV2_USE_BLOCKING=1
        - Thanks to Vaibhav Dutt for the report
    - Handling shared memory collective buffers in a dynamic manner to eliminate
      static setting of maximum CPU core count
    - Fix for validation issue in MPICH2 strided_get_indexed.c
    - Fix a bug in packetized transfers on heterogeneous clusters
    - Fix for deadlock between psm_ep_connect and PMGR_COLLECTIVE calls on
      QLogic systems
        - Thanks to Adam T. Moody for the patch
    - Fix a bug in MPI_Allocate_mem when it is called with size 0
        - Thanks to Michele De Stefano for reporting this issue
    - Create vendor for Open64 compilers and add rpath for unknown compilers
        - Thanks to Martin Hilgemen from Dell Inc. for the initial patch
    - Fix issue due to overlapping buffers with sprintf
        - Thanks to Mark Debbage from QLogic for reporting this issue
    - Fallback to using GNU options for unknown f90 compilers
    - Fix hang in PMI_Barrier due to incorrect handling of the socket return
      values in mpirun_rsh
    - Unify the redundant FTB events used to initiate a migration
    - Fix memory leaks when mpirun_rsh reads hostfiles
    - Fix a bug where library attempts to use in-active rail in multi-rail
      scenario

MVAPICH2-1.8a1p1 (11/14/2011)

* Bug Fixes (since 1.8a1)
    - Fix for a data validation issue in GPU transfers
        - Thanks to Massimiliano Fatica, NVIDIA, for reporting this issue
    - Tuned CUDA block size to 256K for better performance
    - Enhanced error checking for CUDA library calls
    - Fix for mpirun_rsh issue while launching applications on Linux Kernels
      (3.x)

MVAPICH2-1.8a1 (11/09/2011)

* Features and Enhancements (since 1.7):
    - Support for MPI communication from NVIDIA GPU device memory
        - High performance RDMA-based inter-node point-to-point communication
          (GPU-GPU, GPU-Host and Host-GPU)
        - High performance intra-node point-to-point communication for
          multi-GPU adapters/node (GPU-GPU, GPU-Host and Host-GPU)
        - Communication with contiguous datatype
    - Reduced memory footprint of the library
    - Enhanced one-sided communication design with reduced memory requirement
    - Enhancements and tuned collectives (Bcast and Alltoallv)
    - Update to hwloc v1.3.0
    - Flexible HCA selection with Nemesis interface
        - Thanks to Grigori Inozemtsev, Queens University
    - Support iWARP interoperability between Intel NE020 and Chelsio T4 Adapters
    - RoCE enable environment variable name is changed from MV2_USE_RDMAOE to
      MV2_USE_RoCE

* Bug Fixes (since 1.7):
    - Fix for a bug in mpirun_rsh while doing process clean-up in abort and
      other error scenarios
    - Fixes for code compilation warnings
    - Fix for memory leaks in RDMA CM code path

MVAPICH2-1.7 (10/14/2011)

* Features and Enhancements (since 1.7rc2):
    - Support SHMEM collectives upto 64 cores/node
    - Update to hwloc v1.2.2
    - Enhancement and tuned collective (GatherV)
```

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* Bug Fixes:
    - Fixes for code compilation warnings
    - Fix job clean-up issues with mpirun_rsh
    - Fix a hang with RDMA CM

MVAPICH2-1.7rc2 (09/19/2011)

* Features and Enhancements (since 1.7rc1):
    - Based on MPICH2-1.4.1p1
    - Integrated Hybrid (UD-RC/XRC) design to get best performance
      on large-scale systems with reduced/constant memory footprint
    - Shared memory backed Windows for One-Sided Communication
    - Support for truly passive locking for intra-node RMA in shared
      memory and LIMIC based windows
    - Integrated with Portable Hardware Locality (hwloc v1.2.1)
    - Integrated with latest OSU Micro-Benchmarks (3.4)
    - Enhancements and tuned collectives (Allreduce and Allgatherv)
    - MPI_THREAD_SINGLE provided by default and MPI_THREAD_MULTIPLE as an
      option
    - Enabling Checkpoint/Restart support in pure SMP mode
    - Optimization for QDR cards
    - On-demand connection management support with IB CM (RoCE interface)
    - Optimization to limit number of RDMA Fast Path connections for very large
      clusters (Nemesis interface)
    - Multi-core-aware collective support (QLogic PSM interface)

* Bug Fixes:
    - Fixes for code compilation warnings
    - Compiler preference lists reordered to avoid mixing GCC and Intel
      compilers if both are found by configure
    - Fix a bug in transferring very large messages (>2GB)
        - Thanks to Tibor Pausz from Univ. of Frankfurt for reporting it
    - Fix a hang with One-Sided Put operation
    - Fix a bug in ptmalloc integration
    - Avoid double-free crash with mpispawn
    - Avoid crash and print an error message in mpirun_rsh when the hostfile is
      empty
    - Checking for error codes in PMI design
    - Verify programs can link with LiMIC2 at runtime
    - Fix for compilation issue when BLCR or FTB installed in non-system paths
    - Fix an issue with RDMA-Migration
    - Fix for memory leaks
    - Fix an issue in supporting RoCE with second port on available on HCA
        - Thanks to Jeffrey Konz from HP for reporting it
    - Fix for a hang with passive RMA tests (QLogic PSM interface)

MVAPICH2-1.7rc1 (07/20/2011)

* Features and Enhancements (since 1.7a2)
    - Based on MPICH2-1.4
    - CH3 shared memory channel for standalone hosts (including laptops)
      without any InfiniBand adapters
    - HugePage support
    - Improved on-demand InfiniBand connection setup
    - Optimized Fence synchronization (with and without LIMIC2 support)
    - Enhanced mpirun_rsh design to avoid race conditions and support for
      improved debug messages
    - Optimized design for collectives (Bcast and Reduce)
    - Improved performance for medium size messages for QLogic PSM
    - Support for Ekopath Compiler

* Bug Fixes
    - Fixes in Dynamic Process Management (DPM) support
    - Fixes in Checkpoint/Restart and Migration support
    - Fix Restart when using automatic checkpoint
        - Thanks to Alexandr for reporting this
    - Compilation warnings fixes
    - Handling very large one-sided transfers using RDMA
    - Fixes for memory leaks
    - Graceful handling of unknown HCAs
    - Better handling of shmem file creation errors
    - Fix for a hang in intra-node transfer
    - Fix for a build error with --disable-weak-symbols
        - Thanks to Peter Willis for reporting this issue
    - Fixes for one-sided communication with passive target synchronization
    - Proper error reporting when a program is linked with both static and
      shared MVAPICH2 libraries

MVAPICH2-1.7a2 (06/03/2011)

* Features and Enhancements (Since 1.7a)
    - Improved intra-node shared memory communication performance
    - Tuned RDMA Fast Path Buffer size to get better performance
      with less memory footprint (CH3 and Nemesis)
    - Fast process migration using RDMA
    - Automatic inter-node communication parameter tuning
      based on platform and adapter detection (Nemesis)
    - Automatic intra-node communication parameter tuning
      based on platform
    - Efficient connection set-up for multi-core systems
    - Enhancements for collectives (barrier, gather and allgather)
    - Compact and shorthand way to specify blocks of processes on the same
      host with mpirun_rsh
    - Support for latest stable version of HWLOC v1.2
    - Improved debug message output in process management and fault tolerance
      functionality
    - Better handling of process signals and error management in mpispawn
    - Performance tuning for pt-to-pt and several collective operations

* Bug fixes
    - Fixes for memory leaks
    - Fixes in CR/migration
    - Better handling of memory allocation and registration failures
    - Fixes for compilation warnings
    - Fix a bug that disallows '=' from mpirun_rsh arguments
    - Handling of non-contiguous transfer in Nemesis interface
    - Bug fix in gather collective when ranks are in cyclic order
    - Fix for the ignore_locks bug in MPI-IO with Lustre

MVAPICH2-1.7a (04/19/2011)

* Features and Enhancements

    - Based on MPICH2-1.3.2p1
    - Integrated with Portable Hardware Locality (hwloc v1.1.1)
    - Supporting Large Data transfers (>2GB)
    - Integrated with Enhanced LiMIC2 (v0.5.5) to support Intra-node
      large message (>2GB) transfers
    - Optimized and tuned algorithm for AlltoAll
    - Enhanced debugging config options to generate
      core files and back-traces
    - Support for Chelsio's T4 Adapter

MVAPICH2-1.6 (03/09/2011)

* Features and Enhancements (since 1.6-RC3)
    - Improved configure help for MVAPICH2 features
    - Updated Hydra launcher with MPICH2-1.3.3 Hydra process manager
    - Building and installation of OSU micro benchmarks during default
      MVAPICH2 installation
    - Hydra is the default mpiexec process manager

* Bug fixes (since 1.6-RC3)
    - Fix hang issues in RMA
    - Fix memory leaks
    - Fix in RDMA_FP

MVAPICH2-1.6-RC3 (02/15/2011)

* Features and Enhancements
    - Support for 3D torus topology with appropriate SL settings
        - For both CH3 and Nemesis interfaces
    - Thanks to Jim Schutt, Marcus Epperson and John Nagle from
      Sandia for the initial patch
    - Quality of Service (QoS) support with multiple InfiniBand SL
        - For both CH3 and Nemesis interfaces
    - Configuration file support (similar to the one available in MVAPICH).
      Provides a convenient method for handling all runtime variables
      through a configuration file.
    - Improved job-startup performance on large-scale systems
    - Optimization in MPI_Finalize
    - Improved pt-to-pt communication performance for small and
      medium messages
    - Optimized and tuned algorithms for Gather and Scatter collective
      operations
    - Optimized thresholds for one-sided RMA operations
    - User-friendly configuration options to enable/disable various
      checkpoint/restart and migration features
    - Enabled ROMIO's auto detection scheme for filetypes
      on Lustre file system
    - Improved error checking for system and BLCR calls in
      checkpoint-restart and migration codepath
    - Enhanced OSU Micro-benchmarks suite (version 3.3)

Bug Fixes
    - Fix in aggregate ADIO alignment
    - Fix for an issue with LiMIC2 header
    - XRC connection management
    - Fixes in registration cache
    - IB card detection with MV2_IBA_HCA runtime option in
      multi rail design
    - Fix for a bug in multi-rail design while opening multiple HCAs
    - Fixes for multiple memory leaks
    - Fix for a bug in mpirun_rsh
    - Checks before enabling aggregation and migration
    - Fixing the build errors with --disable-cxx
    - Thanks to Bright Yang for reporting this issue
    - Fixing the build errors related to "pthread_spinlock_t"
      seen on RHEL systems

MVAPICH2-1.6-RC2 (12/22/2010)

* Features and Enhancements
    - Optimization and enhanced performance for clusters with nVIDIA
      GPU adapters (with and without GPUDirect technology)
    - Enhanced R3 rendezvous protocol
        - For both CH3 and Nemesis interfaces
    - Robust RDMA Fast Path setup to avoid memory allocation
      failures
        - For both CH3 and Nemesis interfaces
    - Multiple design enhancements for better performance of
      medium sized messages
    - Enhancements and optimizations for one sided Put and Get operations
    - Enhancements and tuning of Allgather for small and medium
      sized messages
    - Optimization of AllReduce
    - Enhancements to Multi-rail Design and features including striping
      of one-sided messages
    - Enhancements to mpirun_rsh job start-up scheme
    - Enhanced designs for automatic detection of various
      architectures and adapters

* Bug fixes
    - Fix a bug in Post-Wait/Start-Complete path for one-sided
      operations
    - Resolving a hang in mpirun_rsh termination when CR is enabled
    - Fixing issue in MPI_Allreduce and Reduce when called with MPI_IN_PLACE
        - Thanks to the initial patch by Alexander Alekhin
    - Fix for an issue in rail selection for small RMA messages
    - Fix for threading related errors with comm_dup
    - Fix for alignment issues in RDMA Fast Path
    - Fix for extra memcpy in header caching
    - Fix for an issue to use correct HCA when process to rail binding
      scheme used in combination with XRC.
    - Fix for an RMA issue when configured with enable-g=meminit
        - Thanks to James Dinan of Argonne for reporting this issue
    - Only set FC and F77 if gfortran is executable


MVAPICH2-1.6RC1 (11/12/2010)

* Features and Enhancements
    - Using LiMIC2 for efficient intra-node RMA transfer to avoid extra
      memory copies
    - Upgraded to LiMIC2 version 0.5.4
    - Removing the limitation on number of concurrent windows in RMA
      operations
    - Support for InfiniBand Quality of Service (QoS) with multiple lanes
    - Enhanced support for multi-threaded applications
    - Fast Checkpoint-Restart support with aggregation scheme
    - Job Pause-Migration-Restart Framework for Pro-active Fault-Tolerance
    - Support for new standardized Fault Tolerant Backplane (FTB) Events
```

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      for Checkpoint-Restart and Job Pause-Migration-Restart Framework
    - Dynamic detection of multiple InfiniBand adapters and using these
      by default in multi-rail configurations (OLA-IB-CH3, OFA-iWARP-CH3 and
      OFA-RoCE-CH3 interfaces)
    - Support for process-to-rail binding policy (bunch, scatter and
      user-defined) in multi-rail configurations (OFA-IB-CH3, OFA-iWARP-CH3 and
      OFA-RoCE-CH3 interfaces)
    - Enhanced and optimized algorithms for MPI_Reduce and MPI_AllReduce
      operations for small and medium message sizes.
    - XRC support with Hydra Process Manager
    - Improved usability of process to CPU mapping with support of
      delimiters (',' , '-') in CPU listing
    - Thanks to Gilles Civario for the initial patch
    - Use of gfortran as the default F77 compiler
    - Support of Shared-Memory-Nemesis interface on multi-core platforms
      requiring intra-node communication only (SMP-only systems, laptops, etc. )

* Bug fixes
    - Fix for memory leak in one-sided code with --enable-g=all
       --enable-error-messages=all
    - Fix for memory leak in getting the context of intra-communicator
    - Fix for shmat() return code check
    - Fix for issues with inter-communicator collectives in Nemesis
    - KNEM patch for osu_bibw issue with KNEM version 0.9.2
    - Fix for osu_bibw error with Shared-memory-Nemesis interface
    - Fix for Win_test error for one-sided RDMA
    - Fix for a hang in collective when thread level is set to multiple
    - Fix for intel test errors with rsend, bsend and ssend operations in Nemesis
    - Fix for memory free issue when it allocated by scandir
    - Fix for a hang in Finalize
    - Fix for issue with MPIU_Find_local_and_external when it is called
      from MPIDI_CH3I_comm_create
    - Fix for handling CPPFLGS values with spaces
    - Dynamic Process Management to work with XRC support
    - Fix related to disabling CPU affinity when shared memory is turned off at run time

- MVAPICH2-1.5.1 (09/14/10)

* Features and Enhancements
    - Significantly reduce memory footprint on some systems by changing the
      stack size setting for multi-rail configurations
    - Optimization to the number of RDMA Fast Path connections
    - Performance improvements in Scatterv and Gatherv collectives for CH3
      interface (Thanks to Dan Kokran and Max Suarez of NASA for identifying
      the issue)
    - Tuning of Broadcast Collective
    - Support for tuning of eager thresholds based on both adapter and platform
      type
    - Environment variables for message sizes can now be expressed in short
      form K=Kilobytes and M=Megabytes (e.g.  MV2_IBA_EAGER_THRESHOLD=12K)
    - Ability to selectively use some or all HCAs using colon separated lists.
      e.g. MV2_IBA_HCA=mlx4_0:mlx4_1
    - Improved Bunch/Scatter mapping for process binding with HWLOC and SMT
      support (Thanks to Dr. Bernd Kallies of ZIB for ideas and suggestions)
    - Update to Hydra code from MPICH2-1.3b1
    - Auto-detection of various iWARP adapters
    - Specifying MV2_USE_IWARP=1 is no longer needed when using iWARP
    - Changing automatic eager threshold selection and tuning for iWARP
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      adapters based on number of nodes in the system instead of the number of
      processes
    - PSM progress loop optimization for QLogic Adapters (Thanks to Dr.
      Avneesh Pant of QLogic for the patch)

* Bug fixes
    - Fix memory leak in registration cache with --enable-g=all
    - Fix memory leak in operations using datatype modules
    - Fix for rdma_cross_connect issue for RDMA CM. The server is prevented
      from initiating a connection.
    - Don't fail during build if RDMA CM is unavailable
    - Various mpirun_rsh bug fixes for CH3, Nemesis and uDAPL interfaces
    - ROMIO panfs build fix
    - Update panfs for not-so-new ADIO file function pointers
    - Shared libraries can be generated with unknown compilers
    - Explicitly link against DL library to prevent build error due to DSO link
      change in Fedora 13 (introduced with gcc-4.4.3-5.fc13)
    - Fix regression that prevents the proper use of our internal HWLOC
      component
    - Remove spurious debug flags when certain options are selected at build
      time
    - Error code added for situation when received eager SMP message is larger
      than receive buffer
    - Fix for Gather and GatherV back-to-back hang problem with LiMIC2
    - Fix for packetized send in Nemesis
    - Fix related to eager threshold in nemesis ib-netmod
    - Fix initialization parameter for Nemesis based on adapter type
    - Fix for uDAPL one sided operations (Thanks to Jakub Fedoruk from Intel
      for reporting this)
    - Fix an issue with out-of-order message handling for iWARP
    - Fixes for memory leak and Shared context Handling in PSM for QLogic
      Adapters (Thanks to Dr. Avneesh Pant of QLogic for the patch)


MVAPICH2-1.5 (07/09/10)

* Features and Enhancements (since 1.5-RC2)
    - SRQ turned on by default for Nemesis interface
    - Performance tuning - adjusted eager thresholds for
      variety of architectures, vbuf size based on adapter
      types and vbuf pool sizes
    - Tuning for Intel iWARP NE020 adapter, thanks to Harry
      Cropper of Intel
    - Introduction of a retry mechanism for RDMA_CM connection
      establishment

* Bug fixes (since 1.5-RC2)
    - Fix in build process with hwloc (for some Distros)
    - Fix for memory leak (Nemesis interface)


MVAPICH2-1.5-RC2 (06/21/10)

* Features and Enhancements (since 1.5-RC1)
    - Support for hwloc library (1.0.1) for defining CPU affinity
    - Deprecating the PLPA support for defining CPU affinity
    - Efficient CPU affinity policies (bunch and scatter) to
      specify CPU affinity per job for modern multi-core platforms
    - New flag in mpirun_rsh to execute tasks with different group IDs
    - Enhancement to the design of Win_complete for RMA operations
    - Flexibility to support variable number of RMA windows
    - Support for Intel iWARP NE020 adapter

* Bug fixes (since 1.5-RC1)
    - Compilation issue with the ROMIO adio-lustre driver, thanks
      to Adam Moody of LLNL for reporting the issue
    - Allowing checkpoint-restart for large-scale systems
    - Correcting a bug in clear_kvc function. Thanks to T J (Chris) Ward,
      IBM Research, for reporting and providing the resolving patch
    - Shared lock operations with RMA with scatter process distribution.
      Thanks to Pavan Balaji of Argonne for reporting this issue
    - Fix a bug during window creation in uDAPL
    - Compilation issue with --enable-alloca, Thanks to E. Borisch,
      for reporting and providing the patch
    - Improved error message for ibv_poll_cq failures
    - Fix an issue that prevents mpirun_rsh to execute programs without
      specifying the path from directories in PATH
    - Fix an issue of mpirun_rsh with Dynamic Process Migration (DPM)
    - Fix for memory leaks (both CH3 and Nemesis interfaces)
    - Updatefiles correctly update LiMIC2
    - Several fixes to the registration cache
      (CH3, Nemesis and uDAPL interfaces)
    - Fix to multi-rail communication
    - Fix to Shared Memory communication Progress Engine
    - Fix to all-to-all collective for large number of processes


MVAPICH2-1.5-RC1 (05/04/10)

* Features and Enhancements
    - MPI 2.2 compliant
    - Based on MPICH2-1.2.1p1
    - OFA-IB-Nemesis interface design
        - OpenFabrics InfiniBand network module support for
          MPICH2 Nemesis modular design
        - Support for high-performance intra-node shared memory
          communication provided by the Nemesis design
        - Adaptive RDMA Fastpath with Polling Set for high-performance
          inter-node communication
        - Shared Receive Queue (SRQ) support with flow control,
          uses significantly less memory for MPI library
        - Header caching
        - Advanced AVL tree-based Resource-aware registration cache
        - Memory Hook Support provided by integration with ptmalloc2
          library. This provides safe release of memory to the
          Operating System and is expected to benefit the memory
          usage of applications that heavily use malloc and free
              operations.
        - Support for TotalView debugger
        - Shared Library Support for existing binary MPI application
          programs to run ROMIO Support for MPI-IO
        - Support for additional features (such as hwloc,
          hierarchical collectives, one-sided, multithreading, etc.),
          as included in the MPICH2 1.2.1p1 Nemesis channel
    - Flexible process manager support
        - mpirun_rsh to work with any of the eight interfaces
```

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          (CH3 and Nemesis channel-based) including OFA-IB-Nemesis,
          TCP/IP-CH3 and TCP/IP-Nemesis
        - Hydra process manager to work with any of the eight interfaces
          (CH3 and Nemesis channel-based) including OFA-IB-CH3,
          OFA-iWARP-CH3, OFA-RoCE-CH3 and TCP/IP-CH3
    - MPIEXEC_TIMEOUT is honored by mpirun_rsh

* Bug fixes since 1.4.1
    - Fix compilation error when configured with
      `--enable-thread-funneled'
    - Fix MPE functionality, thanks to Anthony Chan  for
      reporting and providing the resolving patch
    - Cleanup after a failure in the init phase is handled better by
      mpirun_rsh
    - Path determination is correctly handled by mpirun_rsh when DPM is
      used
    - Shared libraries are correctly built (again)


MVAPICH2-1.4.1

* Enhancements since mvapich2-1.4
   - MPMD launch capability to mpirun_rsh
   - Portable Hardware Locality (hwloc) support, patch suggested by
     Dr. Bernd Kallies <kallies@zib.de>
   - Multi-port support for iWARP
   - Enhanced iWARP design for scalability to higher process count
   - Ring based startup support for RDMAoE

* Bug fixes since mvapich2-1.4
   - Fixes for MPE and other profiling tools
     as suggested by Anthony Chan (chan@mcs.anl.gov)
   - Fixes for finalization issue with dynamic process management
   - Removed overrides to PSM_SHAREDCONTEXT, PSM_SHAREDCONTEXTS_MAX variables.
     Suggested by Ben Truscott <b.s.truscott@bristol.ac.uk>.
   - Fixing the error check for buffer aliasing in MPI_Reduce as
     suggested by Dr. Rajeev Thakur <thakur@mcs.anl.gov>
   - Fix Totalview integration for RHEL5
   - Update simplemake to handle build timestamp issues
   - Fixes for --enable-g={mem, meminit}
   - Improved logic to control the receive and send requests to handle the
     limitation of CQ Depth on iWARP
   - Fixing assertion failures with IMB-EXT tests
   - VBUF size for very small iWARP clusters bumped up to 33K
   - Replace internal mallocs with MPIU_Malloc uniformly for correct
     tracing with --enable-g=mem
   - Fixing multi-port for iWARP
   - Fix memory leaks
   - Shared-memory reduce fixes for MPI_Reduce invoked with MPI_IN_PLACE
   - Handling RDMA_CM_EVENT_TIMEWAIT_EXIT event
   - Fix for threaded-ctxdup mpich2 test
   - Detecting spawn errors, patch contributed by
     Dr. Bernd Kallies <kallies@zib.de>
   - IMB-EXT fixes reported by Yutaka from Cray Japan
   - Fix alltoall assertion error when limic is used

MVAPICH2-1.4
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* Enhancements since mvapich2-1.4rc2
    - Efficient runtime CPU binding
    - Add an environment variable for controlling the use of multiple cq's for
      iWARP interface.
    - Add environmental variables to disable registration cache for All-to-All
      on large systems.
    - Performance tune for pt-to-pt Intra-node communication with LiMIC2
    - Performance tune for MPI_Broadcast

* Bug fixes since mvapich2-1.4rc2
    - Fix the reading error in lock_get_response by adding
      initialization to req->mrail.protocol
    - Fix mpirun_rsh scalability issue with hierarchical ssh scheme
      when launching greater than 8K processes.
    - Add mvapich_ prefix to yacc functions. This can avoid some namespace
      issues when linking with other libraries.  Thanks to Manhui Wang
      <wangm9@cardiff.ac.uk> for contributing the patch.

MVAPICH2-1.4-rc2

* Enhancements since mvapich2-1.4rc1
    - Added Feature: Check-point Restart with Fault-Tolerant Backplane Support
      (FTB_CR)
    - Added Feature: Multiple CQ-based design for Chelsio iWARP
    - Distribute LiMIC2-0.5.2 with MVAPICH2. Added flexibility for selecting
      and using a pre-existing installation of LiMIC2
    - Increase the amount of command line that mpirun_rsh can handle (Thanks
      for the suggestion by Bill Barth @ TACC)

* Bug fixes since mvapich2-1.4rc1
    - Fix for hang with packetized send using RDMA Fast path
    - Fix for allowing to use user specified P_Key's (Thanks to Mike Heinz @
      QLogic)
    - Fix for allowing mpirun_rsh to accept parameters through the
      parmeters file (Thanks to Mike Heinz @ QLogic)
    - Modify the default value of shmem_bcast_leaders to 4K
    - Fix for one-sided with XRC support
    - Fix hang with XRC
    - Fix to always enabling MVAPICH2_Sync_Checkpoint functionality
    - Fix build error on RHEL 4 systems (Reported by Nathan Baca and Jonathan
      Atencio)
    - Fix issue with PGI compilation for PSM interface
    - Fix for one-sided accumulate function with user-defined continguous
      datatypes
    - Fix linear/hierarchical switching logic and reduce threshold for the
      enhanced mpirun_rsh framework.
    - Clean up intra-node connection management code for iWARP
    - Fix --enable-g=all issue with uDAPL interface
    - Fix one sided operation with on demand CM.
    - Fix VPATH build

MVAPICH2-1.4-rc1

* Bugs fixed since MVAPICH2-1.2p1

  - Changed parameters for iWARP for increased scalability

  - Fix error with derived datatypes and Put and Accumulate operations
```

```
      Request was being marked complete before data transfer
      had actually taken place when MV_RNDV_PROTOCOL=R3 was used

  - Unregister stale memory registrations earlier to prevent
    malloc failures

  - Fix for compilation issues with --enable-g=mem and --enable-g=all

  - Change dapl_prepost_noop_extra value from 5 to 8 to prevent
    credit flow issues.

  - Re-enable RGET (RDMA Read) functionality

  - Fix SRQ Finalize error
    Make sure that finalize does not hang when the srq_post_cond is
    being waited on.

  - Fix a multi-rail one-sided error when multiple QPs are used

  - PMI Lookup name failure with SLURM

  - Port auto-detection failure when the 1st HCA did
    not have an active failure

  - Change default small message scheduling for multirail
    for higher performance

  - MPE support for shared memory collectives now available

MVAPICH2-1.2p1 (11/11/2008)

* Changes since MVAPICH2-1.2

  - Fix shared-memory communication issue for AMD Barcelona systems.

MVAPICH2-1.2 (11/06/2008)

* Bugs fixed since MVAPICH2-1.2-rc2

  - Ignore the last bit of the pkey and remove the pkey_ix option since the
    index can be different on different machines. Thanks for Pasha@Mellanox for
    the patch.

  - Fix data types for memory allocations. Thanks for Dr. Bill Barth from TACC
    for the patches.

  - Fix a bug when MV2_NUM_HCAS is larger than the number of active HCAs.

  - Allow builds on architectures for which tuning parameters do not exist.

* Changes related to the mpirun_rsh framework

  - Always build and install mpirun_rsh in addition to the process manager(s)
    selected through the --with-pm mechanism.

  - Cleaner job abort handling

  - Ability to detect the path to mpispawn if the Linux proc filesystem is
```

```
    available.

  - Added Totalview debugger support

  - Stdin is only available to rank 0.  Other ranks get /dev/null.

* Other miscellaneous changes

  - Add sequence numbers for RPUT and RGET finish packets.

  - Increase the number of allowed nodes for shared memory broadcast to 4K.

  - Use /dev/shm on Linux as the default temporary file path for shared memory
    communication. Thanks for Doug Johnson@OSC for the patch.

  - MV2_DEFAULT_MAX_WQE has been replaced with MV2_DEFAULT_MAX_SEND_WQE and
    MV2_DEFAULT_MAX_RECV_WQE for send and recv wqes, respectively.

  - Fix compilation warnings.

MVAPICH2-1.2-RC2 (08/20/2008)

* Following bugs are fixed in RC2

  - Properly handle the scenario in shared memory broadcast code when the
    datatypes of different processes taking part in broadcast are different.

  - Fix a bug in Checkpoint-Restart code to determine whether a connection is a
    shared memory connection or a network connection.

  - Support non-standard path for BLCR header files.

  - Increase the maximum heap size to avoid race condition in realloc().

  - Use int32_t for rank for larger jobs with 32k processes or more.

  - Improve mvapich2-1.2 bandwidth to the same level of mvapich2-1.0.3.

  - An error handling patch for uDAPL interface. Thanks for Nilesh Awate for
    the patch.

  - Explicitly set some of the EP attributes when on demand connection is used
    in uDAPL interface.

MVAPICH2-1.2-RC1 (07/02/08)

* Following features are added for this new mvapich2-1.2 release:

  - Based on MPICH2 1.0.7

  - Scalable and robust daemon-less job startup

       -- Enhanced and robust mpirun_rsh framework (non-MPD-based) to
          provide scalable job launching on multi-thousand core clusters

       -- Available for OpenFabrics (IB and iWARP) and uDAPL interfaces
          (including Solaris)
  - Adding support for intra-node shared memory communication with Checkpoint-restart

       --  Allows best performance and scalability with fault-tolerance
           support

  - Enhancement to software installation

       -- Change to full autoconf-based configuration
       -- Adding an application (mpiname) for querying the MVAPICH2 library
          version and configuration information

  - Enhanced processor affinity using PLPA for multi-core architectures

  - Allows user-defined flexible processor affinity

  - Enhanced scalability for RDMA-based direct one-sided communication
    with less communication resource

  - Shared memory optimized MPI_Bcast operations

  - Optimized and tuned MPI_Alltoall

MVAPICH2-1.0.2 (02/20/08)

* Change the default MV2_DAPL_PROVIDER to OpenIB-cma

* Remove extraneous parameter is_blocking from the gen2 interface for
  MPIDI_CH3I_MRAILI_Get_next_vbuf

* Explicitly name unions in struct ibv_wr_descriptor and reference the
  members in the code properly.

* Change "inline" functions to "static inline" properly.

* Increase the maximum number of buffer allocations for communication
  intensive applications

* Corrections for warnings from the Sun Studio 12 compiler.

* If malloc hook initialization fails, then turn off registration
  cache

* Add MV_R3_THESHOLD and MV_R3_NOCACHE_THRESHOLD which allows
  R3 to be used for smaller messages instead of registering the
  buffer and using a zero-copy protocol.

* Fixed an error in message coalescing.

* Setting application initiated checkpoint as default if CR is turned on.


MVAPICH2-1.0.1 (10/29/07)

* Enhance udapl initializaton, set all ep_attr fields properly.
  Thanks for Kanoj Sarcar from NetXen for the patch.

* Fixing a bug that miscalculates the receive size in case of complex
  datatype is used.
  Thanks for Patrice Martinez from Bull for reporting this problem.

 * Minor patches for fixing (i) NBO for rdma-cm ports and (ii) rank
   variable usage in DEBUG_PRINT in rdma-cm.c
   Thanks to Steve Wise for reporting these.


MVAPICH2-1.0 (09/14/07)

* Following features and bug fixes are added in this new MVAPICH2-1.0 release:

- Message coalescing support to enable reduction of per Queue-pair
  send queues for reduction in memory requirement on large scale
  clusters. This design also increases the small message messaging
  rate significantly. Available for Open Fabrics Gen2-IB.

- Hot-Spot Avoidance Mechanism (HSAM) for alleviating
  network congestion in large scale clusters. Available for
  Open Fabrics Gen2-IB.

- RDMA CM based on-demand connection management for large scale
  clusters. Available for OpenFabrics Gen2-IB and Gen2-iWARP.

- uDAPL on-demand connection management for large scale clusters.
  Available for uDAPL interface (including Solaris IB implementation).

- RDMA Read support for increased overlap of computation and
  communication. Available for OpenFabrics Gen2-IB and Gen2-iWARP.

- Application-initiated system-level (synchronous) checkpointing in
  addition to the user-transparent checkpointing. User application can
  now request a whole program checkpoint synchronously with BLCR by
  calling special functions within the application. Available for
  OpenFabrics Gen2-IB.

- Network-Level fault tolerance with Automatic Path Migration (APM)
  for tolerating intermittent network failures over InfiniBand.
  Available for OpenFabrics Gen2-IB.

- Integrated multi-rail communication support for OpenFabrics
  Gen2-iWARP.

- Blocking mode of communication progress. Available for OpenFabrics
  Gen2-IB.

- Based on MPICH2 1.0.5p4.


* Fix for hang while using IMB with -multi option.
  Thanks to Pasha (Mellanox) for reporting this.

* Fix for hang in memory allocations > 2^31 - 1.
  Thanks to Bryan Putnam (Purdue) for reporting this.

* Fix for RDMA_CM finalize rdma_destroy_id failure.
  Added Timeout env variable for RDMA_CM ARP.
  Thanks to Steve Wise for suggesting these.
```

```
* Fix for RDMA_CM invalid event in finalize. Thanks to Steve Wise and Sean Hefty.

* Fix for shmem memory collectives related memory leaks

* Updated src/mpi/romio/adio/ad_panfs/Makefile.in include path to find mpi.h.
  Contributed by David Gunter, Los Alamos National Laboratory.

* Fixed header caching error on handling datatype messages with small vector
  sizes.

* Change the finalization protocol for UD connection manager.

* Fix for the "command line too long" problem. Contributed by Xavier Bru
  <xavier.bru@bull.net> from Bull (http://www.bull.net/)

* Change the CKPT handling to invalidate all unused registration cache.

* Added ofed 1.2 interface change patch for iwarp/rdma_cm from Steve Wise.

* Fix for rdma_cm_get_event err in finalize. Reported by Steve Wise.

* Fix for when MV2_IBA_HCA is used. Contributed by Michael Schwind
  of Technical Univ. of Chemnitz (Germany).


MVAPICH2-0.9.8 (11/10/06)

* Following features are added in this new MVAPICH2-0.9.8 release:

- BLCR based Checkpoint/Restart support

- iWARP support: tested with Chelsio and Ammasso adapters and OpenFabrics/Gen2 stack

- RDMA CM connection management support

- Shared memory optimizations for collective communication operations

- uDAPL support for NetEffect 10GigE adapter.


MVAPICH2-0.9.6 (10/22/06)

* Following features and bug fixes are added in this new MVAPICH2-0.9.6 release:

- Added on demand connection management.

- Enhance shared memory communication support.

- Added ptmalloc memory hook support.

- Runtime selection for most configuration options.


MVAPICH2-0.9.5 (08/30/06)

* Following features and bug fixes are added in this new MVAPICH2-0.9.5 release:

- Added multi-rail support for both point to point and direct one side
```

```
  operations.

- Added adaptive RDMA fast path.

- Added shared receive queue support.

- Added TotalView debugger support

* Optimization of SMP startup information exchange for USE_MPD_RING to
  enhance performance for SLURM. Thanks to Don and team members from Bull
  and folks from LLNL for their feedbacks and comments.

* Added uDAPL build script functionality to set DAPL_DEFAULT_PROVIDER
  explicitly with default suggestions.

* Thanks to Harvey Richardson from Sun for suggesting this feature.


MVAPICH2-0.9.3 (05/20/06)

* Following features are added in this new MVAPICH2-0.9.3 release:

- Multi-threading support

- Integrated with MPICH2 1.0.3 stack

- Advanced AVL tree-based Resource-aware registration cache

- Tuning and Optimization of various collective algorithms

- Processor affinity for intra-node shared memory communication

- Auto-detection of InfiniBand adapters for Gen2


MVAPICH2-0.9.2 (01/15/06)

* Following features are added in this new MVAPICH2-0.9.2 release:

- InfiniBand support for OpenIB/Gen2

- High-performance and optimized support for many MPI-2
  functionalities (one-sided, collectives, datatype)

- Support for other MPI-2 functionalities (as provided by MPICH2 1.0.2p1)

- High-performance and optimized support for all MPI-1 functionalities


MVAPICH2-0.9.0 (11/01/05)

* Following features are added in this new MVAPICH2-0.9.0 release:

- Optimized two-sided operations with RDMA support

- Efficient memory registration/de-registration schemes for RDMA operations

- Optimized intra-node shared memory support (bus-based and NUMA)
- Shared library support

- ROMIO support

- Support for multiple compilers (gcc, icc, and pgi)



MVAPICH2-0.6.5 (07/02/05)

* Following features are added in this new MVAPICH2-0.6.5 release:

- uDAPL support (tested for InfiniBand, Myrinet, and Ammasso GigE)


MVAPICH2-0.6.0 (11/04/04)

* Following features are added in this new MVAPICH2-0.6.0 release:

- MPI-2 functionalities (one-sided, collectives, datatype)

- All MPI-1 functionalities

- Optimized one-sided operations (Get, Put, and Accumulate)

- Support for active and passive synchronization

- Optimized two-sided operations

- Scalable job start-up

- Optimized and tuned for the above platforms and different
  network interfaces (PCI-X and PCI-Express)

- Memory efficient scaling modes for medium and large clusters
```

5.14 SLURM Release Information

The following is reproduced essentially verbatim from files contained within the SLURM tarball downloaded from https://slurm.schedmd.com.

```
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This file describes changes in recent versions of Slurm. It primarily
documents those changes that are of interest to users and administrators.

* Changes in Slurm 18.08.6-2
============================
 -- Remove deadlock situation when logging and --enable-debug is used.
 -- Fix RPM packaging for accounting_storage/mysql.

* Changes in Slurm 18.08.6
==========================
 -- Added parsing of -H flag with scancel.
 -- Fix slurmsmwd build on 32-bit systems.
 -- acct_gather_filesystem/lustre - add support for Lustre 2.12 client.
 -- Fix per-partition TRES factors/priority
 -- Fix per-partition NICE priority
 -- Fix partition access check validation for multi-partition job submissions.
 -- Prevent segfault on empty response in 'scontrol show dwstat'.
 -- node_features/knl_cray plugin - Preserve node's active features if it has
    already booted when slurmctld daemon is reconfigured.
 -- Detect missing burst buffer script and reject job.
 -- GRES: Properly reset the topo_gres_cnt_alloc counter on slurmctld restart
    to prevent underflow.
 -- Avoid errors from packing accounting_storage_mysql.so when RPM is built
    with out mysql support.
 -- Remove deprecated -t option from slurmctld --help.
 -- acct_gather_filesystem/lustre - fix stats gathering.
 -- Enforce documented default usage start and end times when querying jobs from
    the database.
 -- Fix issues when querying running jobs from the database.
 -- Deny sacct request where start time is later than the end time requested.
 -- Fix sacct verbose about time and states queried.
 -- burst_buffer/cray - allow 'scancel --hurry <jobid>' to tear down a burst
    buffer that is currently staging data out.
 -- X11 forwarding - allow setup if the DISPLAY environment variable lacks
    a screen number. (Permit both "localhost:10.0" and "localhost:10".)
 -- docs - change HTML title to include the page title or man page name.
 -- X11 forwarding - fix an unnecessary error message when using the
    local_xauthority X11Parameters option.
 -- Add use_raw_hostname to X11Parameters.
 -- Fix smail so it passes job arrays to seff correctly.
 -- Don't check InactiveLimit for salloc --no-shell jobs.
 -- Add SALLOC_GRES and SBATCH_GRES as input to salloc/sbatch.
 -- Remove drain state when node doesn't reboot by ResumeTimeout.
 -- Fix considering "resuming" nodes in scheduling.
 -- Do not kill suspended jobs due to exceeding time limit.
 -- Add NoAddrCache CommunicationParameter.
 -- Don't ping powering up cloud nodes.
 -- Add cloud_dns SlurmctldParameter.
 -- Consider --sbindir configure option as the default path to find slurmstepd.
 -- Fix node state printing of DRAINED$
 -- Fix spamming dbd of down/drained nodes in maintenance reservation.
 -- Avoid buffer overflow in time_str2secs.
 -- Calculate suspended time for suspended steps.
 -- Add null check for step_ptr->step_node_bitmap in _pick_step_nodes.
 -- Fix multi-cluster srun issue after 'scontrol reconfigure' was called.
 -- Fix accessing response_cluster_rec outside of write locks.
 -- Fix Lua user messages not showing up on rejected submissions.
 -- Fix printing multi-line error messages on rejected submissions.

* Changes in Slurm 18.08.5-2
============================
 -- Fix Perl build for 32-bit systems.

* Changes in Slurm 18.08.5
==========================
 -- Backfill - If a job has a time_limit guess the end time of a job better
    if OverTimeLimit is Unlimited.
 -- Fix "sacctmgr show events event=cluster"
 -- Fix sacctmgr show runawayjobs from sibling cluster
 -- Avoid bit offset of -1 in call to bit_nclear().
 -- Insure that "hbm" is a configured GresType on knl systems.
 -- Fix NodeFeaturesPlugins=node_features/knl_generic to allow other gres
    other than knl.
 -- cons_res: Prevent overflow on multiply.
 -- Better debug for bad values in gres.conf.
 -- Fix double accounting of energy at end of job.
 -- Read gres.conf for cloud nodes on slurmctld.
 -- Don't assume the first node of a job is the batch host when purging jobs
    from a node.
 -- Better debugging when a job doesn't have a job_resrcs ptr.
 -- Store ave watts in energy plugins.
 -- Add XCC plugin for reading Lenovo Power.
 -- Fix minor memory leak when scheduling rebootable nodes.
 -- Fix debug2 prefix for sched log.
 -- Fix printing correct SLURM_JOB_ACCOUNT_PACK_GROUP_* in env for a Het Job.
 -- sbatch - search current working directory first for job script.
 -- Make it so held jobs reset the AccrueTime and do not count against any
    AccrueTime limits.
 -- Add SchedulerParameters option of bf_hetjob_prio=[min|avg|max] to alter the
    job sorting algorithm for scheduling heterogeneous jobs.
 -- Fix initialization of assoc_mgr_locks and slurmctld_locks lock structures.
 -- Fix segfault with job arrays using X11 forwarding.
 -- Revert regression caused by e0ee1c7054 which caused negative values and
    values starting with a decimal to be invalid for PriorityWeightTRES and
    TRESBillingWeight.
 -- Fix possibility to update a job's reservation to none.
 -- Suppress connection errors to primary slurmdbd when backup dbd is active.
 -- Suppress connection errors to primary db when backup db kicks in
 -- Add missing fields for sacct --completion when using jobcomp/filetxt.
 -- Fix incorrect values set for UserCPU, SystemCPU, and TotalCPU sacct fields
    when JobAcctGatherType=jobacct_gather/cgroup.
 -- Fixed srun from double printing invalid option msg twice.
 -- Remove unused -b flag from getopt call in sbatch.
 -- Disable reporting of node TRES in sreport.
 -- Re-enabling features combined by OR within parenthesis for non-knl setups.
 -- Prevent sending duplicate requests to reboot a node before ResumeTimeout.
 -- Down nodes that don't reboot by ResumeTimeout.
 -- Update seff to reflect API change from rss_max to tres_usage_in_max.
 -- Add missing TRES constants from perl API.
 -- Fix issue where sacct would return incorrect array tasks when querying
    specific tasks.
 -- Add missing variables to slurmdb_stats_t in the perlapi.
 -- Fix nodes not getting reboot RPC when job requires reboot of nodes.
 -- Fix failing update the partition list of a job.
 -- Use slurm.conf gres ids instead of gres.conf names to get a gres type name.
 -- Add mitigation for a potential heap overflow on 32-bit systems in xmalloc.
    CVE-2019-6438.

* Changes in Slurm 18.08.4
==========================
 -- burst_buffer/cray - avoid launching a job that would be immediately
    cancelled due to a DataWarp failure.
 -- Fix message sent to user to display preempted instead of time limit when
    a job is preempted.
 -- Fix memory leak when a failure happens processing a nodes gres config.
 -- Improve error message when failures happen processing a nodes gres config.
 -- When building rpms ignore redundant standard rpaths and insecure relative
    rpaths, for RHEL based distros which use "check-rpaths" tool.
 -- Don't skip jobs in scontrol hold.
 -- Avoid locking the job_list when unneeded.
 -- Allow --cpu-bind=verbose to be used with SLURM_HINT environment variable.
 -- Make it so fixing runaway jobs will not alter the same job requeued
    when not runaway.
 -- Avoid checking state when searching for runaway jobs.
 -- Remove redundant check for end time of job when searching for runaway jobs.
 -- Make sure that we properly check for runawayjobs where another job might
    have the same id (for example, if a job was requeued) by also checking the
    submit time.
 -- Add scontrol update job ResetAccrueTime to clear a job's time
    previously accrued for priority.
 -- cons_res: Delay exiting cr_job_test until after cores/cpus are calculated
    and distributed.
 -- Fix bug where binary in cwd would trump binary in PATH with test_exec.
 -- Fix check to test printf("%s\n", NULL); to not require
    -Wno-format-truncation CFLAG.
 -- Fix JobAcctGatherParams=UsePss to report the correct usage.
 -- Fix minor memory leak in pmix plugin.
 -- Fix minor memory leak in slurmctld when reading configuration.
 -- Handle return codes correctly from pthread_* functions.
 -- Fix minor memory leak when a slurmd is unable to contact a slurmctld
    when trying to register.
 -- Fix sreport sizesbyaccount report when using Flatview and accounts.
 -- Fix incorrect shift when dealing with node weights and scheduling.
 -- libslurm/perl - Fix segfault caused by incorrect hv_to_slurm_ctl_conf.
 -- Add qos and assoc options to confirmation dialogs.
 -- Handle updating identical license or partition information correctly.
 -- Makes sure accounts and QOS' are all lower case to match documentation
    when read in from the slurm.conf file.
 -- Don't consider partitions without enough nodes in reservation,
    main scheduler.
 -- Set SLURM_NTASKS correctly if having to determine from other options.
 -- Removed GCP scripts from contribs. Now located at:
    https://github.com/SchedMD/slurm-gcp.
 -- Don't check existence of srun --prolog or --epilog executables when set to
    "none" and SLURM_TEST_EXEC is used.
 -- Add "P" suffix support to job and step tres specifications.
 -- When doing a reconfigure handle QOS' GrpJobsAccrue correctly.
 -- Remove unneeded extra parentheses from sh5util.
 -- Fix jobacct_gather/cgroup to work correctly when more than one task is
    started on a node.
 -- If requesting --ntasks-per-node with no tasks set tasks correctly.
 -- Accept modifiers for TRES originally added in 6f0342e0358.
 -- Don't remove reservation on slurmctld restart if nodes are removed from
    configuration.
 -- Fix bad xfree in task/cgroup.
 -- Fix removing counters if a job array isn't subject to limits and is
    canceled while pending.
 -- Make sure SLURM_NTASKS_PER_NODE is set correctly when env is overwritten
    by the command line.
 -- Clean up step on a failed node correctly.
 -- mpi/pmix: Fixed the logging of collective state.
 -- mpi/pmix: Make multi-slurmd work correctly when using ring communication.
 -- mpi/pmix: Fix double invocation of the PMIx lib fence callback.
 -- mpi/pmix: Remove unneeded libpmix callback drop in tree-based coll.
 -- Fix race condition in route/topology when the slurmctld is reconfigured.
 -- In route/topology validate the slurmctld doesn't try to initialize the
    node system.
 -- Fix issue when requesting invalid gres.
 -- Validate job_ptr in backfill before restoring preempt state.
 -- Fix issue when job's environment is minimal and only contains variables
    Slurm is going to replace internally.
 -- When handling runaway jobs remove all usage before rollup to remove any
    time that wasn't existent instead of just updating lines that have time
    with a lesser time.
 -- salloc - set SLURM_NTASKS_PER_CORE and SLURM_NTASKS_PER_SOCKET in the
    environment if the corresponding command line options are used.
 -- slurmd - fix handling of the -f flag to specify alternate config file
    locations.
 -- Fix scheduling logic to avoid using nodes that require a reboot for KNL
    node change when possible.
 -- Fix scheduling logic bug. There should have been a test for _not_
    NODE_SET_REBOOT to continue.
 -- Fix a scheuling logic bug with respect to XOR operation support when there
    are down nodes.
```

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 -- If there is a constraint construct of the form "[...&...]"
    then an error is generated if more than one of those specifications
    contains KNL NUMA or MCDRAM modes.
 -- Fix stepd segfault race if slurmctld hasn't registered with the launching
    slurmd yet delivering it's TRES list.
 -- Add SchedulerParameters option of bf_ignore_newly_avail_nodes to avoid
    scheduling lower priority jobs on resources that become available during
    the backfill scheduling cycle when bf_continue is enabled.
 -- Decrement message_connections in stepd code on error path correctly.
 -- Decrease an error message to be debug.
 -- Fix missing suffixes in squeue.
 -- pam_slurm_adopt - send an error message to the user if no Slurm jobs
    can be located on the node.
 -- Run SlurmctldPrimaryOffProg when the primary slurmctld process shuts down.
 -- job_submit/lua: Add several slurmctld return codes.
 -- job_submit/lua: Add user/group info to jobs.
 -- Fix formatting issues when printing uint64_t.
 -- Bump RLIMIT_NOFILE for daemons in systemd services.
 -- Expand %x in job name in 'scontrol show job'.
 -- salloc/sbatch/srun - print warning if mutually exclusive options of --mem
    and --mem-per-cpu are both set.

* Changes in Slurm 18.08.3
==========================
 -- Fix regression in 18.08.1 that caused dbd messages to not be queued up
    when the dbd was down.
 -- Fix regression in 18.08.1 that can cause a slurmctld crash when splitting
    job array elements.

* Changes in Slurm 18.08.2
==========================
 -- Correctly initialize variable in env_array_user_default().
 -- Remove race condition when signaling starting step.
 -- Fix issue where 17.11 job's using GRES in didn't initialize new 18.08
    structures after unpack.
 -- Stop removing nodes once the minimum CPU or node count for the job is
    reached in the cons_res plugin.
 -- Process any changes to MinJobAge and SlurmdTimeout in the slurmctld when
    it is reconfigured to determine changes in its background timers.
 -- Use previous SlurmdTimeout in the slurmctld after a reconfigure to
    determine the time a node has been down.
 -- Fix multi-cluster srun between clusters with different SelectType plugins.
 -- Fix removing job licenses on reconfig/restart when configured license
    counts are 0.
 -- If a job requested multiple licenses and one license was removed then on
    a reconfigure/restart all of the licenses -- including the valid ones
    would be removed.
 -- Fix issue where job's license string wasn't updated after a restart when
    licenses were removed or added.
 -- Add allow_zero_lic to SchedulerParameters.
 -- Avoid scheduling tasks in excess of ArrayTaskThrottle when canceling tasks
    of an array.
 -- Fix jobs that request memory per node and task count that can't be
    scheduled right away.
 -- Avoid infinite loop with jobacct_gather/linux when pids wrap around
    /proc/sys/kernel/pid_max.
 -- Fix --parsable2 output for sacct and sstat commands to remove a stray
    trailing delimiter.
 -- When modifying a user's name in sacctmgr enforce PreserveCaseUser.
 -- When adding a coordinator or user that was once deleted enforce
    PreserveCaseUser.
 -- Correctly handle scenarios where a partitions MaxMemPerCPU is less than
    a jobs --mem-per-cpu and also -c is greater than 1.
 -- Set AccrueTime correctly when MaxJobsAccrue is disabled and BeginTime has
    not been established.
 -- Correctly account for job arrays for new {Max/Grp}JobsAccrue limits.

* Changes in Slurm 18.08.1
==========================
 -- Remove commented-out parts of man pages related to cons_tres work in 19.05,
    as these were showing up on the web version due to a syntax error.
 -- Prevent slurmctld performance issues in main background loop if multiple
    backup controllers are unavailable.
 -- Add missing user read association lock in burst_buffer/cray during init().
 -- Fix incorrect spacing for PartitionName lines in 'scontrol write config'.
 -- Fix creation of step hwloc xml file for after cpuset cgroup has been
    created.
 -- Add userspace as a valid default governor.
 -- Add timers to group_cache_lookup so if going slow advise
    LaunchParameters=send_gids.
 -- Fix SLURM_STEP_GRES=none to work correctly.
 -- Fix potential memory leak when a failure happens unpacking a ctld_multi_msg.
 -- Fix potential double free when a faulure happens when unpacking a
    node_registration_status_msg.
 -- Fix sacctmgr show runaways.
 -- Removed non-POSIX append operator from configure script for non-bash
    support.
 -- Fix incorrect spacing for PartitionName lines in 'scontrol write config'.
 -- Fix sacct to not print huge reserve times when the job was never eligible.
 -- burst_buffer/cray - Add missing locks around assoc_mgr when timing out a
    burst buffer.
 -- burst_buffer/cray - Update burst buffers when an association or qos
    is removed from the system.
 -- Remove documentation for deprecated Cray/ALPS systems. Please switch to
    Native Cray mode instead.
 -- Completely copy features when copying the list in the slurmctld.
 -- PMIX - Fix issue with packing processes when using an arbitrary task
    distribution.
 -- Fix hostlists to be able to handle nodenames with '-' in them surrounded
    by integers.
 -- Fix correct job CPU count allocated.
 -- Fix sacctmgr setting GrpJobs limit when setting GrpJobsAccrue limit.
 -- Change the defaults to MemLimitEnforce=no and NoOverMemoryKill
    (See RELEASE_NOTES).
 -- Prevent abort when using Cray node features plugin on non-knl.
 -- Add ability to reboot down nodes with scontrol reboot_nodes.
 -- Protect against sending to the slurmdbd if the connection has gone away.
 -- Fix invalid read when not using backup slurmctlds.
 -- Prevent acct coordinators from changing default acct on add user.
 -- Don't allow scontrol top do modify job priorities when priority == 1.
 -- slurmsmwd - change parsing code to handle systems with the svid or inst
    fields set in xtconsumer output.
 -- Fix infinite loop in slurmctld if GRES is specified without a count.
 -- sacct: Print error when unknown arguments are found.
 -- Fix checking missing return codes when unpacking structures.
 -- Fix slurm.spec-legacy including slurmsmwd
 -- More explicit error message when cgroup oom-kill events detected.
 -- When updating an association and are unable to find parent association
    initialize old fairshare association pointer correctly.
 -- Wrap slurm_cond_signal() calls with mutexes where needed.
 -- Fix correct timeout with resends in slurm_send_only_node_msg.
 -- Fix pam_slurm_adopt to honor action_adopt_failure.
 -- Have the slurmd recreate the hwloc xml file for the full system on restart.
 -- sdiag - correct the units for the gettimeofday() stat to microseconds.
 -- Set SLURM_CLUSTER_NAME environment variable in MailProg to the ClusterName.
 -- smail - use SLURM_CLUSTER_NAME environment variable.
 -- job_submit/lua - expose argc/argv options through lua interface.
 -- slurmdbd - prevent false-positive warning about innodb settings having
    been set too low if they're actually set over 2GB.

* Changes in Slurm 18.08.0
==========================
 -- Fix segfault on job arrays when starting controller without dbd up.
 -- Fix pmi2 to build with gcc 8.0+.
 -- Remove the development snapshot of select/cons_tres plugin.
 -- Fix slurmd -C to not print benign error from xcpuinfo.
 -- Fix potential double locks in the assoc_mgr.
 -- Fix sacct truncate flag behavior Truncated pending jobs will always
    return a start and end time set to the window end time, so elapsed
    time is 0.
 -- Fix extern step hanging forever when canceled right after creation.
 -- sdiag - add slurmctld agent count.
 -- Remove requirement to have cgroup_allowed_devices_file.conf in order to
    constrain devices. By default all devices are allowed and GRES, that are
    associated with a device file, that are not requested are restricted.
 -- Fix proper alignment of clauses when determining if more nodes are needed
    for an allocation.
 -- Fix race condition when canceling a federation job that just started
    running.
 -- Prevent extra resources from being allocated when combining certain flags.
 -- Fix problem in task/affinity plugin that can lead to slurmd fatal()'ing
    when using --hint=nomultithread.
 -- Fix left over socket file when step is ending and using pmi2 with
     %n or %h in the spool dir.
 -- Don't remove hwloc full system xml file when shutting down the slurmd.
 -- Fix segfault that could happen with a het job when it was canceled while
    starting.
 -- Fix scan-build false-positive warning about invalid memory access in the
    _ping_controller() function.
 -- Add control_inx value to trigger_info_msg_t to permit future work in the
    trigger management code to distinguish which of multiple backup controllers
    has changed state.

* Changes in Slurm 18.08.0rc1
==============================
 -- Add TimelimitRaw sacct output field to display timelimit numbers.
 -- Fix job array preemption during backfill scheduling.
 -- Fix scontrol -o show assoc output.
 -- Add support for sacct --whole-hetjob=[yes|no] option.
 -- Make salloc handle node requests the same as sbatch.
 -- Add shutdown_on_reboot SlurmdParameter to control whether the Slurmd will
    shutdown itself down or not when a reboot request is received.
 -- Add cancel_reboot scontrol option to cancel pending reboot of nodes.
 -- Make Users case insensitive in the database based on
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    Parameters=PreserveCaseUser in the slurmdbd.conf.
 -- Improve scheduling when dealing with node_features that could have a
    boot delay.
 -- Fix issue if a step launch fails we don't get a bunch of '(null)' strings
    in the step record for usage.
 -- Changed the default AuthType for slurmdbd to auth/munge.
 -- Make it so libpmi.so doesn't link to libslurm.so.$apiversion.
 -- Added 'remote-fs.target' to After directive of slurmd.service file.
 -- Fix filetxt plugin to handle it when you aren't running a jobacct_gather
    plugin.
 -- Remove drain on node when reboot nextstate used.
 -- Speed up pack of job's qos.
 -- Fix race condition when trying to update reservation in the database.
 -- For the PrologFlags slurm.conf option, make NoHold mutually exclusive with
    Contain and/or X11 options.
 -- Revise the handling of SlurmctldSyslogLevel and SlurmdSyslogLevel options
    in slurm.conf and DebugLevelSyslog in slurmdbd.conf.
 -- Gate reading the cgroup.conf file.
 -- Gate reading the acct_gather_* plugins.
 -- Add sacctmgr options to prevent/manage job queue stuffing:
    - GrpJobsAccrue=<max_jobs>
      Maximum number of pending jobs in aggregate able to accrue age priority
      for this association and all associations which are children of this
      association. To clear a previously set value use the modify command with
      a new value of -1.
    - MaxJobsAccrue=<max_jobs>
      Maximum number of pending jobs able to accrue age priority at any given
      time for the given association. This is overridden if set directly on a
      user. Default is the cluster's limit. To clear a previously set value use
      the modify command with a new value of -1.
    - MinPrioThreshold
      Minimum priority required to reserve resources when scheduling.

* Changes in Slurm 18.08.0pre2
==============================
 -- Remove support for "ChosLoc" configuration parameter.
 -- Configuration parameters "ControlMachine", "ControlAddr", "BackupController"
    and "BackupAddr" replaced by an ordered list of "SlurmctldHost" records
    with the optional address appended to the name enclosed in parenthesis.
    For example: "SlurmctldHost=head(12.34.56.78)". An arbitrary number of
    backup servers can be configured.
 -- When a pending job's state includes "UnavailableNodes" do not include the
    nodes in FUTURE state.
 -- Remove --immediate option from sbatch.
 -- Add infrastructure for per-job and per-step TRES parameters: tres-per-job,
    tres-per-node, tres-per-socket, tres-per-task, cpus-per-tres, mem-per-tres,
    tres-bind and tres-freq. These new parameters are not currently used, but
    have been added to the appropriate RPCs.
 -- Add DefCpuPerGpu and DefMemPerGpu to global and per-partition configuration
    parameters. Shown in scontrol/sview as "JobDefaults=...". NOTE: These
    options are for future use and currently have no effect.
 -- Fix for setting always the correct status on job update in mysql
 -- Add ValidateMode configuration parameter to knl_cray.conf for static
    MCDRAM/NUMA configurations.
 -- Fix security issue in accounting_storage/mysql plugin by always escaping
    strings within the slurmdbd. CVE-2018-7033.
 -- Disable local PTY output processing when using 'srun --unbuffered'. This
    prevents the PTY subsystem from inserting extraneous \r characters into
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   the output stream.
-- Change the column name for the %U (User ID) field in squeue to 'UID'.
-- CRAY - Add CheckGhalQuiesce to the CommunicationParameters.
-- When a process is core dumping, avoid terminating other processes in that
   task group. This fixes a problem with writing out incomplete OpenMP core
   files.
-- CPU frequency management enhancements: If scaling_available_frequencies
   file is not available, then derive values from scaling_min_freq and
   scaling_max_freq values. If cpuinfo_cur_freq file is not available then
   try to use scaling_cur_freq.
-- Add pending jobs count to sdiag output.
-- Fix update job function. There were some incosistencies on the behavior
   that caused time limits to be modified when swapping QOS, bad permissions
   check for a coordinator and AllowQOS and DenyQOS were not enforced on
   job update.
-- Add configuration paramerers SlurmctldPrimaryOnProg and
   SlurmctldPrimaryOffProg, which define programs to execute when a slurmctld
   daemon becomes the primary server or goes from primary to backup mode.
-- Add configuration paramerers SlurmctldAddr for use with virtual IP to manage
   backup slurmctld daemons.
-- Explicitly shutdown the slurmd process when instructed to reboot.
-- Add ability to create/update partition with TRESBillingWeights through
   scontrol.
-- Calcuate TRES billing values at submission so that billing limits can be
   enforced at submission with QOS DenyOnLimit.
-- Add node_features plugin function "node_features_p_reboot_weight()" to
   return the node weight to be used for a compute node that requires reboot
   for use (e.g. to change the NUMA mode of a KNL node).
-- Add NodeRebootWeight parameter to knl.conf configuration file.
-- Fix insecure handling of job requested gid field. CVE-2018-10995.
-- Fix srun to return highest signal of any task.
-- Completely remove "gres" field from step record. Use "tres_per_node",
   "tres_per_socket", etc.
-- Add "Links" parameter to gres.conf configuration file.
-- Force slurm_mktime() to set tm_isdst to -1 so anyone using the function
   doesn't forget to set it.
-- burst_buffer.conf - Add SetExecHost flag to enable burst buffer access
   from the login node for interactive jobs.
-- Append ", with requeued tasks" to job array "end" emails if any tasks in the
   array were requeued. This is a hint to use "sacct --duplicates" to see the
   whole picture of the array job.
-- Add ResumeFailProgram slurm.conf option to specify a program that is called
   when a node fails to respond by ResumeTimeout.
-- Add new job pending reason of "ReqNodeNotAvail, reserved for maintenance".
-- Remove AdminComment += syntax from 'scontrol update job'.
-- sched/backfill: Reset job time limit if needed for deadline scheduling.
-- For heterogeneous job component with required nodes, explicitly exclude
   those nodes from all other job components.
-- Add name of partition used to output of srun --test-only output (valuable
   for jobs submitted to multiple partitions).
-- If MailProg is not configured and "/bin/mail" (the default) does not exist,
   but "/usr/bin/mail" does exist then use "/usr/bin/mail" as a default value.
-- sdiag output now reports outgoing slurmctld message queue contents.
-- Fix issue in performance when reading slurm conf having nodes with features.
-- Make it so the slurmdbd's pid file gets created before initing
   the database.
-- Improve escaping special characters on user commands when specifying paths.
-- Fix directory names with special char '\' that are not handled correctly.
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 -- Add salloc/sbatch/srun option of --gres-flags=disable-binding to disable
    filtering of CPUs with respect to generic resource locality. This option is
    currently required to use more CPUs than are bound to a GRES (i.e. if a GPU
    is bound to the CPUs on one socket, but resources on more than one socket
    are required to run the job). This option may permit a job to be allocated
    resources sooner than otherwise possible, but may result in lower job
    performance.
 -- SlurmDBD - Print warning if MySQL/MariaDB internal tuning is not at least
    half of the recommended values.
 -- Move libpmi from src/api to contribs/pmi.
 -- Add ability to specify a node reason when rebooting nodes with "scontrol
    reboot".
 -- Add nextstate option to "scontrol reboot" to dictate state of node after
    reboot.
 -- Consider "resuming" (nextstate=resume) nodes as available in backfill
    future scheduling and don't replace "resuming" nodes in reservations.
 -- Add the use of a xml file to help performance when using hwloc.

* Changes in Slurm 18.08.0pre1
==============================
 -- Add new burst buffer state of "teardown-fail" to indicate the burst buffer
    teardown operation is failing on specific buffers. This changes the numeric
    value of the BB_STATE_COMPLETE type. Any Slurm version 17.02 or 17.11 tool
    used to report burst buffer state information will report a state of "66"
    rather than "complete" for burst buffers which have been deleted, but still
    exist in the slurmctld daemon's tables (a very short-lived situation).
 -- Multiple backup slurmctld daemons can be configured:
    * Specify "BackupController#=<hostname> and "BackupAddr#=<address>" to
      identify up to 9 backup servers.
    * Output format of "scontrol ping" and the daemon status at the end of
      "scontrol status" is modified to report up status of the primary and all
      backup servers.
    * "scontrol takeover [#]" command can now identify the SlurmctldHost
      index number. Default value is "1" (the first backup configured
      SlurmctldHost).
 -- Enable jobs with zero node count for creation and/or deletion of persistent
    burst buffers.
    * The partition default MinNodes configuration parameter is now 0
      (previously 1 node).
    * Zero size jobs disabled for job arrays and heterogeneous jobs, but
      supported for salloc, sbatch and srun commands.
 -- Add "scontrol show dwstat" command to display Cray burst buffer status.
 -- Add "GetSysStatus" option to burst_buffer.conf file. For burst_buffer/cray
    this would indicate the location of the "dwstat" command.
 -- Add node and partition configuration options of "CpuBind" to control default
    task binding. Modify the scontrol to report and modify these parameters.
 -- Add "NumaCpuBind" option to knl.conf file to automatically change a node's
    CpuBind parameter based upon changes to a node's NUMA mode.
 -- Add sbatch "--batch" option to identify features required on batch node.
    For example "sbatch --batch=haswell ...".
 -- Add "BatchFeatures" field to output of "scontrol show job".
 -- Add support for "--bb" option to sbatch command.
 -- Add new SystemComment field to job data structure and database. Currently
    used for Burst Buffer error logs.
 -- Expand reservation "flags" field from 32 to 64 bits.
 -- Add job state flag of "SIGNALING" to avoid race condition with multiple
    SIGSTOP/SIGCONT signals for the same job being active at the same time.
 -- Properly handle srun --will-run option when there are jobs in COMPLETING
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    state.
 -- Properly report who is signaling a step.
 -- Don't combine updated reservation records in sreport's reservation report.
 -- node_features plugin - Add suport for XOR & XAND of job constraints (node
    feature specifications).
 -- Add support for parenthesis in a job's constraint specification to group
    like options together. For example
    --constraint="[(knl&snc4&flat)*4&haswell*1]" might be used to specify that
    four nodes with the features "knl", "snc4" and "flat" plus one node with
    the feature "haswell" are required.
 -- Improvements to how srun searches for the executible when using cwd.
 -- Now programs can be checked before execution if test_exec is set when using
    multi-prog option.
 -- Report NodeFeatures plugin configuration with scontrol and sview commands.
 -- Add acct_gather_profile/influxdb plugin.
 -- Add new job state of SO/STAGE_OUT indicating that burst buffer stage-out
    operation is in progress.
 -- Correct SLURM_NTASKS and SLURM_NPROCS environment variable for heterogeneous
    job step. Report values representing full allocation.
 -- Expand advanced reservation feature specification to support parenthesis and
    counts of nodes with specified features. Nodes with the feature currently
    active will be prefered.
 -- Defer job signaling until prolog is completed
 -- Have the primary slurmctld wait until the backup has completely shutdown
    before taking control.
 -- Fix issue where unpacking job state after TRES count changed could lead to
    invalid reads.
 -- Heterogeneous job steps allocations supported with
    * Open MPI (with Slurm's PMI2 and PMIx plugins) and
    * Intel MPI (with Slurm's PMI2 plugin)
 -- Remove redundant function arguments from task plugins:
    * Remove "job_id" field from task_p_slurmd_batch_request() function.
    * Remove "job_id" field from task_p_slurmd_launch_request() function.
    * Remove "job_id" field from task_p_slurmd_reserve_resources() function.
 -- Change function name from node_features_p_changible_feature() to
    node_features_p_changeable_feature in node_features plugin.
 -- Add Slurm configuration file check logic using "slurmctld -t" command.

* Changes in Slurm 17.11.10
===========================
 -- Move priority_sort_part_tier from slurmctld to libslurm to make it possible
    to run the regression tests 24.* without changing that code since it links
    directly to the priority plugin where that function isn't defined.
 -- Fix issue where job time limits can increase to max walltime when updating
    a job with scontrol.
 -- Fix invalid protocol_version manipulation on big endian platforms causing
    srun and sattach to fail.
 -- Fix for QOS, Reservation and Alias env variables in srun.
 -- mpi/pmi2 - Backport 6a702158b49c4 from 18.08 to avoid dangerous detached
    thread.
 -- When allowing heterogeneous steps make sure we copy all the options to
    avoid copying strings that may be overwritten.
 -- Print correctly when sh5util finds and empty file.
 -- Fix sh5util to not seg fault on exit.
 -- Fix sh5util to check correctly for H5free_memory.
 -- Adjust OOM monitoring function in task/cgroup to prevent problems in
    regression suite from leaked file descriptors.
 -- Fix issue with gres when defined with a type and no count
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    (i.e. gres=gpu/tesla) it would get a count of 0.
 -- Allow sstat to talk to slurmd's that are new in protocol version.
 -- Permit database names over 33 characters in accounting_storage/mysql.
 -- Fix negative values when profiling.
 -- Fix srun segfault caused by invalid memory reads on the env.
 -- Fix segfault on job arrays when starting controller without dbd up.
 -- Fix pmi2 to build with gcc 8.0+.
 -- Fix proper alignment of clauses when determining if more nodes are needed
    for an allocation.
 -- Fix race condition when canceling a federation job that just started
    running.
 -- Prevent extra resources from being allocated when combining certain flags.
 -- Fix problem in task/affinity plugin that can lead to slurmd fatal()'ing
    when using --hint=nomultithread.
 -- Fix left over socket file when step is ending and using pmi2 with
    %n or %h in the spool dir.
 -- Fix incorrect spacing for PartitionName lines in 'scontrol write config'.
 -- Fix sacct to not print huge reserve times when the job was never eligible.
 -- burst_buffer/cray - Add missing locks around assoc_mgr when timing out a
    burst buffer.
 -- burst_buffer/cray - Update burst buffers when an association or qos
    is removed from the system.
 -- If failed over to a backup controller, ensure the agent thread is launched
    to handle deferred tasks.
 -- Fix correct job CPU count allocated.
 -- Protect against sending to the slurmdbd if the connection has gone away.
 -- Fix checking missing return codes when unpacking structures.
 -- Fix slurm.spec-legacy including slurmsmwd
 -- More explicit error message when cgroup oom-kill events detected.
 -- When updating an association and are unable to find parent association
    initialize old fairshare association pointer correctly.
 -- Wrap slurm_cond_signal() calls with mutexes where needed.
 -- Fix correct timeout with resends in slurm_send_only_node_msg.
 -- Fix pam_slurm_adopt to honor action_adopt_failure.
 -- job_submit/lua - expose argc/argv options through lua interface.

* Changes in Slurm 17.11.9-2
===========================
 -- Fix printing of node state "drain + reboot" (and other node state flags).
 -- Fix invalid read (segfault) when sorting multi-partition jobs.
 -- Move several new error() messages to debug() to keep them out of users'
    srun output.

* Changes in Slurm 17.11.9
==========================
 -- Fix segfault in slurmctld when a job's node bitmap is NULL during a
    scheduling cycle.  Primarily caused by EnforcePartLimits=ALL.
 -- Remove erroneous unlock in acct_gather_energy/ipmi.
 -- Enable support for hwloc version 2.0.1.
 -- Fix 'srun -q' (--qos) option handling.
 -- Fix socket communication issue that can lead to lost task completition
    messages, which will cause a permanently stuck srun process.
 -- Handle creation of TMPDIR if environment variable is set or changed in
    a task prolog script.
 -- Avoid node layout fragmentation if running with a fixed CPU count but
    without Sockets and CoresPerSocket defined.
 -- burst_buffer/cray - Fix datawarp swap default pool overriding jobdw.
 -- Fix incorrect job priority assignment for multi-partition job with
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    different PriorityTier settings on the partitions.
 -- Fix sinfo to print correct node state.

* Changes in Slurm 17.11.8
==========================
 -- Fix incomplete RESPONSE_[RESOURCE|JOB_PACK]_ALLOCATION building path.
 -- Do not allocate nodes that were marked down due to the node not responding
    by ResumeTimeout.
 -- task/cray plugin - search for "mems" cgroup information in the file
    "cpuset.mems" then fall back to the file "mems".
 -- Fix ipmi profile debug uninitialized variable.
 -- Improve detection of Lua package on older RHEL distributions.
 -- PMIx: fixed the direct connect inline msg sending.
 -- MYSQL: Fix issue not handling all fields when loading an archive dump.
 -- Allow a job_submit plugin to change the admin_comment field during
    job_submit_plugin_modify().
 -- job_submit/lua - fix access into reservation table.
 -- MySQL - Prevent deadlock caused by archive logic locking reads.
 -- Don't enforce MaxQueryTimeRange when requesting specific jobs.
 -- Modify --test-only logic to properly support jobs submitted to more than
    one partition.
 -- Prevent slurmctld from abort when attempting to set non-existing
    qos as def_qos_id.
 -- Add new job dependency type of "afterburstbuffer". The pending job will be
    delayed until the first job completes execution and it's burst buffer
    stage-out is completed.
 -- Reorder proctrack/task plugin load in the slurmstepd to match that of slurmd
    and avoid race condition calling task before proctrack can introduce.
 -- Prevent reboot of a busy KNL node when requesting inactive features.
 -- Revert to previous behavior when requesting memory per cpu/node introduced
    in 17.11.7.
 -- Fix to reinitialize previously adjusted job members to their original value
    when validating the job memory in multi-partition requests.
 -- Fix _step_signal() from always returning SLURM_SUCCESS.
 -- Combine active and available node feature change logs on one line rather
    than one line per node for performance reasons.
 -- Prevent occasionally leaking freezer cgroups.
 -- Fix potential segfault when closing the mpi/pmi2 plugin.
 -- Fix issues with --exclusive=[user|mcs] to work correctly
    with preemption or when job requests a specific list of hosts.
 -- Make code compile with hdf5 1.10.2+
 -- mpi/pmix: Fixed the collectives canceling.
 -- SlurmDBD: improve error message handling on archive load failure.
 -- Fix incorrect locking when deleting reservations.
 -- Fix incorrect locking when setting up the power save module.
 -- Fix setting format output length for squeue when showing array jobs.
 -- Add xstrstr function.
 -- Fix printing out of --hint options in sbatch, salloc --help.
 -- Prevent possible divide by zero in _validate_time_limit().
 -- Add Delegate=yes to the slurmd.service file to prevent systemd from
    interfering with the jobs' cgroup hierarchies.
 -- Change the backlog argument to the listen() syscall within srun to 4096
    to match elsewhere in the code, and avoid communication problems at scale.

* Changes in Slurm 17.11.7
==========================
 -- Fix for possible slurmctld daemon abort with NULL pointer.
 -- Fix different issues when requesting memory per cpu/node.
 -- PMIx - override default paths at configure time if --with-pmix is used.
 -- Have sprio display jobs before eligible time when
    PriorityFlags=ACCRUE_ALWAYS is set.
 -- Make sure locks are always in place when calling _post_qos_list().
 -- Notify srun and ctld when unkillable stepd exits.
 -- Fix slurmstepd deadlock in stepd cleanup caused by race condition in
    the jobacct_gather fini() interfaces introduced in 17.11.6.
 -- Fix slurmstepd deadlock in PMIx startup.
 -- task/cgroup - fix invalid free() if the hwloc library does not return a
    string as expected.
 -- Fix insecure handling of job requested gid field. CVE-2018-10995.

* Changes in Slurm 17.11.6
==========================
 -- CRAY - Add slurmsmwd to the contribs/cray dir.
 -- sview - fix crash when closing any search dialog.
 -- Fix initialization of variable in stepd when using native x11.
 -- Fix reading slurm_io_init_msg to handle partial messages.
 -- Fix scontrol create res segfault when wrong user/account parameters given.
 -- Fix documentation for sacct on parameter -X (--allocations)
 -- Change TRES Weights debug messages to debug3.
 -- FreeBSD - assorted fixes to restore build.
 -- Fix for not tracking environment variables from unrelated different jobs.
 -- PMIX - Added the direct connect authentication.
    When upgrading this may cause issues with jobs using pmix starting on mixed
    slurmstepd versions where some are less than 17.11.6.
 -- Prevent the backup slurmctld from losing the active/available node
    features list on takeover.
 -- Add documentation for fix IDLE*+POWER due to capmc stuck in Cray systems.
 -- Fix missing mutex unlock when prolog is failing on a node, leading to a
    hung slurmd.
 -- Fix locking around Cray CCM prolog/epilog.
 -- Add missing fed_mgr read locks.
 -- Fix issue incorrectly setting a job time_start to 0 while requeueing.
 -- smail - remove stray '-s' from mail subject line.
 -- srun - prevent segfault if ClusterName setting is unset but
    SLURM_WORKING_CLUSTER environment variable is defined.
 -- In configurator.html web pages change default configuration from
    task/none to task/affinity plugin and from select/linear plugin to
    select/cons_res plus CR_Core.
 -- Allow jobs to run beyond a FLEX reservation end time.
 -- Fix problem with wrongly set as Reservation job state_reason.
 -- Prevent bit_ffs() from returnig value out of bitmap range.
 -- Improve performance of 'squeue -u' when PrivateData=jobs is enabled.
 -- Make UnavailableNodes value in job reason be correct for each job.
 -- Fix 'squeue -o %s' on Cray systems.
 -- Fix incorrect error thrown when cancelling part of a job array.
 -- Fix error code and scheduling problem for --exclusive=[user|mcs].
 -- Fix build when lz4 is in a non-standard location.
 -- Be able to force power_down of cloud node even if in power_save state.
 -- Allow cloud nodes to be recognized in Slurm when booted out of band.
 -- Fixes race condition in _pack_job_gres() when is called multiple times.
 -- Increase duration of "sleep" command used to keep extern step alive.
 -- Remove unsafe usage of pthread_cancel in slurmstepd that can lead to
    to deadlock in glibc.
 -- Fix total TRES Billing on partitions.
 -- Don't tear down a BB if a node fails and --no-kill or resize of a job
    happens.
 -- Remove unsafe usage of pthread_cancel in pmix plugin that can lead to
    to deadlock in glibc.
 -- Fix fatal in controller when loading completed trigger
 -- Ignore reservation overlap at submission time.
 -- GRES type model and QOS limits documentation added
 -- slurmd - fix ABRT on SIGINT after reconfigure with MemSpecLimit set.
 -- PMIx - move two error messages on retry to debug level, and only display
    the error after the retry count has been exceeded.
 -- Increase number of tries when sending responses to srun.
 -- Fix checkpointing requeued/completing jobs in a bad state which caused a
    segfault on restart.
 -- Fix srun on ppc64 platforms.
 -- Prevent slurmd from starting steps if the Prolog returns an error when using
    PrologFlags=alloc.
 -- priority/multifactor - prevent segfault running sprio if a partition has
    just been deleted and PriorityFlags=CALCULATE_RUNNING is turned on.
 -- job_submit/lua - add ESLURM_INVALID_TIME_LIMIT return code value.
 -- job_submit/lua - print an error if the script calls log.user in
    job_modify() instead of returning it to the next submitted job erroneously.
 -- select/linear - handle job resize correctly.
 -- select/cons_res - improve handling of --cores-per-socket requests.

* Changes in Slurm 17.11.5
==========================
 -- Fix cloud nodes getting stuck in DOWN+POWER_UP+NO_RESPOND state after not
    responding by ResumeTimeout.
 -- Add job's array_task_cnt and user_name along with partitions
    [max|def]_mem_per_[cpu|node], max_cpus_per_node, and max_share with the
    SHARED_FORCE definition to the job_submit/lua plugin.
 -- srun - fix for SLURM_JOB_NUM_NODES env variable assignment.
 -- sacctmgr - fix runaway jobs identification.
 -- Fix for setting always the correct status on job update in mysql.
 -- Fix issue if running with an association manager cache (slurmdbd was down
    when slurmctld was started) you could loose QOS usage information.
 -- CRAY - Fix spec file to work correctly.
 -- Set scontrol exit code to 1 if attempting to update a node state to DRAIN
    or DOWN without specifying a reason.
 -- Fix race condition when running with an association manager cache
    (slurmdbd was down when slurmctld was started).
 -- Print out missing SLURM_PERSIST_INIT slurmdbd message type.
 -- Fix two build errors related to use of the O_CLOEXEC flag with older glibc.
 -- Add Google Cloud Platform integration scripts into contribs directory.
 -- Fix minor potential memory leak in backfill plugin.
 -- Add missing node flags (maint/power/etc) to node states.
 -- Fix issue where job time limits may end up at 1 minute when using the
    NoReserve flag on their QOS.
 -- Fix security issue in accounting_storage/mysql plugin by always escaping
    strings within the slurmdbd. CVE-2018-7033.
 -- Soften messages about best_fit topology to debug2 to avoid alarm.
 -- Fix issue in sreport reservation utilization report to handle more
    allocated time than 100% (Flex reservations).
 -- When a job is requesting a Flex reservation prefer the reservation's nodes
    over any other nodes.

* Changes in Slurm 17.11.4
==========================
 -- Add fatal_abort() function to be able to get core dumps if we hit an
    "impossible" edge case.
 -- Link slurmd against all libraries that slurmstepd links to.
 -- Fix limits enforce order when they're set at partition and other levels.
 -- Add slurm_load_single_node() function to the Perl API.
 -- slurm.spec - change dependency for --with lua to use pkgconfig.
 -- Fix small memory leaks in node_features plugins on reconfigure.
 -- slurmdbd - only permit requests to update resources from operators or
    administrators.
 -- Fix handling of partial writes in io_init_msg_write_to_fd() which can
    lead to job step launch failure under higher cluster loads.
 -- MYSQL - Fix to handle quotes in a given work_dir of a job.
 -- sbcast - fix a race condition that leads to "Unspecified error".
 -- Log that support for the ChosLoc configuration parameter will end in Slurm
    version 18.08.
 -- Fix backfill performance issue where bf_min_prio_reserve was not respected.
 -- Fix MaxQueryTimeRange checks.
 -- Print MaxQueryTimeRange in "sacctmgr show config".
 -- Correctly check return codes when creating a step to check if needing to
    wait to retry or not.
 -- Fix issue where a job could be denied by Reason=MaxMemPerLimit when not
    requesting any tasks.
 -- In perl tools, fix for regexp that caused extra incorrectly shown results.
 -- Add some extra locks in fed_mgr to be extra safe.
 -- Minor memory leak fixes in the fed_mgr on slurmctld shutdown.
 -- Make sreport job reports also report duplicate jobs correctly.
 -- Fix issues restoring certain Partition configuration elements, especially
    when ReconfigFlags=KeepPartInfo is enabled.
 -- Don't add TRES whose value is NO_VAL64 when building string line.
 -- Fix removing array jobs from hash in slurmctld.
 -- Print out missing user messages from jobsubmit plugin when srun/salloc are
    waiting for an allocation.
 -- Handle --clusters=all as case insensitive.
 -- Only check requested clusters in federation when using --test-only
    submission option.
 -- In the federation, make it so you can cancel stranded sibling jobs.
 -- Silence an error from PSS memory stat collection process.
 -- Requeue jobs allocated to nodes requested to DRAIN or FAIL if nodes are
    POWER_SAVE or POWER_UP, preventing jobs to start on NHC-failed nodes.
 -- Make MAINT and OVERLAP resvervation flags order agnostic on overlap test.
 -- Preserve node features when slurmctld daemons reconfigured including active
    and available KNL features.
 -- Prevent creation of multiple io_timeout threads within srun, which can
    lead to fatal() messages when those unexpected and additional mutexes are
    destroyed when srun shuts down.
 -- burst_buffer/cray - Prevent use of "#DW create_persistent" and
    "#DW destroy_persistent" directives available in Cray CLE6.0UP06. This
    will be supported in Slurm version 18.08. Use "#BB" directives until then.
 -- Fix task/cgroup affinity to behave correctly.
 -- FreeBSD - fix build on systems built with WITHOUT_KERBEROS.
 -- Fix to restore pn_min_memory calculated result to correctly enforce
    MaxMemPerCPU setting on a partition when the job uses --mem.
 -- slurmdbd - prevent infinite loop if a QOS is set to preempt itself.
 -- Fix issue with log rotation for slurmstepd processes.

* Changes in Slurm 17.11.3-2
==========================
 -- Revert node_features changes in 17.11.3 that lead to various segfaults on
    slurmctld startup.
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* Changes in Slurm 17.11.3
==========================
 -- Send SIG_UME correctly to a step.
 -- Sort sreport's reservation report by cluster, time_start, resv_name instead
    of cluster, resv_name, time_start.
 -- Avoid setting node in COMPLETING state indefinitely if the job initiating
    the node reboot is cancelled while the reboot in in progress.
 -- Scheduling fix for changing node features without any NodeFeatures plugins.
 -- Improve logic when summarizing job arrays mail notifications.
 -- Add scontrol -F/--future option to display nodes in FUTURE state.
 -- Fix REASONABLE_BUF_SIZE to actually be 3/4 of MAX_BUF_SIZE.
 -- When a job array is preempting make it so tasks in the array don't wait
    to preempt other possible jobs.
 -- Change free_buffer to FREE_NULL_BUFFER to prevent possible double free
    in slurmstepd.
 -- node_feature/knl_cray - Fix memory leaks that occur when slurmctld
    reconfigured.
 -- node_feature/knl_cray - Fix memory leak that can occur during normal
    operation.
 -- Fix srun environment variables for --prolog script.
 -- Fix job array dependency with "aftercorr" option and some task arrays in
    the first job fail. This fix lets all task array elements that can run
    proceed rather than stopping all subsequent task array elements.
 -- Fix potential deadlock in the slurmctld when using list_for_each.
 -- Fix for possible memory corruption in srun when running heterogeneous job
    steps.
 -- Fix job array dependency with "aftercorr" option and some task arrays in
    the first job fail. This fix lets all task array elements that can run
    proceed rather than stopping all subsequent task array elements.
 -- Fix output file containing "%t" (task ID) for heterogeneous job step to
    be based upon global task ID rather than task ID for that component of the
    heterogeneous job step.
 -- MYSQL - Fix potential abort when attempting to make an account a parent of
    itself.
 -- Fix potentially uninitialized variable in slurmctld.
 -- MYSQL - Fix issue for multi-dimensional machines when using sacct to
    find jobs that ran on specific nodes.
 -- Reject --acctg-freq at submit if invalid.
 -- Added info string on sh5util when deleting an empty file.
 -- Correct dragonfly topology support when job allocation specifies desired
    switch count.
 -- Fix minor memory leak on an sbcast error path.
 -- Fix issues when starting the backup slurmdbd.
 -- Revert uid check when requesting a jobid from a pid.
 -- task/cgroup - add support to detect OOM_KILL cgroup events.
 -- Fix whole node allocation cpu counts when --hint=nomultihtread.
 -- Allow execution of task prolog/epilog when uid has access
    rights by a secondary group id.
 -- Validate command existence on the srun *[pro|epi]log options
    if LaunchParameter test_exec is set.
 -- Fix potential memory leak if clean starting and the TRES didn't change
    from when last started.
 -- Fix for association MaxWall enforcement when none is given at submission.
 -- Add a job's allocated licenses to the [Pro|Epi]logSlurmctld.
 -- burst_buffer/cray: Attempts by job to create persistent burst buffer when
    one already exists owned by a different user will be logged and the job
    held.
 -- CRAY - Remove race in the core_spec where we add the slurmstepd to the
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    job container where if the step was canceled would also cancel the stepd
    erroneously.
 -- Make sure the slurmstepd blocks signals like SIGTERM correctly.
 -- SPANK - When slurm_spank_init_post_opt() fails return error correctly.
 -- When revoking a sibling job in the federation we want to send a start
    message before purging the job record to get the uid of the revoked job.
 -- Make JobAcctGatherParams options case-insensitive. Previously, UsePss
    was the only correct capitialization; UsePSS or usepss were silently
    ignored.
 -- Prevent pthread_atfork handlers from being added unnecessarily after
    'scontrol reconfigure', which can eventually lead to a crash if too
    many handlers have been registered.
 -- Better debug messages when MaxSubmitJobs is hit.
 -- Docs - update squeue man page to describe all possible job states.
 -- Prevent orphaned step_extern steps when a job is cancelled while the
    prolog is still running.

* Changes in Slurm 17.11.2
==========================
 -- jobcomp/elasticsearch - append Content-Type to the HTTP header.
 -- MYSQL - Fix potential abort of slurmdbd when job has no TRES.
 -- Add advanced reservation flag of "REPLACE_DOWN" to replace DOWN or DRAINED
    nodes.
 -- slurm.spec-legacy - add missing libslurmfull.so to slurm.files.
 -- Fix squeue job ID filtering for pending job array records.
 -- Fix potential deadlock in _run_prog() in power save code.
 -- MYSQL - Add dynamic_offset in the database to force range for auto
    increment ids for the tres_table.
 -- MYSQL - Fix fallout from MySQL auto increment bug, see RELEASE_NOTES,
    only affects current 17.11 users tracking licenses or GRES in the database.
 -- Refactor logging logic to avoid possible memory corruption on non-x86
    architectures.
 -- Fix memory leak when getting jobs from the slurmdbd.
 -- Fix incorrect logic behind MemorySwappiness, and only set the value when
    specified in the configuration.

* Changes in Slurm 17.11.1-2
============================
 -- MYSQL - Make index for pack_job_id

* Changes in Slurm 17.11.1
==========================
 -- Fix --with-shared-libslurm option to work correctly.
 -- Make it so only daemons log errors on configuration option duplicates.
 -- Fix for ConstrainDevices=yes to work correctly.
 -- Fix to purge old jobs using burst buffer if slurmctld daemon restarted
    after the job's burst buffer work was already completed.
 -- Make logging prefix for slurmstepd to happen as soon as possible.
 -- mpi/pmix: Fix the job registration for the PMIx v2.1.
 -- Fix uid check for signaling a step with anything but SIGKILL.
 -- Return ESLURM_TRANSITION_STATE_NO_UPDATE instead of EAGAIN when trying to
    signal a step that is still running a prolog.
 -- Update Cray slurm_playbook.yaml with latest recommended version.
 -- Only say a prolog is done running after the extern step is launched.
 -- Wait to start a batch step until the prolog and extern step are
    fully ran/launched.  Only matters if running with
    PrologFlags=[contain|alloc].
 -- Truncate a range for SlurmctldPort to FD_SETSIZE elements and throw an
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    error, otherwise network traffic may be lost due to poll() not detecting
    traffic.
 -- Fix for srun --pack-group option that can reuse/corrupt memory.
 -- Fix handling ultra long hostlists in a hostfile.
 -- X11: fix xauth regex to handle '-' in hostnames again.
 -- Fix potential node reboot timeout problem for "scontrol reboot" command.
 -- Add ability for squeue to sort jobs by submit time.
 -- CRAY - Switch to standard pid files on Cray systems.
 -- Update jobcomp records on duplicate inserts.
 -- If unrecognized configuration file option found then print an appropriate
    fatal error message rather than relying upon random errno value.
 -- Initialize job_desc_msg_t's instead of just memset'ing them.
 -- Fix divide by zero when job requests no tasks and more memory than
    MaxMemPer{CPU|NODE}.
 -- Avoid changing Slurm internal errno on syslog() failures.
 -- BB - Only launch dependent jobs after the burst buffer is staged-out
    completely instead of right after the parent job finishes.
 -- node_features/knl_generic - If plugin can not fully load then do not spawn
    a background pthread (which will fail with invalid memory reference).
 -- Don't set the next jobid to give out to the highest jobid in the system on
    controller startup. Just use the checkpointed next use jobid.
 -- Docs - add Slurm/PMIx and OpenMPI build notes to the mpi_guide page.
 -- Add lustre_no_flush option to LaunchParameters for Native Cray systems.
 -- Fix rpmbuild issue with rpm 4.13+ / Fedora 25+.
 -- sacct - fix the display for the NNodes field when using the --units option.
 -- Prevent possible double-xfree on a buffer in stepd_completion.
 -- Fix for record job state on successful allocation but failed reply message.
 -- Fill in the user_name field for batch jobs if not sent by the slurmctld.
    (Which is the default behavior if PrologFlags=send_gids is not enabled.)
    This prevents job launch problems for sites using UsePAM=1.
 -- Handle syncing federated jobs that ran on non-origin clusters and were
    cancelled while the origin cluster was down.
 -- Fix accessing variable outside of lock.
 -- slurm.spec: move libpmi to a separate package to solve a conflict with the
    version provided by PMIx. This will require a separate change to PMIx as
    well.
 -- X11 forwarding: change xauth handling to use hostname/unix:display format,
    rather than localhost:display.
 -- mpi/pmix - Fix warning if not compiling with debug.

* Changes in Slurm 17.11.0
==========================
 -- Fix documentation for MaxQueryTimeRange option in slurmdbd.conf.
 -- Avoid srun abort trying to run on heterogeneous job component that has
    ended.
 -- Add SLURM_PACK_JOB_ID,SLURM_PACK_JOB_OFFSET to PrologSlurmctld and
    EpilogSlurmctld environment.
 -- Treat ":" in #SBATCH arguments as fatal error. The "#SBATCH packjob" syntax
    must be used instead.
 -- job_submit/lua plugin: expose pack_job fields to get.
 -- Prevent scheduling deadlock with multiple components of heterogeneous job
    in different partitions (i.e. one heterogeneous job component is higher
    priority in one partition and another component is lower priority in a
    different partition).
 -- Fix for heterogeneous job starvation bug.
 -- Fix some slurmctld memory leaks.
 -- Add SLURM_PACK_JOB_NODELIST to PrologSlurmctld and EpilogSlurmctld
    environment.
 -- If PrologSlurmctld fails for pack job leader then requeue or kill all
    components of the job.
 -- Fix for mulitple --pack-group srun arguments given out of order.
 -- Update slurm.conf(5) man page with updated example logrotate script.
 -- Add SchedulerParameters=whole_pack configuration parameter. If set, then
    hold, release and cancel operations on any component of a heterogeneous job
    will be applied to all components
 -- Handle FQDNs in xauth cookies for x11 display forwarding properly.
 -- For heterogeneous job steps, the srun --open-mode option default value will
    be set to "append".
 -- Pack job scheduling list not being cleared between runs of the backfill
    scheduler resulted in various anomalies.
 -- Fix that backward compat for pmix version < 1.1.5.
 -- Fix use-after-free that can lead to slurmstepd segfaulting when setting
    ulimit values.
 -- Add heterogeneous job start data to sdiag output.
 -- X11 forwarding - handle systems with X11UseLocalhost=no set in sshd_config.
 -- Fix potential missing issue with missin symbols in gres plugins.
 -- Ignore querying clusters in federation that are down from status commands.
 -- Base federated jobs off of origin job and not the local cluster in API.
 -- Remove erroneous double '-' on rpath for libslurmfull.
 -- Remove version from libslurmfull and move it to $LIBDIR/slurm since the ABI
    could change from one version to the other.
 -- Fix unused wall time for reservations.
 -- Convert old reservation records to insert unused wall into the rows.
 -- slurm.spec: further restructing and improvements.
 -- Allow nodes state to be updated between FAIL and DRAIN.
 -- x11 forwarding: handle build with alternate location for libssh2.

* Changes in Slurm 17.11.0rc3
==============================
 -- Fix extern step to wait until launched before allowing job to start.
 -- Add missing locks around figuring out TRES when clean starting the
    slurmctld.
 -- Cray modulefile: avoid removing /usr/bin from path on module unload.
 -- Make reoccurring reservations show up in the database.
 -- Adjust related resources (cpus, tasks, gres, mem, etc.) when updating
    NumNodes with scontrol.
 -- Don't initialize MPI plugins for batch or extern steps.`
 -- slurm.spec - do not install a slurm.conf file under /etc/ld.so.conf.d.
 -- X11 forwarding - fix keepalive message generation code.
 -- If heterogeneous job step is unable to acquire MPI reserved ports then
    avoid referencing NULL pointer. Retry assigning ports ONLY for
    non-heterogeneous job steps.
 -- If any acct_gather_*_init fails fatal instead of error and keep going.
 -- launch/slurm plugin - Avoid using global variable for heterogeneous job
    steps, which could corrupt memory.

* Changes in Slurm 17.11.0rc2
==============================
 -- Prevent slurmctld abort with NodeFeatures=knl_cray and non-KNL nodes lacking
    any configured features.
 -- The --cpu_bind and --mem_bind options have been renamed to --cpu-bind
    and --mem-bind for consistency with the rest of Slurm's options. Both
    old and new syntaxes are supported for now.
 -- Add slurmdb_connection_commit to the slurmdb api to commit when needed.
 -- Add the federation api's to the slurmdb.h file.
 -- Add job functions to the db_api.
 -- Fix sacct to always use the db_api instead of sometimes calling functions
    directly.
 -- Fix sacctmgr to always use the db_api instead of sometimes calling functions
    directly.
 -- Fix sreport to always use the db_api instead of sometimes calling functions
    directly.
 -- Make global uid to the db_api to minimize calls to getuid().
 -- Add support for HWLOC version 2.0.
 -- Added more validation logic for updates to node features.
 -- Added node_features_p_node_update_valid() function to node_features plugin.
 -- If a job is held due to bad constraints and a node's features change then
    test the job again to see if can run with the new features.
 -- Added node_features_p_changible_feature() function to node_features plugin.
 -- Avoid rebooting a node if a job's requested feature is not under the control
    of the node_features plugin and is not currently active.
 -- node_features/knl_generic plugin: Do not clear a node's non-KNL features
    specified in slurm.conf.
 -- Added SchedulerParameters configuration option "disable_hetero_steps" to
    disable job steps that span multiple components of a heterogeneous job.
    Disabled by default except with mpi/none plugin. This limitation to be
    removed in Slurm version 18.08.

* Changes in Slurm 17.11.0rc1
==============================
 -- Added the following jobcomp/script environment variables: CLUSTER,
    DEPENDENCY, DERIVED_EC, EXITCODE, GROUPNAME, QOS, RESERVATION, USERNAME.
    The format of LIMIT (job time limit) has been modified to D-HH:MM:SS.
 -- Fix QOS usage factor applying to individual TRES run minute usage.
 -- Print numbers using exponential format if required to fit in allocated
    field width. The sacctmgr and sshare commands are impacted.
 -- Make it so a backup DBD doesn't attempt to create database tables and
    relies on the primary to do so.
 -- By default have Slurm dynamically link to libslurm.so instead of static
    linking.  If static linking is desired configure with
    --without-shared-libslurm.
 -- Change --workdir in sbatch to be --chdir as in all other commands (salloc,
    srun).
 -- Add WorkDir to the job record in the database.
 -- Make the UsageFactor of a QOS work when a qos has the nodecay flag.
 -- Add MaxQueryTimeRange option to slurmdbd.conf to limit accounting query
    ranges when fetching job records.
 -- Add LaunchParameters=batch_step_set_cpu_freq to allow the setting of the cpu
    frequency on the batch step.
 -- CRAY - Fix statically linked applications to CRAY's PMI.
 -- Fix - Raise an error back to the user when trying to update currently
    unsupported core-based reservations.
 -- Do not print TmpDisk space as part of 'slurmd -C' line.
 -- Fix to test MaxMemPerCPU/Node partition limits when scheduling, previously
    only checked on submit.
 -- Work for heterogeneous job support (complete solution in v17.11):
    * Set SLURM_PROCID environment variable to reflect global task rank (needed
      by MPI).
    * Set SLURM_NTASKS environment variable to reflect global task count (needed
      by MPI).
    * In srun, if only some steps are allocated and one step allocation fails,
      then delete all allocated steps.
    * Get SPANK plungins working with heterogeneous jobs. The
      spank_init_post_opt() function is executed once per job component.
```

```
   * Modify sbcast command and srun's --bcast option to support heterogeneous
     jobs.
   * Set more environment variables for MPI: SLURM_GTIDS and SLURM_NODEID.
   * Prevent a heterogeneous job allocation from including the same nodes in
     multiple components (required by MPI jobs spanning components).
   * Modify step create logic so that call components of a heterogeneous job
     launched by a single srun command have the same step ID value.
-- Modify output of "--mpi=list" to avoid duplicates for version numbers in
   mpi/pmix plugin names.
-- Allow nodes to be rebooted while in a maintenance reservation.
-- Show nodes as down even when nodes are in a maintenance reservation.
-- Harden the slurmctld HA stack to mitigate certain split-brain issues.
-- Work for heterogeneous job support (complete solution in v17.11):
   * Add burst buffer support.
   * Remove srun's --mpi-combine option (always combined).
   * Add SchedulerParameters configuration option "enable_hetero_steps" to
     enable job steps that span multiple components of a heterogeneous job.
     Disabled by default as most MPI implementations and Slurm configurations
     are not currently supported. Limitation to be removed in Slurm version
     18.08.
   * Synchronize application launch across multiple components with debugger.
   * Modify slurm_kill_job_step() to cancel all components of a heterogeneous
     job step (used by MPI).
   * Set SLURM_JOB_NUM_NODES environment variable as needed by MVAPICH.
   * Base time limit upon the time that the latest job component is available
     (after all nodes in all components booted and ready for use).
-- Add cluster name to smail tool email header.
-- Speedup arbitrary distribution algorithm.
-- Modify "srun --mpi=list" output to match valid option input by removing the
   "mpi/" prefix on each line of output.
-- Automatically set the reservation's partition for the job if not the
   cluster default.
-- mpi/pmi2 plugin - vestigial pointer could be referenced at shutdown with
   invalid memory reference resulting.
-- Fix to _is_gres_cnt_zero() return false for improper input string
-- Cleanup all pthread_create calls and replace with new slurm_thread_create
   macro.
-- Removed obsolete MPI plugins. Remaining options are openmpi, pmi2, pmix.
-- Removed obsolete checkpoint/poe plugin.
-- Process spank environment variable options before processing spank command
   line options. Spank plugins should be able to handle option callbacks being
   called multiple times.
-- Add support for specialized cores with task/affinity plugin (previously
   only supported with task/cgroup plugin).
-- Add "TaskPluginParam=SlurmdOffSpec" option that will prevent the Slurm
   compute node daemons (slurmd and slurmstepd) from executing on specialized
   cores.
-- CRAY - Make native mode default, use --disable-native-cray to use ALPS
   instead of native Slurm.
-- Add ability to prevent suspension of some count of nodes in a specified
   range using the SuspendExcNodes configuration parameter.
-- Add SLURM_WCKEY to PrologSlurmctld and EpilogSlurmctld  environment.
-- Return user response string in response to successful job allocation request
   not only on failure. Set in LUA using function 'slurm.user_msg("STRING")'.
-- Add 'scontrol write batch_script <jobid>' command to retrieve the batch
   script for a given job.
-- Remove option to display the batch script as part of 'scontrol show job'.
-- On native Cray system the configured RebootProgram is executed on on the
```

```
    head node by the slurmctld daemon rather than by the slurmd daemons on the
    compute nodes. The "capmc_resume" program from "contribs/cray" can be used.
 -- Modify "scontrol top" command to accept a comma separated list of job IDs
    as an argument rather than a single job ID.
 -- Add MemorySwappiness value to cgroup.conf.
 -- Add new "billing" TRES which allows jobs to be limited based on the job's
    billable TRES calculated by the job's partition's TRESBillingWeights.
 -- sbatch - force line-buffered output so 'sbatch -W' returns the jobid
    over a piped output immediately.
 -- Regular user use of "scontrol top" command is now diabled. Use the
    configuration parameter "SchedulerParameters=enable_user_top" to enable
    that functionality. The configuration parameter
    "SchedulerParameters=disable_user_top" will be silently ignored.
 -- Add -TALL to sreport.
 -- Removed unused SlurmdPlugstack option and associated framework.
 -- Correct logic for line continuation in srun --multi-prog file.
 -- Add DBD Agent queue size to sdiag output.
 -- Add running job count to sdiag output.
 -- Print unix timestamps next to ASCII timestamps in sdiag output.
 -- In a job allocation spanning KNL and non-KNL nodes and requiring a reboot,
    do not attempt to set default NUMA or MCDRAM modes on non-KNL nodes.
 -- Change default to let pending jobs run outside of reservation after
    reservation is gone to put jobs in held state. Added NO_HOLD_JOBS_AFTER_END
    reservation flag to use old default.
 -- When creating a reservation, validate the CoreCnt specification matches
    the number of nodes listed.
 -- When creating a reservation, correct logic to ignoring job allocations on
    request.
 -- Deprecate BLCR plugin, and do not build by default.
 -- Change sreport report titles from "Use" to "Usage"

* Changes in Slurm 17.11.0pre2
==============================
 -- Initial work for heterogeneous job support (complete solution in v17.11):
    * Modified salloc, sbatch and srun commands to parse command line, job
      script and environment variables to recognize requests for heterogeneous
      jobs. Same commands also modified to set environment variables describing
      each component of the heterogeneous job.
    * Modified job allocate, batch job submit and job "will-run" requests to
      pass a list of job specifications and get a list of responses.
    * Modify slurmctld daemon to process a heterogeneous job request and create
      multiple job records as needed.
    * Added new fields to job record: pack_job_id, pack_job_offset and
      pack_job_set (set of job IDs). Added to slurmctld state save/restore
      logic and job information reported.
    * Display new job fields in "scontrol show job" output.
    * Modify squeue command to display heterogeneous job records using "#+#"
      format. The squeue --job=# output lists all components of a heterogeneous
      job.
    * Modify scancel logic to cancel all components of a heterogeneous job with
      a single request/RPC.
    * Configuration parameter DebugFlags value of "HeteroJobs" added.
    * Job requeue and suspend/resume modified to operate on all components of
      a heterogeneous job with a single request/RPC.
    * New web page added to describe heterogeneous jobs.
    * Descriptions of new API added to man pages.
    * Modified email notifications to only operate on the first job component.
    * Purge heterogeneous job records at the same time and not by individual
```

```
     components.
   * Modified logic for heterogeneous jobs submitted to multiple clusters
     ("--clusters=...") so the job will be routed to the cluster that is
     expected to start all components earliest.
   * Modified srun to create multiple job steps for heterogeneous job
     allocations.
   * Modified launch plugin to accept a pointer to job step options structure
     rather than work from a single/common data structure.
-- Improve backfill scheduling algorithm with respect to starting jobs as soon
   as possible while avoiding advanced reservations.
-- Add URG as an option to 'scancel --signal'.
-- Check if the buffer returned from slurm_persist_msg_pack() isn't NULL.
-- Modify all daemons to re-open log files on receipt of SIGUSR2 signal. This
   is much than using SIGHUP to re-read the configuration file and rebuild
   various tables.
-- Add PrivateData=events configuration parameter
-- Work for heterogeneous job support (complete solution in v17.11):
   * Add pointer to job option structure to job_step_create_allocation()
     function used by srun.
   * Parallelize task launch for heterogeneous job allocations (initial work).
   * Make packjobid, packjoboffset, and packjobidset fields available in squeue
     output.
   * Modify smap command to display heterogeneous job records using "#+#"
     format.
   * Add srun --pack-group and --mpi-combine options to control job step
     launch behaviour (not fully implemented).
   * Add pack job component ID to srun --label output (e.g. "P0 1:" for
     job component 0 and task 1).
   * jobcomp/elasticsearch: Add pack_job_id and pack_job_offset fields.
   * sview: Modified to display pack job information.
   * Major re-write of task state container logic to support for list of
     containers rather than one container per srun command.
   * Add some regression tests.
   * Add srun pack job environment variables when performing job allocation.
-- Set Reason=dependency over Reason=JobArrayTaskLimit for pending jobs.
-- Add slurm.conf configuration parameters SlurmctldSyslogDebug and
   SlurmdSyslogDebug to control which messages from the slurmctld and slurmd
   daemons get written to syslog.
-- Add slurmdbd.conf configuration parameter DebugLevelSyslog to control which
   messages from the slurmdbd daemon get written to syslog.
-- Fix handling of GroupUpdateForce option.
-- Work for heterogeneous job support (complete solution in v17.11):
   * Add support to sched/backfill for concurrent allocation of all pack job
     components including support of --time-min option.
   * Defer initiation of a heterogeneous job until a components can be started
     at the same time, taking into consideration association and QOS limits
     for the job as a whole.
   * Perform limit check on heterogeneous job as a whole at submit time to
     reject jobs that will never be able to run.
   * Add pack_job_id and pack_job_offset to accounting database.
   * Modified sacct to accept pack job ID specification using "#+#" notation.
   * Modified sstat to accept pack job ID specification using "#+#" notation.
-- Clear a job's "wait reason" value of BeginTime" after that time has passed.
   Previously a readon of "BeginTime" could be reported long after the job's
   requested begin time had passed.
-- Split group_info in slurm_ctl_conf_t into group_force and group_time.
-- Work for heterogeneous job support (complete solution in v17.11):
   * Fix I/O race condition on step termination for srun launching multiple
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      pack job groups.
    * If prolog is running when attempting to signal a step, then return EAGAIN
      and retry rather than simply returning SLURM_ERROR and aborting.
    * Modify launch/slurm plugin to signal all components of a pack job rather
      than just the one (modify to use a list of step context records).
    * Add logic to support srun --mpi-combine option.
    * Set up debugger data structures.
    * Disable cancellation of individual component while the job is pending.
    * Modify scontrol job hold/release and update to operate with heterogeneous
      job id specification (e.g. "scontrol hold 123+4").
    * If srun lacks application specification for some component, the next one
      specified will be used for earlier components.

* Changes in Slurm 17.11.0pre1
==============================
 -- Interpet all format options in output/error file to log prolog errors. Prior
    logic only supported "%j" (job ID) option.
 -- Add the configure option --with-shared-libslurm which will link to
    libslurm.so instead of libslurm.o thus reducing the footprint of all the
    binaries.
 -- In switch plugin, added plugin_id symbol to plugins and wrapped
    switch_jobinfo_t with dynamic_plugin_data_t in interface calls in
    order to pass switch information between clusters with different switch
    types.
 -- Switch naming of acct_gather_infiniband to acct_gather_interconnect
 -- Make it so you can "stack" the interconnect plugins.
 -- Add a last_sched_eval timestamp to record when a job was last evaluated
    by the main scheduler or backfill.
 -- Add scancel "--hurry" option to avoid staging out any burst buffer data.
 -- Simplify the sched plugin interface.
 -- Add new advanced reservation flags of "weekday" (repeat on each weekday;
    Monday through Friday) and "weekend" (repeat on each weekend day; Saturday
    and Sunday).
 -- Add new advanced reservation flag of "flex", which permits jobs requesting
    the reservation to begin prior to the reservation's start time and use
    resources inside or outside of the reservation. A typical use case is to
    prevent jobs not explicitly requesting the reservation from using those
    reserved resources rather than forcing jobs requesting the reservation to
    use those resources in the time frame reserved.
 -- Add NoDecay flag to QOS.
 -- Node "OS" field expanded from "sysname" to "sysname release version" (e.g.
    change from "Linux" to
    "Linux 4.8.0-28-generic #28-Ubuntu SMP Sat Feb 8 09:15:00 UTC 2017").
 -- jobcomp/elasticsearch - Add "job_name" and "wc_key" fields to stored
    information.
 -- jobcomp/filetxt - Add ArrayJobId, ArrayTaskId, ReservationName, Gres,
    Account, QOS, WcKey, Cluster, SubmitTime, EligibleTime, DerivedExitCode and
    ExitCode.
 -- scontrol modified to report core IDs for reservation containing individual
    cores.
 -- MYSQL - Get rid of table join during rollup which speeds up the process
    dramatically on large job/step tables.
 -- Add ability to define features on clusters for directing federated jobs to
    different clusters.
 -- Add new RPC to process multiple federation RPCs in a single communication.
 -- Modify slurm_load_jobs() function to load job information from all clusters
    in a federation.
 -- Add squeue --local and --sibling options to modify filtering of jobs on
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   federated clusters.
-- Add SchedulerParameters option of bf_max_job_user_part to specifiy the
   maximum number of jobs per user for any single partition. This differs from
   bf_max_job_user in that a separate counter is applied to each partition
   rather than having a single counter per user applied to all partitions.
-- Modify backfill logic so that bf_max_job_user, bf_max_job_part and
   bf_max_job_user_part options can all be used independently of each other.
-- Add sprio -p/--partition option to filter jobs by partition name.
-- Add partition name to job priority factor response message.
-- Add sprio --local and --sibling options for use in federation of clusters.
-- Add sprio "%c" format to print cluster name in federation mode.
-- Modify sinfo logic to provided unified view of all nodes and partitions
   in a federation, add --local option to only report local state information
   even in a cluster, print cluster name with "%V" format option, and
   optionally sort by cluster name.
-- If a task in a parallel job fails and it was launched with the
   --kill-on-bad-exit option then terminate the remaining tasks using the
   SIGCONT, SIGTERM and SIGKILL signals rather than just sending SIGKILL.
-- Include submit_time when doing the sort for job scheduling.
-- Modify sacct to report all jobs in federation by default. Also add --local
   option.
-- Modify sacct to accept "--cluster all" option (in addition to the old
   "--cluster -1", which is still accepted).
-- Modify sreport to report all jobs in federation by default. Also add --local
   option.
-- sched/backfill: Improve assoc_limit_stop configuration parameter support.
-- KNL features: Always keep active and available features in the same order:
   first site-specific features, next MCDRAM modes, last NUMA modes.
-- Changed default ProctrackType to cgroup.
-- Add "cluster_name" field to node_info_t and partition_info_t data structure.
   It is filled in only when the cluster is part of a federation and
   SHOW_FEDERATION flag used.
-- Functions slurm_load_node() slurm_load_partitions() modified to show all
   nodes/partitions in a federation when the SHOW_FEDERATION flag is used.
-- Add federated views to sview.
-- Add --federation option to sacct, scontrol, sinfo, sprio, squeue, sreport to
   show a federated view. Will show local view by default.
-- Add FederationParameters=fed_display slurm.conf option to configure status
   commands to display a federated view by default if the cluster is a member
   of a federation.
-- Log the down nodes whenever slurmctld restarts.
-- Report that "CPUs" plus "Boards" in node configuration invalid only if the
   CPUs value is not equal to the total thread count.
-- Extend the output of the seff utility to also include the job's wall-clock
   time.
-- Add bf_max_time to SchedulerParameters.
-- Add bf_max_job_assoc to SchedulerParameters.
-- Add new SchedulerParameters option bf_window_linear to control the rate at
   which the backfill test window expands. This can be used on a system with
   a modest number of running jobs (hundreds of jobs) to help prevent expected
   start times of pending jobs to get pushed forward in time. On systems with
   large numbers of running jobs, performance of the backfill scheduler will
   suffer and fewer jobs will be evaluated.
-- Improve scheduling logic with respect to license use and node reboots.
-- CRAY - Alter algorithm to come up with the SLURM_ID_HASH.
-- Implement federated scheduling and federated status outputs.
-- The '-q' option to srun has changed from being the short form of
   '--quit-on-interrupt' to '--qos'.
```

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 -- Change sched_min_interval default from 0 to 2 microseconds.

* Changes in Slurm 17.02.11
===========================
 -- Fix insecure handling of user_name and gid fields. CVE-2018-10995.

* Changes in Slurm 17.02.10
===========================
 -- Fix updating of requested TRES memory.
 -- Cray modulefile: avoid removing /usr/bin from path on module unload.
 -- Fix issue when resetting the partition pointers on nodes.
 -- Show reason field in 'sinfo -R' when nodes is marked as failed.
 -- Fix potential of slurmstepd segfaulting when the extern step fails to start.
 -- Allow nodes state to be updated between FAIL and DRAIN.
 -- Avoid registering a job'd credential multiple times.
 -- Fix sbatch --wait to stop waiting after job is gone from memory.
 -- Fix memory leak of MailDomain configuration string when slurmctld daemon is
    reconfigured.
 -- Fix to properly remove extern steps from the starting_steps list.
 -- Fix Slurm to work correctly with HDF5 1.10+.
 -- Add support in salloc/srun --bb option for "access_mode" in addition to
    "access" for consistency with DW options.
 -- Fix potential deadlock in _run_prog() in power save code.
 -- MYSQL - Add dynamic_offset in the database to force range for auto
    increment ids for the tres_table.
 -- Avoid setting node in COMPLETING state indefinitely if the job initiating
    the node reboot is cancelled while the reboot in in progress.
 -- node_feature/knl_cray - Fix memory leaks that occur when slurmctld
    reconfigured.
 -- node_feature/knl_cray - Fix memory leak that can occur during normal
    operation.
 -- Fix job array dependency with "aftercorr" option and some task arrays in
    the first job fail. This fix lets all task array elements that can run
    proceed rather than stopping all subsequent task array elements.
 -- Fix whole node allocation cpu counts when --hint=nomultihtread.
 -- NRT - Fix issue when running on a HFI (p775) system with multiple protocols.
 -- Fix uninitialized variables when unpacking slurmdb_archive_cond_t.
 -- Fix security issue in accounting_storage/mysql plugin by always escaping
    strings within the slurmdbd. CVE-2018-7033.

* Changes in Slurm 17.02.9
==========================
 -- When resuming powered down nodes, mark DOWN nodes right after ResumeTimeout
    has been reached (previous logic would wait about one minute longer).
 -- Fix sreport not showing full column name for TRES Count.
 -- Fix slurmdb_reservations_get() giving wrong usage data when job's spanned
    reservation that was modified.
 -- Fix sreport reservation utilization report showing bad data.
 -- Show all TRES' on a reservation in sreport reservation utilization report by
    default.
 -- Fix sacctmgr show reservation handling "end" parameter.
 -- Work around issue with sysmacros.h and gcc7 / glibc 2.25.
 -- Fix layouts code to only allow setting a boolean.
 -- Fix sbatch --wait to keep waiting even if a message timeout occurs.
 -- CRAY - If configured with NodeFeatures=knl_cray and there are non-KNL
    nodes which include no features the slurmctld will abort without
    this patch when attemping strtok_r(NULL).
 -- Fix regression in 17.02.7 which would run the spank_task_privileged as
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    part of the slurmstepd instead of it's child process.
 -- Fix security issue in Prolog and Epilog by always prepending SPANK_ to
    all user-set environment variables. CVE-2017-15566.

* Changes in Slurm 17.02.8
==========================
 -- Add 'slurmdbd:' to the accounting plugin to notify message is from dbd
    instead of local.
 -- mpi/mvapich - Buffer being only partially cleared. No failures observed.
 -- Fix for job --switch option on dragonfly network.
 -- In salloc with --uid option, drop supplementary groups before changing UID.
 -- jobcomp/elasticsearch - strip any trailing slashes from JobCompLoc.
 -- jobcomp/elasticsearch - fix memory leak when transferring generated buffer.
 -- Prevent slurmstepd ABRT when parsing gres.conf CPUs.
 -- Fix sbatch --signal to signal all MPI ranks in a step instead of just those
    on node 0.
 -- Check multiple partition limits when scheduling a job that were previously
    only checked on submit.
 -- Cray: Avoid running application/step Node Health Check on the external
    job step.
 -- Optimization enhancements for partition based job preemption.
 -- Address some build warnings from GCC 7.1, and one possible memory leak if
    /proc is inaccessible.
 -- If creating/altering a core based reservation with scontrol/sview on a
    remote cluster correctly determine the select type.
 -- Fix autoconf test for libcurl when clang is used.
 -- Fix default location for cgroup_allowed_devices_file.conf to use correct
    default path.
 -- Document NewName option to sacctmgr.
 -- Reject a second PMI2_Init call within a single step to prevent slurmstepd
    from hanging.
 -- Handle old 32bit values stored in the database for requested memory
    correctly in sacct.
 -- Fix memory leaks in the task/cgroup plugin when constraining devices.
 -- Make extremely verbose info messages debug2 messages in the task/cgroup
    plugin when constraining devices.
 -- Fix issue that would deny the stepd access to /dev/null where GRES has a
    'type' but no file defined.
 -- Fix issue where the slurmstepd would fatal on job launch if you have no
    gres listed in your slurm.conf but some in gres.conf.
 -- Fix validating time spec to correctly validate various time formats.
 -- Make scontrol work correctly with job update timelimit [+|-]=.
 -- Reduce the visibily of a number of warnings in _part_access_check.
 -- Prevent segfault in sacctmgr if no association name is specified for
    an update command.
 -- burst_buffer/cray plugin modified to work with changes in Cray UP05
    software release.
 -- Fix job reasons for jobs that are violating assoc MaxTRESPerNode limits.
 -- Fix segfault when unpacking a 16.05 slurm_cred in a 17.02 daemon.
 -- Fix setting TRES limits with case insensitive TRES names.
 -- Add alias for xstrncmp() -- slurm_xstrncmp().
 -- Fix sorting of case insensitive strings when using xstrcasecmp().
 -- Gracefully handle race condition when reading /proc as process exits.
 -- Avoid error on Cray duplicate setup of core specialization.
 -- Skip over undefined (hidden in Slurm) nodes in pbsnodes.
 -- Add empty hashes in perl api's slurm_load_node() for hidden nodes.
 -- CRAY - Add rpath logic to work for the alpscomm libs.
 -- Fixes for administrator extended TimeLimit (job reason & time limit reset).
 -- Fix gres selection on systems running select/linear.
 -- sview: Added window decorator for maximize,minimize,close buttons for all
    systems.
 -- squeue: interpret negative length format specifiers as a request to
    delimit values with spaces.
 -- Fix the torque pbsnodes wrapper script to parse a gres field with a type
    set correctly.

* Changes in Slurm 17.02.7
==========================
 -- Fix deadlock if requesting to create more than 10000 reservations.
 -- Fix potential memory leak when creating partition name.
 -- Execute the HealthCheckProgram once when the slurmd daemon starts rather
    than executing repeatedly until an exit code of 0 is returned.
 -- Set job/step start and end times to 0 when using --truncate and start > end.
 -- Make srun --pty option ignore EINTR allowing windows to resize.
 -- When resuming node only send one message to the slurmdbd.
 -- Modify srun --pty option to use configured SrunPortRange range.
 -- Fix issue with whole gres not being printed out with Slurm tools.
 -- Fix issue with multiple jobs from an array are prevented from starting.
 -- Fix for possible slurmctld abort with use of salloc/sbatch/srun
    --gres-flags=enforce-binding option.
 -- Fix race condition when using jobacct_gather/cgroup where the memory of the
    step wasn't always gathered correctly.
 -- Better debug when slurmdbd queue is filling up in the slurmctld.
 -- Fixed truncation on scontrol show config output.
 -- Serialize updates from from the dbd to the slurmctld.
 -- Fix memory leak in slurmctld when agent queue to the DBD has filled up.
 -- CRAY - Throttle step creation if trying to create too many steps at once.
 -- If failing after switch_g_job_init happened make sure switch_g_job_fini is
    called.
 -- Fix minor memory leak if launch fails in the slurmstepd.
 -- Fix issue where UnkillableStepProgram if step was in an ending state.
 -- Fix bug when tracking multiple simultaneous spawned ping cycles.
 -- jobcomp/elasticsearch plugin now saves state of pending requests on
    slurmctld daemon shutdown so then can be recovered on restart.
 -- Fix issue when an alternate munge key when communicating on a persistent
    connection.
 -- Document inconsistent behavior of GroupUpdateForce option.
 -- Fix bug in selection of GRES bound to specific CPUs where the GRES count
    is 2 or more. Previous logic could allocate CPUs not available to the job.
 -- Increase buffer to handle long /proc/<pid>/stat output so that Slurm can
    read correct RSS value and take action on jobs using more memory than
    requested.
 -- Fix srun job jobs that can run immediately to run in the highest priority
    partion when multiple partitions are listed. scontrol show jobs can
    potentially show the partition list in priority order.
 -- Fix starting controller if StateSaveLocation path didn't exist.
 -- Fix inherited association 'max' TRES limits combining multiple limits in
    the tree.
 -- Sort TRES id's on limits when getting them from the database.
 -- Fix issue with pmi[2|x] when TreeWidth=1.
 -- Correct buffer size used in determining specialized cores to avoid possible
    truncation of core specification and not reserving the specified cores.
 -- Close race condition on Slurm structures when setting DebugFlags.
 -- Make it so the cray/switch plugin grabs new DebugFlags on a reconfigure.
 -- Fix incorrect lock levels when creating or updating a reservation.
 -- Fix overlapping reservation resize.
 -- Add logic to help support Dell KNL systems where syscfg is different than
    the normal Intel syscfg.
 -- CRAY - Fix BB to handle type= correctly, regression in 17.02.6.

* Changes in Slurm 17.02.6
==========================
 -- Fix configurator.easy.html to output the SelectTypeParameters line.
 -- If a job requests a specific memory requirement then gets something else
    from the slurmctld make sure the step allocation is made aware of it.
 -- Fix missing initialization in slurmd.
 -- Fix potential degradation when running HTC (> 100 jobs a sec) like
    workflows through the slurmd.
 -- Fix race condition which could leave a stepd hung on shutdown.
 -- CRAY - Add configuration for ATP to the ansible play script.
 -- Fix potential to corrupt DBD message.
 -- burst_buffer logic modified to support sizes in both SI and EIC size units
    (e.g. M/MiB for powers of 1024, MB for powers of 1000).

* Changes in Slurm 17.02.5
==========================
 -- Prevent segfault if a job was blocked from running by a QOS that is then
    deleted.
 -- Improve selection of jobs to preempt when there are multiple partitions
    with jobs subject to preemption.
 -- Only set kmem limit when ConstrainKmemSpace=yes is set in cgroup.conf.
 -- Fix bug in task/affinity that could result in slurmd fatal error.
 -- Increase number of jobs that are tracked in the slurmd as finishing at one
    time.
 -- Note when a job finishes in the slurmd to avoid a race when launching a
    batch job takes longer than it takes to finish.
 -- Improve slurmd startup on large systems (> 10000 nodes)
 -- Add LaunchParameters option of cray_net_exclusive to control whether all
    jobs on the cluster have exclusive access to their assigned nodes.
 -- Make sure srun inside an allocation gets --ntasks-per-[core|socket]
    set correctly.
 -- Only make the extern step at job creation.
 -- Fix for job step task layout with --cpus-per-task option.
 -- Fix --ntasks-per-core option/environment variable parsing to set
    the requested value, instead of always setting one (srun).
 -- Correct error message when ClusterName in configuration files does not match
    the name in the slurmctld daemon's state save file.
 -- Better checking when a job is finishing to avoid underflow on job's
    submitted to a QOS/association.
 -- Handle partition QOS submit limits correctly when a job is submitted to
    more than 1 partition or when the partition is changed with scontrol.
 -- Performance boost for when Slurm is dealing with credentials.
 -- Fix race condition which could leave a stepd hung on shutdown.
 -- Add lua support for opensuse.

* Changes in Slurm 17.02.4
==========================
 -- Do not attempt to schedule jobs after changing the power cap if there are
    already many active threads.
 -- Job expansion example in FAQ enhanced to demonstrate operation in
    heterogeneous environments.
 -- Prevent scontrol crash when operating on array and no-array jobs at once.
 -- knl_cray plugin: Log incomplete capmc output for a node.
 -- knl_cray plugin: Change capmc parsing of mcdram_pct from string to number.
 -- Remove log files from test20.12.
 -- When rebooting a node and using the PrologFlags=alloc make sure the
    prolog is ran after the reboot.
 -- node_features/knl_generic - If a node is rebooted for a pending job, but
    fails to enter the desired NUMA and/or MCDRAM mode then drain the node and
    requeue the job.
 -- node_features/knl_generic disable mode change unless RebootProgram
    configured.
 -- Add new burst_buffer function bb_g_job_revoke_alloc() to be executed
    if there was a failure after the initial resource allocation. Does not
    release previously allocated resources.
 -- Test if the node_bitmap on a job is NULL when testing if the job's nodes
    are ready.  This will be NULL is a job was revoked while beginning.
 -- Fix incorrect lock levels when testing when job will run or updating a job.
 -- Add missing locks to job_submit/pbs plugin when updating a jobs
    dependencies.
 -- Add support for lua5.3
 -- Add min_memory_per_node|cpu to the job_submit/lua plugin to deal with lua
    not being able to deal with pn_min_memory being a uint64_t.  Scripts are
    urged to change to these new variables avoid issue.  If not set the
    variables will be 'nil'.
 -- Calculate priority correctly when 'nice' is given.
 -- Fix minor typos in the documentation.
 -- node_features/knl_cray: Preserve non-KNL active features if slurmctld
    reconfigured while node boot in progress.
 -- node_features/knl_generic: Do not repeatedly log errors when trying to read
    KNL modes if not KNL system.
 -- Add missing QOS read lock to backfill scheduler.
 -- When doing a dlopen on liblua only attempt the version compiled against.
 -- Fix null-dereference in sreport cluster ulitization when configured with
    memory-leak-debug.
 -- Fix Partition info in 'scontrol show node'. Previously duplicate partition
    names, or Partitions the node did not belong to could be displayed.
 -- Fix it so the backup slurmdbd will take control correctly.
 -- Fix unsafe use of MAX() macro, which could result in problems cleaning up
    accounting plugins in slurmd, or repeat job cancellation attempts in
    scancel.
 -- Fix 'scontrol update reservation duration=unlimited' to set the duration
    to 365-days (as is done elsewhere), rather than 49710 days.
 -- Check if variable given to scontrol show job is a valid jobid.
 -- Fix WithSubAccounts option to not include WithDeleted unless requested.
 -- Prevent a job tested on multiple partitions from being marked
    WHOLE_NODE_USER.
 -- Prevent a race between completing jobs on a user-exclusive node from
    leaving the node owned.
 -- When scheduling take the nodes in completing jobs out of the mix to reduce
    fragmentation.  SchedulerParameters=reduce_completing_frag
 -- For jobs submited to multiple partitions, report the job's earliest start
    time for any partition.
 -- Backfill partitions that use QOS Grp limits to "float" better.
 -- node_features/knl_cray: don't clear configured GRES from non-KNL node.
 -- sacctmgr - prevent segfault in command when a request is denied due
    to a insufficient priviledges.
 -- Add warning about libcurl-devel not being installed during configure.
 -- Streamline job purge by handling file deletion on a separate thread.
 -- Always set RLIMIT_CORE to the maximum permitted for slurmd, to ensure
    core files are created even on non-developer builds.
 -- Fix --ntasks-per-core option/environment variable parsing to set
```

```
    the requested value, instead of always setting one.
 -- If trying to cancel a step that hasn't started yet for some reason return
    a good return code.
 -- Fix issue with sacctmgr show where user=''

* Changes in Slurm 17.02.3
==========================
 -- Increase --cpu_bind and --mem_bind field length limits.
 -- Fix segfault when using AdminComment field with job arrays.
 -- Clear Dependency field when all dependencies are satisfied.
 -- Add --array-unique to squeue which will display one unique pending job
    array element per line.
 -- Reset backfill timers correctly without skipping over them in certain
    circumstances.
 -- When running the "scontrol top" command, make sure that all of the user's
    jobs have a priority that is lower than the selected job. Previous logic
    would permit other jobs with equal priority (no jobs with higher priority).
 -- Fix perl api so we always get an allocation when calling Slurm::new().
 -- Fix issue with cleaning up cpuset and devices cgroups when multiple steps
    end at the same time.
 -- Document that PriorityFlags option of DEPTH_OBLIVIOUS precludes the use of
    FAIR_TREE.
 -- Fix issue if an invalid message came in a Slurm daemon/command may abort.
 -- Make it impossible to use CR_CPU* along with CR_ONE_TASK_PER_CORE. The
    options are mutually exclusive.
 -- ALPS - Fix scheduling when ALPS doesn't agree with Slurm on what nodes
    are free.
 -- When removing a partition make sure it isn't part of a reservation.
 -- Fix seg fault if loading attempting to load non-existent burstbuffer plugin.
 -- Fix to backfill scheduling with respect to QOS and association limits. Jobs
    submitted to multiple partitions are most likley to be effected.
 -- sched/backfill: Improve assoc_limit_stop configuration parameter support.
 -- CRAY - Add ansible play and README.
 -- sched/backfill: Fix bug related to advanced reservations and the need to
    reboot nodes to change KNL mode.
 -- Preempt plugins - fix check for 'preempt_youngest_first' option.
 -- Preempt plugins - fix incorrect casts in preempt_youngest_first mode.
 -- Preempt/job_prio - fix incorrect casts in sort function.
 -- Fix to make task/affinity work with ldoms where there are more than 64
    cpus on the node.
 -- When using node_features/knl_generic make it so the slurmd doesn't segfault
    when shutting down.
 -- Fix potential double-xfree() when using job arrays that can lead to
    slurmctld crashing.
 -- Fix priority/multifactor priorities on a slurmctld restart if not using
    accounting_storage/[mysql|slurmdbd].
 -- Fix NULL dereference reported by CLANG.
 -- Update proctrack documentation to strongly encourage use of
    proctrack/cgroup.
 -- Fix potential memory leak if job fails to begin after nodes have been
    selected for a job.
 -- Handle a job that made it out of the select plugin without a job_resrcs
    pointer.
 -- Fix potential race condition when persistent connections are being closed at
    shutdown.
 -- Fix incorrect locks levels when submitting a batch job or updating a job
    in general.
 -- CRAY - Move delay waiting for job cleanup to after we check once.
 -- MYSQL - Fix memory leak when loading archived jobs into the database.
 -- Fix potential race condition when starting the priority/multifactor plugin's
    decay thread.
 -- Sanity check to make sure we have started a job in acct_policy.c before we
    clear it as started.
 -- Allow reboot program to use arguments.
 -- Message Aggr - Remove race condition on slurmd shutdown with respects to
    destroying a mutex.
 -- Fix updating job priority on multiple partitions to be correct.
 -- Don't remove admin comment when updating a job.
 -- Return error when bad separator is given for scontrol update job licenses.

* Changes in Slurm 17.02.2
==========================
 -- Update hyperlink to LBNL Node Health Check program.
 -- burst_buffer/cray - Add support for line continuation.
 -- If a job is cancelled by the user while it's allocated nodes are being
    reconfigured (i.e. the capmc_resume program is rebooting nodes for the job)
    and the node reconfiguration fails (i.e. the reboot fails), then don't
    requeue the job but leave it in a cancelled state.
 -- capmc_resume (Cray resume node script) - Do not disable changing a node's
    active features if SyscfgPath is configured in the knl.conf file.
 -- Improve the srun documentation for the --resv-ports option.
 -- burst_buffer/cray - Fix parsing for discontinuous allocated nodes. A job
    allocation of "20,22" must be expressed as "20\n22".
 -- Fix rare segfault when shutting down slurmctld and still sending data to
    the database.
 -- Fix gres output of a job if it is updated while pending to be displayed
    correctly with Slurm tools.
 -- Fix pam_slurm_adopt.
 -- Fix missing unlock when job_list doesn't exist when starting priority/
    multifactor.
 -- Fix segfault if slurmctld is shutting down and the slurmdbd plugin was
    in the middle of setting db_indexes.
 -- Add ESLURM_JOB_SETTING_DB_INX to errno to note when a job can't be updated
    because the dbd is setting a db_index.
 -- Fix possible double insertion into database when a job is updated at the
    moment the dbd is assigning a db_index.
 -- Fix memory error when updating a job's licenses.
 -- Fix seff to work correctly with non-standard perl installs.
 -- Export missing slurmdbd_defs_[init|fini] needed for libslurmdb.so to work.
 -- Fix sacct from returning way more than requested when querying against a job
    array task id.
 -- Fix double read lock of tres when updating gres or licenses on a job.
 -- Make sure locks are always in place when calling
    assoc_mgr_make_tres_str_from_array.
 -- Prevent slurmctld SEGV when creating reservation with duplicated name.
 -- Consider QOS flags Partition[Min|Max]Nodes when doing backfill.
 -- Fix slurmdbd_defs.c to not have half symbols go to libslurm.so and the
    other half go to libslurmdb.so.
 -- Fix 'scontrol show jobs' to remove an errant newline when 'Switches' is
    printed.
 -- Better code for handling memory required by a task on a heterogeneous
    system.
 -- Fix regression in 17.02.0 with respects to GrpTresMins on a QOS or
    Association.
 -- Cleanup to make make dist work.
 -- Schedule interactive jobs quicker.
 -- Perl API - correct value of MEM_PER_CPU constant to correctly handle
    memory values.
 -- Fix 'flags' variable to be 32 bit from the old 16 bit value in the perl api.
 -- Export sched_nodes for a job in the perl api.
 -- Improve error output when updating a reservation that has already started.
 -- Fix --ntasks-per-node issue with srun so DenyOnLimit would work correctly.
 -- node_features/knl_cray plugin - Fix memory leak.
 -- Fix wrong cpu_per_task count issue on heterogeneous system when dealing with
    steps.
 -- Fix double free issue when removing usage from an association with sacctmgr.
 -- Fix issue with SPANK plugins attempting to set null values as environment
    variables, which leads to the command segfaulting on newer glibc versions.
 -- Fix race condition on slurmctld startup when plugins have not gone through
    init() ahead of the rpc_manager processing incoming messages.
 -- job_submit/lua - expose admin_comment field.
 -- Allow AdminComment field to be set by the job_submit plugin.
 -- Allow AdminComment field to be changed by any Administrator.
 -- Fix key words in jobcomp select.
 -- MYSQL - Streamline job flush sql when doing a clean start on the slurmctld.
 -- Fix potential infinite loop when talking to the DBD when shutting down
    the slurmctld.
 -- Fix MCS filter.
 -- Make it so pmix can be included in the plugin rpm without having to
    specify --with-pmix.
 -- MYSQL - Fix initial load when not using he DBD.
 -- Fix scontrol top to not make jobs priority 0 (held).
 -- Downgrade info message about exceeding partition time limit to a debug2.

* Changes in Slurm 17.02.1-2
============================
 -- Replace clock_gettime with time(NULL) for very old systems without the call.

* Changes in Slurm 17.02.1
==========================
 -- Modify pam module to work when configured NodeName and NodeHostname differ.
 -- Update to sbatch/srun man pages to explain the "filename pattern" clearer
 -- Add %x to sbatch/srun filename pattern to represent the job name.
 -- job_submit/lua - Add job "bitflags" field.
 -- Update slurm.spec file to note obsolete RPMs.
 -- Fix deadlock scenario when dumping configuration in the slurmctld.
 -- Remove unneeded job lock when running assoc_mgr cache.  This lock could
    cause potential deadlock when/if TRES changed in the database and the
    slurmctld wasn't made aware of the change.  This would be very rare.
 -- Fix missing locks in gres logic to avoid potential memory race.
 -- If gres is NULL on a job don't try to process it when returning detailed
    information about a job to scontrol.
 -- Fix print of consumed energy in sstat when no energy is being collected.
 -- Print formatted tres string when creating/updating a reservation.
 -- Fix issues with QOS flags Partition[Min|Max]Nodes to work correctly.
 -- Prevent manipulation of the cpu frequency and governor for batch or
    extern steps. This addresses an issue where the batch step would
    inadvertently set the cpu frequency maximum to the minimum value
    supported on the node.
 -- Convert a slurmctd power management data structure from array to list in
    order to eliminate the possibility of zombie child suspend/resume
    processes.
 -- Burst_buffer/cray - Prevent slurmctld daemon abort if "paths" operation
    fails. Now job will be held. Update job update time when held.
 -- Fix issues with QOS flags Partition[Min|Max]Nodes to work correctly.
 -- Refactor slurmctld agent logic to eliminate some pthreads.
 -- Added "SyscfgTimeout" parameter to knl.conf configuration file.
 -- Fix for CPU binding for job steps run under a batch job.

* Changes in Slurm 17.02.0
==========================
 -- job_submit/lua - Make "immediate" parameter available.
 -- Fix srun I/O race condtion to eliminate a error message that might be
    generated if the application exits with outstanding stdin.
 -- Fix regression when purging/archiving jobs/events.
 -- Add new job state JOB_OOM indicating Out Of Memory condition as detected
    by task/cgroup plugin.
 -- If QOS has been added to the system go refigure out Deny/AllowQOS on
    partitions.
 -- Deny job with duplicate GRES requested.
 -- Fix loading super old assoc_mgr usage without segfaulting.
 -- CRAY systems: Restore TaskPlugins order of task/cray before task/cgroup.
 -- Task/cray: Treat missing "mems" cgroup with "debug" messages rather than
    "error" messages. The file may be missing at step termination due to a
    change in how cgroups are released at job/step end.
 -- Fix for job constraint specification with counts, --ntasks-per-node value,
    and no node count.
 -- Fix ordering of step task allocation to fill in a socket before going into
    another one.
 -- Fix configure to not require C++
 -- job_submit/lua - Remove access to slurmctld internal reservation fields of
    job_pend_cnt and job_run_cnt.
 -- Prevent job_time_limit enforcement from blocking other internal operations
    if a large number of jobs need to be cancelled.
 -- Add 'preempt_youngest_order' option to preempt/partition_prio plugin.
 -- Fix controller being able to talk to a pre-released DBD.
 -- Added ability to override the invoking uid for "scontrol update job"
    by specifying "--uid=<uid>|-u <uid>".
 -- Changed file broadcast "offset" from 32 to 64 bits in order to support files
    over 2 GB.
 -- slurm.spec - do not install init scripts alongside systemd service files.

* Changes in Slurm 17.02.0rc1
=============================
 -- Add port info to 'sinfo' and 'scontrol show node'.
 -- Fix errant definition of USE_64BIT_BITSTR which can lead to core dumps.
 -- Move BatchScript to end of each job's information when using
    "scontrol -dd show job" to make it more readable.
 -- Add SchedulerParameters configuration parameter of "default_gbytes", which
    treats numeric only (no suffix) value for memory and tmp disk space as being
    in units of Gigabytes. Mostly for compatability with LSF.
 -- Fix race condtion in srun/sattach logic which would prevent srun from
    terminating.
 -- Bitstring operations are now 64bit instead of 32bit.
 -- Replace hweight() function in bitstring with faster version.
 -- scancel would treat a non-numeric argument as the name of jobs to be
    cancelled (a non-documented feature). Cancelling jobs by name now require
    the "--jobname=" command line argument.
 -- scancel modified to note that no jobs satisfy the filter options when the
    --verbose option is used along with one or more job filters (e.g. "--qos=").
 -- Change _pack_cred to use pack_bit_str_hex instead of pack_bit_fmt for
    better scalability and performance.
 -- Add BootTime configuration parameter to knl.conf file to optimize resource
    allocations with respect to required node reboots.
 -- Add node_features_p_boot_time() to node_features plugin to optimize
    scheduling with respect to node reboots.
 -- Avoid allocating resources to a job in the event that its run time plus boot
    time (if needed) extent into an advanced reservation.
 -- Burst_buffer/cray - Avoid stage-out operation if job never started.
 -- node_features/knl_cray - Add capability to detected Uncorrectable Memory
    Errors (UME) and if detected then log the event in all job and step stderr
    with a message of the form:
    error: *** STEP 1.2 ON tux1 UNCORRECTABLE MEMORY ERROR AT 2016-12-14T09:09:37 ***
    Similar logic added to node_features/knl_generic in version 17.02.0pre4.
 -- If job is allocated nodes which are powered down, then reset job start time
    when the nodes are ready and do not charge the job for power up time.
 -- Add the ability to purge transactions from the database.
 -- Add support for requeue'ing of federated jobs (BETA).
 -- Add support for interactive federated jobs (BETA).
 -- Add the ability to purge rolled up usage from the database.
 -- Properly set SLURM_JOB_GPUS environment variable for Prolog.

* Changes in Slurm 17.02.0pre4
==============================
 -- Add support for per-partitiion OverTimeLimit configuration.
 -- Add --mem_bind option of "sort" to run zonesort on KNL nodes at step start.
 -- Add LaunchParameters=mem_sort option to configure running of zonesort
    by default at step startup.
 -- Add "FreeSpace" information for each pool to the "scontrol show burstbuffer"
    output. Required changes to the burst_buffer_info_t data structure.
 -- Add new node state flag of NODE_STATE_REBOOT for node reboots triggered by
    "scontrol reboot" commands. Previous logic re-used NODE_STATE_MAINT flag,
    which could lead to inconsistencies. Add "ASAP" option to "scontrol reboot"
    command that will drain a node in order to reboot it as soon as possible,
    then return it to service.
 -- Allow unit conversion routine to convert 1024M to 1G.
 -- switch/cray plugin - change legacy spool directory location.
 -- Add new PriorityFlags option of INCR_ONLY, which prevents a job's priority
    from being decremented.
 -- Make it so we don't purge job start messages until after we purge step
    messages.  Hopefully this will reduce the number of messages lost when
    filling up memory when the database/DBD is down.
 -- Added SchedulingParameters option of "bf_job_part_count_reserve". Jobs below
    the specified threshold will not have resources reserved for them.
 -- If GRES are configured with file IDs, then "scontrol -d show node" will
    not only identify the count of currently allocated GRES, but their specific
    index numbers (e.g. "GresUsed=gpu:alpha:2(IDX:0,2),gpu:beta:0(IDX:N/A)").
    Ditto for job information with "scontrol -d show job".
 -- Add new mcs/account plugin.
 -- Add "GresEnforceBind=Yes" to "scontrol show job" output if so configured.
 -- Add support for SALLOC_CONSTRAINT, SBATCH_CONSTRAINT and SLURM_CONSTRAINT
    environment variables to set default constraints for salloc, sbatch and
    srun commands respectively.
 -- Provide limited support for the MemSpecLimit configuration parameter without
    the task/cgroup plugin.
 -- node_features/knl_generic - Add capability to detected Uncorrectable Memory
    Errors (UME) and if detected then log the event in all job and step stderr
    with a message of the form:
    error: *** STEP 1.2 ON tux1 UNCORRECTABLE MEMORY ERROR AT 2016-12-14T09:09:37 ***
 -- Add SLURM_JOB_GID to TaskProlog environment.
 -- burst_buffer/cray - Remove leading zeros from node ID lists passed to
    dw_wlm_cli program.
 -- Add "Partitions" field to "scontrol show node" output.
 -- Remove sched/wiki and sched/wiki2 plugins and associated code.
 -- Remove SchedulerRootFilter option and slurm_get_root_filter() API call.
 -- Add SchedulerParameters option of spec_cores_first to select specialized
    cores from the lowest rather than highest number cores and sockets.
 -- Add PrologFlags option of Serial to disable concurrent launch of
    Prolog and Epilog scripts.
 -- Fix security issue caused by insecure file path handling triggered by the
    failure of a Prolog script. To exploit this a user needs to anticipate or
    cause the Prolog to fail for their job. CVE-2016-10030.

* Changes in Slurm 17.02.0pre3
==============================
 -- Add srun host & PID to job step data structures.
 -- Avoid creating duplicate pending step records for the same srun command.
 -- Rewrite srun's logic for pending steps for better efficiency (fewer RPCs).
 -- Added new SchedulerParameters options step_retry_count and step_retry_time
    to control scheduling behaviour of job steps waiting for resources.
 -- Optimize resource allocation logic for --spread-job job option.
 -- Modify cpu_bind and mem_bind map and mask options to accept a repetition
    count to better support large task count. For example:
    "mask_mem:0x0f*2,0xf0*2" is equivalent to "mask_mem:0x0f,0x0f,0xf0,0xf0".
 -- Add support for --mem_bind=prefer option to prefer, but not restrict memory
    use to the identified NUMA node.
 -- Add mechanism to constrain kernel memory allocation using cgroups. New
    cgroup.conf parameters added: ConstrainKmemSpace, MaxKmemPercent, and
    MinKmemSpace.
 -- Correct invokation of man2html, which previously could cause FreeBSD builds
    to hang.
 -- MYSQL - Unconditionally remove 'ignore' clause from 'alter ignore'.
 -- Modify service files to not start Slurm daemons until after Munge has been
    started.
    NOTE: If you are not using Munge, but are using the "service" scripts to
    start Slurm daemons, then you will need to remove this check from the
    etc/slurm*service scripts.
 -- Do not process SALLOC_HINT, SBATCH_HINT or SLURM_HINT environment variables
    if any of the following salloc, sbatch or srun command line options are
    specified: -B, --cpu_bind, --hint, --ntasks-per-core, or --threads-per-core.
 -- burst_buffer/cray: Accept new jobs on backup slurmctld daemon without access
    to dw_wlm_cli command. No burst buffer actions will take place.
 -- Do not include SLURM_JOB_DERIVED_EC, SLURM_JOB_EXIT_CODE, or
    SLURM_JOB_EXIT_CODE in PrologSlurmctld environment (not available yet).
 -- Cray - set task plugin to fatal() if task/cgroup is not loaded after
    task/cray in the TaskPlugin settings.
 -- Remove separate slurm_blcr package. If Slurm is built with BLCR support,
    the files will now be part of the main Slurm packages.
 -- Replace sjstat, seff and sjobexit RPM packages with a single "contribs"
    package.
 -- Remove long since defunct slurmdb-direct scripts.
 -- Add SbcastParameters configuration option to control default file
    destination directory and compression algorithm.
 -- Add new SchedulerParameter (max_array_tasks) to limit the maximum number of
    tasks in a job array independently from the maximum task ID (MaxArraySize).
 -- Fix issue where number of nodes is not properly allocated when sbatch and
    salloc are requested with -n tasks < hosts from -w hostlist or from -N.
 -- Add infrastructure for submitting federated jobs.
```

```
* Changes in Slurm 17.02.0pre2
==============================
 -- Add new RPC (REQUEST_EVENT_LOG) so that slurmd and slurmstepd can log events
    through the slurmctld daemon.
 -- Remove sbatch --bb option. That option was never supported.
 -- Automatically clean up task/cgroup cpuset and devices cgroups after steps
    are completed.
 -- Add federation read/write locks.
 -- Limit job purge run time to 1 second at a time.
 -- The database index for jobs is now 64 bits.  If you happen to be close to
    4 billion jobs in your database you will want to update your slurmctld at
    the same time as your slurmdbd to prevent roll over of this variable as
    it is 32 bit previous versions of Slurm.
 -- Optionally lock slurmstepd in memory for performance reasons and to avoid
    possible SIGBUS if the daemon is paged out at the time of a Slurm upgrade
    (changing plugins). Controlled via new LaunchParameters options of
    slurmstepd_memlock and slurmstepd_memlock_all.
 -- Add event trigger on burst buffer errors (see strigger man page,
    --burst_buffer option).
 -- Add job AdminComment field which can only be set by a Slurm administrator.
 -- Add salloc, sbatch and srun option of --delay-boot=<time>, which will
    temporarily delay booting nodes into the desired state for a job in the
    hope of using nodes already in the proper state which will be available at
    a later time.
 -- Add job burst_buffer_state and delay_boot fields to scontrol and squeue
    output. Also add ability to modify delay_boot from scontrol.
 -- Fix for node's available TRES array getting filled in with configured GRES
    model types.
 -- Log if job --bb option contains any unrecognized content.
 -- Display configured and allocated TRES for nodes in scontrol show nodes.
 -- Change all memory values (in MB) to uint64_t to accommodate > 2TB per node.
 -- Add MailDomain configuration parameter to qualify email addresses.
 -- Refactor the persistent connections within the federation code to use
    the same logic that was found in the slurmdbd.  Now both functionalities
    share the same code.
 -- Remove BlueGene/L and BlueGene/P support.
 -- Add "flag" field to launch_tasks_request_msg. Remove the following fields
    (moved into flags): multi_prog, task_flags, user_managed_io, pty,
    buffered_stdio, and labelio.
 -- Add protocol version to slurmd startup communications for slurmstepd to
    permit changes in the protocol.

* Changes in Slurm 17.02.0pre1
==============================
 -- burst_buffer/cray - Add support for rounding up the size of a buffer reqeust
    if the DataWarp configuration "equalize_fragments" is used.
 -- Remove AIX support.
 -- Rename "in" to "input" in slurm_step_io_fds data structure defined in
    slurm.h. This is needed to avoid breaking Python with by using one of its
    keywords in a Slurm data structure.
 -- Remove eligible_time from jobcomp/elasticsearch.
 -- Enable the deletion of a QOS, even if no clusters have been added to the
    database.
 -- SlurmDBD - change all timestamps to bigint from int to solve Y2038 problem.
 -- Add salloc/sbatch/srun --spread-job option to distribute tasks over as many
    nodes as possible. This also treats the --ntasks-per-node option as a
    maximum value.
 -- Add ConstrainKmemSpace to cgroup.conf, defaulting to yes, to allow
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    cgroup Kmem enforcement to be disabled while still using ConstrainRAMSpace.
 -- Add support for sbatch --bbf option to specify a burst buffer input file.
 -- Added burst buffer support for job arrays. Add new SchedulerParameters
    configuration parameter of bb_array_stage_cnt=# to indicate how many pending
    tasks of a job array should be made available for burst buffer resource
    allocation.
 -- Fix small memory leak when a job fails to load from state save.
 -- Fix invalid read when attempting to delete clusters from database with
    running jobs.
 -- Fix small memory leak when deleting clusters from database.
 -- Add SLURM_ARRAY_TASK_COUNT environment variable. Total number of tasks in a
    job array (e.g. "--array=2,4,8" will set SLURM_ARRAY_TASK_COUNT=3).
 -- Add new sacctmgr commands: "shutdown" (shutdown the server), "list stats"
    (get server statistics) "clear stats" (clear server statistics).
 -- Restructure job accounting query to use 'id_job in (1, 2, .. )' format
    instead of logically equivalent 'id_job = 1 || id_job = 2 || ..' .
 -- Added start_delay field to jobcomp/elasticsearch.
 -- In order to support federated jobs, the MaxJobID configuration parameter
    default value has been reduced from 2,147,418,112 to 67,043,328 and its
    maximum value is now 67,108,863. Upon upgrading, any pre-existing jobs that
    have a job ID above the new range will continue to run and new jobs will get
    job IDs in the new range.
 -- Added infrastructure for setting up federations in database and establishing
    connections between federation clusters.

* Changes in Slurm 16.05.12
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* Changes in Slurm 16.05.11
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 -- burst_buffer/cray - Add support for line continuation.
 -- If a job is cancelled by the user while it's allocated nodes are being
    reconfigured (i.e. the capmc_resume program is rebooting nodes for the job)
    and the node reconfiguration fails (i.e. the reboot fails), then don't
    requeue the job but leave it in a cancelled state.
 -- capmc_resume (Cray resume node script) - Do not disable changing a node's
    active features if SyscfgPath is configured in the knl.conf file.
 -- Fix memory error when updating a job's licenses.
 -- Fix double read lock of tres when updating gres or licenses on a job.
 -- Fix regression in 16.05.10 with respects to GrpTresMins on a QOS or
    Association.
 -- ALPS - Fix scheduling when ALPS doesn't agree with Slurm on what nodes
    are free.
 -- Fix seg fault if loading attempting to load non-existent burstbuffer plugin.
 -- Fix to backfill scheduling with respect to QOS and association limits. Jobs
    submitted to multiple partitions are most likley to be effected.
 -- Avoid erroneous errno set by the mariadb 10.2 api.
 -- Fix security issue in Prolog and Epilog by always prepending SPANK_ to
    all user-set environment variables. CVE-2017-15566.

* Changes in Slurm 16.05.10-2
=============================
 -- Replace clock_gettime with time(NULL) for very old systems without the call.

* Changes in Slurm 16.05.10
===========================
 -- Record job state as PREEMPTED instead of TIMEOUT when GraceTime is reached.
 -- task/cgroup - print warnings to stderr when --cpu_bind=verbose is enabled
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    and the requested processor affinity cannot be set.
 -- power/cray - Disable power cap get and set operations on DOWN nodes.
 -- Jobs preempted with PreemptMode=REQUEUE were incorrectly recorded as
    REQUEUED in the accounting.
 -- PMIX - Use volatile specifier to avoid flag caching and lock the flag to
    make sure it is protected.
 -- PMIX/PMI2 - Make it possible to use %n or %h in a spool dir.
 -- burst_buffer/cray - Support default pool which is not the first pool
    reported by DataWarp and log in Slurm when pools that are added or removed
    from DataWarp.
 -- Insure job does not start running before PrologSlurmctld is complete and
    node is booted (all nodes for interactive job, at least first node for batch
    job without burst buffers).
 -- Fix minor memory leak in the slurmctld when removing a QOS.
 -- burst_buffer/cray - Do not execute "pre_run" operation until after all nodes
    are booted and ready for use.
 -- scontrol - return an error when attempting to use the +=/-+ syntax to
    update a field where this is not appropriate.
 -- Fix task/affinity to work correctly with --ntasks-per-socket.
 -- Honor --ntasks-per-node and --ntasks option when used with job constraints
    that contain node counts.
 -- Prevent deadlocked slurmstepd processes due to unsafe use of regcomp with
    older glibc versions.
 -- Fix squeue when SLURM_BITSTR_LEN=0 is set in the user environment.
 -- Fix comments in acct_policy.c to reflect actual variables instead of
    old ones.
 -- Fix correct variables when validating GrpTresMins on a QOS.
 -- Better debug output when a job is being held because of a GrpTRES[Run]Min
    limits.
 -- Fix correct state reason when job can't run 'safely' because of an
    association GrpWall limit.
 -- Squeue always loads new data if user_id option specified
 -- Fix for possible job ID parsing failure and abort.
 -- If node boot in progress when slurmctld daemon is restarted, then allow
    sufficient time for reboot to complete and not prematurely DOWN the node as
    "Not responding".
 -- For job resize, correct logic to build "resize" script with new values.
    Previously the scripts were based upon the original job size.
 -- Fix squeue to not limit the size of partition, burst_buffer, exec_host, or
    reason to 32 chars.
 -- Fix potential packing error when packing a NULL slurmdb_clus_res_rec_t.
 -- Fix potential packing errors when packing a NULL slurmdb_reservation_cond_t.
 -- Burst_buffer/cray - Prevent slurmctld daemon abort if "paths" operation
    fails. Now job will be held. Update job update time when held.
 -- Fix issues with QOS flags Partition[Min|Max]Nodes to work correctly.
 -- Increase number of ResumePrograms that can be managed without leaving
    zombie/orphan processes from 10 to 100.
 -- Refactor slurmctld agent logic to eliminate some pthreads.

* Changes in Slurm 16.05.9
==========================
 -- Fix parsing of SBCAST_COMPRESS environment variable in sbcast.
 -- Change some debug messages to errors in task/cgroup plugin.
 -- backfill scheduler: Stop trying to determine expected start time for a job
    after 2 seconds of wall time. This can happen if there are many running jobs
    and a pending job can not be started soon.
 -- Improve performance of cr_sort_part_rows() in cons_res plugin.
 -- CRAY - Fix dealock issue when updating accounting in the slurmctld and
```

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    scheduling a Datawarp job.
 -- Correct the job state accounting information for jobs requeued due to burst
    buffer errors.
 -- burst_buffer/cray - Avoid "pre_run" operation if not using buffer (i.e.
    just creating or deleting a persistent burst buffer).
 -- Fix slurm.spec file support for BlueGene builds.
 -- Fix missing TRES read lock in acct_policy_job_runnable_pre_select() code.
 -- Fix debug2 message printing value using wrong array index in
    _qos_job_runnable_post_select().
 -- Prevent job timeout on node power up.
 -- MYSQL - Fix minor memory leak when querying steps and the sql fails.
 -- Make it so sacctmgr accepts column headers like MaxTRESPU and not MaxTRESP.
 -- Only look at SLURM_STEP_KILLED_MSG_NODE_ID on startup, to avoid race
    condition later when looking at a steps env.
 -- Make backfill scheduler behave like regular scheduler in respect to
    'assoc_limit_stop'.
 -- Allow a lower version client command to talk to a higher version contoller
    using the multi-cluster options (e.g. squeue -M<cluster>).
 -- slurmctld/agent race condition fix: Prevent job launch while PrologSlurmctld
    daemon is running or node boot in progress.
 -- MYSQL - Fix a few other minor memory leaks when uncommon failures occur.
 -- burst_buffer/cray - Fix race condition that could cause multiple batch job
    launch requests resulting in drained nodes.
 -- Correct logic to purge old reservations.
 -- Fix DBD cache restore from previous versions.
 -- Fix to logic for getting expected start time of existing job ID with
    explicit begin time that is in the past.
 -- Clear job's reason of "BeginTime" in a more timely fashion and/or prevents
    them from being stuck in a PENDING state.
 -- Make sure acct policy limits imposed on a job are correct after requeue.

* Changes in Slurm 16.05.8
==========================
 -- Remove StoragePass from being printed out in the slurmdbd log at debug2
    level.
 -- Defer PATH search for task program until launch in slurmstepd.
 -- Modify regression test1.89 to avoid leaving vestigial job. Also reduce
    logging to reduce likelyhood of Expect buffer overflow.
 -- Do not PATH search for mult-prog launches if LaunchParamters=test_exec is
    enabled.
 -- Fix for possible infinite loop in select/cons_res plugin when trying to
    satisfy a job's ntasks_per_core or socket specification.
 -- If job is held for bad constraints make it so once updated the job doesn't
    go into JobAdminHeld.
 -- sched/backfill - Fix logic to reserve resources for jobs that require a
    node reboot (i.e. to change KNL mode) in order to start.
 -- When unpacking a node or front_end record from state and the protocol
    version is lower than the min version, set it to the min.
 -- Remove redundant lookup for part_ptr when updating a reservation's nodes.
 -- Fix memory and file descriptor leaks in slurmd daemon's sbcast logic.
 -- Do not allocate specialized cores to jobs using the --exclusive option.
 -- Cancel interactive job if Prolog failure with "PrologFlags=contain" or
    "PrologFlags=alloc" configured. Send new error prolog failure message to
    the salloc or srun command as needed.
 -- Prevent possible out-of-bounds read in slurmstepd on an invalid #! line.
 -- Fix check for PluginDir within slurmctld to work with multiple directories.
 -- Cancel interactive jobs automatically on communication error to launching
    srun/salloc process.
 -- Fix security issue caused by insecure file path handling triggered by the
    failure of a Prolog script. To exploit this a user needs to anticipate or
    cause the Prolog to fail for their job. CVE-2016-10030.

* Changes in Slurm 16.05.7
==========================
 -- Fix issue in the priority/multifactor plugin where on a slurmctld restart,
    where more time is accounted for than should be allowed.
 -- cray/busrt_buffer - If total_space in a pool decreases, reset used_space
    rather than trying to account for buffer allocations in progress.
 -- cray/busrt_buffer - Fix for double counting of used_space at slurmctld
    startup.
 -- Fix regression in 16.05.6 where if you request multiple cpus per task (-c2)
    and request --ntasks-per-core=1 and only 1 task on the node
    the slurmd would abort on an infinite loop fatal.
 -- cray/busrt_buffer - Internally track both allocated and unusable space.
    The reported UsedSpace in a pool is now the allocated space (previously was
    unusable space). Base available space on whichever value leaves least free
    space.
 -- cray/burst_buffer - Preserve job ID and don't translate to job array ID.
 -- cray/burst_buffer - Update "instance" parsing to match updated dw_wlm_cli
    output.
 -- sched/backfill - Insure we don't try to start a job that was already started
    and requeued by the main scheduling logic.
 -- job_submit/lua - add access to the job features field in job_record.
 -- select/linear plugin modified to better support heterogeneous clusters when
    topology/none is also configured.
 -- Permit cancellation of jobs in configuring state.
 -- acct_gather_energy/rapl - prevent segfault in slurmd from race to gather
    data at slurmd startup.
 -- Integrate node_feature/knl_generic with "hbm" GRES information.
 -- Fix output routines to prevent rounding the TRES values for memory or BB.
 -- switch/cray plugin - fix use after free error.
 -- docs - elaborate on how way to clear TRES limits in sacctmgr.
 -- knl_cray plugin - Avoid abort from backup slurmctld at start time.
 -- cgroup plugins - fix two minor memory leaks.
 -- If a node is booting for some job, don't allocate additional jobs to the
    node until the boot completes.
 -- testsuite - fix job id output in test17.39.
 -- Modify backfill algorithm to improve performance with large numbers of
    running jobs. Group running jobs that end in a "similar" time frame using a
    time window that grows exponentially rather than linearly. After one second
    of wall time, simulate the termination of all remaining running jobs in
    order to respond in a reasonable time frame.
 -- Fix slurm_job_cpus_allocated_str_on_node_id() API call.
 -- sched/backfill plugin: Make malloc match data type (defined as uint32_t and
    allocated as int).
 -- srun - prevent segfault when terminating job step before step has launched.
 -- sacctmgr - prevent segfault when trying to reset usage for an invalid
    account name.
 -- Make the openssl crypto plugin compile with openssl >= 1.1.
 -- Fix SuspendExcNodes and SuspendExcParts on slurmctld reconfiguration.
 -- sbcast - prevent segfault in slurmd due to race condition between file
    transfers from separate jobs using zlib compression
 -- cray/burst_buffer - Increase time to synchronize operations between threads
    from 5 to 60 seconds ("setup" operation time observed over 17 seconds).
 -- node_features/knl_cray - Fix possible race condition when changing node
    state that could result in old KNL mode as an active features.
 -- Make sure if a job can't run because of resources we also check accounting
    limits after the node selection to make sure it doesn't violate those limits
    and if it does change the reason for waiting so we don't reserve resources
    on jobs violating accounting limits.
 -- NRT - Make it so a system running against IBM's PE will work with PE
    version 1.3.
 -- NRT - Make it so protocols pgas and test are allowed to be used.
 -- NRT - Make it so you can have more than 1 protocol listed in MP_MSG_API.
 -- cray/burst_buffer - If slurmctld daemon restarts with pending job and burst
    buffer having unknown file stage-in status, teardown the buffer, defer the
    job, and start stage-in over again.
 -- On state restore in the slurmctld don't overwrite the mem_spec_limit given
    from the slurm.conf when using FastSchedule=0.
 -- Recognize a KNL's proper NUMA count (rather than setting it to the value
    in slurm.conf) when using FastSchedule=0.
 -- Fix parsing in regression test1.92 for some prompts.
 -- sbcast - use slurmd's gid cache rather than a separate lookup.
 -- slurmd - return error if setgroups() call fails in _drop_privileges().
 -- Remove error messages about gres counts changing when a job is resized on
    a slurmctld restart or reconfig, as they aren't really error messages.
 -- Fix possible memory corruption if a job is using GRES and changing size.
 -- jobcomp/elasticsearch - fix printf format for a value on 32-bit builds.
 -- task/cgroup - Change error message if CPU binding can not take place to
    better identify the root cause of the problem.
 -- Fix issue where task/cgroup would not always honor --cpu_bind=threads.
 -- Fix race condition in with getgrouplist() in slurmd that can lead to
    user accounts being granted access to incorrect group memberships during
    job launch.

* Changes in Slurm 16.05.6
==========================
 -- Docs - the correct default value for GroupUpdateForce is 0.
 -- mpi/pmix - improve point to point communication performance.
 -- SlurmDB - include pending jobs in search during 'sacctmgr show runawayjobs'.
 -- Add client side out-of-range checks to --nice flag.
 -- Fix support for sbatch "-W" option, previously eeded to use "--wait".
 -- node_features/knl_cray plugin and capmc_suspend/resume programs modified to
    sleep and retry capmc operations if the Cray State Manager is down. Added
    CapmcRetries configuration parameter to knl_cray.conf.
 -- node_features/knl_cray plugin: Remove any KNL MCDRAM or NUMA features from
    node's configuration if capmc does NOT report the node as being KNL.
 -- node_features/knl_cray plugin: drain any node not reported by
    "capmc node_status" on startup or reconfig.
 -- node_features/knl_cray plugin: Substantially streamline and speed up logic
    to load current node state on reconfigure failure or unexpected node boot.
 -- node_features/knl_cray plugin: Add separate thread to interact with capmc
    in response to unexpected node reboots.
 -- node_features plugin - Add "mode" argument to node_features_p_node_xlate()
    function to fix some bugs updating a node's features using the node update
    RPC.
 -- node_features/knl_cray plugin: If the reconfiguration of nodes for an
    interactive job fails, kill the job (it can't be requeued like a batch job).
 -- Testsuite - Added srun/salloc/sbatch tests with --use-min-nodes option.
 -- Fix typo when an error occurs when discovering pmix version on
    configure.
 -- Fix configuring pmix support when you have your lib dir symlinked to lib64.
 -- Fix waiting reason if a job is waiting for a specific limit instead of
    always just AccountingPolicy.
 -- Correct SchedulerParameters=bf_busy_nodes logic with respect to the job's
    minimum node count. Previous logic would not decremement counter in some
    locations and reject valid job request for not reaching minimum node count.
 -- Fix FreeBSD-11 build by using llabs() function in place of abs().
 -- Cray: The slurmd can manipulate the socket/core/thread values reported based
    upon the configuration. The logic failed to consider select/cray with
    SelectTypeParameters=other_cons_res as equivalent to select/cons_res.
 -- If a node's socket or core count are changed at registration time (e.g. a
    KNL node's NUMA mode is changed), change it's board count to match.
 -- Prevent possible divide by zero in select/cons_res if a node's board count
    is higher than it's socket count.
 -- Allow an advanced reservation to contain a license count of zero.
 -- Preserve non-KNL node features when updating the KNL node features for a
    multi-node job in which the non-KNL node features vary by node.
 -- task/affinity plugin: Honor a job's --ntasks-per-socket and
    --ntasks-per-core options in task binding.
 -- slurmd - do not print ClusterName when using 'slurmd -C'.
 -- Correct a bitmap test function (used only by the select/bluegene plugin).
 -- Do not propagate SLURM_UMASK environment variable to batch script.
 -- Added node_features/knl_generic plugin for KNL support on non-Cray systems.
 -- Cray: Prevent abort in backfill scheduling logic for requeued job that has
    been cancelled while NHC is running.
 -- Improve reported estimates of start and end times for pending jobs.
 -- pbsnodes: Show OS value as "unknown" for down nodes.
 -- BlueGene - correctly scale node counts when enforcing MaxNodes limit take 2.
 -- Fix "sbatch --hold" to set JobHeldUser correctly instead of JobHeldAdmin.
 -- Cray - print warning that task/cgroup is required, and must be after
    task/cray in the TaskPlugin settings.
 -- Document that node Weight takes precedence over load with LLN scheduling.
 -- Fix issue where gang scheduling could happen even with OverSubscribe=NO.
 -- Expose JOB_SHARED_* values to job_submit/lua plugin.
 -- Fix issue where number of nodes is not properly allocated when srun is
    requested with -n tasks < hosts from -w hostlist.
 -- Update srun documentation for -N, -w and -m arbitrary.
 -- Fix bug that was clearing MAINT mode on nodes scheduled for reboot (bug
    introduced in version 16.05.5 to address bug in overlapping reservations).
 -- Add logging of node reboot requests.
 -- Docs - remove recommendation for ReleaseAgent setting in cgroup.conf.
 -- Make sure a job cleans up completely if it has a node fail.  Mostly an
    issue with gang scheduling.

* Changes in Slurm 16.05.5
==========================
 -- Fix accounting for jobs requeued after the previous job was finished.
 -- slurmstepd modified to pre-load all relevant plugins at startup to avoid
    the possibility of modified plugins later resulting in inconsistent API
    or data structures and a failure of slurmstepd.
 -- Export functions from parse_time.c in libslurm.so.
 -- Export unit convert functions from slurm_protocol_api.c in libslurm.so.
 -- Fix scancel to allow multiple steps from a job to be cancelled at once.
 -- Update and expand upgrade guide (in Quick Start Administrator web page).
 -- burst_buffer/cray: Requeue, but do not hold a job which fails the pre_run
    operation.
 -- Insure reported expected job start time is not in the past for pending jobs.
 -- Add support for PMIx v2.
 -- mpi/pmix: support for passing TMPDIR path through info key
 -- Cray: update slurmconfgen_smw.py script to correctly identify service nodes
    versus compute nodes.
```

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-- FreeBSD - fix build issue in knl_cray plugin.
-- Corrections to gres.conf parsing logic.
-- Make partition State independent of EnforcePartLimits value.
-- Fix multipart srun submission with EnforcePartLimits=NO and job violating
   the partition limits.
-- Fix problem updating job state_reason.
-- pmix - Provide HWLOC topology in the job-data if Slurm was configured
   with hwloc.
-- Cray - Fix issue restoring jobs when blade count increases due to hardware
   reconfiguration.
-- burst_buffer/cray - Hold job after 3 failed pre-run operations.
-- sched/backfill - Check that a user's QOS is allowed to use a partition
   before trying to schedule resources on that partition for the job.
-- sacctmgr - Fix displaying nodenames when printing out events or
   reservations.
-- Fix mpiexec wrapper to accept task count with more than one digit.
-- Add mpiexec man page to the script.
-- Add salloc_wait_nodes option to the SchedulerParameters parameter in the
   slurm.conf file controlling when the salloc command returns in relation to
   when nodes are ready for use (i.e. booted).
-- Handle case when slurmctld daemon restart while compute node reboot in
   progress. Return node to service rather than setting DOWN.
-- Preserve node "RESERVATION" state when one of multiple overlapping
   reservations ends.
-- Restructure srun command locking for task_exit processing logic for improved
   parallelism.
-- Modify srun task completion handling to only build the task/node string for
   logging purposes if it is needed. Modified for performance purposes.
-- Docs - update salloc/sbatch/srun man pages to mention corresponding
   environment variables for --mem/--mem-per-cpu and allowed suffixes.
-- Silence srun warning when overriding the job ntasks-per-node count
   with a lower task count for the step.
-- Docs - assorted spelling fixes.
-- node_features/knl_cray: Fix bug where MCDRAM state could be taken from
   capmc rather than cnselect.
-- node_features/knl_cray: If a node is rebooted outside of Slurm's direction,
   update it's active features with current MCDRAM and NUMA mode information.
-- Restore ability to manually power down nodes, broken in 15.08.12.
-- Don't log error for job end_time being zero if node health check is still
   running.
-- When powering up a node to change it's state (e.g. KNL NUMA or MCDRAM mode)
   then pass to the ResumeProgram the job ID assigned to the nodes in the
   SLURM_JOB_ID environment variable.
-- Allow a node's PowerUp state flag to be cleared using update_node RPC.
-- capmc_suspend/resume - If a request modify NUMA or MCDRAM state on a set of
   nodes or reboot a set of nodes fails then just requeue the job and abort the
   entire operation rather than trying to operate on individual nodes.
-- node_features/knl_cray plugin: Increase default CapmcTimeout parameter from
   10 to 60 seconds.
-- Fix squeue filter by job license when a job has requested more than 1
   license of a certain type.
-- Fix bug in PMIX_Ring in the pmi2 plugin so that it supports singleton mode.
   It also updates the testpmixring.c test program so it can be used to check
   singleton runs.
-- Automically clean up task/cgroup cpuset and devices cgroups after steps are
   completed.
-- Testsuite - Fix test1.83 to handle gaps in node names properly.
-- BlueGene - correctly scale node counts when enforcing MaxNodes limit.
```

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 -- Make sure no attempt is made to schedule a requeued job until all steps are
    cleaned (Node Health Check completes for all steps on a Cray).
 -- KNL: Correct task affinity logic for some NUMA modes.
 -- Add salloc/sbatch/srun --priority option of "TOP" to set job priority to
    the highest possible value. This option is only available to Slurm operators
    and administrators.
 -- Add salloc/sbatch/srun option --use-min-nodes to prefer smaller node counts
    when a range of node counts is specified (e.g. "-N 2-4").
 -- Validate salloc/sbatch --wait-all-nodes argument.
 -- Add "sbatch_wait_nodes" to SchedulerParameters to control default sbatch
    behaviour with respect to waiting for all allocated nodes to be ready for
    use. Job can override the configuration option using the --wait-all-nodes=#
    option.
 -- Prevent partition group access updates from resetting last_part_update when
    no changes have been made. Prevents backfill scheduler from restarting
    mid-cycle unnecessarily.
 -- Cray - add NHC_ABSOLUTELY_NO to never run NHC, even on certain edge cases
    that it would otherwise be run on with NHC_NO.
 -- Ignore GRES/QOS updates that maintain the same value as before.
 -- mpi/pmix - prepare temp directory for application.
 -- Fix display for the nice and priority values in sprio/scontrol/squeue.

* Changes in Slurm 16.05.4
==========================
 -- Fix potential deadlock if running with message aggregation.
 -- Streamline when schedule() is called when running with message aggregation
    on batch script completes.
 -- Fix incorrect casting when [un]packing derived_ec on slurmdb_job_rec_t.
 -- Document that persistent burst buffers can not be created or destroyed using
    the salloc or srun --bb options.
 -- Add support for setting the SLURM_JOB_ACCOUNT, SLURM_JOB_QOS and
    SLURM_JOB_RESERVAION environment variables are set for the salloc command.
    Document the same environment variables for the salloc, sbatch and srun
    commands in their man pages.
 -- Fix issue where sacctmgr load cluster.cfg wouldn't load associations
    that had a partition in them.
 -- Don't return the extern step from sstat by default.
 -- In sstat print 'extern' instead of 4294967295 for the extern step.
 -- Make advanced reservations work properly with core specialization.
 -- Fix race condition in the account_gather plugin that could result in job
    stuck in COMPLETING state.
 -- Regression test fixes if SelectTypePlugin not managing memory and no node
    memory size set (defaults to 1 MB per node).
 -- Add missing partition write locks to _slurm_rpc_dump_nodes/node_single to
    prevent a race condition leading to inconsistent sinfo results.
 -- Fix task:CPU binding logic for some processors. This bug was introduced
    in version 16.05.1 to address KNL bunding problem.
 -- Fix two minor memory leaks in slurmctld.
 -- Improve partition-specific limit logging from slurmctld daemon.
 -- Fix incorrect access check when using MaxNodes setting on the partition.
 -- Fix issue with sacctmgr when specifying a list of clusters to query.
 -- Fix issue when calculating future StartTime for a job.
 -- Make EnforcePartLimit support logic work with any ordering of partitions
    in job submit request.
 -- Prevent restoration of wrong CPU governor and frequency when using
    multiple task plugins.
 -- Prevent slurmd abort if hwloc library fails to populate the "children"
    arrays (observed with hwloc version "dev-333-g85ea6e4").
 -- burst_buffer/cray: Add "--groupid" to DataWarp "setup" command.
 -- Fix lustre profiling putting it in the Filesystem dataset instead of the
    Network dataset.
 -- Fix profiling documentation and code to match be consistent with
    Filesystem instead of Lustre.
 -- Correct the way watts is calculated in the rapl plugin when using a poll
    frequency other than AcctGatherNodeFreq.
 -- Don't about step launch if job reaches expected end time while node is
    configuring/booting (NOTE: The job end time will be adjusted after node
    becomes ready for use).
 -- Fix several print routines to respect a custom output delimiter when
    printing NO_VAL or INFINITE.
 -- Correct documented configurations where --ntasks-per-core and
    --ntasks-per-socket are supported.
 -- task/affinity plugin buffer allocated too small, can corrupt memory.

* Changes in Slurm 16.05.3
==========================
 -- Make it so the extern step uses a reverse tree when cleaning up.
 -- If extern step doesn't get added into the proctrack plugin make sure the
    sleep is killed.
 -- Fix areas the slurmctld can segfault if an extern step is in the system
    cleaning up on a restart.
 -- Prevent possible incorrect counting of GRES of a given type if a node has
    the multiple "types" of a given GRES "name", which could over-subscribe
    GRES of a given type.
 -- Add web links to Slurm Diamond Collectors (from Harvard University) and
    collectd (from EDF).
 -- Add job_submit plugin for the "reboot" field.
 -- Make some more Slurm constants (INFINITE, NO_VAL64, etc.) available to
    job_submit/lua plugins.
 -- Send in a -1 for a taskid into spank_task_post_fork for the extern_step.
 -- MYSQL - Sightly better logic if a job completion comes in with an end time
    of 0.
 -- task/cgroup plugin is configured with ConstrainRAMSpace=yes, then set soft
    memory limit to allocated memory limit (previously no soft limit was set).
 -- Document limitations in burst buffer use by the salloc command (possible
    access problems from a login node).
 -- Fix proctrack plugin to only add the pid of a process once
    (regression in 16.05.2).
 -- Fix for sstat to print correct info when requesting jobid.batch as part of
    a comma-separated list.
 -- CRAY - Fix issue if pid has already been added to another job container.
 -- CRAY - Fix add of extern step to AELD.
 -- burstbufer/cray: avoid batch submit error condition if waiting for stagein.
 -- CRAY - Fix for reporting steps lingering after they are already finished.
 -- Testsuite - fix test1.29 / 17.15 for limits with values above 32-bits.
 -- CRAY - Simplify when a NHC is called on a step that has unkillable
    processes.
 -- CRAY - If trying to kill a step and you have NHC_NO_STEPS set run NHC
    anyway to attempt to log the backtraces of the potential
    unkillable processes.
 -- Fix gang scheduling and license release logic if single node job killed on
    bad node.
 -- Make scontrol show steps show the extern step correctly.
 -- Do not scheduled powered down nodes in FAILED state.
 -- Do not start slurmctld power_save thread until partition information is read
    in order to prevent race condition that can result invalid pointer when
    trying to resolve configured SuspendExcParts.
 -- Add SLURM_PENDING_STEP id so it won't be confused with SLURM_EXTERN_CONT.
 -- Fix for core selection with job --gres-flags=enforce-binding option.
    Previous logic would in some cases allocate a job zero cores, resulting in
    slurmctld abort.
 -- Minimize preempted jobs for configurations with multiple jobs per node.
 -- Improve partition AllowGroups caching. Update the table of UIDs permitted to
    use a partition based upon it's AllowGroups configuration parameter as new
    valid UIDs are found rather than looking up that user's group information
    for every job they submit. If the user is now allowed to use the partition,
    then do not check that user's group access again for 5 seconds.
 -- Add routing queue information to Slurm FAQ web page.
 -- Do not select_g_step_finish() a SLURM_PENDING_STEP step, as nothing has
    been allocated for the step yet.
 -- Fixed race condition in PMIx Fence logic.
 -- Prevent slurmctld abort if job is killed or requeued while waiting for
    reboot of its allocated compute nodes.
 -- Treat invalid user ID in AllowUserBoot option of knl.conf file as error
    rather than fatal (log and do not exit).
 -- qsub - When doing the default output files for an array in qsub style
    make them using the master job ID instead of the normal job ID.
 -- Create the extern step while creating the job instead of waiting until the
    end of the job to do it.
 -- Always report a 0 exit code for the extern step instead of being canceled
    or failed based on the signal that would always be killing it.
 -- Fix to allow users to update QOS of pending jobs.
 -- CRAY - Fix minor memory leak in switch plugin.
 -- CRAY - Change slurmconfgen_smw.py to skip over disabled nodes.
 -- Fix eligible_time for elasticsearch as well as add queue_wait
    (difference between start of job and when it was eligible).

* Changes in Slurm 16.05.2
==========================
 -- CRAY - Fix issue where the proctrack plugin could hang if the container
    id wasn't able to be made.
 -- Move test for job wait reason value of BurstBufferResources and
    BurstBufferStageIn later in the scheduling logic.
 -- Document which srun options apply to only job, only step, or job and step
    allocations.
 -- Use more compatible function to get thread name (>= 2.6.11).
 -- Fix order of job then step id when noting cleaning flag being set.
 -- Make it so the extern step sends a message with accounting information
    back to the slurmctld.
 -- Make it so the extern step calls the select_g_step_start|finish functions.
 -- Don't print error when extern step is canceled because job is ending.
 -- Handle a few error codes when dealing with the extern step to make sure
    we have the pids added to the system correctly.
 -- Add support for job dependencies with job array expressions. Previous logic
    required listing each task of job array individually.
 -- Make sure tres_cnt is set before creating a slurmdb_assoc_usage_t.
 -- Prevent backfill scheduler from starting a second "singleton" job if another
    one started during a backfill sleep.
 -- Fix for invalid array pointer when creating advanced reservation when job
    allocations span heterogeneous nodes (differing core or socket counts).
 -- Fix hostlist_ranged_string_xmalloc_dims to correctly not put brackets on
    hostlists when brackets == 0.
 -- Make sure we don't get brackets when making a range of reserved ports
    for a step.
 -- Change fatal to an error if port ranges aren't correct when reading state
    for steps.

* Changes in Slurm 16.05.1
==========================
 -- Fix __cplusplus macro in spank.h to allow compilation with C++.
 -- Fix compile issue with older glibc < 2.12
 -- Fix for starting batch step with mpi/pmix plugin.
 -- Fix for "scontrol -dd show job" with respect to displaying the specific
    CPUs allocated to a job on each node. Prior logic would only display
    the CPU information for the first node in the job allocation.
 -- Print correct return code on failure to update active node features
    through sview.
 -- Allow QOS timelimit to override partition timelimit when EnforcePartLimits
    is set to all/any.
 -- Make it so qsub will do a "basename" on a wrapped command for the output
    and error files.
 -- Fix issue where slurmd could core when running the ipmi energy plugin.
 -- Documentation - clean up typos.
 -- Add logic so that slurmstepd can be launched under valgrind.
 -- Increase buffer size to read /proc/*/stat files.
 -- Fix for tracking job resource allocation when slurmctld is reconfigured
    while Cray Node Health Check (NHC) is running. Previous logic would fail to
    record the job's allocation then perform release operation upon NHC
    completion, resulting in underflow error messages.
 -- Make "scontrol show daemons" work with long node names.
 -- CRAY - Collect energy using a uint64_t instead of uint32_t.
 -- Fix incorrect if statements when determining if the user has a default
    account or wckey.
 -- Prevent job stuck in configuring state if slurmctld daemon restarted while
    PrologSlurmctld is running. Also re-issue burst_buffer/pre-load operation
    as needed.
 -- Correct task affinity support for FreeBSD.
 -- Fix for task affinity on KNL in SNC2/Flat mode.
 -- Recalculate a job's memory allocation after node reboot if job requests all
    of a node's memory and FastSchedule=0 is configured. Intel KNL memory size
    can change on reboot with various MCDRAM modes.
 -- Fix small memory leak when printing HealthCheckNodeState.
 -- Eliminate memory leaks when AuthInfo is configured.
 -- Improve sdiag output description in man page.
 -- Cray/capmc_resume script modify a node's features (as needed) when the
    reinit (reboot) command is issued rather than wait for the nodes to change
    to the "on" state.
 -- Correctly print ranges when using step values in job arrays.
 -- Allow from file names / paths over 256 characters when launching steps,
    as well as spaces in the executable name.
 -- job_submit.license.lua example modified to send message back to user.
 -- Document job --mem=0 option means all memory on a node.
 -- Set SLURM_JOB_QOS environment variable to QOS name instead of description.
 -- knl_cray.conf file option of CnselectPath added.
 -- node_features/knl_cray plugin modified to get current node NUMA and MCDRAM
    modes using cnselect command rather than capmc command.
 -- liblua - add SLES12 paths to runtime search list.
 -- Fix qsub default output and error files for task arrays.
 -- Fix qsub to set job_name correctly when wrapping a script (-b y)
 -- Cray - set EnforcePartLimits=any in slurm.conf template.

* Changes in Slurm 16.05.0
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==========================
 -- Update seff to fix warnings with ncpus, and list slurm-perlapi dependency
    in spec file.
 -- Fix testsuite to consistent use /usr/bin/env {bash,expect} construct.
 -- Cray - Ensure that step completion messages get to the database.
 -- Fix step cpus_per_task calculation for heterogeneous job allocation.
 -- Fix --with-json= configure option to use specified path.
 -- Add back thread_id to "thread_id" LogTimeFormat to distinguish between
    mutliple threads with the same name. Now displays thread name and id.
 -- Change how Slurm determines the NUMA count of a node. Ignore KNL NUMA
    that only include memory.
 -- Cray - Fix node list parsing in capmc_suspend/resume programs.
 -- Fix sbatch #BSUB parsing for -W and -M options.
 -- Fix GRES task layout bug that could cause slurmctld to abort.
 -- Fix to --gres-flags=enforce-binding logic when multiple sockets needed.

* Changes in Slurm 16.05.0rc2
=============================
 -- Cray node shutdown/reboot scripts, perform operations on all nodes in one
    capmc command. Only if that fails, issue the operations in parallel on
    individual nodes. Required for scalability.
 -- Cleanup two minor Coverity warnings.
 -- Make it so the tres units in a job's formatted string are converted like
    they are in a step.
 -- Correct partition's MaxCPUsPerNode enforcement when nodes are shared by
    multiple partitions.
 -- node_feature/knl_cray - Prevent slurmctld GRES errors for "hbm" references.
 -- Display thread name instead of thread id and remove process name in stderr
    logging for "thread_id" LogTimeFormat.
 -- Log IP address of bad incomming message to slurmctld.
 -- If a user requests tasks, nodes and ntasks-per-node and
    tasks-per-node/nodes != tasks print warning and ignore ntasks-per-node.
 -- Release CPU "owner" file locks.
 -- Fix for job step memory allocation: Reject invalid step at submit time
    rather than leaving it queued.
 -- Whenever possible, avoid allocating nodes that require a reboot.

* Changes in Slurm 16.05.0rc1
==============================
 -- Remove the SchedulerParameters option of "assoc_limit_continue", making it
    the default value. Add option of "assoc_limit_stop". If "assoc_limit_stop"
    is set and a job cannot start due to association limits, then do not attempt
    to initiate any lower priority jobs in that partition. Setting this can
    decrease system throughput and utlization, but avoid potentially starving
    larger jobs by preventing them from launching indefinitely.
 -- Update a node's socket and cores per socket counts as needed after a node
    boot to reflect configuration changes which can occur on KNL processors.
    Note that the node's total core count must not change, only the distribution
    of cores across varying socket counts (KNL NUMA nodes treated as sockets by
    Slurm).
 -- Rename partition configuration from "Shared" to "OverSubscribe". Rename
    salloc, sbatch, srun option from "--shared" to "--oversubscribe". The old
    options will continue to function. Output field names also changed in
    scontrol, sinfo, squeue and sview.
 -- Add SLURM_UMASK environment variable to user job.
 -- knl_conf: Added new configuration parameter of CapmcPollFreq.
 -- squeue: remove errant spaces in column formats for "squeue -o %all".
 -- Add ARRAY_TASKS mail option to send emails to each task in a job array.
 -- Change default compression library for sbcast to lz4.
 -- select/cray - Initiate step node health check at start of step termination
    rather than after application completely ends so that NHC can capture
    information about hung (non-killable) processes.
 -- Add --units=[KMGTP] option to sacct to display values in specific unit type.
 -- Modify sacct and sacctmgr to display TRES values in converted units.
 -- Modify sacctmgr to accept TRES values with [KMGTP] suffixes.
 -- Replace hash function with more modern SipHash functions.
 -- Add "--with-cray_dir" build/configure option.
 -- BB- Only send stage_out email when stage_out is set in script.
 -- Add r/w locking to file_bcast receive functions in slurmd.
 -- Add TopologyParam option of "TopoOptional" to optimize network topology
    only for jobs requesting it.
 -- Fix build on FreeBSD.
 -- Configuration parameter "CpuFreqDef" used to set default governor for job
    step not specifying --cpu-freq (previously the parameter was unused).
 -- Fix sshare -o<format> to correctly display new lengths.
 -- Update documentation to rename Shared option to OverSubscribe.
 -- Update documentation to rename partition Priority option to PriorityTier.
 -- Prevent changing of QOS on running jobs.
 -- Update accounting when changing QOS on pending jobs.
 -- Add support to ntasks_per_socket in task/affinity.
 -- Generate init.d and systemd service scripts in etc/ through Make rather
    than at configure time to ensure all variable substitutions happen.
 -- Use TaskPluginParam for default task binding if no user specified CPU
    binding. User --cpu_bind option takes precident over default. No longer
    any error if user --cpu_bind option does not match TaskPluginParam.
 -- Make sacct and sattach work with older slurmd versions.
 -- Fix protocol handling between 15.08 and 16.05 for 'scontrol show config'.
 -- Enable prefixes (e.g. info, debug, etc.) in slurmstepd debugging.

* Changes in Slurm 16.05.0pre2
==============================
 -- Split partition's "Priority" field into "PriorityTier" (used to order
    partitions for scheduling and preemption) plus "PriorityJobFactor" (used by
    priority/multifactor plugin in calculating job priority, which is used to
    order jobs within a partition for scheduling).
 -- Revert call to getaddrinfo, restoring gethostbyaddr (introduced in Slurm
    16.05.0pre1) which was failing on some systems.
 -- knl_cray.conf - Added AllowMCDRAM, AllowNUMA and ALlowUserBoot
    configuration options.
 -- Add node_features_p_user_update() function to node_features plugin.
 -- Don't print Weight=1 lines in 'scontrol write config' (its the default).
 -- Remove PARAMS macro from slurm.h.
 -- Remove BEGIN_C_DECLS and END_C_DECLS macros.
 -- Check that PowerSave mode configured for node_features/knl_cray plugin.
    It is required to reconfigure and reboot nodes.
 -- Update documentation to reflect new cgroup default location change from
    /cgroup to /sys/fs/cgroup.
 -- If NodeHealthCheckProgram configured HealthCheckInterval is non-zero, then
    modify slurmd to run it before registering with slurmctld.
 -- Fix for tasks being packed onto cores when the requested --cpus-per-task is
    greater than the number of threads on a core and --ntasks-per-core is 1.
 -- Make it so jobs/steps track ':' named gres/tres, before hand gres/gpu:tesla
    would only track gres/gpu, now it will track both gres/gpu and
    gres/gpu:tesla as separate gres if configured like
    AccountingStorageTRES=gres/gpu,gres/gpu:tesla
 -- Added new job dependency type of "aftercorr" which will start a task of a
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    job array after the corresponding task of another job array completes.
 -- Increase default MaxTasksPerNode configuration parameter from 128 to 512.
 -- Enable sbcast data compression logic (compress option previously ignored).
 -- Add --compress option to srun command for use with --bcast option.
 -- Add TCPTimeout option to slurm[dbd].conf. Decouples MessageTimeout from TCP
    connections.
 -- Don't call primary controller for every RPC when backup is in control.
 -- Add --gres-flags=enforce-binding option to salloc, sbatch and srun commands.
    If set, the only CPUs available to the job will be those bound to the
    selected GRES (i.e. the CPUs identifed in the gres.conf file will be
    strictly enforced rather than advisory).
 -- Change how a node's allocated CPU count is calculated to avoid double
    counting CPUs allocated to multiple jobs at the same time.
 -- Added SchedulingParameters option of "bf_min_prio_reserve". Jobs below
    the specified threshold will not have resources reserved for them.
 -- Added "sacctmgr show lostjobs" to report any orphaned jobs in the database.
 -- When a stepd is about to shutdown and send it's response to srun
    make the wait to return data only hit after 500 nodes and configurable
    based on the TcpTimeout value.
 -- Add functionality to reset the lft and rgt values of the association table
    with the slurmdbd.
 -- Add SchedulerParameter no_env_cache, if set no env cache will be use when
    launching a job, instead the job will fail and drain the node if the env
    isn't loaded normally.
 -- burst_buffer/cray - Plug small memory leak on DataWarp create_persistent
    buffer error.
 -- burst_buffer/cray - Do not purge a job record if it's stage-out operation
    fails. The description of the failure will be in the job's "Reason" field.
 -- burst_buffer/cray - Append information about errors to job's AdminComments
    field.
 -- DBD - When using LogTimeFormat=thread_id fill in the cluster name before
    printing anything for a connection.
 -- Have srun read in modern env var's instead of obsolete ones
 -- mpi/pmix: add the thresholds for the parameters of micro-benchmarks.

* Changes in Slurm 16.05.0pre1
==============================
 -- Add sbatch "--wait" option that waits for job completion before exiting.
    Exit code will match that of spawned job.
 -- Modify advanced reservation save/restore logic for core reservations to
    support configuration changes (changes in configured nodes or cores counts).
 -- Allow ControlMachine, BackupController, DbdHost and DbdBackupHost to be
    either short or long hostname.
 -- Job output and error files can now contain "%" character by specifying
    a file name with two consecutive "%" characters. For example,
    "sbatch -o "slurm.%%.%j" for job ID 123 will generate an output file named
    "slurm.%.123".
 -- Pass user name in Prolog RPC from controller to slurmd when using
    PrologFlags=Alloc. Allows SLURM_JOB_USER env variable to be set when using
    Native Slurm on a Cray.
 -- Add "NumTasks" to job information visible to Slurm commands.
 -- Add mail wrapper script "smail" that will include job statistics in email
    notification messages.
 -- Remove vestigial "SICP" job option (inter-cluster job option). Completely
    different logic will be forthcoming.
 -- Fix case where the primary and backup dbds would both be performing rollup.
 -- Add an ack reply from slurmd to slurmstepd when job setup is done and the
    job is ready to be executed.
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-- Removed support for authd. authd has not been developed and supported since
   several years.
-- Introduce a new parameter requeue_setup_env_fail in SchedulerParameters.
   A job that fails to setup the environment will be requeued and the node
   drained.
-- Add ValidateTimeout and OtherTimeout to "scontrol show burst" output.
-- Increase default sbcast buffer size from 512KB to 8MB.
-- Enable the hdf5 profiling of the batch step.
-- Eliminate redundant environment and script files for job arrays.
-- Stop searching sbatch scripts for #PBS directives after 100 lines of
   non-comments. Stop parsing #PBS or #SLURM directives after 1024 characters
   into a line. Required for decent perforamnce with huge scripts.
-- Add debug flag for timing Cray portions of the code.
-- Remove all *.la files from RPMs.
-- Add Multi-Category Security (MCS) infrastructure to permit nodes to be bound
   to specific users or groups.
-- Install the pmi2 unix sockets in slurmd spool directory instead of /tmp.
-- Implement the getaddrinfo and getnameinfo instead of gethostbyaddr and
   gethostbyname.
-- Finished PMIx implementation.
-- Implemented the --without=package option for configure.
-- Fix sshare to show each individual cluster with -M,--clusters option.
-- Added --deadline option to salloc, sbatch and srun. Jobs which can not be
   completed by the user specified deadline will be terminated with a state of
   "Deadline" or "DL".
-- Implemented and documented PMIX protocol which is used to bootstrap an
   MPI job. PMIX is an alternative to PMI and PMI2.
-- Change default CgroupMountpoint (in cgroup.conf) from "/cgroup" to
   "/sys/fs/cgroup" to match current standard.
-- Add #BSUB options to sbatch to read in from the batch script.
-- HDF: Change group name of node from nodename to nodeid.
-- The partition-specific SelectTypeParameters parameter can now be used to
   change the memory allocation tracking specification in the global
   SelectTypeParameters configuration parameter. Supported partition-specific
   values are CR_Core, CR_Core_Memory, CR_Socket and CR_Socket_Memory. If the
   global SelectTypeParameters value includes memory allocation management and
   the partition-specific value does not, then memory allocation management for
   that partition will NOT be supported (i.e. memory can be over-allocated).
   Likewise the global SelectTypeParameters might not include memory management
   while the partition-specific value does.
-- Burst buffer/cray - Add support for multiple buffer pools including support
   for different resource granularity by pool.
-- Burst buffer advanced reservation units treated as bytes (per documentation)
   rather than GB.
-- Add an "scontrol top <jobid>" command to re-order the priorities of a user's
   pending jobs. May be disabled with the "disable_user_top" option in the
   SchedulerParameters configuration parameter.
-- Modify sview to display negative job nice values.
-- Increase job's nice value field from 16 to 32 bits.
-- Remove deprecated job_submit/cnode plugin.
-- Enhance slurm.conf option EnforcePartLimit to include options like "ANY" and
   "ALL".  "Any" is equivalent to "Yes" and "All" will check all partitions
   a job is submitted to and if any partition limit is violated the job will
   be rejected even if it could possibly run on another partition.
-- Add "features_act" field (currently active features) to the node
   information. Output of scontrol, sinfo, and sview changed accordingly.
   The field previously displayed as "Features" is now "AvailableFeatures"
   while the new field is displayed as "ActiveFeatures".
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 -- Remove Sun Constellation, IBM Federation Switches (replaced by NRT switch
    plugin) and long-defunct Quadrics Elan support.
 -- Add -M<clusters> option to sreport.
 -- Rework group caching to work better in environments with
    enumeration disabled. Removed CacheGroups config directive, group
    membership lists are now always cached, controlled by
    GroupUpdateTime parameter. GroupUpdateForce parameter default
    value changed to 1.
 -- Add reservation flag of "purge_comp" which will purge an advanced
    reservation once it has no more active (pending, suspended or running) jobs.
 -- Add new configuration parameter "KNLPlugins" and plugin infrastructure.
 -- Add optional job "features" to node reboot RPC.
 -- Add slurmd "-b" option to report node rebooted at daemon start time. Used
    for testing purposes.
 -- contribs/cray: Add framework for powering nodes up and down.
 -- For job constraint, convert comma separator to "&".
 -- Add Max*PerAccount options for QOS.
 -- Protect slurm_mutex_* calls with abort() on failure.

* Changes in Slurm 15.08.14
===========================
 -- For job resize, correct logic to build "resize" script with new values.
    Previously the scripts were based upon the original job size.

* Changes in Slurm 15.08.13
===========================
 -- Fix issue where slurmd could core when running the ipmi energy plugin.
 -- Print correct return code on failure to update node features through sview.
 -- Documentation - cleanup typos.
 -- Add logic so that slurmstepd can be launched under valgrind.
 -- Increase buffer size to read /proc/*/stat files.
 -- MYSQL - Handle ER_HOST_IS_BLOCKED better by failing when it occurs instead
    of continuously printing the message over and over as the problem will
    most likely not resolve itself.
 -- Add --disable-bluegene to configure.  This will make it so Slurm
    can work on a BGAS node.
 -- Prevent job stuck in configuring state if slurmctld daemon restarted while
    PrologSlurmctld is running.
 -- Handle association correctly if using FAIR_TREE as well as shares=Parent
 -- Fix race condition when setting priority of a job and the association
    doesn't have a parent.
 -- MYSQL - Fix issue with adding a reservation if the name has single quotes in
    it.
 -- Correctly print ranges when using step values in job arrays.
 -- Fix for invalid array pointer when creating advanced reservation when job
    allocations span heterogeneous nodes (differing core or socket counts).
 -- Fix for sstat to print correct info when requesting jobid.batch as part of
    a comma-separated list.
 -- Cray - Fix issue restoring jobs when blade count increases due to hardware
    reconfiguration.
 -- Ignore warnings about depricated functions. This is primarily there for
    new glibc 2.24+ that depricates readdir_r.
 -- Fix security issue caused by insecure file path handling triggered by the
    failure of a Prolog script. To exploit this a user needs to anticipate or
    cause the Prolog to fail for their job. CVE-2016-10030.

* Changes in Slurm 15.08.12
===========================
 -- Do not attempt to power down a node which has never responded if the
    slurmctld daemon restarts without state.
 -- Fix for possible slurmstepd segfault on invalid user ID.
 -- MySQL - Fix for possible race condition when archiving multiple clusters
    at the same time.
 -- Fix compile for when you don't have hwloc.
 -- Fix issue where daemons would only listen on specific address given in
    slurm.conf instead of all.  If looking for specific addresses use
    TopologyParam options No*InAddrAny.
 -- Cray - Better robustness when dealing with the aeld interface.
 -- job_submit.lua - add array_inx value for job arrays.
 -- Perlapi - Remove unneeded/undefined mutex.
 -- Fix issue when TopologyParam=NoInAddrAny is set the responses wouldn't
    make it to the slurmctld when using message aggregation.
 -- MySQL - Fix potential memory leak when rolling up data.
 -- Fix issue with clustername file when running on NFS with root_squash.
 -- Fix race condition with respects to cleaning up the profiling threads
    when in use.
 -- Fix issues when building on NetBSD.
 -- Fix jobcomp/elasticsearch build when libcurl is installed in a
    non-standard location.
 -- Fix MemSpecLimit to explicitly require TaskPlugin=task/cgroup and
    ConstrainRAMSpace set in cgroup.conf.
 -- MYSQL - Fix order of operations issue where if the database is locked up
    and the slurmctld doesn't wait long enough for the response it would give
    up leaving the connection open and create a situation where the next message
    sent could receive the response of the first one.
 -- Fix CFULL_BLOCK distribution type.
 -- Prevent sbatch from trying to enable debug messages when using job arrays.
 -- Prevent sbcast from enabling "--preserve" when specifying a jobid.
 -- Prevent wrong error message from spank plugin stack on GLOB_NOSPACE error.
 -- Fix proctrack/lua plugin to prevent possible deadlock.
 -- Prevent infinite loop in slurmstepd if execve fails.
 -- Prevent multiple responses to REQUEST_UPDATE_JOB_STEP message.
 -- Prevent possible deadlock in acct_gather_filesystem/lustre on error.
 -- Make it so --mail-type=NONE didn't throw an invalid error.
 -- If no default account is given for a user when creating (only a list of
    accounts) no default account is printed, previously NULL was printed.
 -- Fix for tracking a node's allocated CPUs with gang scheduling.
 -- Fix Hidden error during _rpc_forward_data call.
 -- Fix bug resulting from wrong order-of-operations in _connect_srun_cr(),
    and two others that cause incorrect debug messages.
 -- Fix backwards compatibility with sreport going to <= 14.11 coming from
    >= 15.08 for some reports.

* Changes in Slurm 15.08.11
===========================
 -- Fix for job "--contiguous" option that could cause job allocation/launch
    failure or slurmctld crash.
 -- Fix to setup logs for single-character program names correctly.
 -- Backfill scheduling performance enhancement with large number of running
    jobs.
 -- Reset job's prolog_running counter on slurmctld restart or reconfigure.
 -- burst_buffer/cray - Update job's prolog_running counter if pre_run fails.
 -- MYSQL - Make the error message more specific when removing a reservation
    and it doesn't meet basic requirements.
 -- burst_buffer/cray - Fix for script creating or deleting persistent buffer
    would fail "paths" operation and hold the job.
 -- power/cray - Prevent possible divide by zero.
 -- power/cray - Fix bug introduced in 15.08.10 preventin operation in many
    cases.
 -- Prevent deadlock for flow of data to the slurmdbd when sending reservation
    that wasn't set up correctly.
 -- burst_buffer/cray - Don't call Datawarp "paths" function if script includes
    only create or destroy of persistent burst buffer. Some versions of Datawarp
    software return an error for such scripts, causing the job to be held.
 -- Fix potential issue when adding and removing TRES which could result
    in the slurmdbd segfaulting.
 -- Add cast to memory limit calculation to prevent integer overflow for
    very large memory values.
 -- Bluegene - Fix issue with reservations resizing under the covers on a
    restart of the slurmctld.
 -- Avoid error message of "Requested cpu_bind option requires entire node to
    be allocated; disabling affinity" being generated in some cases where
    task/affinity and task/cgroup plugins used together.
 -- Fix version issue when packing GRES information between 2 different versions
    of Slurm.
 -- Fix for srun hanging with OpenMPI and PMIx
 -- Better initialization of node_ptr when dealing with protocol_version.
 -- Fix incorrect type when initializing header of a message.
 -- MYSQL - Fix incorrect usage of limit and union.
 -- MYSQL - Remove 'ignore' from alter ignore when updating a table.
 -- Documentation - update prolog_epilog page to reflect current behavior
    if the Prolog fails.
 -- Documentation - clarify behavior of 'srun --export=NONE' in man page.
 -- Fix potential gres underflow on restart of slurmctld.
 -- Fix sacctmgr to remove a user who has no associations.

* Changes in Slurm 15.08.10
===========================
 -- Fix issue where if a slurmdbd rollup lasted longer than 1 hour the
    rollup would effectively never run again.
 -- Make error message in the pmi2 code to debug as the issue can be expected
    and retries are done making the error message a little misleading.
 -- Power/cray: Don't specify NID list to Cray APIs. If any of those nodes are
    not in a ready state, the API returned an error for ALL nodes rather than
    valid data for nodes in ready state.
 -- Fix potential divide by zero when tree_width=1.
 -- checkpoint/blcr plugin: Fix memory leak.
 -- If using PrologFlags=contain: Don't launch the extern step if a job is
    cancelled while launching.
 -- Remove duplicates from AccountingStorageTRES
 -- Fix backfill scheduler race condition that could cause invalid pointer in
    select/cons_res plugin. Bug introduced in 15.08.9.
 -- Avoid double calculation on partition QOS if the job is using the same QOS.
 -- Do not change a job's time limit when updating unrelated field in a job.
 -- Fix situation on a heterogeneous memory cluster where the order of
    constraints mattered in a job.

* Changes in Slurm 15.08.9
==========================
 -- BurstBuffer/cray - Defer job cancellation or time limit while "pre-run"
    operation in progress to avoid inconsistent state due to multiple calls
    to job termination functions.
 -- Fix issue with resizing jobs and limits not be kept track of correctly.
 -- BGQ - Remove redeclaration of job_read_lock.
 -- BGQ - Tighter locks around structures when nodes/cables change state.
 -- Make it possible to change CPUsPerTask with scontrol.
 -- Make it so scontrol update part qos= will take away a partition QOS from
    a partition.
 -- Fix issue where SocketsPerBoard didn't translate to Sockets when CPUS=
    was also given.
 -- Add note to slurm.conf man page about setting "--cpu_bind=no" as part
    of SallocDefaultCommand if a TaskPlugin is in use.
 -- Set correct reason when a QOS' MaxTresMins is violated.
 -- Insure that a job is completely launched before trying to suspend it.
 -- Remove historical presentations and design notes. Only distribute
    maintained doc/html and doc/man directories.
 -- Remove duplicate xmalloc() in task/cgroup plugin.
 -- Backfill scheduler to validate correct job partition for job submitted to
    multiple partitions.
 -- Force close on exec on first 256 file descriptors when launching a
    slurmstepd to close potential open ones.
 -- Step GRES value changed from type "int" to "int64_t" to support larger
    values.
 -- Fix getting reservations to database when database is down.
 -- Fix issue with sbcast not doing a correct fanout.
 -- Fix issue where steps weren't always getting the gres/tres involved.
 -- Fixed double read lock on getting job's gres/tres.
 -- Fix display for RoutePlugin parameter to display the correct value.
 -- Fix route/topology plugin to prevent segfault in sbcast when in use.
 -- Fix Cray slurmconfgen_smw.py script to use nid as nid, not nic.
 -- Fix Cray NHC spawning on job requeue. Previous logic would leave nodes
    allocated to a requeued job as non-usable on job termination.
 -- burst_buffer/cray plugin: Prevent a requeued job from being restarted while
    file stage-out is still in progress. Previous logic could restart the job
    and not perform a new stage-in.
 -- Fix job array formatting to allow return [0-100:2] display for arrays with
    step functions rather than [0,2,4,6,8,...] .
 -- FreeBSD - replace Linux-specific set_oom_adj to avoid errors in slurmd log.
 -- Add option for TopologyParam=NoInAddrAnyCtld to make the slurmctld listen
    on only one port like TopologyParam=NoInAddrAny does for everything else.
 -- Fix burst buffer plugin to prevent corruption of the CPU TRES data when bb
    is not set as an AccountingStorageTRES type.
 -- Surpress error messages in acct_gather_energy/ipmi plugin after repeated
    failures.
 -- Change burst buffer use completion email message from
    "SLURM Job_id=1360353 Name=tmp Staged Out, StageOut time 00:01:47" to
    "SLURM Job_id=1360353 Name=tmp StageOut/Teardown time 00:01:47"
 -- Generate burst buffer use completion email immediately afer teardown
    completes rather than at job purge time (likely minutes later).
 -- Fix issue when adding a new TRES to AccountingStorageTRES for the first
    time.
 -- Update gang scheduling tables when job manually suspended or resumed. Prior
    logic could mess up job suspend/resume sequencing.
 -- Update gang scheduling data structures when job changes in size.
 -- Associations - prevent hash table corruption if uid initially unset for
    a user, which can cause slurmctld to crash if that user is deleted.
 -- Avoid possibly aborting srun on SIGSTOP while creating the job step due to
    threading bug.
 -- Fix deadlock issue with burst_buffer/cray when a newly created burst
    buffer is found.
 -- burst_buffer/cray: Set environment variables just before starting job rather
    than at job submission time to reflect persistent buffers created or
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    modified while the job is pending.
 -- Fix check of per-user qos limits on the initial run by a user.
 -- Fix gang scheduling resource selection bug which could prevent multiple jobs
    from being allocated the same resources. Bug was introduced in 15.08.6.
 -- Don't print the Rgt value of an association from the cache as it isn't
    kept up to date.
 -- burst_buffer/cray - If the pre-run operation fails then don't issue
    duplicate job cancel/requeue unless the job is still in run state. Prevents
    jobs hung in COMPLETING state.
 -- task/cgroup - Fix bug in task binding to CPUs.

* Changes in Slurm 15.08.8
==========================
 -- Backfill scheduling properly synchronized with Cray Node Health Check.
    Prior logic could result in highest priority job getting improperly
    postponed.
 -- Make it so daemons also support TopologyParam=NoInAddrAny.
 -- If scancel is operating on large number of jobs and RPC responses from
    slurmctld daemon are slow then introduce a delay in sending the cancel job
    requests from scancel in order to reduce load on slurmctld.
 -- Remove redundant logic when updating a job's task count.
 -- MySQL - Fix querying jobs with reservations when the id's have rolled.
 -- Perl - Fix use of uninitialized variable in slurm_job_step_get_pids.
 -- Launch batch job requsting --reboot after the boot completes.
 -- Move debug messages like "not the right user" from association manager
    to debug3 when trying to find the correct association.
 -- Fix incorrect logic when querying assoc_mgr information.
 -- Move debug messages to debug3 notifying a gres_bit_alloc was NULL for
    gres types without a file.
 -- Sanity Check Patch to setup variables for RAPL if in a race for it.
 -- GRES - Fix minor typecast issues.
 -- burst_buffer/cray - Increase size of intermediate variable used to store
    buffer byte size read from DW instance from 32 to 64-bits to avoid overflow
    and reporting invalid buffer sizes.
 -- Allow an existing reservation with running jobs to be modified without
    Flags=IGNORE_JOBS.
 -- srun - don't attempt to execve() a directory with a name matching the
    requested command
 -- Do not automatically relocate an advanced reservation for individual cores
    that spans multiple nodes when nodes in that reservation go down (e.g.
    a 1 core reservation on node "tux1" will be moved if node "tux1" goes
    down, but a reservation containing 2 cores on node "tux1" and 3 cores on
    "tux2" will not be moved node "tux1" goes down). Advanced reservations for
    whole nodes will be moved by default for down nodes.
 -- Avoid possible double free of memory (and likely abort) for slurmctld in
    background mode.
 -- contribs/cray/csm/slurmconfgen_smw.py - avoid including repurposed compute
    nodes in configs.
 -- Support AuthInfo in slurmdbd.conf that is different from the value in
    slurm.conf.
 -- Fix build on FreeBSD 10.
 -- Fix hdf5 build on ppc64 by using correct fprintf formatting for types.
 -- Fix cosmetic printing of NO_VALs in scontrol show assoc_mgr.
 -- Fix perl api for newer perl versions.
 -- Fix for jobs requesting cpus-per-task (eg. -c3) that exceed the number of
    cpus on a core.
 -- Remove unneeded perl files from the .spec file.
 -- Flesh out filters for scontrol show assoc_mgr.
 -- Add function to remove assoc_mgr_info_request_t members without freeing
    structure.
 -- Fix build on some non-glibc systems by updating includes.
 -- Add new PowerParameters options of get_timeout and set_timeout. The default
    set_timeout was increased from 5 seconds to 30 seconds. Also re-read current
    power caps periodically or after any failed "set" operation.
 -- Fix slurmdbd segfault when listing users with blank user condition.
 -- Save the ClusterName to a file in SaveStateLocation, and use that to
    verify the state directory belongs to the given cluster at startup to avoid
    corruption from multiple clusters attempting to share a state directory.
 -- MYSQL - Fix issue when rerolling monthly data to work off correct time
    period.  This would only hit you if you rerolled a 15.08 prior to this
    commit.
 -- If FastSchedule=0 is used make sure TRES are set up correctly in accounting.
 -- Fix sreport's truncation of columns with large TRES and not using
    a parsing option.
 -- Make sure count of boards are restored when slurmctld has option -R.
 -- When determine if a job can fit into a TRES time limit after resources
    have been selected set the time limit appropriately if the job didn't
    request one.
 -- Fix inadequate locks when updating a partition's TRES.
 -- Add new assoc_limit_continue flag to SchedulerParameters.
 -- Avoid race in acct_gather_energy_cray if energy requested before available.
 -- MYSQL - Avoid having multiple default accounts when a user is added to
    a new account and making it a default all at once.

* Changes in Slurm 15.08.7
==========================
 -- sched/backfill: If a job can not be started within the configured
    backfill_window, set it's start time to 0 (unknown) rather than the end
    of the backfill_window.
 -- Remove the 1024-character limit on lines in batch scripts.
 -- burst_buffer/cray: Round up swap size by configured granularity.
 -- select/cray: Log repeated aeld reconnects.
 -- task/affinity: Disable core-level task binding if more CPUs required than
    available cores.
 -- Preemption/gang scheduling: If a job is suspended at slurmctld restart or
    reconfiguration time, then leave it suspended rather than resume+suspend.
 -- Don't use lower weight nodes for job allocation when topology/tree used.
 -- BGQ - If a cable goes into error state remove the under lying block on
    a dynamic system and mark the block in error on a static/overlap system.
 -- BGQ - Fix regression in 9cc4ae8add7f where blocks would be deleted on
    static/overlap systems when some hardware issue happens when restarting
    the slurmctld.
 -- Log if CLOUD node configured without a resume/suspend program or suspend
    time.
 -- MYSQL - Better locking around g_qos_count which was previously unprotected.
 -- Correct size of buffer used for jobid2str to avoid truncation.
 -- Fix allocation/distribution of tasks across multiple nodes when
    --hint=nomultithread is requested.
 -- If a reservation's nodes value is "all" then track the current nodes in the
    system, even if those nodes change.
 -- Fix formatting if using "tree" option with sreport.
 -- Make it so sreport prints out a line for non-existent TRES instead of
    error message.
 -- Set job's reason to "Priority" when higher priority job in that partition
    (or reservation) can not start rather than leaving the reason set to
    "Resources".
 -- Fix memory corruption when a new non-generic TRES is added to the
    DBD for the first time.  The corruption is only noticed at shutdown.
 -- burst_buffer/cray - Improve tracking of allocated resources to handle race
    condition when reading state while buffer allocation is in progress.
 -- If a job is submitted only with -c option and numcpus is updated before
    the job starts update the cpus_per_task appropriately.
 -- Update salloc/sbatch/srun documentation to mention time granularity.
 -- Fixed memory leak when freeing assoc_mgr_info_msg_t.
 -- Prevent possible use of empty reservation core bitmap, causing abort.
 -- Remove unneeded pack32's from qos_rec when qos_rec is NULL.
 -- Make sacctmgr print MaxJobsPerUser when adding/altering a QOS.
 -- Correct dependency formatting to print array task ids if set.
 -- Update sacctmgr help with current QOS options.
 -- Update slurmstepd to initialize authentication before task launch.
 -- burst_cray/cray: Eliminate need for dedicated nodes.
 -- If no MsgAggregationParams is set don't set the internal string to
    anything.  The slurmd will process things correctly after the fact.
 -- Fix output from api when printing job step not found.
 -- Don't allow user specified reservation names to disrupt the normal
    reservation sequeuece numbering scheme.
 -- Fix scontrol to be able to accept TRES as an option when creating
    a reservation.
 -- contrib/torque/qstat.pl - return exit code of zero even with no records
    printed for 'qstat -u'.
 -- When a reservation is created or updated, compress user provided node names
    using hostlist functions (e.g. translate user input of "Nodes=tux1,tux2"
    into "Nodes=tux[1-2]").
 -- Change output routines for scontrol show partition/reservation to handle
    unexpectedly large strings.
 -- Add more partition fields to "scontrol write config" output file.
 -- Backfill scheduling fix: If a job can't be started due to a "group" resource
    limit, rather than reserve resources for it when the next job ends, don't
    reserve any resources for it.
 -- Avoid slurmstepd abort if malloc fails during accounting gather operation.
 -- Fix nodes from being overallocated when allocation straddles multiple nodes.
 -- Fix memory leak in slurmctld job array logic.
 -- Prevent decrementing of TRESRunMins when AccountingStorageEnforce=limits is
    not set.
 -- Fix backfill scheduling bug which could postpone the scheduling of jobs due
    to avoidance of nodes in COMPLETING state.
 -- Properly account for memory, CPUs and GRES when slurmctld is reconfigured
    while there is a suspended job. Previous logic would add the CPUs, but not
    memory or GPUs. This would result in underflow/overflow errors in select
    cons_res plugin.
 -- Strip flags from a job state in qstat wrapper before evaluating.
 -- Add missing job states from the qstat wrapper.
 -- Cleanup output routines to reduce number of fixed-sized buffer function
    calls and allow for unexpectedly large strings.

* Changes in Slurm 15.08.6
==========================
 -- In slurmctld log file, log duplicate job ID found by slurmd. Previously was
    being logged as prolog/epilog failure.
 -- If a job is requeued while in the process of being launch, remove it's
    job ID from slurmd's record of active jobs in order to avoid generating a
    duplicate job ID error when launched for the second time (which would
    drain the node).
 -- Cleanup messages when handling job script and environment variables in
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    older directory structure formats.
 -- Prevent triggering gang scheduling within a partition if configured with
    PreemptType=partition_prio and PreemptMode=suspend,gang.
 -- Decrease parallelism in job cancel request to prevent denial of service
    when cancelling huge numbers of jobs.
 -- If all ephemeral ports are in use, try using other port numbers.
 -- Revert way lib lua is handled when doing a dlopen, fixing a regression in
    15.08.5.
 -- Set the debug level of the rmdir message in xcgroup_delete() to debug2.
 -- Fix the qstat wrapper when user is removed from the system but still
    has running jobs.
 -- Log the request to terminate a job at info level if DebugFlags includes
    the Steps keyword.
 -- Fix potential memory corruption in _slurm_rpc_epilog_complete as well as
    _slurm_rpc_complete_job_allocation.
 -- Fix cosmetic display of AccountingStorageEnforce option "nosteps" when
    in use.
 -- If a job can never be started due to unsatisfied job dependencies, report
    the full original job dependency specification rather than the dependencies
    remaining to be satisfied (typically NULL).
 -- Refactor logic to synchronize active batch jobs and their script/environment
    files, reducing overhead dramatically for large numbers of active jobs.
 -- Avoid hard-link/copy of script/environment files for job arrays. Use the
    master job record file for all tasks of the job array.
    NOTE: Job arrays submitted to Slurm version 15.08.6 or later will fail if
    the slurmctld daemon is downgraded to an earlier version of Slurm.
 -- Move slurmctld mail handler to separate thread for improved performance.
 -- Fix containment of adopted processes from pam_slurm_adopt.
 -- If a pending job array has multiple reasons for being in a pending state,
    then print all reasons in a comma separated list.

* Changes in Slurm 15.08.5
==========================
 -- Prevent "scontrol update job" from updating jobs that have already finished.
 -- Show requested TRES in "squeue -O tres" when job is pending.
 -- Backfill scheduler: Test association and QOS node limits before reserving
    resources for pending job.
 -- burst_buffer/cray: If teardown operations fails, sleep and retry.
 -- Clean up the external pids when using the PrologFlags=Contain feature
    and the job finishes.
 -- burst_buffer/cray: Support file staging when job lacks job-specific buffer
    (i.e. only persistent burst buffers).
 -- Added srun option of --bcast to copy executable file to compute nodes.
 -- Fix for advanced reservation of burst buffer space.
 -- BurstBuffer/cray: Add logic to terminate dw_wlm_cli child processes at
    shutdown.
 -- If job can't be launch or requeued, then terminate it.
 -- BurstBuffer/cray: Enable clearing of burst buffer string on completed job
    as a means of recovering from a failure mode.
 -- Fix wrong memory free when parsing SrunPortRange=0-0 configuration.
 -- BurstBuffer/cray: Fix job record purging if cancelled from pending state.
 -- BGQ - Handle database throw correctly when syncing users on blocks.
 -- MySQL - Make sure we don't have a NULL string returned when not
    requesting any specific association.
 -- sched/backfill: If max_rpc_cnt is configured and the backlog of RPCs has
    not cleared after yielding locks, then continue to sleep.
 -- Preserve the job dependency description displayed in 'scontrol show job'
    even if the dependee jobs was terminated and cleaned causing the
    dependent to never run because of DependencyNeverSatisfied.
 -- Correct job task count calculation if only node count and ntasks-per-node
    options supplied.
 -- Make sure the association manager converts any string to be lower case
    as all the associations from the database will be lower case.
 -- Sanity check for xcgroup_delete() to verify incoming parameter is valid.
 -- Fix formatting for sacct with variables that switched from uint32_t to
    uint64_t.
 -- Fix a typo in sacct man page.
 -- Set up extern step to track any children of an ssh if it leaves anything
    else behind.
 -- Prevent slurmdbd divide by zero if no associations defined at rollup time.
 -- Multifactor - Add sanity check to make sure pending jobs are handled
    correctly when PriorityFlags=CALCULATE_RUNNING is set.
 -- Add slurmdb_find_tres_count_in_string() to slurm db perl api.
 -- Make lua dlopen() conditional on version found at build.
 -- sched/backfill - Delay backfill scheduler for completing jobs only if
    CompleteWait configuration parameter is set (make code match documentation).
 -- Release a job's allocated licenses only after epilog runs on all nodes
    rather than at start of termination process.
 -- Cray job NHC delayed until after burst buffer released and epilog completes
    on all allocated nodes.
 -- Fix abort of srun if using PrologFlags=NoHold
 -- Let devices step_extern cgroup inherit attributes of job cgroup.
 -- Add new hook to Task plugin to be able to put adopted processes in the
    step_extern cgroups.
 -- Fix AllowUsers documentation in burst_buffer.conf man page. Usernames are
    comma separated, not colon delimited.
 -- Fix issue with time limit not being set correctly from a QOS when a job
    requests no time limit.
 -- Various CLANG fixes.
 -- In both sched/basic and backfill: If a job can not be started due to some
    account/qos limit, then don't start other jobs which could delay jobs. The
    old logic would skip the job and start other jobs, which could delay the
    higher priority job.
 -- select/cray: Prevent NHC from running more than once per job or step.
 -- Fix fields not properly printed when adding an account through sacctmgr.
 -- Update LBNL Node Health Check (NHC) link on FAQ.
 -- Fix multifactor plugin to prevent slurmctld from getting segmentation fault
    should the tres_alloc_cnt be NULL.
 -- sbatch/salloc - Move nodelist logic before the time min_nodes is used
    so we can set it correctly before tasks are set.

* Changes in Slurm 15.08.4
==========================
 -- Fix typo for the "devices" cgroup subsystem in pam_slurm_adopt.c
 -- Fix TRES_MAX flag to work correctly.
 -- Improve the systemd startup files.
 -- Added burst_buffer.conf flag parameter of "TeardownFailure" which will
    teardown and remove a burst buffer after failed stage-in or stage-out.
    By default, the buffer will be preserved for analysis and manual teardown.
 -- Prevent a core dump in srun if the signal handler runs during the job
    allocation causing the step context to be NULL.
 -- Don't fail job if multiple prolog operations in progress at slurmctld
    restart time.
 -- Burst_buffer/cray: Fix to purge terminated jobs with burst buffer errors.
 -- Burst_buffer/cray: Don't stall scheduling of other jobs while a stage-in
    is in progress.
 -- Make it possible to query 'extern' step with sstat.
 -- Make 'extern' step show up in the database.
 -- MYSQL - Quote assoc table name in mysql query.
 -- Make SLURM_ARRAY_TASK_MIN, SLURM_ARRAY_TASK_MAX, and SLURM_ARRAY_TASK_STEP
    environment variables available to PrologSlurmctld and EpilogSlurmctld.
 -- Fix slurmctld bug in which a pending job array could be canceled
    by a user different from the owner or the administrator.
 -- Support taking node out of FUTURE state with "scontrol reconfig" command.
 -- Sched/backfill: Fix to properly enforce SchedulerParameters of
    bf_max_job_array_resv.
 -- Enable operator to reset sdiag data.
 -- jobcomp/elasticsearch plugin: Add array_job_id and array_task_id fields.
 -- Remove duplicate #define IS_NODE_POWER_UP.
 -- Added SchedulerParameters option of max_script_size.
 -- Add REQUEST_ADD_EXTERN_PID option to add pid to the slurmstepd's extern
    step.
 -- Add unique identifiers to anchor tags in HTML generated from the man pages.
 -- Add with_freeipmi option to spec file.
 -- Minor elasticsearch code improvements

* Changes in Slurm 15.08.3
==========================
 -- Correct Slurm's RPM build if Munge is not installed.
 -- Job array termination status email ExitCode based upon highest exit code
    from any task in the job array rather than the last task. Also change the
    state from "Ended" or "Failed" to "Mixed" where appropriate.
 -- Squeue recombines pending job array records only if their name and partition
    are identical.
 -- Fix some minor leaks in the job info and step info API.
 -- Export missing QOS id when filling in association with the association
    manager.
 -- Fix invalid reference if a lua job_submit plugin references a default qos
    when a user doesn't exist in the database.
 -- Use association enforcement in the lua plugin.
 -- Fix a few spots missing defines of accounting_enforce or acct_db_conn
    in the plugins.
 -- Show requested TRES in scontrol show jobs when job is pending.
 -- Improve sched/backfill support for job features, especially XOR construct.
 -- Correct scheduling logic for job features option with XOR construct that
    could delay a job's initiation.
 -- Remove unneeded frees when creating a tres string.
 -- Send a tres_alloc_str for the batch step
 -- Fix incorrect check for slurmdb_find_tres_count_in_string in various places,
    it needed to check for INFINITE64 instead of zero.
 -- Don't allow scontrol to create partitions with the name "DEFAULT".
 -- burst_buffer/cray: Change error from "invalid request" to "permssion denied"
    if a non-authorized user tries to create/destroy a persistent buffer.
 -- PrologFlags work: Setting a flag of "Contain" implicitly sets the "Alloc"
    flag. Fix code path which could prevent execution of the Prolog when the
    "Alloc" or "Contain" flag were set.
 -- Fix for acct_gather_energy/cray|ibmaem to work with missed enum.
 -- MYSQL - When inserting a job and begin_time is 0 do not set it to
    submit_time.  0 means the job isn't eligible yet so we need to treat it so.
 -- MYSQL - Don't display ineligible jobs when querying for a window of time.
 -- Fix creation of advanced reservation of cores on nodes which are DOWN.
 -- Return permission denied if regular user tries to release job held by an
    administrator.
 -- MYSQL - Fix rollups for multiple jobs running by the same association
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    in an hour counting multiple times.
 -- Burstbuffer/Cray plugin - Fix for persistent burst buffer use.
    Don't call paths if no #DW options.
 -- Modifications to pam_slurm_adopt to work correctly for the "extern" step.
 -- Alphabetize debugflags when printing them out.
 -- Fix systemd's slurmd service from killing slurmstepds on shutdown.
 -- Fixed counter of not indexed jobs, error_cnt post-increment changed to
    pre-increment.

* Changes in Slurm 15.08.2
==========================
 -- Fix for tracking node state when jobs that have been allocated exclusive
    access to nodes (i.e. entire nodes) and later relinquish some nodes. Nodes
    would previously appear partly allocated and prevent use by other jobs.
 -- Correct some cgroup paths ("step_batch" vs. "step_4294967294", "step_exter"
    vs. "step_extern", and "step_extern" vs. "step_4294967295").
 -- Fix advanced reservation core selection logic with network topology.
 -- MYSQL - Remove restriction to have to be at least an operator to query TRES
    values.
 -- For pending jobs have sacct print 0 for nnodes instead of the bogus 2.
 -- Fix for tracking node state when jobs that have been allocated exclusive
    access to nodes (i.e. entire nodes) and later relinquish some nodes. Nodes
    would previously appear partly allocated and prevent use by other jobs.
 -- Fix updating job in db after extending job's timelimit past partition's
    timelimit.
 -- Fix srun -I<timeout> from flooding the controller with step create requests.
 -- Requeue/hold batch job launch request if job already running (possible if
    node went to DOWN state, but jobs remained active).
 -- If a job's CPUs/task ratio is increased due to configured MaxMemPerCPU,
    then increase it's allocated CPU count in order to enforce CPU limits.
 -- Don't mark powered down node as not responding. This could be triggered by
    race condition of the node suspend and ping logic, preventing use of the
    node.
 -- Don't requeue RPC going out from slurmctld to DOWN nodes (can generate
    repeating communication errors).
 -- Propagate sbatch "--dist=plane=#" option to srun.
 -- Add acct_gather_energy/ibmaem plugin for systems with IBM Systems Director
    Active Energy Manager.
 -- Fix spec file to look for mariadb or mysql devel packages for build
    requirements.
 -- MySQL - Improve the code with asking for jobs in a suspended state.
 -- Fix slurcmtld allowing root to see job steps using squeues -s.
 -- Do not send burst buffer stage out email unless the job uses burst buffers.
 -- Fix sacct to not return all jobs if the -j option is given with a trailing
    ','.
 -- Permit job_submit plugin to set a job's priority.
 -- Fix occasional srun segfault.
 -- Fix issue with sacct, printing 0_0 for array's that had finished in the
    database but the start record hadn't made it yet.
 -- sacctmgr - Don't allow default account associations to be removed
    from a user.
 -- Fix sacct -j, (nothing but a comma) to not return all jobs.
 -- Fixed slurmctld not sending cold-start messages correctly to the database
    when a cold-start (-c) happens to the slurmctld.
 -- Fix case where if the backup slurmdbd has existing connections when it gives
    up control that the it would be killed.
 -- Fix task/cgroup affinity to work correctly with multi-socket
    single-threaded cores.  A regression caused only 1 socket to be used on
    this kind of node instead of all that were available.
 -- MYSQL - Fix minor issue after an index was added to the database it would
    previously take 2 restarts of the slurmdbd to make it stick correctly.
 -- Add hv_to_qos_cond() and qos_rec_to_hv() functions to the Perl interface.
 -- Add new burst_buffer.conf parameters: ValidateTimeout and OtherTimeout.
    See man page for details.
 -- Fix burst_buffer/cray support for interactive allocations >4GB.
 -- Correct backfill scheduling logic for job with INFINITE time limit.
 -- Fix issue on a scontrol reconfig all available GRES/TRES would be zeroed
    out.
 -- Set SLURM_HINT environment variable when --hint is used with sbatch or
    salloc.
 -- Add scancel -f/--full option to signal all steps including batch script and
    all of its child processes.
 -- Fix salloc -I to accept an argument.
 -- Avoid reporting more allocated CPUs than exist on a node. This can be
    triggered by resuming a previosly suspended job, resulting in
    oversubscription of CPUs.
 -- Fix the pty window manager in slurmstepd not to retry IO operation with
    srun if it read EOF from the connection with it.
 -- sbatch --ntasks option to take precedence over --ntasks-per-node plus node
    count, as documented. Set SLURM_NTASKS/SLURM_NPROCS environment variables
    accordingly.
 -- MYSQL - Make sure suspended time is only subtracted from the CPU TRES
    as it is the only TRES that can be given to another job while suspended.
 -- Clarify how TRESBillingWeights operates on memory and burst buffers.

* Changes in Slurm 15.08.1
==========================
 -- Fix test21.30 and 21.34 to check grpwall better.
 -- Add time to the partition QOS the job is running on instead of just the
    job QOS.
 -- Print usage for GrpJobs, GrpSubmitJobs and GrpWall even if there is no
    limit.
 -- If AccountingEnforce=safe is set make sure a job can finish before going
    over the limit with grpwall on a QOS or association.
 -- burst_buffer/cray - Major updates based upon recent Cray changes.
 -- Improve clean up logic of pmi2 plugin.
 -- Improve job state reason string when required nodes not available.
 -- Fix missing else when packing an update partition message
 -- Fix srun from inheriting the SLURM_CPU_BIND and SLURM_MEM_BIND environment
    variables when running in an existing srun (e.g. an srun within an salloc).
 -- Fix missing else when packing an update partition message.
 -- Use more flexible mechnanism to find json installation.
 -- Make sure safe_limits was initialized before processing limits in the
    slurmctld.
 -- Fix for burst_buffer/cray to parse type option correctly.
 -- Fix memory error and version number in the nonstop plugin and reservation
    code.
 -- When requesting GRES in a step check for correct variable for the count.
 -- Fix issue with GRES in steps so that if you have multiple exclusive steps
    and you use all the GRES up instead of reporting the configuration isn't
    available you hold the requesting step until the GRES is available.
 -- MYSQL - Change debug to print out with DebugFlags=DB_Step instead of debug4
 -- Simplify code when user is selecting a job/step/array id and removed
    anomaly when only asking for 1 (task_id was never set to INFINITE).
 -- MYSQL - If user is requesting various task_ids only return requested steps.
 -- Fix issue when tres cnt for energy is 0 for total reported.
 -- Resolved scalability issues of power adaptive scheduling with layouts.
 -- Burst_buffer/cray bug - Fix teardown race condition that can result in
    infinite loop.
 -- Add support for --mail-type=NONE option.
 -- Job "--reboot" option automatically, set's exclusive node mode.
 -- Fix memory leak when using PrologFlags=Alloc.
 -- Fix truncation of job reason in squeue.
 -- If a node is in DOWN or DRAIN state, leave it unavailable for allocation
    when powered down.
 -- Update the slurm.conf man page documenting better nohold_on_prolog_fail
    variable.
 -- Don't trucate task ID information in "squeue --array/-r" or "sview".
 -- Fix a bug which caused scontrol to core dump when releasing or
    holding a job by name.
 -- Fix unit conversion bug in slurmd which caused wrong memory calculation
    for cgroups.
 -- Fix issue with GRES in steps so that if you have multiple exclusive steps
    and you use all the GRES up instead of reporting the configuration isn't
    available you hold the requesting step until the GRES is available.
 -- Fix slurmdbd backup to use DbdAddr when contacting the primary.
 -- Fix error in MPI documentation.
 -- Fix to handle arrays with respect to number of jobs submitted.  Previously
    only 1 job was accounted (against MaxSubmitJob) for when an array was
    submitted.
 -- Correct counting for job array limits, job count limit underflow possible
    when master cancellation of master job record.
 -- Combine 2 _valid_uid_gid functions into a single function to avoid
    diversion.
 -- Pending job array records will be combined into single line by default,
    even if started and requeued or modified.
 -- Fix sacct --format=nnodes to print out correct information for pending
    jobs.
 -- Make is so 'scontrol update job 1234 qos='' will set the qos back to
    the default qos for the association.
 -- Add [Alloc|Req]Nodes to sacct to be more like cpus.
 -- Fix sacct documentation about [Alloc|Req]TRES
 -- Put node count in TRES string for steps.
 -- Fix issue with wrong protocol version when using the srun --no-allocate
    option.
 -- Fix TRES counts on GRES on a clean start of the slurmctld.
 -- Add ability to change a job array's maximum running task count:
    "scontrol update jobid=# arraytaskthrottle=#"

* Changes in Slurm 15.08.0
==========================
 -- Fix issue with frontend systems (outside ALPs or BlueGene) where srun
    wouldn't get the correct protocol version to launch a step.
 -- Fix for message aggregation return rpcs where none of the messages are
    intended for the head of the tree.
 -- Fix segfault in sreport when there was no response from the dbd.
 -- ALPS - Fix compile to not link against -ljob and -lexpat with every lib
    or binary.
 -- Fix testing for CR_Memory when CR_Memory and CR_ONE_TASK_PER_CORE are used
    with select/linear.
 -- When restarting or reconfiging the slurmctld, if job is completing handle
    accounting correctly to avoid meaningless errors about overflow.
 -- Add AccountingStorageTRES to scontrol show config
 -- MySQL - Fix minor memory leak if a connection ever goes away whist using it.
 -- ALPS - Make it so srun --hint=nomultithread works correctly.
 -- Make MaxTRESPerUser work in sacctmgr.
 -- Fix handling of requeued jobs with steps that are still finishing.
 -- Cleaner copy for PriorityWeightTRES, it also fixes a core dump when trying
    to free it otherwise.
 -- Add environment variables SLURM_ARRAY_TASK_MAX, SLURM_ARRAY_TASK_MIN,
    SLURM_ARRAY_TASK_STEP for job arrays.
```

CHAPTER

SIX

PROGRAMMER'S GUIDE

6.1 Under Revision

The Programmer's Guide is currently under revision.

CHAPTER

SEVEN

REFERENCE GUIDE

7.1 Preface

Welcome to the Scyld ClusterWare *Reference Guide*. This document describes Scyld ClusterWare commands that can be invoked by the ordinary user and the maintenance utilities that are intended for the cluster administrator. It also provides in-depth information on the configuration file **/etc/beowulf/config** and the cluster node file system table **/etc/beowulf/fstab**. The document also includes an extensive library/function reference for the **beostat** Beowulf Status library and the **BProc** Beowulf Process Control library.

The Scyld Beowulf functionality is implemented through several packages, notably the following:

- The **BProc** package, which implements the Scyld **BProc** unified process space functionality.
- The **libbeostat** package, which monitors the state of the compute nodes and gathers performance metrics, making these metrics available through a library API.

This *Reference Guide* is written with the assumption that the reader has a background in a Linux or Unix operating environment. Therefore, this document does not cover basic Linux system use, administration, or application development.

7.2 Scyld ClusterWare Commands

This section of the *Reference Guide* describes the Scyld ClusterWare commands that are intended to be invoked by the ordinary user. Most of the commands are found in the directory `/opt/scyld/bin`.

7.2.1 beoboot

Name

beoboot – Generate Scyld ClusterWare boot images

Synopsis

beoboot [-h] [-v] [-2] [-a] [-i] [-n] [-o output_file] [-L dir, –libdir dir] [-k kernimg, –kernel kernimg] [-c cmdline, –cmdline cmdline] [-m dir, –modules dir]

Description

beoboot is a script that builds images to boot for Scyld compute nodes.

The final boot image is provided by one or more master nodes designated as “boot masters”. This final boot image has the run-time kernel and initial information needed to contact an operational master.

Options

-h Display a help message and exit.

-v Display version information and exit.

-2 Create a phase 2 image. This image contains the final kernel to run.

-i Create stand-alone images (kernel and ramdisk). These images will be appropriate for use with other boot mechanisms. The kernel and ramdisk image will be stored in: outfile and outfile.initrd

-n Create a netboot image. If no output_file argument is specified, then the image file will be named `/var/beowulf/boot.img`.

-o output_file Set output filename to `output_file`.

-L, --libdir dir Find beoboot files in `dir` instead of `/usr/lib/beoboot/`.

-k, --kernel kernimg Use `kernimg` as the kernel image instead of the image given in the configuration file (final boot image only).

If this is not specified on the command line, the default is taken out of `/etc/beowulf/config`. If it is not specified there, `/boot/vmlinuz` is used.

-c, --cmdline cmdline Use the command line `cmdline` instead of the default “kernelcommandline” line found in the `etc/beowulf/config` config file.

-m, --modules dir Look for modules matching the kernel image in `dir` instead of `/lib/modules/<kernelversion>`, which is the default.

Caution

When you are making a final boot image, you must be running the kernel you are putting in the image, whether this kernel is specified on the command line or in `/etc/beowulf/config`.

Examples

Creating a final boot image:

```
Building phase 2 file system image in /tmp/beoboot.6684...
ram disk image size (uncompressed): 1888K
compressing...done
ram disk image size (compressed): 864K
Kernel image is:    "/tmp/beoboot.6684".
Initial ramdisk is: "/tmp/beoboot.6684.initrd".
Netboot image is in: /var/beowulf/boot.img
```

7.2.2 beoconfig

Name

beoconfig – View or manipulate a Scyld ClusterWare configuration files.

Synopsis

beoconfig [-a, –all string] [-c, –config file] [-d, –delete string] [-D, –deleteall string] [-i, –insert string] [-r, –replace string1 string2] [-n, –node nodes] [-w, –withcomments] [-l, –syslog] [-h, –help] [-u, –usage] [-V, –version]

Description

beoconfig manipulates a Scyld ClusterWare configuration file to insert, replace, or delete “string” entries. A “string” consists of an initial keyword, plus zero or more parameters, plus an optional comment. This utility is commonly used in script files to retrieve parameters from the config file.

Options

The following options are available to the **beoconfig** program.

-a, --all search-string Return all entries with specified `search-string` keyword.

-c file, --config file Read configuration file `file`. Default is `/etc/beowulf/config`.

-d, --delete string Delete the specified `string` from the config file.

-D, --deleteall string Delete all instances of specified `string` from the config file.

-h, --help Show a usage message.

-i, --insert string Append the specified `string` to the config file if it does not already exist. When inserting a “node” entry, you must also specify a `--node nodes` argument.

-l, --syslog Log error messages to the syslog (`/var/log/messages`).

-n, --node nodes Perform action on specified `nodes` only. Nodes can be specified individually, as ranges, or as a comma-separated list of individual nodes and/or ranges.

-r, --replace <string1 string2> Replace `string1` with `string2`.

-u, --usage Show a usage summary.

-V, --version Show this version number.

-w, --withcomments Show entries including comments.

Examples

```
[user@cluster user] $ export CLUSTERDEV="beoconfig interface"
[user@cluster user] $ $CLUSTERDEV
eth1
```

View MAC addresses for all nodes in `/etc/beowulf/config`:

```
[user@cluster user] $ beoconfig -a "node"
00:50:45:01:03:68 00:50:45:01:03:69
00:50:45:5C:29:F6 00:50:45:5C:29:F7
00:50:45:BB:A6:EA 00:50:45:BB:A6:EB
off
off
00:50:45:CD:BE:61
```

Demonstrate –withcomments

```
[root@cluster ~]#  beoconfig --insert "newkeyword param1 # with comment"
[root@cluster ~]#  beoconfig newkeyword
param1
[root@cluster ~]#  beoconfig -w newkeyword
param1 # with comment
# Now remove the unnecessary "newkeyword" entry:
[root@cluster ~]#  beoconfig -d newkeyword
```

Enable only Nodes 1, 2 and 8, to use IPMI

```
[root@cluster ~]#  beoconfig --node 1 --insert "ipmi enabled"
[root@cluster ~]#  beoconfig --node 8 --insert "ipmi enabled"
[root@cluster ~]#  beoconfig --node 2 --insert "ipmi enabled"
[root@cluster ~]#  beoconfig --node 1 "ipmi"
enabled
[root@cluster ~]#  beoconfig --node 3 "ipmi"
disabled
```

Looking in `/etc/beowulf/config`, one will see that the 'ipmi' keyword has a global value of 'disabled'. However, there is another 'ipmi' keyword entry, and this one has an embedded node-set.

```
[root@cluster ~]# cat /etc/beowulf/config | grep ipmi
ipmi disabled
ipmi 1-2,8 enabled
```

Replace functionality: Suppose the config file has a 'nodewake' line to invoke an IPMI version 2.0 script for nodes 1 through 10, but node 5 has been replaced with a machine that supports only IPMI version 1.5. An admin must now replace node 5's nodewake script.

```
[root@cluster ~]#  cat /etc/beowulf/config | grep nodewake
#nodewake /usr/lib/beoboot/bin/node_wake_ipmi
nodewake 1-10 /nfs/support/scripts/nodeup_ipmiv2.0
[root@cluster ~]#  beoconfig --node 5 --replace "nodewake *" "nodewake /nfs/support/scripts/nodeup_ip
[root@cluster ~]#  cat /etc/beowulf/config | grep nodewake
#nodewake /usr/lib/beoboot/bin/node_wake_ipmi
nodewake 1-4,6-10 /nfs/support/scripts/nodeup_ipmiv2.0
nodewake 5 /nfs/support/scripts/nodeup_ipmiv1.5
```

Insert node-holes for node's 0 through 9, while adding a MAC address for node 10

```
[root@cluster ~]#  beoconfig -a node
[root@cluster ~]#  beoconfig -i "node 00:11:22:33:44:55 " --node 10
[root@cluster ~]#  beoconfig -a node
off ##node number 000
off ##node number 001
off ##node number 002
off ##node number 003
off ##node number 004
off ##node number 005
off ##node number 006
off ##node number 007
off ##node number 008
off ##node number 009
node 00:11:22:33:44:55
```

Get the MAC address for node 10

```
[root@cluster ~]# beoconfig -n 10 node
00:11:22:33:44:55
```

7.2.3 beomap

Name

beomap – Show a job map from the beomap scheduler.

Synopsis

beomap [-h, –help] [-V, –version] [–all-cpus] [–all-nodes] [–all-local] [–no-local] [–map nodelist] [–exclude nodelist] [–np num-processes]

Description

This program retrieves a job map from the currently installed `beomap` scheduler. This is the same job map that would be used by an integrated application (such as **beorun** or **mpprun**) started with the same scheduling parameters at that instant in time.

The **beomap** command may be used to generate a job map for applications that do not have their own scheduler interface, in scripts, or to examine the current scheduling state of the system.

You can influence the job map either by setting environment variables or by entering command line options. Note that command-line options take precedence over the environment variable settings.

Options

The following general command line options are available to **beomap**. Also see the next section, which describes the job map parameters.

-h, --help Print the command usage message and exit. If `-h` is in the option list, all other options will be ignored.

-V, --version Print the command version number and exit. Any other options will be parsed and handled.

You can influence the **beomap** job map either by entering command line options or by setting environment variables. Following are the available command line options, together with their equivalent environment variables. Note that the command line options take precedence over the environment variables.

All the **beomap** job map parameters listed below can also be used directly with **beorun** and **mpprun**.

--all-cpus Create a process map consisting of all “up” nodes, with each node number repeated to represent the number of CPUs on that node. This parameter is not allowed in conjunction with the `--map` parameter.

--all-nodes Create a process map consisting of all "up" nodes, with one CPU mapped on each of the "up" nodes. This parameter is not allowed in conjunction with the `--map` parameter.

The equivalent environment variable is *ALL_NODES*.

--all-local Create a process map consisting entirely of master node entries. This option eliminates everything except node -1 from the pool of candidate node numbers, thus forcing the map to use node -1 (the master node) for everything.

The equivalent environment variable is *ALL_LOCAL*.

--no-local Exclude the master in the process map. This option is essentially a syntactic shortcut for including `-1` in the `--exclude nodelist` option. For MPI jobs, this option puts the "rank 0" job on a compute node instead of on the master node. This parameter is not allowed in conjunction with the `--map` parameter.

The equivalent environment variable is *NO_LOCAL*.

--exclude nodelist Build a process map that excludes listed nodes. The `nodelist` consists of a colon-delimited list. This parameter is not allowed in conjunction with the `--map` parameter.

The equivalent environment variable is *EXCLUDE=nodelist*.

--map nodelist Explicitly specify a process map consisting of a colon-delimited list of nodes. Each node in `nodelist` indicates where one process will be assigned. The number of entries in the job map implies the number of ranks in the job.

Listing a node more than once in the list will assign multiple processes to that node. Typically, this is done to assign one process to each processor (or core) on a node, but this can also be used to "oversubscribe", i.e., to assign more processes to a node than it has processors (or cores).

The equivalent environment variable is *BEOWULF_JOB_MAP=nodelist*.

--np num-processes Specify the number of processes to run. The **beomap** command attempts to place one process per processor (or core), but will "oversubscribe" and assign multiple processes per processor (or core) if there are not enough individual processors or cores available. This parameter is not allowed in conjunction with the `--map` parameter.

The equivalent environment variable is *NP=num-processes*.

The environment variables have an order of priority. The *BEOWULF_JOB_MAP* variable acts as a "master override" for the other environment variables. If *BEOWULF_JOB_MAP* is not set, then the following priorities apply:

Three of the environment variables determine *how many ranks* to schedule in the map: (1) *ALL_CPUS*, (2) *ALL_NODES*, and (3) *NP*. If none of these are set explicitly by the user, then *NP=1* is the default.

Three of the environment variables determine *what node numbers* are candidates for being mapped: (1) *ALL_LOCAL*, (2) *NO_LOCAL*, and (3) *EXCLUDE*.

Note: it is improper to use *NO_LOCAL* and *ALL_LOCAL* together. If both are used, then *ALL_LOCAL* takes precedence.

Examples

Find the set of machines available for use:

```
[user@cluster ~] $ beomap --all-cpus
  -1:0:1:2:3:4:5:6:7:8:9:10:11:12:13:14:15
```

Create a process map to run 20 processes on a cluster with 10 idle dual-processor compute nodes:

```
[user@cluster user] $ beomap --np 20
  -1:0:0:1:1:2:2:3:3:4:4:5:5:6:6:7:7:8:8:9
```

Note: Since `--no-local` was not specified, then the master node (listed as “-1”) is included in the map, and node 9 is listed only once.

Select an available machine to start up an application, while handling application termination or machine failure; note that the following works only for the sh family of shells (bash):

```
[user@cluster user] $ while :; do export NODE=`beomap --no-local -np 1`; bpsh $NODE application-to-ru
```

Provide an explicit map to run 5 processes on node 0:

```
[user@cluster user] $ beomap --np 5 --map 0:0:0:0:0
```

Special Notes

The underlying **beomap** system calls pluggable schedulers, which may use arbitrary scheduling inputs. The command line options replace and delete environment variables used by the Scyld-provided default schedulers/mappers, but other schedulers are free to ignore these advisory settings. Specifically, the **beomap** command does not confirm that the parameters, such as `--no-local`, are true in the resulting job map.

7.2.4 beonpc

Name

beonpc – Show the count of all user processes started by this master running on the specified compute node.

Synopsis

beonpc [-h, –help, -u, –usage] [-V, –version] [-p, –pids] [-s, –sum] node

Description

The **beonpc** program prints the count of running processes on the specified cluster node. The count includes only the processes started by the current machine and running on the specified node.

beonpc prints “-1” for nodes that are not controlled by this master or are otherwise inaccessible.

beonpc is typically used to make and observe scheduling and job mapping decisions.

Options

The following options are available to the **beonpc** program.

-h, --help, -u, --usage Print the command usage message on `stdout` and exit. When one of these options is recognized in the option list, all following options will be ignored.

-V Print the command version number on `stdout` and exit. Any following options will be ignored.

-p, --pids Show the process IDs in a process list.

-s, --sum Emit only a total cluster process count.

node Optionally, show for the specific node number, or *all* (the default) for all nodes, or *list* for nodes with a nonzero count.

Example

Find the number of jobs this master is running on cluster compute node 23:

```
[user@cluster user] $ beonpc 23
3
```

7.2.5 beorun

Name

beorun – Run a job on a Scyld cluster using dynamically selected nodes.

Synopsis

beorun [-h, –help] [-V, –version] [–all-cpus] [–all-nodes] [–all-local] [–no-local] [–map nodelist] [–exclude nodelist] [–np processes] command [command-args...]

Description

The **beorun** program runs the specified program on a dynamically selected set of cluster nodes. It generates a job map from the currently installed **beomap** scheduler, and starts the program on each node specified in the map. The scheduling parameters from the command line and environment are the same as for **beomap**, and the resulting job map is identical to the job map that **beomap** would if generate at that instant in time for that program name.

The **beorun** command may be used to start applications that are not cluster-aware or do not have their own scheduler interface.

Options

The following general command line options are available to **beorun**. Also see the next section, which describes the **beomap** job map parameters.

-h, --help, -u, --usage Print the command usage message on `stdout` and exit. When one of these options is recognized in the option list, all following options will be ignored.

-V Print the command version number on `stdout` and exit. Any following options will be ignored.

You can influence the **beorun** job map either by entering command line options or by setting environment variables. Following are the available command line options, together with their equivalent environment variables. Note that the command line options take precedence over the environment variables.

All the **beorun** job map parameters listed below can also be used directly with **beomap** and **mpprun**.

--all-cpus Create a process map consisting of all “up” nodes, with each node number repeated to represent the number of CPUs on that node. This parameter is not allowed in conjunction with the `--map` parameter.

--all-nodes Create a process map consisting of all “up” nodes, with one CPU mapped on each of the “up” nodes. This parameter is not allowed in conjunction with the `--map` parameter.

The equivalent environment variable is *ALL_NODES*.

--all-local Create a process map consisting entirely of master node entries. This option eliminates everything except node -1 from the pool of candidate node numbers, thus forcing the map to use node -1 (the master node) for everything.

The equivalent environment variable is *ALL_LOCAL*.

--no-local Exclude the master in the process map. This option is essentially a syntactic shortcut for including `-1` in the `--exclude nodelist` option. For MPI jobs, this option puts the “rank 0” job on a compute node instead of on the master node. This parameter is not allowed in conjunction with the `--map` parameter.

The equivalent environment variable is *NO_LOCAL*.

--exclude nodelist Build a process map that excludes listed nodes. The `nodelist` consists of a colon-delimited list. This parameter is not allowed in conjunction with the `--map` parameter.

The equivalent environment variable is *EXCLUDE=nodelist*.

--map nodelist Explicitly specify a process map consisting of a colon-delimited list of nodes. Each node in `nodelist` indicates where one process will be assigned. The number of entries in the job map implies the number of ranks in the job.

Listing a node more than once in the list will assign multiple processes to that node. Typically, this is done to assign one process to each processor (or core) on a node, but this can also be used to “oversubscribe”, i.e., to assign more processes to a node than it has processors (or cores).

The equivalent environment variable is *BEOWULF_JOB_MAP=nodelist*.

--np num-processes Specify the number of processes to run. The **beorun** command attempts to place one process per processor (or core), but will “oversubscribe” and assign multiple processes per processor (or core) if there are not enough individual processors or cores available. This parameter is not allowed in conjunction with the `--map` parameter.

The equivalent environment variable is *NP=num-processes*.

The environment variables have an order of priority. The *BEOWULF_JOB_MAP* variable acts as a “master override” for the other environment variables. If *BEOWULF_JOB_MAP* is not set, then the following priorities apply:

Three of the environment variables determine *how many ranks* to schedule in the map: (1) *ALL_CPUS*, (2) *ALL_NODES*, and (3) *NP*. If none of these are set explicitly by the user, then *NP=1* is the default.

Three of the environment variables determine *what node numbers* are candidates for being mapped: (1) *ALL_LOCAL*, (2) *NO_LOCAL*, and (3) *EXCLUDE*.

Note: it is improper to use *NO_LOCAL* and *ALL_LOCAL* together. If both are used, then *ALL_LOCAL* takes precedence.

Unrecognized options and invalid option formats are reported on `stderr` and the command exits with exit status 1 (invalid option) or 2 (no command specified or invalid command).

NOTE: **beorun** does not pass information from `stdin` to applications. In cases where an application must read data from `stdin`, it is suggested that **bpsh** be used instead. Please see the **bpsh** man page for usage information; command line options for **bpsh** are similar to those for **beorun**, but not exactly the same.

Examples

Run **uptime** on any two available cluster compute nodes:

```
11:05am  up 2 days, 11:16,  0 users,  load average: 0.05, 0.24, 0.65
11:05am  up 2 days, 11:16,  0 users,  load average: 0.01, 0.07, 0.37
```

7.2.6 beosi

Name

beosi – Collects or extracts cluster configuration information.

Synopsis

beosi [-m] [-n] [-I] [-d file] [-h] [-v]

Description

The primary function of the **beosi** utility is to collect configuration and state information from the master node and/or compute nodes on a Scyld ClusterWare cluster, organize the information into ASCII files within a new directory in the current working directory, and finally **tar** that directory and **uuencode** the gzipped tarball into a compressed, portable archive file that can be saved locally or transmitted (e.g., by ftp or email). **beosi** can also be used to **uudecode** a previously assembled archive to reform the tarball for later extraction as desired.

beosi should be executed with root access, since much of the interesting information can only be accessed as root. The `-m` and `-n` options are typically used together to produce a directory named `conf-<date>`, where the `YY-MM-DD` date indicates the current year, month, and day. The `-m` option creates ASCII files in the subdirectory `conf-<date>/master/`, and the `-n` option creates ASCII files in per-node subdirectories, e.g., `conf-/Node0/` and `conf-/Node1/`. The **beosi** default end product is an archive file named `conf-<date>.encoded`.

beosi can be used to capture configuration information for later retrieval and comparison. For example, if the current configuration is working, you can execute **beosi** and store the archive file for safekeeping. If a subsequent configuration change causes your cluster to stop working, then you can create another archive, extract both the new archive and the previous archive, and examine the differences between the two configurations (e.g. using **diff**) to determine which change caused the problem.

Options

The following options are available to the **beosi** utility.

-m
Collect information about the master node, typically used together with the `-n` option. By default, produces a uuencoded gzipped tar file in the current directory called `conf-<date>.encoded`

-n
Collect information about individual (compute) nodes, typically used together with the `-m` option. By default, produces a uuencoded gzipped tar file in the current directory called `conf-<date>.encoded`

-I The `-I` option overrides the default action of converting the `conf-<date>` directory of captured information into a uuencoded gzipped tar file. Thus, the directory of information is retained in its fully "exploded" form, `conf-<date>`, which allows the cluster administrator to view all the information that would otherwise be bundled into the uuencoded gzipped tar file. This is especially useful to discern why **beosi** might be producing an unexpectedly large uuencoded file.

-d file Decodes information from an archive created previously by **beosi**. The result is a gzipped tar file with the same root filename.

-h Display a summary of beosi command arguments.

-v Display program version information and exit.

Examples

Suppose the current date is May 22, 2018. To inspect the configuration information on the master node, first run:

```
[root@cluster ~]# beosi -m
[root@cluster ~]# ls
  conf-18-05-22.encoded
```

Then extract the information:

```
[root@cluster ~]# beosi -d conf-18-05-22.encoded
[root@cluster ~]# tar -zxvf conf-18-05-22.tar.gz
  conf-18-05-22/
  conf-18-05-22/master/
  conf-18-05-22/master/dmesg
  conf-18-05-22/master/lsmod
  conf-18-05-22/master/syslog
  ...
```

Alternatively, avoid producing a uuencoded tar file and thus retain the fully explorable directory of information:

```
[root@cluster ~]# beosi -m -I
[root@cluster ~]# ls
  conf-18-05-22
```

Use a prior configuration to identify individual files that differ:

```
[root@cluster ~]# diff -r --brief conf-17-12-30 conf-18-05-22
  Files conf-17-12-30/master/ifconfig and conf-18-05-22/master/ifconfig differ
  Files conf-17-12-30/master/lsmod and conf-18-05-22/master/lsmod differ
  Files conf-17-12-30/master/network and conf-18-05-22/master/network differ
  Files conf-17-12-30/master/proc_buddyinfo and conf-18-05-22/master/proc_buddyinfo differ
  ...
```

Use a prior configuration to compare individual files:

```
[root@cluster ~]# diff -u conf-17-12-30/master/lsmod conf-18-05-22/master/lsmod
--- conf-17-12-30/master/lsmod 2009-12-14 09:19:45.000000000 -0800
+++ conf-18-05-22/master/lsmod 2015-07-21 18:27:31.000000000 -0800
@@ -1,11 +1,12 @@
 Module                 Size  Used by
+iptable_filter         7745  0
 bproc                181208  2
 task_packer           24708  1 bproc
 filecache             28220  2 bproc,task_packer
 ipt_MASQUERADE         9025  1
 iptable_nat           34149  2 ipt_MASQUERADE
 ip_conntrack          57369  2 ipt_MASQUERADE,iptable_nat
-ip_tables             25537  2 ipt_MASQUERADE,iptable_nat
+ip_tables             25537  3 iptable_filter,ipt_MASQUERADE,iptable_nat
 nfsd                 274657  17
 exportfs              10945  1 nfsd
 lockd                 82833  2 nfsd
```

To gather complete information about the cluster (i.e., master and all `up` compute nodes):

```
[root@cluster ~]# beosi -m -n
[root@cluster ~]# ls
  conf-18-05-22.encoded
```

7.2.7 beostatus

Name

beostatus – Display status information about the cluster.

Synopsis

beostatus [–classic] [-c, –curses] [-H, –html] [-C, –combined-spider] [-d, –dots] [-l, –levometer] [-p, –pie] [-s, –spider] [-S, –stripchart] [-r, –remote=host] [-P, –port=port] [-U, –user=name] [–disable-ssl] [-u seconds, –update=seconds] [-v, –version] [-h, –help]

Description

beostatus is a utility that displays status information for the master node and all compute nodes in the cluster.

The default display is a graphical user interface (GUI) known as the “Classic” mode, which is a tabular format, one row per node, showing per-node specific state and resource usage information. An optional non-GUI “Curses” display mode is also available that shows the same per-node information as the “Classic” mode: the assigned number for each node, the node state, CPU usage, memory usage, swap space usage, root filesystem usage, and network bandwidth usage.

Alternate GUI display modes can be selected by **beostatus** command line option or by using a pulldown menu within each of the GUI displays.

Various filtering options are available in the “Curses” display mode that limit the displayed information to nodes that are being currently utilized by a specified user. Note: filtering functionality requires that TORQUE be installed on the cluster.

beostatus can also be used to access cluster state information for a remote node. This requires the presence of **beoweb** functionality on the remote node.

See the Administrator’s Guide for additional information about **beostatus**.

Options

The following options are available to the **beostatus** utility:

--classic Display output in GUI “Classic” mode. This is the default display mode.

-c, --curses Display output in non-GUI "Curses" mode. It displays the same information as the GUI "Classic" mode. It is appropriate for simple terminal windows and when X is unavailable.

-C, --combined-spider Display output in GUI "Combined Spider" mode.

-d, --dots Display output in GUI "Dots" mode. Each node is represented by a colored box. The user selects the status element that the box represents (e.g., node state or CPU utilization), and different colors indicate different status values for that element (e.g., node state "up" vs. "down", or gradations of CPU loading).

-H, --html Display output in HTML format.

-l, --levometer Display output in GUI "Levometer" mode.

-p, --pie Display output in GUI "Piechart" mode.

-P port, --port=port When retrieving remote beostatus information, override the default port number 5000 with another port value.

-r host, --remote=host Retrieve beostatus information from a remote host.

-s, --stripchart Display output in GUI "Stripchart" mode.

-u seconds, --update=seconds Override the default update rate of 5 seconds. Units are integer seconds.

-U name, --user=name When retrieving remote beostatus information, authenticate as user name.

--disable-ssl When retrieving remote beostatus information, don't use SSL encryption.

-v, --version Show version information.

-h, --help Show usage information and exit. If `-h` is one of the first two options, all other options will be ignored. If `-h` is not one of the first two options, it will be ignored.

FILTERING OPTIONS

Various filtering options are available when in "Curses" mode. Each is enabled by a single lowercase letter keystroke, and is disabled by a matching uppercase letter keystroke:

f, F Limit the display to only those nodes that are running TORQUE jobs for a specific user. If the current user is root, then **beostatus** prompts for a username; otherwise, the username defaults to the current user.

j, J Limit the display to only those nodes that are running TORQUE jobs for a specific user, and yet those jobs have no processes actually executing. If the current user is root, then **beostatus** prompts for a username; otherwise, the username defaults to the current user.

p, P Limit the display to only those nodes that are running processes (irrespective of TORQUE) for a specific user. If the current user is root, then **beostatus** prompts for a username; otherwise, the username defaults to the current user.

z, Z Limit the display to only those nodes that are running TORQUE jobs for any user, and yet those jobs have no processes actually executing.

q, Q Terminate the **beostatus** utility.

Examples

Print cluster status. Use "q" to exit continuously updating display:

```
[user@cluster user] $ beostatus -c
       BeoStatus - 3.0
Node  State  CPU 0  CPU 1  CPU 2  CPU 3  Memory   Swap   Disk   Network
 -1      up   0.2%  11.5%   0.0%   0.0%   12.4%   0.0%  38.2%     36 kBps
  0      up   0.0% 100.0%                  9.6%   0.0%   2.2%     23 kBps
  1      up  90.0%   0.0%                 22.1%   0.0%   2.2%     13 kBps
  2    down
  3    down
```

7.2.8 beostat

Name

beostat – Display raw data from the Beostat system.

Synopsis

beostat [-h, –help] [-v, –verbose] [-N node-num, –node=node-num] [-c, –cpuinfo] [-m, –meminfo] [-l, –loadavg] [-n, –net] [-s, –stat] [-f, –file] [-C, –cpupercent] [-D, –diskusage] [-R, –netrate] [-I, –idle=thres] [-b, –brief] [–version]

Description

The **beostat** command is a low-level utility that displays data being managed by the **beostat** package. This data is collected on each compute node and sent by the **sendstats** daemon to the **recvstats** daemon on the master node. Other commands, such as **beostatus**, present a more user-friendly higher-level picture of the cluster.

The default **beostat** command shows all available information on all "up" nodes. The `--verbose` option shows all nodes, including "down" nodes. Various other options constrain the output to show more specific information. You may present multiple options to see multiple data classifications.

Options

The following options are available to the **beostat** command.

-v, --verbose Verbose, display information on all nodes, even if those nodes are down. Normally, **beostat** displays only "up" nodes.

-N node-num, --node=node-num Show only the data for node `node-num` rather than for all nodes.

-c, --cpuinfo Display the CPU model information.

-m, --meminfo Display memory statistics.

-l, --loadavg Display load average information.

-n, --net Display network interface information.

-s, --stat Display CPU statistics information.

-f, --file Display root filesystem information.

-h, --help Display brief help and exit.

-C, --cpupercent Convenience option to display CPU info.

-D, --diskusage Convenience option to display disk usage of root filesystem.

-R, --netrate Convenience option to display network rate of all interfaces.

-I, --idle=threshold Convenience option to display number of CPUs more idle than `threshold`.

-b, --brief Display convenience values (`cpupercent`, `diskusage`, `netrate`, or `idle`) with no extra text. This eliminates the need to parse the output to obtain the specific values. Only valid when used with one of the convenience options (-C, -D, -R, or -I).

--version Display program version information and exit.

7.2.9 bpcp

Name

bpcp – Copies files and/or directories between cluster machines.

Synopsis

bpcp [-h] [-v] [-a] [-p] [-r] [host1: {file1 }] [host2: {file2 }]

Description

The **bpcp** utility is part of the `BProc` package and is installed by default. It is similar to the Linux **rcp** command. **bpcp** will copy files and/or directories between machines. Each file or directory is either a remote file name of the form `rhost:path` or a local file name. You must have read permission on the source and write permission on the destination. **bpcp** also handles node-to-node copies, where neither the source nor destination files are on the current node.

Options

The following options are available to the **bpcp** program.

-h Print the **bpcp** usage message and exit. If `-h` is the first option, all other options will be ignored. If `-h` is not the first option, the other options will be parsed up to the `-h` option, but no action will be taken.

-v Print the **bpcp** version number and exit. If `-v` is the first option, all other options will be ignored. If `-v` is not the first option, the other options will be parsed up to the `-v` option, but no action will be taken.

-a Copy the local file(s) to every *up* node. This option does not allow for a *host1* option specifying a source node, nor for a *host2* option specifying a target node.

-p Preserve the attributes of the source files, ignoring the umask. By default, **bpcp** will modify the time, permission bits, user and group information when the file is copied. This parameter will cause time and permission bits to be unchanged, but the user and group will change to reflect the new user.

-r Descend source directory tree recursively and copy files and tree to destination. In this case, the destination must be a directory.

[host1:]file1 The name of the file to be copied (and optionally the name of the host it resides on if other than the local host). file1 can be the directory name when used with the `-r` option.

[host2:]file2 The name of the file and/or host where the specified file should be copied. file2 can be a directory name.

Examples

Copy file1 from the master node to compute node 1 as file2 in `/home/user`. Like **cp**, the directory will not be created if it does not exist.

```
[user@cluster user] $ bpcp /home/user/file1 1:/home/user/file2
```

Copy file1 from the master node to every *up* compute node as file2 in `/home/user`. Like **cp**, the directory will not be created if it does not exist.

```
[user@cluster user] $ bpcp -a /home/user/file1 /home/user/file2
```

Copy all files and sub-directories from compute node 2 in `/home/user` to compute node 1 in `/home/user`. The directory tree will be created if it does not exist.

```
[user@cluster user] $  bpcp -r 2:/home/user/ 1:/home/user/
```

Using node 1 as an intermediary, copy `file1.txt` on node 0 to `file1.txt` on node 2.

```
[user@cluster user] $ bpsh 1 bpcp 0:/tmp/file1.txt 2:/tmp/
```

Copy `/tmp/file.txt` from the master node to the `/tmp` directory on every node in the cluster that is “up”.

```
[user@cluster user] $ bpsh -a bpcp master:/tmp/file1.txt /tmp
```

Note: **bpcp** will give an “rfork: Invalid argument” message when the node is unreachable.

7.2.10 bpdate

Name

bpdate – Set the time on a compute node

Synopsis

bpdate node

Description

This program replicates the master node’s time-of-day to a compute node. The program has one required argument: the number of the compute node.

This program is usually run from the **node_up** script, so that the time gets set on the compute nodes at node boot. After the node is up, `BProc`‘s **bpmaster** daemon on the master node works with the **bpslave** daemon on each compute node to synchronize the time-of-day across the cluster.

Options

The following options are available to the **bpdate** program.

node The number of the node to set the time on.

Examples

Set the time on node 1:

```
[user@cluster user] $ bpdate 1
```

7.2.11 bpsh

Name

bpsh, **bprsh** – Run a command on the indicated node(s).

Synopsis

bpsh [-h] [-v] [-a] [-A] [-L] [-p] [-s] [-d] [-b num] [-n] [-N] [-I file, –stdin file] [-O file, –stdout file] [-E file, –stderr file] targetnodes command [command-args]

Description

This utility is part of the `BProc` package and is installed by default on Scyld ClusterWare systems. It is the basic mechanism for running programs on nodes, and it is patterned after the **rsh** and **ssh** commands.

The `targetnodes` can range from -1 (the master) to one less than the number of accessible nodes. **bpsh** will also accept a delimited list of nodes; use `-a` for all nodes that are "up" and `-A` for all nodes that are communicating (e.g., states "up", "error" and "unavailable").

bpsh forwards `stdin`, `stdout` and `stderror` for the remote processes, unless directed otherwise by `-n` or `-N` arguments. `stdin` will be duplicated for every process on each remote node selected. For a single remote process, the exit status of **bpsh** will be the exit status of that process. Non-normal exit status will also be captured and displayed. For multiple processes, **bpsh** exits with the highest exit status.

bpsh throttles the maximum number of `command` executions that are outstanding at any point in time as **bpsh** services the entire `targetnodes` list. The default fanout is 64, which can be overriden by the environment variable BPSH_FANOUT=<number>, which is currently capped at 128. The fanout when using the `-s` (serialize) option is fixed at 1.

The **bprsh** utility is a variant of **bpsh**. See the EXAMPLES.

Options

The following options are available to the **bpsh** program.

-h
Print the command usage message and exit. If `-h` is the first option, all other options will be ignored. If `-h` is not the first option, the other options will be parsed up to the `-h` option, but no action will be taken.

-v
Print the command version number and exit. If `-v` is the first option, all other options will be ignored. If `-v` is not the first option, the other options will be parsed up to the `-v` option, but no action will be taken.

-a
Specifies that the command will be run on all nodes in the "up" state.

-A num Specifies that the command will be run on all nodes in either the "up", "error", and "unavailable" states. Note that non-root users may get "BProc move failed" errors, since they are only allowed to run on "up" nodes, regardless of other node permissions.

-L state Line buffer output from nodes.

-p Prefix the node number on each output line from the node that sent it.

-s List sequentially all the output from each node.

-d Print a divider line between the sequential output from each node.

-b num Set the IO line buffer size to the number of bytes. The default is 4096.

-n Get `stdin` from `/dev/null`. On any read from `stdin`, `/dev/null` will return EOF. This is useful for any program that you background or daemonize. Like **rsh**, **bpsh** will not exit immediately if `stdin` is left open and the program has not completed. **bpsh** assumes the program may want input from `stdin`.

-N No IO forwarding.

-I file, --stdin file Redirect standard input from the specified file on the remote node.

-O file, --stdout file Redirect standard output to the specified file on the remote node.

-E file, --stderr file Redirect standard error to the specified file on the remote node.

targetnodes The node(s) on which to run the command.

command The command/program to run.

command-args The arguments for command.

Examples

Run the **ls** command on nodes -1, 0 and 2, and prefix the node number to each line. Note, due to the way **getopt** works, the master (node -1) cannot be first in the node list:

```
[user@cluster user] $ bpsh 0,-1,2 -p ls /tmp
  -1: f1.txt
  -1: foo.txt
  0: f3.txt
  2: newfoo.txt
  2: oops.txt
```

Run the **uptime** command on nodes in the "up" state:

```
[user@cluster user] $ bpsh -a -d uptime
  0 ---------------------------------------------------------------
    2:42pm  up 2 days, 23:51,  0 users
  1 ---------------------------------------------------------------
    2:41pm  up 3 days,  5:38,  0 users
  3 ---------------------------------------------------------------
    2:42pm  up 3 days,  5:38,  0 users
```

Run the same command with a `fanout` value override:

```
[user@cluster user] $ BPSH_FANOUT=128 bpsh -a -d uptime
```

Run a single instance of the **uptime** command on a node chosen by the scheduler, displaying the node number before the output.

```
[user@cluster user] $ bpsh -p 0-3 uptime
  0 2:42pm  up 2 days, 23:51,  0 users
  1 2:42pm  up 3 days,  5:38,  0 users
Node 2 is down
  3 2:42pm  up 3 days,  5:38,  0 users
```

Run a complex command that consists of multiple commands that displays all the "up" nodes that have been up for less than 24 hours. Note: the **bpsh** utility expects command to be a single command, so to execute multiple commands you must use **bash -c** with the desired command in quotes:

```
[user@cluster user] $ bpsh -sap bash -c "uptime | grep -v days"
```

Alternatively, **bprsh** accepts the more complex command as-is, just as **rsh** would do:

```
[user@cluster user] $ bprsh -sap "uptime | grep -v days"
```

7.2.12 bpstat

Name

bpstat – Show cluster node status and cluster process mapping.

Synopsis

bpstat [-h, –help] [-V, –version] [-U, –update] [-c, –compact] [-l, –long] [-a, –address] [-s, –status] [-n, –number] [-t, –total] [-N, –sort-number] [-S, –sort-status] [-O, –keep-order] [-R, –sort-reverse] [-p] [-P [nodes]] [-A hostname] [-M] [nodes | allstate]

Description

This utility displays the `BProc` status of cluster nodes, and processes running on those nodes. Node information includes the node's IP address, state, user ownership, group ownership, and running node user processes.

Options

The following options are available to the **bpstat** program.

-a, --address
Prints the IP address of the indicated node.

-A hostname
Prints the node number that corresponds to the specified hostname or IP address.

-c, --compact
Print compacted listing of nodes (default).

-h, --help
Print the command usage message and exit. If `-h` is the first option, all other options will be ignored. If `-h` is not the first option, the other options will be parsed up to the `-h` option, and those options will be processed.

-l, --long
Print long list of node status. This includes IP address, status, mode, user and group information.

-M
Prints the status of the master node, in addition to the specified compute node(s), for the default case where no specific nodes are specified.

-n, --number
Prints the node numbers that are being used and/or are available for the nodes in the cluster.

-N, --sort-number Prints the node list sorted by node number.

-O, --keep-order Prints the nodes in the order returned by the system (no sorting is done).

-p Prints a list of processes (by PID) that are currently running on the specified node.

-P nodes Postprocesses the output from the **ps** command, prepending the node number that `BProc`-controlled processes are running on. This is typically used as **ps aux | bpstat -P**. Processes not controlled by the `BProc` system will not have a number appended. If the optional [nodes] is supplied, then the **ps** output is filtered to show only the specified node(s). Node(s) can be identified by names, numbers, or a list of numbers.

-R, --sort-reverse Prints the node list in reverse sorted order.

-s, --status Prints the state for the indicated node. The `BProc` states are “down”, “boot”, “error”, “unavailable”, “up”, “reboot”, “halt”, and “pwroff”.

-S, --sort-status Prints the node list sorted by node status.

-t, --total Prints the total number of compute nodes configured for the cluster. The number is calculated from the cluster configuration in the `/etc/beowulf/config` file. Note that this is the potential maximum size of the cluster, not the current number of available nodes or the count of machines assigned node numbers.

-U, --update Continuously update the status; otherwise, print status once and exit.

-V, --version Print the command version number and exit. If `-V` is the first option, all other options will be ignored. If `-V` is not the first option, the other options will be parsed up to the `-V` option, and those options will be processed.

[nodes | allstate] Optionally, specify the nodes for which information is to be displayed. Nodes can be specified individually, as ranges, or in a comma-separated list of individual nodes and/or ranges. Alternatively, `all`state specifies all nodes that are in a particular state, e.g., allup, alldown, allboot, allerror. Note: `allup` does not include the master node, even if `-M` is present.

Examples

Print the number of available nodes:

```
[user@cluster user] $ bpstat --total allup
  9
```

Generate a list of all usable nodes:

```
[user@cluster user] $ bpstat --number allup
  0 1 2 4 5 10 16 17 20
[user@cluster user] $ bpstat --number allup | awk '{ print "."$1 }'
  .0 .1 .2 .4 .5 .10 .16 .17 .20
```

Print status for all nodes, including the master node:

```
[user@cluster user] $ bpstat
 Node(s)                        Status       Mode       User       Group
 8,11,22-31                     down         ---------- root       root
 3,6-7,9,12-15,18-19,21         error        ---x------ root       root
 -1,0-2,4-5,10,16-17,20         up           ---x--x--x root       root
```

Print the PIDs and associated node number of currently running processes:

```
[user@cluster user] $ bpstat -p
 PID    Node
  7503  0
  8262  1
```

Print status for specific nodes:

```
[user@cluster user] $ bpstat 0-2,3,8
 Node(s)                        Status      Mode       User       Group
  8                              down         ---------- root       root
  3                              error        ---x------ root       root
  0-2                            up           ---x--x--x root       root
```

Augment **ps aux** for node numbers:

```
[user@cluster user] $ ps aux | bpstat -P
NODE    USER       PID %CPU %MEM   VSZ  RSS TTY      STAT START   TIME COMMAND
        root         1  0.0  0.0  4756  552 ?        S    10:58   0:02 init [5]
        root         2  0.0  0.0     0    0 ?        S    10:58   0:00 [migration/0]
  (etc.)
```

Filter **ps aux** for nodes n1 and n2:

```
[user@cluster user] $ ps aux | bpstat -P n1,n2
NODE    USER       PID %CPU %MEM   VSZ  RSS TTY      STAT START   TIME COMMAND
1       root      1328  0.0  0.0  6864  692 ?        Ss   12:45   0:00 [portmap]
2       root     32397  0.0  0.0  6864  692 ?        Ss   12:45   0:00 [portmap]
```

7.2.13 mpprun

Name

mpprun – Run a series of commands on a Scyld cluster using a dynamically generated job map.

Synopsis

mpprun [-h, –help] [-V, –version] [-p,–prefix] [–all-cpus] [–all-nodes] [–all-local] [–no-local] [–map nodelist] [–exclude nodelist] [–np processes] command [command-args...]

Description

The **mpprun** program sequentially runs the specified program on a dynamically selected set of cluster nodes. It generates a job map from the currently installed **beomap** scheduler, and runs the program on each node specified in the map. The scheduling parameters from the command line and environment are the same as for **beomap**, and the resulting job map is identical to the job map that **beomap** would if generate at that instant in time for that program name.

mpprun is similar to the **beorun** program, but **beorun** starts the job simultaneously on the cluster nodes, whereas **mpprun** starts the job sequentially.

Options

The following general command line options are available to **mpprun**. Also see the next section, which describes the **beomap** job map parameters.

-h, --help, -u, --usage Print the command usage message on `stdout` and exit. When one of these options is recognized in the option list, all following options will be ignored.

-V Print the command version number on `stdout` and exit. Any following options will be ignored.

-p, --prefix Prefix each line of output the node number.

You can influence the **mpprun** job map either by entering command line options or by setting environment variables. Following are the available command line options, together with their equivalent environment variables. Note that the command line options take precedence over the environment variables.

All the **mpprun** job map parameters listed below can also be used directly with **beorun** and **beomap**.

--all-cpus Create a process map consisting of all "up" nodes, with each node number repeated to represent the number of CPUs on that node. This parameter is not allowed in conjunction with the `--map` parameter.

--all-nodes Create a process map consisting of all "up" nodes, with one CPU mapped on each of the "up" nodes. This parameter is not allowed in conjunction with the `--map` parameter.

The equivalent environment variable is *ALL_NODES*.

--all-local Create a process map consisting entirely of master node entries. This option eliminates everything except node -1 from the pool of candidate node numbers, thus forcing the map to use node -1 (the master node) for everything.

The equivalent environment variable is *ALL_LOCAL*.

--no-local Exclude the master in the process map. This option is essentially a syntactic shortcut for including `-1` in the `--exclude nodelist` option. For MPI jobs, this option puts the "rank 0" job on a compute node instead of on the master node. This parameter is not allowed in conjunction with the `--map` parameter.

The equivalent environment variable is *NO_LOCAL*.

--exclude nodelist Build a process map that excludes listed nodes. The `nodelist` consists of a colon-delimited list. This parameter is not allowed in conjunction with the `--map` parameter.

The equivalent environment variable is *EXCLUDE=nodelist*.

--map nodelist Explicitly specify a process map consisting of a colon-delimited list of nodes. Each node in `nodelist` indicates where one process will be assigned. The number of entries in the job map implies the number of ranks in the job.

Listing a node more than once in the list will assign multiple processes to that node. Typically, this is done to assign one process to each processor (or core) on a node, but this can also be used to "oversubscribe", i.e., to assign more processes to a node than it has processors (or cores).

The equivalent environment variable is *BEOWULF_JOB_MAP=nodelist*.

--np num-processes Specify the number of processes to run. The **mpprun** command attempts to place one process per processor (or core), but will "oversubscribe" and assign multiple processes per processor (or core) if there are not enough individual processors or cores available. This parameter is not allowed in conjunction with the `--map` parameter.

The equivalent environment variable is *NP=num-processes*.

The environment variables have an order of priority. The *BEOWULF_JOB_MAP* variable acts as a "master override" for the other environment variables. If *BEOWULF_JOB_MAP* is not set, then the following priorities apply:

Three of the environment variables determine *how many ranks* to schedule in the map: (1) *ALL_CPUS*, (2) *ALL_NODES*, and (3) *NP*. If none of these are set explicitly by the user, then *NP=1* is the default.

Three of the environment variables determine *what node numbers* are candidates for being mapped: (1) *ALL_LOCAL*, (2) *NO_LOCAL*, and (3) *EXCLUDE*.

Note: it is improper to use *NO_LOCAL* and *ALL_LOCAL* together. If both are used, then *ALL_LOCAL* takes precedence.

Unrecognized options and invalid option formats are reported on `stderr` and the command exits with exit status 1 (invalid option) or 2 (no command specified or invalid command).

Examples

Run **uptime** on any two available cluster compute nodes.

```
[user@cluster user] $ mpprun --np 2 --no-local uptime
  11:05am  up 2 days, 11:16,  0 users,  load average: 0.05, 0.24, 0.65
  11:05am  up 2 days, 11:16,  0 users,  load average: 0.01, 0.07, 0.37
```

7.3 Scyld ClusterWare Maintenance Commands

This section of the *Reference Guide* describes the Scyld ClusterWare maintenance utilities. These commands can be used by the cluster administrator, and are not intended for use by the ordinary user.

7.3.1 beofdisk

Name

beofdisk – Query and modify hard drive partitions on compute nodes.

Synopsis

beofdisk [-h, –help] [-v, –version] [-q, –query] [-w, –write] [-d, –default] [-M, –mbr] [-n num, –node num]

Description

This script allows you to partition the hard drives on compute nodes.

When you query, it will create files in `/etc/beowulf/fdisk/`, one for each device/drive geometry it finds. These files can then be modified by hand, or with the defaults options, then written back to the hard drives.

Options

-h, --help Display a help message and exit.

-v, --version Display version information and exit.

-q, --query Queries the hard drives and writes their current partition tables into files in `/etc/beowulf/fdisk/`. If no `-n num` node is specified, then all nodes are queried.

-w, --write Matches the files in `/etc/beowulf/fdisk/` with the hard drives and changes the partition tables on the compute nodes to match what is in the files. If no -n num node is specified, then all nodes are written.

WARNING: This option is potentially dangerous. It modifies partition tables, and incorrect partition tables can cause problems.

-d, --default This will cause beofdisk to go through the files in `/etc/beowulf/fdisk/` and set them all to contain default partitioning schemes that include a beoboot partition, a swap partition, and the rest as `/`.

-M, --MBR Write a simple Master Boot Record to the hard drive that directs the BIOS to “boot next device” after each failure to boot. Typically, this ultimately results in a PXE boot. If no `-n num` node is specified, then all nodes are written with this new MBR.

-n num, --node num By default, the apply the specified operation to all nodes. Optionally, apply the operation only to node num.

Examples

Creating default partition schemes:

```
[root@cluster ~] # beofdisk -d
 Creating a default partition table for hda:2495:255:63
 Creating a default partition table for hda:1222:255:63
```

Writing the defaults to node 0’s hard drive:

```
[root@cluster ~] #  beofdisk -w -n 0

Disk /dev/hda: 2495 cylinders, 255 heads, 63 sectors/track
Old situation:
Units = cylinders of 8225280 bytes, blocks of 1024 bytes, counting from 0

   Device Boot Start     End   #cyls   #blocks   Id  System
/dev/hda1   *      0+      0       1-     8001   89  Unknown
/dev/hda2          1      32      32    257040   82  Linux swap
/dev/hda3         33    2494    2462  19776015   83  Linux
/dev/hda4          0       -       0         0    0  Empty
New situation:
Units = sectors of 512 bytes, counting from 0

   Device Boot    Start       End  #sectors  Id  System
/dev/hda1   *        63     16064     16002  89  Unknown
/dev/hda2         16065    546209    530145  82  Linux swap
/dev/hda3        546210  40082174  39535965  83  Linux
/dev/hda4             0         -         0   0  Empty
Successfully wrote the new partition table

Re-reading the partition table ...

If you created or changed a DOS partition, /dev/foo7, say, then use dd(1)
to zero the first 512 bytes:  dd if=/dev/zero of=/dev/foo7 bs=512 count=1
(See fdisk(8).)
```

```
Node partition tables have been modified.
You must reboot each affected node for changes to take effect.
```

Query the disks on the compute nodes to determine how they are partitioned:

```
[root@cluster ~] # beofdisk -q
```

The following creates a partition file in `/etc/beowulf/fdisk`, with a name similar to `sda:512:128:32` and containing lines similar to the following:

```
[root@cluster ~] # cat sda:512:128:32
 /dev/sda1  :  start=    32,  size=  8160,   id=89,  bootable
 /dev/sda2  :  start=    8192,   size=    1048576,  Id=82
 /dev/sda3  :  start=    1056768,    size=    1040384,  Id=83
 /dev/sda4  :  start=    0, size=  0,  Id=0
```

7.3.2 beorsync

Name

beorsync – Sync files between two servers in an HA configuration.

Synopsis

beorsync syncfiles

Description

beorsync is a perl script used to synchronize individual files and the contents of entire directories between master nodes in a High Availability master node failover environment.

The script has one required argument: `syncfiles`, which is the name of a file containing a list of files and directories to be synchronized.

beorsync expects to execute on the passive master node of a passive-active pair. Both the source and target nodes must be running heartbeat. The script pulls only those files that have changed on the active master node.

Diagnostic messages are logged to `/var/log/beorsync.log`.

Errors

If **beorsync** is invoked on the active master node, then the script exits with an error message.

Examples

A typical `syncfiles` contains the following list of files and directories to be synchronized:

```
/etc/hosts
/etc/resolv.conf
/etc/ntp.conf
/root/bin/
/var/spool/cron/
/etc/beowulf/
```

```
/etc/passwd
/etc/shadow
/etc/group
/etc/nsswitch.conf
/etc/exports
/etc/services
/etc/ha.d/haresources
/var/spool/torque/mom_priv/config
/var/spool/torque/server_priv/jobs/
/var/spool/torque/server_priv/serverdb
```

Commonly, a cron job should be set up that periodically executes the **beorsync** script. For example, the following cron entry executes the script every 5 minutes, syncing all of the files and directories listed in the syncfiles file named `/etc/beowulf/beorsyncfiles`:

```
*/5 * * * * beorsync /etc/beowulf/beorsyncfiles
```

7.3.3 beoserv

Name

beoserv – The daemon that serves IP addresses and boot files to compute nodes

Synopsis

beoserv [-h] [-V, –version] [-v] [-f file] [-n file]

Description

The **beoserv** daemon is started by the ClusterWare service and responds to to DHCP, PXEboot, TFTP, and TCP get-file requests from compute node clients. The daemon reports cluster events to `/var/log/messages`.

Options

-h, --help Display a help message and exit.

-V, --version Display version information and exit.

-v Increase verbosity level. Each additional 'v' increases verbosity.

-f file Read configuration from `file` instead of `/etc/beowulf/config`.

-n file Write unrecognized nodes to `file` instead of `/var/beowulf/unknown_addresses`.

Examples

Start daemon using file `myconfig`.

```
[root@cluster ~] # /usr/sbin/beoserv -f /etc/beowulf/myconfig
```

7.3.4 bpctl

Name

bpctl – Control the operational state and ownership of compute nodes.

Synopsis

bpctl [-h, –help] [-v, –version] [-f] [-M, –master] [-S num, –slave num] [-s state, –state state] [-m mode, –mode mode] [-u user, –user user] [-g group, –group group] [-H, –halt] [-P, –poweroff, –pwroff] [-R, –reboot] [-O, –orphan] [-C r2c-state, –completion r2c-state] [-I idle-threshold, –idle idle-threshold]

Description

This utility is part of the BProc package and is installed by default. It allows the root user to modify the state of the compute nodes. Compute nodes may be in one of eight states: down, boot, up, error, unavailable, reboot, halt, poweroff. The states are described as follows:

down No communication with compute node, and prior node state is unknown.

boot Node has initialized communication and started but not completed the node_up script. This state is not commandable. It is status information only.

up Node is communicating and has completed the node_up script without errors.

error Node is communicating and encountered an error while running the node_up script.

unavailable Node is communicating and the cluster administrator has marked the node as unavailable to non-root users.

reboot Node will do a software reboot. Node status will show reboot through start of machine shutdown until node_up script has begun.

halt Node has been commanded to halt. This command causes the node CPUs to execute the halt machine instruction. Once halted the node must be reset by external means to resume normal operations.

poweroff, pwroff Node will power off. This command is valid for nodes that meet the ATX specification. This command requires BIOS support. Non-ATX machines may reboot on this command.

Normally the node will transition from down to boot to up, and will remain up until commanded otherwise. up is the operational state for user programs. User BProc commands will be rejected if the node is not up.

BProc supports a simplified user and group compute node access scheme. Before any action is taken on a node, BProc checks if the user or group match. If either is matched the user action is processed. Note, normal file permissions are still in affect on each node. BProc permissions simply allow users to execute a program on a node. Root bypasses the check and always has access.

User and group changes made with **bpctl** remain in effect until the affected node(s) are restarted. After a restart, the user and group information is read from the /etc/beowulf/config file. For persistent changes, you must edit the config file. Changes to the config file take effect when you issue a ClusterWare service reload or you reboot the nodes via a restart. With reload, running jobs will not be affected unless they start a new process and are denied node access based on the permission changes.

Whenever the ClusterWare daemons are restarted, all nodes are initialized to the down state and node history is lost. When this occurs, previously communicating nodes will reboot and attempt to re-establish communication after the "ping timeout", which by default is 30 seconds.

Options

The following options are available to **bpctl**:

-h Print the command usage message and exit. If -h is the first option, all other options will be ignored. If -h is not the first option, the other options will be parsed up to the -h option, but no action will be taken.

-v Print the command version number and exit. If -v is the first option, all other options will be ignored. If -v is not the first option, the other options will be parsed up to the -v option, but no action will be taken.

-f Fast mode. Whenever possible, do not wait for acknowledgment from compute nodes.

-M Specifies that the remaining options apply to the master node.

-S num Specifies that the remaining options apply to the specified compute node. The num can range from 0 to the total number of nodes minus one.

-s state Set the node to the indicated state. Valid state values are `down`, `up`, `error`, `unavailable`, `reboot`, `halt`, or `pwroff`. Setting state to `down` causes the node to reboot due to a communications timeout after the "ping timeout" interval, which by default is 30 seconds.

-m mode Set the permission bits for the indicated node. Only the Execute mode bits are recognized, i.e., a logical or'ing of octal values 001, 010, and/or 100.

-u user Set the user id for the indicated node. Will reject invalid users. Numbers or strings may be used. A numeric user id will be converted to a name if the name is known.

-g group Set the group id for the indicated node. Will reject invalid groups. Numbers or strings may be used. A numeric group id will be converted to a names if the name is known.

-H, --halt Halt the indicated node.

-P, --poweroff, --pwroff Power off the indicated node.

-R, --reboot Reboot the indicated node.

-O, --orphan Direct the indicated node to become an immediate orphan.

-C r2c-state, --completion r2c-state Turn run-to-completion mode on or off for the nodes specified by `-S` num. Acceptable r2c-state values are `on` (an "orphaned" node stays up indefinitely, until manually rebooted), `off` (an "orphaned" node reboots immediately), or a positive number of seconds of "effectively idle" time that an orphaned node will wait until rebooting.

-I idle-threshold, --idle idle-threshold Override the default cpu usage percentage threshold that an "orphaned" compute node uses to determine whether or not the node is "effectively idle".

When a compute node becomes an "orphan" and the r2c-state specifies that the node reboot after the specified number of "effectively idle" seconds, BProc periodically determines how much cpu usage has occurred during the preceding interval (which is nominally 10 seconds). If the cpu usage is above the idle-threshold percentage, then the time-until-reboot is reset back to r2c-state seconds. The idle-threshold value must be a positive numeric value, and it may be an integer or a floating-point number. A too-low value means BProc will mistakenly interpret trivial amounts of cpu usage (e.g., executed by daemons that wake up and check for work) as being significant, and thus the node may never reboot. A too-high value means BProc will mistakenly interpret significant cpu usage as being insignificant, and thus the node may reboot while a low-usage process is doing important work.

Examples

This command will cause all nodes to reboot:

```
[root@cluster ~] # bpctl -S all -s reboot
```

This command returns an error, because boot is not commandable:

```
[root@cluster ~] # bpctl -S 4 -s boot
 Non-commandable node state: boot
```

The following sets nodes 3 and 4 ownership to user “foo”, which must be a valid user:

```
[root@cluster ~] # bpctl -S 3-4 -u foo
```

The following sets permission on the master node to allow only user root to execute on the master node, e.g., to disallow a non-root user to execute on a compute node and **bpsh** a command to execute on the master:

```
[root@cluster ~] # bpctl -M -m 100
```

And this resets permission on the master node to allow any user to execute on the master node:

```
[root@cluster ~] # bpctl -M -m 111
```

This command resets the run-to-completion timeout to five minutes, and sets the “effectively idle” cpu usage percent to 1.5%:

```
[root@cluster ~] # bpctl -C 300 -I 1.5
```

Return Values

Upon successful completion, **bpctl** returns 0. On failure, an error message is printed to `stderr` and **bpctl** returns 1.

7.3.5 bplib

Name

bplib – manages the VMAdump in-kernel library list and individual file list of cached files .

Synopsis

bplib [-h, –help] [-v, –version] [-c] [-l] [-a [libs...]] [-d [libs...]]

Description

This utility is part of the `BProc` package and is installed by default. It is used to modify entries of the in-kernel cache list

Options

The following options are available to the **bplib** program.

-h Print the command usage message and exits success.

-v Print the command version number and exits success.

-c Clears ALL cached entries in the in-kernel cache list

-a libs Adds the specified file or directory to the in-kernel cache list

-d lib Deletes the specified file or directory to the in-kernel cache list

-l Lists all entries known by the in-kernel cache list

7.3.6 bpmaster

Name

bpmaster – Daemon for cluster control and communication.

Synopsis

bpmaster [options] [-h] [-V] [-d] [-v] [-i] [-c file] [-m file]

Description

This daemon is part of the `BProc` package and is installed by default. It is the controller and message/IO manager for all the compute nodes and must be running for the cluster to function.

bpmaster is started by the ClusterWare initialization script, along with other `BProc` daemons, and forks a copy of itself for IO forwarding. With normal cluster operation there should be 2 PIDs for **bpmaster**. Type **ps -x |grep bpmaster** to check.

The **bpmaster** daemon may be restarted at any time by using a ClusterWare service `restart`, but note that this will cause all nodes to reboot. During normal operations, use a service `reload` to enable `/etc/beowulf/config` configuration changes. The daemon reports cluster events to `/var/log/messages`.

Options

The following options are available to the **bpmaster** program.

-h Print the command usage message and exit. If `-h` is the first option, all other options will be ignored. If `-h` is not the first option, the other options will be parsed up to the `-h` option, but no action will be taken.

-V Print the command version number and exit. If `-v` is the first option, all other options will be ignored. If `-v` is not the first option, the other options will be parsed up to the `-v` option, but no action will be taken.

-d Start the program in debug (verbose) mode. **bpmaster** will not daemonize, and all information and error messages will go to `stdout`. This information is useful when the daemon exits abnormally during operation as the information is not mixed in with the normal `/var/log/messages`.

-v Increase verbosity level. This may be specified multiple times.

-i Ignore interface version mismatch. This can be dangerous.

-c file Specifies a different configuration file is to be used. The default is set to `/etc/beowulf/config`. This option is for debug and development. This option is not recommended for normal use.

-m file Log master and node `BProc` messages to the indicated file. This information is intended for `BProc` debugging, and should not be enabled unless requested by a Scyld support engineer. This file grows in size rapidly depending of the number of nodes, approximately 2 megabytes/minute with six nodes.

Examples

Don't start as daemon.

```
[root@cluster ~] # bpmaster -d
```

Start the daemon using the startup script.

```
[root@cluster ~] # service beowulf start
 Configuring network interface (eth1):                      [  OK  ]
 Loading modules:                                           [  OK  ]
 Setting up libraries:                                      [  OK  ]
 Starting bpmaster:
 Starting beoserv:
 Starting recvstats:
 Starting sendstats:
```

7.3.7 bpslave

Name

bpslave – This program is the BProc distributed process space slave daemon that executes on each compute node.

Synopsis

bpslave [options] [-h] [-V] [-l logfacility] [-r] [-i] [-d] [-s addr] [-c dir] [-p port] [-m file] [-v]

Description

The **bpslave** daemon is part of the `BProc` package, and is installed by default. It is the controller and message and I/O manager run on each compute node, and must be running for the node to function.

bpslave is started by the Scyld compute node init process, which sets parameters based on what is passed in through the kernel command line option in the `/etc/beowulf/config` file. All parameters of the **bpslave** daemon are not accessible via the "kernelcommandline" keyword in `/etc/beowulf/config`.

The **bpslave** daemon is not intended to be run from the command line, nor otherwise executed started, except implicitly by the compute node init process.

Options

The following options are available to the **bpslave** program. These options are mainly intended for using `BProc` in a standard linux environment where the master and compute nodes both have full system installs.

-h Show this message and exit. If `-h` is the first option, all other options will be ignored. If `-h` is not the first option, the other options will be parsed up to the `-h` option, but no action will be taken.

-V Print version information and exit.

-l logfacility Log to this log facility (default=daemon).

-r Automatic reconnect on error or lost connection.

-i Ignore `BProc` version mismatches (dangerous).

-d Do not daemonize self.

-s addr Connect from source address `addr`.

-c dir Set library cache to `dir`.

-p port Set library cache file request port to `port`. The default is port 932, which can be overridden by a config file directive `server beofs2`.

Debugging options:

-m file Enable message trace to `file`.

-v Increase verbose level (implies `-d`).

Masterhostname [[port]] The host name and (optionally) the port number of the **bpmaster** daemon. The default is port 933, which can be overridden by a config file directive `server bproc`.

7.3.8 node_down

Name

node_down – Bring a compute node down cleanly.

Synopsis

/usr/lib/beoboot/bin/node_down node [state]

Description

This script can be used to bring a node down ("reboot", "halt", "pwroff") in such a way that the local filesystems on the compute node remain in a constant state.

node_down works by first changing the node's state to "unavailable", then remounting all of the filesystems read-only, followed by using **bpctl** to perform the actual state change you requested.

Options

node The node number of the node to bring down.

state The state to put the node in after remounting all the filesystems. The state defaults to "reboot" if unspecified.

Examples

Cleanly bringing down node 3:

```
[root@cluster ~] #  /usr/lib/beoboot/bin/node_down 3
 Remounting / readonly...
 Remounting /proc readonly...
 Remounting /home readonly...
 Remounting /dev/pts readonly...
 Syncing disks on node 3.
 Shutting down node 3 (reboot)
```

7.3.9 recvstats

Name

recvstats – master node daemon that receives status messages from compute nodes

Synopsis

recvstats [-p port] [-N initial-max-num-nodes] [-f]

Description

The **recvstats** daemon is part of the `beostat` package. It executes on the master node, receives periodic per-node status data sent by each cluster node's **sendstats** daemon, and makes the data available to various commands and services on the master node.

The **recvstats** daemon parses the received data to ensure basic validity. The exact content and format of the **sendstats** messages is version specific, though it typically includes a unique node number identifying the sender, plus the dynamic values of the following `proc` file system files: `/proc/cpuinfo`, `/proc/meminfo`, `/proc/loadavg`, `/proc/net/dev`, and `/proc/stat`.

The **recvstats** daemon stores the incoming data in shared memory in the `/dev/shm` filesystem, which should be readable by everyone. If that filesystem doesn't exist or the file permissions are not set correctly, then **recvstats** and the consumers of that data will not function correctly. Note: most consumers of this **recvstats** data access it using various commands (e.g., `beostat(1)`, `beostatus(1)`, `ganglia`, `Scyld IMF`) or use the `libbeostat` abstracted library interface.

The **recvstats** daemon is started by the ClusterWare service, and the **sendstats** daemon is started for BProc nodes by the node initialization script `/etc/beowulf/init.d/13sendstats`.

Options

The following options are available to the **recvstats** daemon.

-p port Override the default listen port of 5545. Only use this option if there is a conflict with the default port, and use the same non-default port when executing **sendstats** on each cluster node.

-N initial-max-num-nodes Start **recvstats** with an explicit non-default guess about how many cluster nodes will be sending data. If a node number above this initial maximum sends data, then **recvstats** dynamically expands the shared memory structure to accommodate it.

Examples

Start the **recvstats** daemon on the master node:

```
[root@cluster ~] # /usr/bin/recvstats -p 5545 -N `beoconfig nodes`
```

7.3.10 sendstats

Name

sendstats – compute node daemon that sends node status to the master node

Synopsis

sendstats [-h] [nodenumber] [IPaddress[:port] ...]

Description

The **sendstats** daemon is part of the beostat package. Typically, the daemon executes on each node in the cluster and periodically transmits status data to a **recvstats** daemon that executes on the master node. In a cluster with multiple master nodes, **sendstats** typically sends status data to every master node.

The optional nodenumber is unnecessary for normal uses of **sendstats**. The **recvstats** daemon is normally able to discern the sender's node number from the sender's IP address. If nodenumber is specified, then it must be seen by the receiving **recvstats** as being unique to one and only one sending node in the cluster.

The exact content and format of the **sendstats** messages is version specific, though it typically includes a unique identifying nodenumber plus the dynamic values of the following proc file system files: /proc/cpuinfo, /proc/meminfo, /proc/loadavg, /proc/net/dev, and /proc/stat.

The port number is optional, defaulting to port 5545. In the event of a collision with another preexisting service, which would typically be defined in /etc/services, you must override the default. Choose a new value that is not currently employed on the system, then add a server beostats `` directive to ``/etc/beowulf/config.

The **recvstats** daemon is started by the ClusterWare service, and the **sendstats** daemon is started for BProc nodes by the node initialization script /etc/beowulf/init.d/13sendstats.

The **sendstats** daemon may be used on machines outside of the BProc cluster management domain. In any case, the port number must match the port on which **recvstats** listens.

Examples

Start the daemon on ClusterWare node n0, sending stats to the master at 10.20.30.1 using the default port:

```
[root@cluster ~] # bpsh 0 /usr/sbin/sendstats 10.20.30.1
```

Start the daemon on ClusterWare node n0, sending stats to the master at 10.20.30.1 and a second master at 10.20.30.2, using a non-default port:

```
[root@c ~] # bpsh 0 /usr/sbin/sendstats 10.20.30.1:939 10.20.30.2:939
```

Start the daemon on a non-ClusterWare node n1, using the default port:

```
[root@c ~] # ssh n1 /usr/sbin/sendstats 10.20.30.1:5545
```

7.4 Scyld ClusterWare Special Files

This section of the *Reference Guide* describes `/etc/beowulf/config` and `/etc/beowulf/fstab`, the configuration files that are used by the Scyld ClusterWare system.

7.4.1 beowulf-config

Name

/etc/beowulf/config – Scyld ClusterWare Configuration file

Description

The Beowulf config file `/etc/beowulf/config` defines the structure of a Scyld ClusterWare cluster and provides a central location for many of the operational parameters. The file contains the settings for `beoboot`, node initialization, `BProc` communication parameters, and other aspects of cluster operation.

The syntax of the ClusterWare configuration files is standardized and is intended for human editing with embedded comments. Tools are provided for reading and writing from common programming and scripting languages, with writing retaining comments and formatting.

> **Tip**
>
> Care must be taken when editing or otherwise modifying `/etc/beowulf/config`, e.g., avoid editing while new compute nodes are coming online and ClusterWare itself is adding or modifying ‘node’ lines. Also note that incorrect editing may leave the cluster unuseable.

Config File Format

The config file is a line-oriented sequence of configuration entries. Each configuration entry starts with a keyword followed by parameters. A line is terminated by a newline or ‘#’. The latter character starts a comment.

The keyword and following parameters have the same syntax rules: they may be preceded by whitespace and continue to the next whitespace or the end of the line.

Keywords and following parameters may include whitespace by quoting between a matching pair of “”” (double quote) or “’” (single quote) characters. A ‘\’ (backslash) removes the special meaning of the following quote character.

Note that comments and newlines take precedence over any other processing, thus a ‘#’ may not be used in a keyword or embedded in a parameter, and a backslash followed by a newline does not join lines.

Each configuration option is contained on a single line, with a keyword and optional parameters. Blank lines are ignored. Comments begin with an unquoted ‘#’ and continue to the end of the line.

Keywords

bootmodule modulename The `bootmodule` keyword specifies that the kernel binary module modulename be included in the compute nodes’ initrd image. These are typically network drivers needed to fully initialize a booting node. At node startup, the `beoclient` daemon on a compute node scans the node’s `/proc/bus/pci/devices` list and automatically executes a `modprobe` for every modulename driver named by a PCI device so discovered. However, note that if the PCI scan does not find a need for a particular driver, then no automatic modprobe occurs. Add an additional modprobe keyword to forcibly load the modulename.

firmware firmfile The firmware keyword specifies that the firmfile file, which typically resides on the master node in /lib/firmware/firmfile, be included in the compute nodes' initrd image, if known to be needed by a particular bootmodule modulename. Adding one or more firmware keywords significantly increases the size of the initrd image. See the Administrator's Guide for details.

fsck fsck-policy The fsck keyword specifies the file system checking policy to be used at node boot time. The valid policies are "never", "safe" or "full".

never The file system on the compute nodes will not be checked on boot.

safe The file system on the compute nodes will go through a safe check every time the compute node boots.

full The file system on the compute nodes will go through a full check every time the compute node boots. The full check might possibly remove files from the filesystem if they cannot be repaired.

host MACaddress IPaddress [hostname(s)] The host keyword assigns an IP addresses to a specific client device identified by its MAC address, if and when that client makes a DHCP request to the master. The IP addresses must be in dotted notation (e.g., 192.168.1.100), and it must be within the range of one of the hostrange IP address ranges. These host clients are not Scyld nodes, which are identified by node keywords and are assigned IP addresses from the iprange range. Rather, typically they are devices like smart Ethernet switches that connect to the cluster private network and issue a DHCP request to obtain an IP address. Up to six optional hostname names may be assigned to a client, and these names are recognized by the Beo NSS service.

hostrange [name] IPaddress-lwb IPaddress-upb The hostrange is used in conjunction with the host keyword. It declares a range of IP addresses that may later be used for host clients doing DHCP requests. An optional name] may be associated with this range. Multiple hostrange keywords may be present.

ignore MACaddress The ignore keyword specifies a MAC address (e.g., 00:11:22:AA:BB:CC) that beoserv should ignore DHCP and PXE requests from. Multiple ignore keywords are allowed.

initrdimage [noderange] imagename The initrdimage keyword specifies the full path to the initrd image that should be used when creating the final boot images for the compute nodes. If noderange is specified, then this imagename applies only to the specified range of nodes; otherwise, imagename applies to all nodes.

insmod module-name [options] The insmod keyword specifies a kernel module to be loaded (usually a network driver). Options for the module may be specified as well.

interface interfacename The interface keyword specifies the name of the interface that connects the master node to the compute nodes. This is used by the cluster services and management tools such as the bpmaster daemon and the beoserv daemon. Common values are "eth0" or "eth1". If present, entries after the interface name specify the IP address and netmask that the interface should be configured to.

iprange [nodenumber] IPaddress1 IPaddress2 The iprange keyword specifies the range of IP addresses to be assigned to nodes. If the optional nodenumber is given, the first address in the range will be assigned to that node, the second address to the next node, etc. If no node number is given, the address assignment will begin with the node following the node that was last assigned. If no nodes have been assigned, the assignment will begin with node 0.

kernelcommandline [noderange] options The kernelcommandline keyword specifies any options you wish to have passed to the kernel on the compute nodes. These are the same options that are normally passed with "append=" in lilo, or on the lilo prompt while the machine is booting (e.g., "kernelcommandline apm=poweroff"). If noderange is specified, then these options apply only to the specified range of nodes; otherwise, options apply to all nodes.

kernelimage [noderange] imagename The kernelimage keyword specifies the full path to the kernel that should be used when creating the final boot images for the compute nodes. If noderange is specified, then this imagename applies only to the specified range of nodes; otherwise, imagename applies to all nodes.

libraries librarypath1 [, librarypath2, ...] The `libraries` keyword specifies a list of libraries that should be cached on the compute nodes when an application on the node references the library. The library path can be a directory or file. If a file name is specified, then that specific file may be cached, if needed. If a directory name is specified, then every file in that directory may be cached. If the directory name ends with "/", then subdirectories under the specified directory may be cached.

logfacility facility The `logfacility` keyword specifies the log facility that the `BProc` master daemon should use. Some example log facility names are "daemon", "syslog", and "local0" (see the `syslog` documentation for more information). The default log facility is "daemon".

masterdelay SECS The `masterdelay` keyword specifies the timeout value in seconds for a non-primary master node to delay sending a response to an incoming dhcp request. The default value is 15 seconds.

masterorder nodes IPaddress_primary IPaddress_secondary The `masterorder` keyword specifies the cluster IP addresses of the primary master node and the secondary master node(s) for a given set of nodes. This is used by the `beoserv` daemon for Master-Failover (cold reparenting). A compute node's PXE request broadcasts across the cluster network. The primary master node is given `masterpxedelay` seconds to respond, after which the first secondary master node will respond. If multiple secondary master nodes are specified, then each waits in turn for `masterpxedelay` seconds for a preferred master to respond. Similarly, the compute node's subsequent DHCP broadcast gets serviced in the same order, with each secondary master waiting `masterdelay` seconds for a preferred master to respond.

Example:

```
masterorder 0,5,10-20 10.1.0.1 10.2.0.1
masterorder 1-4,21-30 10.2.0.1 10.1.0.1
```

If master 10.1.0.1 is down or fails to respond to PXE/DHCP requests to compute node 10, then master 10.2.0.1 becomes the primary parent for compute node 10.

masterpxedelay SECS The `masterpxedelay` keyword specifies the timeout value in seconds for a non-primary master node to delay sending a response to an incoming PXE request. The default value is 5 seconds.

mcastbcast interface The `mcastbcast` keyword directs the `beoserv` daemon to use broadcast instead of multicast when transmitting files over the interface. This is useful when network equipment has trouble with heavy multicast traffic.

mcastthrottle interface rate The `mcastthrottle` keyword controls the rate at which data is transmitted over the specified interface. The rate is given in megabits per second. This is useful when the compute node interfaces cannot keep up with the master interface when sending large files.

mkfs mkfs-policy The `mkfs` keyword specifies the policy to use when building a Linux file system on the compute nodes. The valid policies are "never", "if_needed", or "always".

never The filesystem on the compute nodes will never be recreated on boot.

if_needed The filesystem on the compute nodes will only be recreated if the filesystem check fails.

always The filesystem on the compute nodes will be recreated on every boot. `fsck` will be assumed to be set to "never" when this is set.

modarg options The `modarg` keyword specifies options to be used for modules that are loaded during the boot process without options. This is useful for specifying options to modules that get loaded during the PCI scan.

moddep module-list The `moddep` keyword is used to specify module dependencies. The first module listed is dependent on the remaining modules in the space separated list. The first module will be loaded after all other listed modules. Module dependency information is normally automatically generated by the `beoboot` script.

modprobe modulename [options] The `modprobe` keyword specifies the name of the kernel module to be loaded with dependency checking, along with any specified module options. Note that the modulename must also be named by a `bootmodule` keyword.

node [nodenumber] MACaddress The node keyword is used to assign MAC addresses to node numbers. There should be one of these lines for each node in your cluster. Note the following:

- If a value is not provided for the nodenumber argument, the first node entry is node 0, the second is node 1, the third is node 2, etc.
- The value "off" can be used for the MACaddress argument to leave a place holder for that node number.
- To skip a node number, use the value "node" or "node off" for the MACaddress argument.
- To skip a node number and make sure it will never be automatically filled in by something later in the future, use the value "node reserved" for the MACaddress argument.

nodeacceses [-M | -S nodenumber | all] arglist The nodeaccess keyword overrides the default access permissions for the master node (-M), for all compute nodes (all), or for a specific compute node (nodenumber). The remaining arglist is passed directly to the bpctl command for parsing and execution. See the Administrator's Guide for details about node access permissions.

Example:

```
nodeaccess -M -m 0110
nodeaccess -S 5 -g physics
nodeaccess -S 6 -g physics
```

nodeassign nodeassign-method The nodeassign keyword specifies the node assignment strategy used when the beoserv daemon receives a new, unknown MAC address from a computer that is not currently entered in the node database. The total number of entries in the node database is limited to the number specified with the nodes keyword (see above).

The valid node assignment methods are "append", "insert", "manual", or "locked". Note the following:

- "Append" and "insert" are the only two choices that allow new nodes to be automatically given node numbers and welcomed into the cluster.
- Any failures of automatic node assignment through "append" or "insert" (such as when the node table is full) will cause the node assignment to be treated as "manual".

append This is the default setting. The system will append new MAC addresses to the end of the node list in the /etc/beowulf/config file. This is done by seeking out the highest already-assigned node number and attempting to go one number beyond it. If the highest node number in the cluster has already been assigned, the "append" method will fail and the "manual" method will take precedence.

insert The system will insert new MAC addresses into the node list in the /etc/beowulf/config file, starting with the lowest vacant node number. If no spaces are available, the "append" method will be used instead. Typically, a user would choose "insert" when replacing a single node if they want the new node entry to appear in the same place as the old node entry. If the node table is full, the "insert" method will fail and the "manual" method will take precedence.

manual The system will enter new MAC addresses in the /var/beowulf/unknown_addresses file, and require the user to manually assign the new nodes. The node entries will appear in the "Unknown" list in the BeoSetup GUI, which simplifies the node assignment process. An alternative to using the BeoSetup GUI is to manually edit the /etc/beowulf/config file and copy in the new MAC addresses from the /var/beowulf/unknown_addresses file.

locked The system will ignore DHCP requests from any MAC addresses not already listed in the /etc/beowulf/config file. This prevents nodes from getting added to the cluster accidentally. This is particularly useful in a cluster with multiple masters, because it enables the Cluster Administrator to control which master responds to a new node request. When you are troubleshooting issues related to the cluster not "seeing" new nodes, one of the first things to check is whether nodeassign is set to "locked".

See the Administrator's Guide for additional information on configuring nodes with the BeoSetup GUI and on manual node configuration.

nodename name-format [IPv4 Offset or Base] [netgroup] The `nodename` keyword defines the primary hostname, as well as additional hostname-aliases for compute nodes. It can also be used to define hostnames and hostname-aliases for non-compute node entities with a per compute node relationship (e.g., to define a hostname and IP address for the IPMI management interface on each compute node). The presence of the (optional) IPv4 parameter determines if the entry is for compute nodes or for non-compute node entities. If no 'nodename' keyword is defined for compute nodes, then compute nodes' primary hostname is of the 'dot-number' format (e.g., node 10's primary hostname is '.10').

name-format Define a hostname or hostname-alias. The first instance of the nodename keyword with no IPv4 parameter defines the primary hostname format for compute nodes. While the user may define the primary hostname, the FIRST hostname alias shall always be of the 'dot-number' format. This allows compute nodes to always resolve their address from the 'dot-number' notation. Additional nodename entries without an IPv4 parameter define additional hostname aliases.

The name-format string must contain a conversion specification for node number substitution. The conversion specification is introduced by a percent sign (the '%' symbol). An optional following digit in the range 1..5 specifies a zero-padded minimum field width. The specification is completed with an 'N'. An unspecified or zero field width allows numeric interpretation to match compute node host names. For example, "n%N" will match "n23", "n+23", and "n0000023". By contrast, "n%3N" will only match "n001" or "n023", but not "n1" or "n23".

IPv4 Offset or Base The presence of the optional IPv4 argument defines if the entry is for "compute nodes" (i.e. the entry will resolve to the 'dot-number' name) or if the entry is for non-cluster entities that are loosely associated with the compute node. If the argument has a leading zero, then the parameter specifies an IPv4 Offset. If the argument does not lead with a zero, then the argument specifies a 'base' from which IP addresses are computed, by adding the 'node-number' associated with the non-compute node entity.

Netgroup The netgroup parameter specifies a netgroup that contains all the entries generated by the nodename entry

nodes numnodes The `nodes` keyword specifies the total possible number of nodes in the cluster. This should normally be set to match the `iprange`. However, if multiple `ipranges` are specified, then this value should represent the total number of nodes in all the `iprange` entries.

pingtimeout SECS The `bpmaster` daemon that executes on the master node sends periodic "ping" messages to the `bpslave` daemon that executes on each compute node, and each bpslave dutifully responds. This interaction serves as mutual bpmasterbpslave assurance that the other daemon and the network link is still alive and well. If bpslave does not see this "ping" message for SECS seconds, then the bpslave goes into "orphan mode". If run-to-completion is enabled (see the Administrator's Guide for details), then the node attempts to remain alive and functioning, despite its apparent inability to communicate with the master node. If run-to-completion is not enabled (which is the default), then the node reboots immediately. If bpmaster does not see a ping reply for SECS seconds, then it syslogs this event and breaks its side of the network connection to the compute node.

The default `pingtimeout` value is 32 seconds. In rare cases, a particular workload may trigger such a "ping timeout" and its associated spontaneous reboot, and using a `pingtimeout` keyword to increase the timeout value may stop the spontaneous rebooting.

pci vendorid deviceid drivername The `pci` keyword specifies what driver should be used in support of the specified PCI device. A device is identified by a unique vendor ID and device ID pair. The vendor and device ID's can be either in decimal or hexadecimal with the "0x" notation. You should have one of these lines for each PCI ID (a vendor ID combined with a device ID) for each device on your compute nodes that is not already recognized. Any module dependencies or arguments should be specified with `moddep` and `modarg`.

prestage pathname The `prestage` keyword names a specific file that each compute node pulls from the master at node boot time. Multiple instances of `prestage` can be used. If the pathname is a file in one of the `libraries` directories, then the pathname gets pulled into the compute node's library cache. Otherwise, the file (and its directory hierarchy) is copied from the master to the compute nodes.

server transport-protocol port The `server` keyword specifies the port numbers that ClusterWare uses for specified transport protocols. Each transport protocol uses a unique default port number. In the event that a default port value conflicts with a port number used by another service (typically, specified in `/etc/services`), a `server` keyword must specify an override value. The allowable transport-protocol keywords are “beofs2” (default port 932), “bproc” (default port 933), “beonss” (default port 3045), and “beostats” (default port 5545). (The keyword “tcp” is deprecated - use “beofs2” instead.)

Examples

```
iprange 192.168.1.0 192.168.1.50
nodename ipmi-n%N 0.0.1.0
```

In the above example, the hostname “ipmi-n0” has an address of 192.168.2.50. That is, the compute node’s address (192.168.1.50 for compute node 0) plus the IPv4 Offset of 0.0.1.0. The hostname “ipmi-n12” has an address of 192.168.2.12, which is compute node 12’s address plus the IPv4 Offset of 0.0.1.0.

```
nodename ib0-n%N 0.1.0.0 infiniband
```

In the above example, define a hostname for the infiniband interface for each compute node. Using the `iprange` values in the previous example, the infiniband interface for compute node 0 has a primary hostname of “ib-n0” and resolves to the address 192.169.1.0: node 0’s basic `iprange` IP address, plus the increment 0.1.0.0. The infiniband interface for compute node 10 has a primary hostname of “ib-n10” and resolves to the address 192.169.1.10. Each of the “ib0-n%N” hostnames belong to the “infiniband” netgroup.

```
nodename computenode%N
nodename cnode%3N
```

In the above example, the primary hostname for compute node 0 is “computenode0”, and the primary hostname for compute node 12 is “computenode12”. The second nodename entry defines additional hostname aliases. The FIRST hostname alias will always be the ‘dot-number’ notation, so compute node 12’s first hostname alias is ”.12”, and the second hostname alias will be “cnode012”. The ‘%’ followed by a three specifies a three-digit field width format for the entry.

The following is an example of a complete Beowulf Configuration File

```
# Beowulf Configuration file

# Network interface used for Beowulf
# Only first argument to interface is important
interface eth1 192.168.1.1 255.255.255.1

# These two should probably agree for most users
iprange 192.168.1.100 192.168.1.107
nodes 8

# Default location of boot images
bootfile /var/beowulf/boot.img
kernelimage /boot/vmlinuz-2.4.17-0.18.12.beo
kernelcommandline apm=power-off

# Default libraries
libraries /lib /usr/lib

# Default file system policies.
fsck full
mkfs if_needed
```

```
# beoserv settings
server beofs2 932

# Default Modules
bootmodule 3c59x 8139too dmfe eepro100 epic100 hp100 natsemi
bootmodule ne2k-pci pcnet32 sis900 starfire sundance tlan
bootmodule tulip via-rhine winbond-840 yellowfin

# Non-kernel integrated drivers
bootmodule e100 bcm5700 # gm

# Node assignment method
nodeassign append

# PCI Gigabit Ethernet.
#  * AceNIC and SysKonnect firmwares are very large.
#  * Some of these are distributed separate from the kernel
bootmodule dl2k hamachi e1000 ns83820 # acenic sk98lin

node 00:50:8B:D3:25:4D
node 00:50:8B:D3:07:8B
ignore 00:50:8B:D3:31:FB
node 00:50:8B:D3:62:A0
node 00:50:8B:D3:00:66
node 00:50:8B:D3:30:42
node 00:50:8B:D3:98:EA
```

7.4.2 beowulf-fstab

Name

/etc/beowulf/fstab – ClusterWare compute node filesystem control table

Description

The /etc/beowulf/fstab file on the master node contains a list of filesystems to be mounted on compute nodes at boot time. Its purpose, format, and contents are similar to the traditional /etc/fstab, plus a few additional cluster-specific features.

The ClusterWare fstab system is designed to keep all configuration information on a master node. The /etc/beowulf/fstab file is the default for all compute nodes. Any optional node-specific /etc/beowulf/fstab.*N* file overrides this default file for node number *N*.

The root filesystem on each compute node is a tmpfs filesystem that is automatically sized for the available RAM. In earlier versions of Scyld ClusterWare, this root filesystem was explicitly declared in fstab, but this is no longer done.

The compute node's root filesystem is used to dynamically cache binaries and libraries from the master, to provide space for /tmp and /var/tmp, to provide mountpoints for NFS mounts, etc. Although ClusterWare does not require a harddrive on a Scyld compute node, some clusters employ harddrive(s) for node-local persistent storage, for "scratch" storage to avoid having /tmp and /var/tmp consume tmpfs RAM, or for swap space to expand the available virtual memory space and thus reduce Out-of-Memory conditions.

The ClusterWare fstab interacts with the *mkfs* and *fsck* directives in the /etc/beowulf/config file (see man beowulf-config) to control automatic creation or boot-time checking (and potentially repairing) of compute node filesystems on node-local harddrives.

A directive *mkfs always* specifies to rebuild at boot time every harddrive partition specified in /etc/beowulf/fstab, and thus should be used with *great* care so as to not automatically rebuild a partition and thus destroy data that is expected to survive across compute node reboots. Normally the default directive *mkfs never* is used.

A directive *fsck full* specifies to check and potentially repair at boot time every harddrive partition. Alternatively, *fsck safe* specifies to perform an fsck, but to not attempt any repairs; after boot, the cluster administrator may manually perform repairs as needed. A directive *fsck never* is the default, which specifies that no checking be done at boot time.

Syntax

The syntax and layout is identical to the master node's /etc/fstab file. The file contents are processed line by line. All blank lines and lines that begin with a "#" are ignored. All other lines should have six fields, separated by tabs or spaces.

The first field is the device to mount. For filesystems on local harddrives, this should point to a /dev entry, such as /dev/hda2. If mounting an NFS filesystem, the device should be specified as hostname:directory, where hostname is the IP address of the NFS server, and directory is the path on the NFS server you want to mount. If the NFS server is the master node, you can use "$MASTER" as the hostname. Currently, hostname cannot be an actual alphanumeric host name because /etc/beowulf/fstab is evaluated at boot time before the compute node's name service is initialized. For some special filesystems, such as proc and devpts, the hostname can be set to "none".

The second field is the mount point. For a swap partition, this should be "swap", but for all other filesystems, this must be a path that begins with "/". Any paths that you specify as mount points will be automatically created by the node_up script before it tries to mount the filesystem. Ensure that you do not specify the same mount point on more than one line, because this can cause problems. You can have multiple lines that use "swap" as the mount point, but that is the only exception to the rule.

The third field is the filesystem type. This should be "swap" for swap partitions, or a standard Linux filesystem type (e.g., "ext2", "ext3", "xfs"), or "nfs" for an NFS file system, or particular pseudo filesystem types (e.g., "proc" for the proc filesystem, "devpts" for the devpts filesystem). Any filesystem that can normally be used by Linux can also be specified here, but you must also take steps to create the harddrive filesystems on the compute nodes before attempting to mount them.

The fourth field lists the mount options for the filesystem. All options should be comma-separated with no spaces. If you do not know of any specific options to use, then you should use the "defaults" keyword.

In addition to the mount options normally supported by Linux, one additional option is supported by ClusterWare: "nonfatal". Normally, any mount failure results in an immediate abort of the node boot, and the node state transitions from "boot" to "error". Adding "nonfatal" to the options overrides this behavior and allows the node boot to continue, potentially to a node "up" state. However, because filesystem mounts have in fact failed, the node may not actually have full functionality. When using the "nonfatal" option, the cluster administrator is encouraged to view the ClusterWare boot log files found in directory /var/log/beowulf/ to discover potential mount failures and other warnings or soft error conditions. The "nonfatal" option is useful for harddrive filesystems when not all compute nodes share the same number and partitioning of drives, or when NFS mounts might fail because an NFS server is temporarily unavailable or the specified filesystem is not currently exported.

The fifth and sixth fields are left there for compatibility with the standard fstab format. These fields are not used at the moment, but are required to be there. We recommend they both be set to "0".

Examples

```
# This file is the fstab for nodes.
# One difference is that we allow for shell variable expansions...
#
# Variables that will get substituted:
```

```
#  MASTER = IP address of the master node.  (good for doing NFS mounts)

# This is the default setup from beofdisk, once you setup your disks.
#/dev/hda2  swap        swap    defaults,nonfatal   0 0
#/dev/hda3  /       ext2    defaults,nonfatal   0 0

# These should always be added
none        /proc       proc    defaults    0 0
none        /dev/pts    devpts  gid=5,mode=620  0 0

# NFS (for example and default friendliness)
$MASTER:/home   /home       nfs nolock,nonfatal     0 0
```

Files

/etc/beowulf/fstab, /etc/beowulf/fstab., /etc/beowulf/config

7.4.3 beowulf-nsswitch.conf

Name

/etc/beowulf/conf.d/nsswitch.conf – NSS config file for compute nodes

Description

The Linux Name Service Switch (NSS) is configured by the /etc/nsswitch.conf file, which describes what *sources* the Name Service uses to resolve queries for each *database* category. For example, simple nsswitch.conf entries are:

```
passwd: files
group:  files
hosts:  files dns
```

A query for a user password uses the *passwd* database, which informs the Name Service to search the file /etc/passwd. A query for a group name uses the *group* database, searching /etc/group. A query for a host name uses the *hosts* database, first searching /etc/hosts, and then if that fails to find the name, then using /lib64/libnss_dns.so to query the DNS server.

The Scyld ClusterWare *beonss* package enhances the Name Service to provide consistent naming across the cluster.

Installing the *beonss* package modifies the master's /etc/nsswitch.conf, adding "beo" and "bproc" sources to various *database* categories. For example, for the *hosts* database, the "beo" source uses functionality in /lib64/libnss_beo.so, interpreting the /etc/beowulf/config file's *nodename* and *iprange* values to translate the node name "n32" into that node's IP address, and the "bproc" source uses /lib64/libnss_bproc.so to translate the node name ".32" into the same IP address result.

/etc/beowulf/conf.d/nsswitch.conf is copied to each booting compute node and installed there as /etc/nsswitch.conf. A file with a numeric suffix, e.g., /etc/beowulf/conf.d/nsswitch.conf.32, specifies an alternative node-specific file, in this case copied to node n32 at boot time.

The /etc/nsswitch.conf on compute nodes understands the same "bproc" source, plus an additional "kickback" source for various database categories, using functionality in /lib64/libnss_kickback.so to further query the master node for name resolution, assuming that the /etc/beowulf/init.d/03kickbackproxyd is enabled on the master node.

For example, suppose the compute node's `nsswitch.conf` includes:

```
passwd: files kickback
group:  files kickback
hosts:  files bproc kickback
```

The addition of a new user and group on the master node amends the master's `/etc/passwd` and `/etc/group` files, although that does not affect those files on the already-booted compute nodes. When a compute node client subsequently asks for that new user name's password, the compute node's `Name Service` fails when searching the *passwd* "files" source, then the "kickback" functionality queries the master node for the name, which successfully replies with the new user's password information.

See Also

`nss(5)`, `nsswitch.conf(5)`, `services(5)`, `beowulf-config(5)`, `getent(1)`, `getpwent(3)`, `gethostbyname(3)`, `getservent(3)`, `getnetent(3)`

7.5 Scyld ClusterWare Beostat Libraries

This part of the *Reference Guide* describes the functions included in the Scyld ClusterWare C libraries for **Beostat**, the Beowulf Status library. The functions in this library can be used for retrieving performance information about the nodes on the cluster, such as CPU and memory utilization.

7.5.1 beostat_count_idle_cpus

Name

beostat_count_idle_cpus – count number of idle CPUS in cluster

Synopsis

```
#include <sys/beostat.h>
```

Arguments

`threshold` The value of CPU usage below which the CPU will be considered idle.

Description

`beostat_count_idle_cpus` executes on the master node and counts the number of CPUs in the entire cluster that are available to the current user/group and have CPU usage below a given threshold. Note that an easy way to count the total number of CPUs available to a user independent of the usage is to use an arbitrarily large threshold value.

Examples

```
int max, fif;
max = beostat_count_idle_cpus (9999.0);
fif = beostat_count_idle_cpus (0.5);
printf ("%d of the %d CPUs available are busy.\n", (max-fif), max);
```

Return Value

Returns the number of CPUs that are both available for the caller and have usage below the threshold. If an error occurs, it will return -1.

Errors

This function relies on the `Beostat` subsystem, which consists of the `proc` filesystem on the remote node, the `sendstats` daemon on the remote node, the `recvstats` daemon on the master node, and two shared memory files in the directory `/var/shm`. If any part of the system breaks down, this function could fail.

7.5.2 beostat_count_idle_cpus_on_node

Name

beostat_count_idle_cpus_on_node – count number of idle CPUS on a given node

Synopsis

```
#include <sys/beostat.h>
int beostat_count_idle_cpus_on_node (int node, float cpu_idle_threshold);
```

Arguments

`node` The node of interest

`cpu_idle_threshold` The value of CPU usage below which the CPU will be considered idle.

Description

`beostat_count_idle_cpus_on_node` executes on the master node and counts the number of CPUs on a given node that have CPU usage below a given threshold.

Examples

```
int cnt;
cnt = beostat_count_idle_cpus_on_node (3, 0.5);
printf ("Node 3 has %d CPUs below 50% usage.\n", cnt);
```

Return Value

Returns the number of CPUs on the give node that have usage below the threshold. If an error occurs, it will return -1.

Errors

This function relies on the Beostat subsystem, which consists of the proc filesystem on the remote node, the sendstats daemon on the remote node, the recvstats daemon on the master node, and two shared memory files in the directory /var/shm. If any part of the system breaks down, this function could fail.

7.5.3 beostat_get_avail_nodes_by_id

Name

beostat_get_avail_nodes_by_id – get a list of available nodes for a given identity

Synopsis

```
#include <sys/beostat.h>
int beostat_get_avail_nodes_by_id (int **node_list, uid_t uid, gid_t *gid_list, int gid_size);
```

Arguments

node_list A handle that will have memory allocated and filled with the array of nodes. This memory must be freed by the caller.

uid The user identifier number

gid_list A pointer to a list of group identifier numbers

gid_size The number of elements in the previous arguments array

Description

beostat_get_avail_nodes_by_id executes on the master node and returns a list of nodes that are available to the given user identifier number who also is a member of the group identifier numbers listed. Memory allocated by the function for node_list must be freed by the caller.

Examples

```
int cnt, *node_list, gid_size, i;
uid_t uid;
gid_t *gid_list;
uid = getuid();
gid_size = getgroups (0, gid_list);
gid_list = malloc (sizeof (gid_t) * gid_size);
getgroups (gid_size, gid_list);
cnt = beostat_get_avail_nodes_by_id (&node_list, uid,
gid_list, gid_size);
printf ("You may run jobs on nodes: ");
for (i = 0; i screen>
```

Return Value

Returns the number of nodes in node_list. If an error occurs, it will return -1.

Errors

This function relies on the Beostat subsystem, which consists of the proc filesystem on the remote node, the sendstats daemon on the remote node, the recvstats daemon on the master node, and two shared memory files in the directory /var/shm. If any part of the system breaks down, this function could fail.

7.5.4 beostat_get_cpu_count

Name

beostat_get_cpu_count – return the number of CPUs on the specified node

Synopsis

```
#include <sys/beostat.h>
int beostat_get_cpu_count (int node, size_t *ncpus);
```

Arguments

node The node to query.

ncpus A pointer to a size_t, which upon successful completion will contain the number of CPUs on the node specified by the node parameter.

Description

beostat_get_cpu_count executes on the master node and returns the number of CPUs on a specified compute node. A CPU count of zero means that the node‘s sendstats daemon is not executing.

Return Value

Return 0 on success. If an error occurs, it will return -1.

Errors

This function relies on the Beostat subsystem, which consists of the proc filesystem on the remote node, the sendstats daemon on the remote node, the recvstats daemon on the master node, and two shared memory files in the directory /var/shm. If any part of the system breaks down, this function could fail.

7.5.5 beostat_get_cpu_percent

Name

beostat_get_cpu_percent – get the CPU usage on a node

Synopsis

```
#include <sys/beostat.h>
float beostat_get_cpu_percent (int node, int cpu);
```

Arguments

node The node to query

cpu The CPU index on the particular node

Description

`beostat_get_cpu_percent` executes on the master node and returns the current CPU usage as a floating-point value between 0.0 and 1.0.

Examples

```
printf ("CPU 0 on node 3 is %f percent busy.\n", beostat_get_cpu_percent (3, 0));
```

Return Value

Return a float between 0.0 and 1.0. If an error occurs, it will return -1.0.

Errors

This function relies on the `Beostat` subsystem, which consists of the `proc` filesystem on the remote node, the `sendstats` daemon on the remote node, the `recvstats` daemon on the master node, and two shared memory files in the directory `/var/shm`. If any part of the system breaks down, this function could fail.

7.5.6 beostat_get_cpuinfo_x86

Name

beostat_get_cpuinfo_x86 – get the time of the last update for node

Synopsis

```
#include <sys/beostat.h>
int beostat_get_cpuinfo_x86 (int node, struct cpuinfo_x86*cpuinfo);
```

Arguments

node The node to query

‘‘ **cpuinfo**‘‘ A pointer to a `struct beostat_cpuinfo_x86`, which is defined as follows (names in comments are entries from cpuinfo_x86 in `asm/processor.h`):

```
     struct beostat_cpuinfo_x86
     {
       int processor;             /* [which cpu (SMP)] */
       char vendor_id[16];        /* x86_vendor_id */
       int family;                /* x86 */
       int model;                 /* x86 model */
       char name[64];             /* x86 model ID */
       int stepping;              /* x86 mask */
       float MHz;                 /* derived from bogomips */
       int cache_size_KB;         /* x86_cache_size */
       boolean fdiv_bug;          /* same */
       boolean hlt_bug;           /* ~hlt_works_ok */
       boolean sep_bug;           /* [Derived] */
       boolean f00f_bug;          /* same */
       boolean coma_bug;          /* same */
       boolean fpu;               /* hard_math */
       boolean fpu_exception;     /* based on exception 16 */
       int cpuid_level;           /* same */
       boolean wp;                /* wp_works_ok */
       float bogomips;            /* loops_per_sec derived */
     };
```

Description

`beostat_get_cpuinfo_x86` executes on the master node and returns a structure describing information about the CPU on the host node. The information in this structure parallels the output seen in `/proc/cpuinfo`. Note that since this information is architecture specific, this function has "x86" in its name.

Examples

```
struct beostat_cpuinfo_x86 cpuinfo;
beostat_get_cpuinfo_x86 (3, &cpuinfo);
printf ("Node 3 has a %f MHz processor\n", cpuinfo.MHz);
```

Return Value

Return 0 on success. If an error occurs, it will return -1.

Errors

This function relies on the `Beostat` subsystem, which consists of the `proc` filesystem on the remote node, the `sendstats` daemon on the remote node, the `recvstats` daemon on the master node, and two shared memory files in the directory `/var/shm`. If any part of the system breaks down, this function could fail.

7.5.7 beostat_get_disk_usage

Name

beostat_get_disk_usage – get the disk usage on root partition of a node

Synopsis

```
#include <sys/beostat.h>
int beostat_get_disk_usage (int node, int *max, int *curr);
```

Arguments

node The node to query

max A pointer to an int. Upon successful completion, will contain the capacity of the root partition of the node's disk in megabytes.

curr A pointer to an int. Upon successful completion will contain the current usage of the root partition of the node's disk in megabytes.

Description

beostat_get_disk_usage executes on the master node and returns the current disk usage, as well as the total capacity of the disk in megabytes.

Examples

```
int max, curr;
beostat_get_disk_usage (3, &max, &curr)
printf ("CPU 0 on node 3's disk is %f percent full.\n",
  (double) curr / (double) max );
```

Return Value

Returns 0 upon successful completion. If an error occurs, it will return -1.

Errors

This function relies on the Beostat subsystem, which consists of the proc filesystem on the remote node, the sendstats daemon on the remote node, the recvstats daemon on the master node, and two shared memory files in the directory /var/shm. If any part of the system breaks down, this function could fail.

7.5.8 beostat_get_last_multicast

Name

beostat_get_last_multicast – get file system statistics for the root file system on a node

Synopsis

```
#include <sys/beostat.h>
time_t beostat_get_last_multicast (void);
```

Description

`beostat_get_last_multicast` executes on the master node and returns the time of the last multicast request sent to the nodes. It is usually reserved for internal use.

Return Value

Returns the time in seconds since Epoch (00:00:00 UTC, January 1, 1970) of the last multicast request. If an error occurs, it will return -1.

Errors

This function relies on the `Beostat` subsystem, which consists of the `proc` filesystem on the remote node, the `sendstats` daemon on the remote node, the `recvstats` daemon on the master node, and two shared memory files in the directory `/var/shm`. If any part of the system breaks down, this function could fail.

7.5.9 beostat_get_loadavg

Name

beostat_get_loadavg – get load average on a node

Synopsis

```
#include <sys/beostat.h>
int beostat_get_loadavg (int node, struct beostat_loadavg *loadavg);
```

Arguments

`node` The node to query

`loadavg` A pointer to a `struct beostat_loadavg`, which is defined as follows:

```
    struct beostat_loadavg
    {
      float load[3];
      int num_active_procs;
      int total_procs;
      int last_pid;
    };
```

Description

`beostat_get_loadavg` executes on the master node and returns the load average information of a node in the cluster. The three values returned are averages over increasing time durations.

Examples

```
struct beostat_loadavg loadavg;
beostat_get_loadavg (3, &loadavg);
printf ("The load process ID on node 3 was %d.\n", loadavg.last_pid);
```

Return Value

Return 0 on success. If an error occurs, it will return -1.

Errors

This function relies on the `Beostat` subsystem, which consists of the `proc` filesystem on the remote node, the `sendstats` daemon on the remote node, the `recvstats` daemon on the master node, and two shared memory files in the directory `/var/shm`. If any part of the system breaks down, this function could fail.

7.5.10 beostat_get_meminfo

Name

beostat_get_meminfo – get information about the memory usage on a node

Synopsis

```
#include <sys/beostat.h>
int beostat_get_meminfo (int node, struct beostat_meminfo *meminfo);
```

Arguments

`node` The node to query

`meminfo` A pointer to a `struct beostat_meminfo`, which is defined as follows:

```
struct beostat_meminfo
{
  struct beostat_memusage mem;
  struct beostat_memusage swap;
  unsigned long long shared;
  unsigned long long buffers;
  unsigned long long cached;
};
```

where `struct beostat_memusage` is defined as follows:

```
struct beostat_memusage
{
  unsigned long long used;
  unsigned long long free;
};
```

Description

beostat_get_meminfo executes on the master node and returns the memory usage of a node in the cluster. All values are in bytes.

Warning: Since Linux aggressively caches the hard disk into memory it will often appear to always be about 90% used. Some have suggested that the values of buffers and cached added together should be subtracted from the reported memory usage. However, these values may not be mutually exclusive.

Examples

```
meminfo_t meminfo;
beostat_get_meminfo (3, &meminfo);
printf ("The node 3 has %s bytes free\n", meminfo.mem.free);
```

Return Value

Return 0 on success. If an error occurs, it will return -1.

Errors

This function relies on the Beostat subsystem, which consists of the proc filesystem on the remote node, the sendstats daemon on the remote node, the recvstats daemon on the master node, and two shared memory files in the directory /var/shm. If any part of the system breaks down, this function could fail.

7.5.11 beostat_get_MHz

Name

beostat_get_MHz – get the speed of the processor on a node

Synopsis

```
#include <sys/beostat.h>
int beostat_get_MHz (int node, float *MHz);
```

Arguments

node The node to query

MHz A pointer to a float, which will contain the speed of processor on the node in megahertz upon successful completion.

Description

beostat_get_MHz executes on the master node and returns the speed of CPU(s) on a given node in units of megahertz. On multi-CPU (SMP) machines it is assumed that all CPUs are the same speed. This is currently a hardware requirement on all known SMP machines.

Examples

```
float speed;
beostat_get_MHz (3, &speed);
printf ("The node 3 has a %f MHz processor\n", speed);
```

Return Value

Return 0 on success. If an error occurs, it will return -1.

Errors

This function relies on the `Beostat` subsystem, which consists of the `proc` filesystem on the remote node, the `sendstats` daemon on the remote node, the `recvstats` daemon on the master node, and two shared memory files in the directory `/var/shm`. If any part of the system breaks down, this function could fail.

7.5.12 beostat_get_name

Name

beostat_get_name – get the name of node

Synopsis

```
#include <sys/beostat.h>
int beostat_get_name (int node, char **name);
```

Arguments

node The node to query

name A handle to a `char`, which will be allocated with an appropriate amount of memory and then set to the name of a node. The caller must free the allocated memory when it is done with the memory.

Description

`beostat_get_name` executes on the master node and returns the name of a given node.

Examples

```
char *name;
beostat_get_name (3, &name);
printf ("The name for node 3 is %s\n", name);
free (name);
```

Return Value

Return 0 on success. If an error occurs, it will return -1.

Errors

This function relies on the `Beostat` subsystem, which consists of the `proc` filesystem on the remote node, the `sendstats` daemon on the remote node, the `recvstats` daemon on the master node, and two shared memory files in the directory `/var/shm`. If any part of the system breaks down, this function could fail.

7.5.13 beostat_get_net_dev

Name

beostat_get_net_dev – get the network interface statistics on a node

Synopsis

```
#include <sys/beostat.h>
int beostat_get_net_dev (int node, struct beostat_net_dev *devs, int size);
```

Arguments

node The node to query

devs A pointer to a array of structures of the type `struct beostat_net_dev`, which is defined as follows:

```
struct beostat_net_dev
{
  char name[16];
  struct beostat_net_stat recv;
  unsigned long frame;
  unsigned long multicast;
  struct beostat_net_stat trans;
  unsigned long colls;
  unsigned long carrier;
};
```

where `beostat_net_stat` is defined as follows:

```
struct beostat_net_stat
{
  unsigned long bytes;
  unsigned long packets;
  unsigned long errs;
  unsigned long drop;
  unsigned long fifo;
  unsigned long compressed;
};
```

size The number of `beostat_net_dev` structures allocated by the caller.

Description

`beostat_get_net_dev` executes on the master node and returns the network interface statistics of a node. The caller must allocate the memory for the array of structures, and a maximum of `MAX_NET_DEV` or `size` entries will be filled (whichever is smaller). Unused space in the structure(s) are filled with zeros.

Examples

```
int i;
struct beostat_net_dev net_dev[MAX_NET_DEV];
beostat_get_net_dev (3, net_dev, MAX_NET_DEV);
for (i = 0; i screen>
```

Return Value

Return 0 on success. If an error occurs, it will return -1.

Errors

This function relies on the `Beostat` subsystem, which consists of the `proc` filesystem on the remote node, the `sendstats` daemon on the remote node, the `recvstats` daemon on the master node, and two shared memory files in the directory `/var/shm`. If any part of the system breaks down, this function could fail.

7.5.14 beostat_get_net_rate

Name

beostat_get_net_rate – get the cumulative network interface on a node

Synopsis

```
#include <sys/beostat.h>
unsigned long beostat_get_net_rate (int node);
```

Arguments

`node` The node to query

Description

`beostat_get_net_rate` executes on the master node and returns the current network usage rate in bytes per second across all interfaces on that node.

Examples

```
printf ("Node 3 is currently transferring %d bytes / second.\n", beostat_get_net_rate (3));
```

This function can give erroneous results for its transfer counts during the moment of rollover of each interface.

Return Value

Returns an unsigned long, which represents the network transfer rate. If an error occurs, it will return -1.

Errors

This function relies on the `Beostat` subsystem, which consists of the `proc` filesystem on the remote node, the `sendstats` daemon on the remote node, the `recvstats` daemon on the master node, and two shared memory files in the directory `/var/shm`. If any part of the system breaks down, this function could fail.

7.5.15 beostat_get_stat_cpu

Name

beostat_get_stat_cpu – get the statistics of CPU utilization

Synopsis

```
#include <sys/beostat.h>
int beostat_get_stat_cpu (int node, int cpu, struct beostat_stat_cpu *stat_cpu);
```

Arguments

`node` The node to query

`cpu` The CPU index on the particular node

`stat_cpu` A pointer to a `struct beostat_stat_cpu`, which will be filled upon successful completion. `struct beostat_stat_cpu` is defined as follows:

```
    struct beostat_stat_cpu
    {
      long user;
      long system;
      long nice;
      long idle;
    };
```

The members of this structure have the following meanings:

`user` The number of CPU ticks spend processing normal priority (0) user level instructions.

`nice` The number of CPU ticks spend processing nice priority (>0) user level instructions.

`system` The number of CPU ticks spend processing system (kernel) level instructions.

`idle` The number of CPU ticks spend idle.

Description

`beostat_get_stat_cpu` executes on the master node and returns the cpu ticks counts on a given node/CPU. These ticks just keep incrementing over time until they overflow and wrap back around. To get actual CPU usage over some time period, you must either take the derivative of these values or use the `beostat` convenience function `beostat_get_cpu_percent`.

Examples

```
struct beostat_stat_cpu stat_cpu;
beostat_get_stat_cpu (3, 0, &stat_cpu);
printf ("There have been %ld idle ticks on cpu 0 for node 3 is %s\n", stat_cpu.idle);
free (name);
```

Return Value

Return 0 on success. If an error occurs, it will return -1.

Errors

This function relies on the `Beostat` subsystem, which consists of the `proc` filesystem on the remote node, the `sendstats` daemon on the remote node, the `recvstats` daemon on the master node, and two shared memory files in the directory `/var/shm`. If any part of the system breaks down, this function could fail.

7.5.16 beostat_get_statfs_p

Name

beostat_get_statfs_p – get file system statistics for the root file system on a node

Synopsis

```
#include <sys/beostat.h>
int beostat_get_statfs_p (int node, struct statfs *statfs);
```

Arguments

`node` The node to query

`statfs` A pointer to a `statfs` structure that will be filled upon successful completion. See the man page for statfs2 for a description of the fields.

Description

`beostat_get_statfs_p` executes on the master node and returns the filesystem statistics for the root filesystem on a given node.

Warning: Since Linux aggressively caches the hard disk into memory it will often appear to always be about 90% used. Some have suggested that the values of `buffers` and `cached` added together should be subtracted from the reported memory usage. However, these values may not be mutually exclusive.

Examples

```
statfs_p_t statfs_p;
beostat_get_statfs_p (3, &statfs_p);
printf ("The node 3 has %s bytes free\n", statfs_p.mem.free);
```

Return Value

Return 0 on success. If an error occurs, it will return -1.

Errors

This function relies on the Beostat subsystem, which consists of the proc filesystem on the remote node, the sendstats daemon on the remote node, the recvstats daemon on the master node, and two shared memory files in the directory /var/shm. If any part of the system breaks down, this function could fail.

7.5.17 beostat_get_time

Name

beostat_get_time – get the time of the last update for node

Synopsis

```
#include <sys/beostat.h>
int beostat_get_time (int node, struct node_time *node_time);
```

Arguments

node The node to query

node_time A pointer to a struct node_time, which is defined as follows:

```
    struct node_time {
      time_t time;
    };
```

Description

beostat_get_time executes on the master node and returns the time of the last update to the Beostat system by a given node. The Beostat functionality works by the having the sendstats daemon on each compute node periodically send node status information to the master node's recvstats daemon. This function provides the time of the last update from a given node. It is useful when timely information is required and old information should be disregarded. The time is measured in seconds since the standard UNIX Epoch (00:00:00 UTC, January 1, 1970). Use functions like ctime() to convert to a human readable string.

Examples

```
time_t time;
beostat_get_time (3, &time);
printf ("The time of the last update for node 3 is %s\n", ctime(&time));
```

Return Value

Return 0 on success. If an error occurs, it will return -1.

Errors

This function relies on the Beostat subsystem, which consists of the proc filesystem on the remote node, the sendstats daemon on the remote node, the recvstats daemon on the master node, and two shared memory files in the directory /var/shm. If any part of the system breaks down, this function could fail.

7.5.18 beostat_is_node_available

Name

beostat_is_node_available – determine if a given user/group can run on a given node

Synopsis

```
#include <sys/beostat.h>
int beostat_is_node_available (int node, uid_t uid, gid_t *gid_list, int gid_size);
```

Arguments

node The node of interest

uid The user identifier number

gid_list A pointer to a list of group identifier numbers

gid_size The number of elements in the previous arguments array

Description

beostat_is_node_available executes on the master node and determines if the given user with specified UID and belonging to the groups in gid_list has permission to run on a given node.

See the manual page for beostat_get_avail_nodes_by_id for a example of a similar function.

Return Value

Returns 1 if the node can be used, 0 if not, and -1 if an error occurs.

Errors

This function relies on the Beostat subsystem, which consists of the proc filesystem on the remote node, the sendstats daemon on the remote node, the recvstats daemon on the master node, and two shared memory files in the directory /var/shm. If any part of the system breaks down, this function could fail.

7.6 Scyld ClusterWare BProc Libraries

This part of the *Reference Guide* describes the functions included in the Scyld ClusterWare C libraries for **BProc**, the Beowulf Process Control library. The functions in this library are used to control jobs running on the cluster.

7.6.1 bproc_access

Name

bproc_access – Check if the current user may use a cluster node.

Synopsis

```
#include <sys/bproc.h>
int bproc_access (int node, int mode);
int _bproc_access (struct bproc_node_info_t *nodeinfo, int mode);
```

Arguments

`node` The node number to check.

`mode` The mode bits to check against.

`nodeinfo` A filled-in `bproc_node_info` structure to check against.

Description

The current user's ability to execute processes on the specified cluster `node` is checked. The `mode` parameter specifies the mode bits to check.

See the Administrator's Guide for details of the semantics of node ownership and how the settings interact with schedulers.

Return Value

If a process may be started on the node, 0 is returned.

If the node is not available or there is an error, -1 is returned and `errno` is set.

Errors

ENOSYS The `BProc` system is not available.

EIO The `BProc` system is loaded but is not configured or active.

EACCES This user does not have permission to start jobs on the node.

ENOMEM Insufficient kernel memory was available.

7.6.2 bproc_chown

Name

bproc_chown – Change the ownership for a cluster node.

Synopsis

```
#include <sys/bproc.h>
int bproc_chown (int node, int user);
int bproc_chgrp (int node, int group);
int bproc_chown (int node, int user, int group);
```

Arguments

node The node to change ownership of

user The numeric user ID to assign to the node

group The numeric group ID to assign to the node

Description

The owner of the cluster `node` is changed. The `user` specifies the desired user ID (UID). The second form, available only with the `BProc` v2 compatibility library, sets the group owner to `group`.

Previous `BProc` versions used the values `BPROC_USER_ANY` and `BPROC_GROUP_ANY`. The same effect can be achieved by setting world-execute permission using bproc_chmod3

See the Administrator's Guide for details of the semantics of node ownership and how the settings interact with schedulers.

Return Value

Returns 0 on success.

Returns -1 on error, and sets `errno`.

Errors

ENOSYS The `BProc` system is not available.

EIO The `BProc` system is loaded but not configured or active.

EPERM This process does not have permission to change node ownership.

ENOMEM Insufficient kernel memory was available to change ownership.

7.6.3 bproc_currnode

Name

bproc_currnode – Get the current node number

Synopsis

```
#include <sys/bproc.h>
int bproc_currnode (void);
```

Return Value

Returns the node number of the machine on which this process is currently running. The value `BPROC_NODE_MASTER`, -1, indicates that the process is running on the master.

Bugs

This function will return -1 if there is an error in processing, or if you are on the master node. If there is the possibility of ambiguity, the `errno` variable should be initialized to 0 before the call and checked for errors after the call.

Errors

ENOSYS The `BProc` system is not available.

EIO The `BProc` system is loaded, but is not configured or active.

ENOMEM Insufficient kernel memory was available to return a value.

7.6.4 bproc_detach

Name

bproc_detach – Remove the current process from the BProc process space.

Synopsis

```
#include <sys/bproc.h>
int bproc_detach(long code);
```

Description

`bproc_detach` removes the current process from the global BProc process space. After `bproc_detach` succeeds, the process continues to execute on its node, but is no longer visible from other nodes. From the viewpoint of other processes in the BProc system, the effect is as if the process had executed `exit`(code). See exit2 for a description of the effects seen by the parent process.

Return Value

On success, `bproc_detach` returns zero.

On error, `bproc_detach` returns -1 and sets errno appropriately.

Errors

EPERM The caller does not have root permissions.

ENOSYS The `BProc` system is not loaded in the current kernel.

In addition, any errors listed in fork(2) may occur.

Notes

In the current release, bproc_detach may change the PID and PPID of the current process, but is not guaranteed to do so. The PPID may change at some point after bproc_detach has returned, but such behavior is not guaranteed.

In future releases, bproc_detach may be implemented to remove the current process from the BProc system, or it may be implemented to make a copy of the current process outside of the BProc system; other options are also possible. The user should make no assumptions beyond those documented in this man page.

Some implementations of GNU libc cache the value of getpid in userspace; thus, getpid may return inaccurate values if called both before and after bproc_detach.

7.6.5 bproc_execmove

Name

bproc_execmove – Exec a local binary on a remote node

Synopsis

```
#include <sys/bproc.h>
int _bproc_execmove_io (int node, int port, const char * cmd, char * const argv[], char * const envp
int bproc_execmove (int node, const char * cmd, char * const argv[], char * const envp[]);
```

Arguments

node The destination node for the child process.

port The IP port BProc should connect back to for I/O forwarding.

cmd The program to execute

argv The argument list

envp The environment

Description

This function allows execution of local binaries on remote nodes. BProc will load the binary image on the current node and then move it to a remote node, prior to executing the binary image.

NOTE: This migration mechanism will move the binary image but not any dynamically loaded libraries that the application might need. Therefore any libraries that the application uses must be present on the remote system. Function does not return on success. On failure, it returns -1 and sets errno appropriately.

port is the TCP port BProc should connect back to to handle I/O forwarding. A port value of 0 means it assumes I/O forwarding is being done on the existing socket for stdout and stderr only. Any other value and it will try to connect back to that port and open three connections, one for stdout, one for stderr, and one for stdin.

If you use bproc_execmove, port has a default value of 0.

Return Value

Does not return on success.

Returns on error, and sets errno.

Errors

EPERM The filesystem where cmd resides is mounted nosuid and the program is suid or sgid

ENOMEM Out of memory

EBUSY No Master

EFAULT cmd, envp, or argv points to memory that is not accessible the by the program.

EACCES The program does not have execute permission on cmd

E2BIG Argument list is too big

ENOEXEC cmd is not in a recognized executable format or is for the wrong architecture

ENAMETOOLONG cmd is too long

ENOENT cmd does not exist.

ENOTDIR Part of the path to cmd is not a directory.

ELOOP Too many symbolic links were encountered when resolving cmd.

ETXTBSY cmd is open for writing by another program.

EIO An I/O error occurred.

ENFILE The limit on open files has been reached.

EINVAL An ELF executable had more than one PT_INTERP segment.

7.6.6 bproc_getnodebyname

Name

bproc_getnodebyname – Get a node number from a node name.

Synopsis

```
#include <sys/bproc.h>
int bproc_getnodebyname (const char * name);
```

Arguments

name A machine name

Description

This function returns the node number associated with the string name. Valid strings include “master”, “self”, a string representation of a decimal number, and the string representation of a decimal number prepended with a ”.”

Note that this function duplicates some of the functionality of the BeoNSS system, but with a limited set of names. Note also that this function does not use BProc kernel information: it returns a value even when the cluster system is not active, and it may return a node number that is outside the valid range of nodes.

Return Value

Returns the node number represented by name.

May return BPROC_NODE_SELF if the string is “self”.

Returns BPROC_NODE_NONE if a valid string was not passed.

Errors

No errors

7.6.7 bproc_masteraddr

Name

bproc_masteraddr – Get the private cluster network IP address for the master node.

Synopsis

```
#include <sys/bproc.h>
int bproc_masteraddr (struct sockaddr * addr, int * size);
```

Arguments

addr pointer to a struct sockaddr

size The size of addr

Description

Save the master node’s IP address in the struct sockaddr pointed to by addr. size should be initialized to indicate the amount of space pointed to by addr. On return it contains the actual size of the addr returned (in bytes).

Return Value

Returns 0 on success.

Returns -1 on error, and sets errno.

Errors

EFAULT `addr` or `size` points to memory that is not accessible by the program.

EIO There was an I/O error.

ENOMEM Out of memory error.

7.6.8 bproc_move

Name

bproc_move – Move the running process to another node

Synopsis

```
#include <sys/bproc.h>
int _bproc_move_io (int node, int flags, int port);
int _bproc_move (int node, int flags);
int bproc_move (int node);
```

Arguments

`node` The node to move to

`flags` Flags for VMAdump.

`port` The IP port `BProc` should connect back to for I/O forwarding.

Description

This call will move the current process to the remote node number given by `node`. It returns 0 on success, -1 on failure. `errno` is set on failure.

`node` is the node to move to.

`flags` can be one of the following: `BPROC_DUMP_LIBS`, `BPROC_DUMP_EXEC`, `BPROC_DUMP_OTHER` or any combination of them binary OR'd together. A binary OR of all three, `BPROC_DUMP_ALL`, is also provided as a shortcut. These flags tell `VMAdump` how much of the running process to dump and send to the compute node.

`port` is the port `BProc` should connect back to, to handle I/O forwarding. A `port` value of 0 means it assumes I/O forwarding is being done on the existing socket for `stdout` and `stderr` only. Any other value and it will try to connect back to that port and open three connections, one for `stdout`, one for `stderr`, and one for `stdin`.

If you use `_bproc_move` or `bproc_move`, `port` has a default value of `0`. If you use `bproc_move`, `flags` takes a default value that is `BPROC_DUMP_EXEC|BPROC_DUMP_OTHER` if you're trying to move to an up node or the master, otherwise it is `BPROC_DUMP_EXEC|BPROC_DUMP_LIBS|BPROC_DUMP_OTHER`

Return Value

Returns 0 on success.

Returns -1 on error, and sets `errno`.

Errors

EBUSY No master?

ENOMEM Out of memory.

EIO An I/O error occurred.

7.6.9 bproc_nodeaddr

Name

bproc_nodeaddr – Get the IP address for a node.

Synopsis

```
#include <sys/bproc.h>
int bproc_nodeaddr (int node, struct sockaddr * addr, int * size);
```

Arguments

`node` The node number

`addr` pointer to a `struct sockaddr`

`size` The size of `addr`

Description

Save the node's IP address in the `struct sockaddr` pointed to by `addr`. The `size` element should be initialized to indicate the amount of space pointed to by `addr`. On return it contains the actual size of the `addr` returned (in bytes).

Return Value

Returns 0 on success.

Returns -1 on error, and sets `errno`.

Errors

EFAULT `addr` or `size` points to memory that is not accessible by the program.

EIO There was an I/O error.

ENOMEM Out of memory error.

7.6.10 bproc_nodeinfo

Name

bproc_nodeinfo – Get general status information for a node

Synopsis

```
#include <sys/bproc.h>
int bproc_nodeinfo (int node, struct bproc_node_info_t * info);
```

Arguments

node The node you want information on.

info Pointer to a `struct bproc_node_info_t`.

Description

This function will get information about the node and fill that information into the `struct bproc_node_info_t`.

```
struct bproc_node_info_t {
   int      node;         /* Same as bproc_currnode() */
   int      status;       /* Same as bproc_nodestatus() */
   int      mode;         /* The node's access permissions */
   uid_t    user;         /* The uid and gid of the user    */
   gid_t    group;        /*  to which the node is assigned */
   uint32_t addr;         /* The node's 32-bit struct sockaddr */
}
```

See the Administrator's Guide for more information on the user and group.

Return Value

Returns 0 on success.

Returns -1 on error, and sets `errno`.

Errors

EFAULT `info` points to memory that is inaccessible by the program.

EIO I/O Error

ENOMEM Out of Memory

7.6.11 bproc_nodenumber

Name

bproc_nodenumber – Get the node number based on the given IP address.

Synopsis

```
#include <sys/bproc.h>
int bproc_nodenumber (struct sockaddr * addr, int size);
```

Arguments

addr pointer to a struct sockaddr, that has the IP filled in

size The size of addr

Description

Retrieves the IP address from the sockaddr structure and provides the number of the node with that address. There is a direct one-to-one mapping of node number to IP address as given in the /etc/beowulf/config file. Node numbering starts at 0 with the first IP address in the range and increments by 1 up to the last IP address in the range.

Return Value

Returns the node number associated with the IP address.

Returns BPROC_NODE_NONE if no valid node was found.

Errors

EFAULT addr points to memory that is not accessible by the program.

EIO There was an I/O error.

ENOMEM Out of memory error.

7.6.12 bproc_nodestatus

Name

bproc_nodestatus – Returns the status of the given node.

Synopsis

```
#include <sys/bproc.h>
int bproc_nodestatus (int node);
```

Arguments

node The node number.

Description

This node argument should list one of the compute nodes, not the master. The master is considered to be always up.

Return Value

On error, it will return -1 and set `errno` appropriately.

The possible states are:

`bproc_node_down` The node is not connected to the master daemon. It may be off or crashed or not far enough along in its boot process to connect to the master daemon.

`bproc_node_unavailable` The node is running but is currently unavailable to users. Nodes are only in this state if set that way explicitly by the administrator.

`bproc_node_error` There is a problem with the node. Nodes are assigned this state if booting is unsuccessful.

`bproc_node_up` The node is up and ready to accept processes. This is the only state in which non-root users can send jobs to the node.

`bproc_node_reboot` The node was told to reboot and has not come back up yet.

`bproc_node_halt` The node was told to halt and is still down.

`bproc_node_pwroff` The node was told to power off and is still down.

`bproc_node_boot` The node is in the process of coming up (running the `node_up` script).

Errors

There was an I/O error.

ENOMEM Out of memory error.

7.6.13 bproc_numnodes

Name

bproc_numnodes – Get the count of cluster nodes.

Synopsis

```
#include <sys/bproc.h>
int bproc_numnodes (void );
```

Description

This function returns the number of nodes the cluster is configured to support. Note that this is the potential size of the cluster, not the current number of available nodes or the count of machines assigned node numbers.

Return Value

Returns the number of compute nodes the system is configured to support. If the `BProc` system is not loaded, returns 0 and sets `errno` to `ENOSYS`.

Returns -1 on error, and sets `errno`.

Errors

EIO The `BProc` system is loaded but not configured or active.

ENOMEM Insufficient kernel memory was available.

7.6.14 bproc_pidnode

Name

bproc_pidnode – Get the node a PID is running on.

Synopsis

```
#include <sys/bproc.h>
int bproc_pidnode (int pid);
```

Arguments

`pid` The process id

Description

Retrieves the node number associated with the given Process ID from the `BProc` process space. Note that only user processes ghosted on the master are available in this way. Node kernel and internal `BProc` PIDs are not accessible.

Return Value

Return the node number that the PID is running on.

Returns `BPROC_NODE_NONE` if the PID is running on the master node or isn't a valid PID.

Bugs

This functions returns `BPROC_NODE_NONE` if there was an error accessing the `BProc` status file, or if `pid` was not found in the status file. There is currently no way to tell if `BPROC_NODE_NONE` resulted from an error or from `pid` not being masqueraded by `BProc`.

Errors

EACCES The program does not have access to read the `BProc` status file.

ENOENT The `BProc` status file does not exist.

ENOMEM Insufficient kernel memory.

EMFILE The limit of files that can be opened by the process has been reached.

ENFILE The limit of files that can be opened by the system has been reached.

EAGAIN The `BProc` status file has been locked.

7.6.15 bproc_rexec

Name

bproc_rexec – exec a program on a remote node

Synopsis

```
#include <sys/bproc.h>
int _bproc_rexec_io (int node, int port, const char * cmd, char * const argv[], char * const envp[]);
int bproc_rexec (int node, const char * cmd, char * const argv[], char * const envp[]);
```

Arguments

node The node the child should be on.

port The port to BProc should connect back to for I/O forwarding.

cmd The program to execute

argv The argument list

envp The environment

Description

This call has semantics similar to execve. It replaces the current process with a new one. The new process is created on node and the local process becomes the ghost representing it. All arguments are interpreted on the remote machine. The binary and all libraries it needs must be present on the remote machine. Currently, if remote process creation is successful but exec fails, the process will just exit with status 1. If remote process creation fails, the function will return -1 and errno is set appropriately.

port is the TCP port BProc should connect back to to handle I/O forwarding. A port value of 0 means it assumes I/O forwarding is being done on the existing socket for stdout and stderr only. Any other value and it will try to connect back to that port and open three connections, one for stdout, one for stderr, and one for stdin.

If you use bproc_execmove, port has a default value of 0.

Return Value

Does not return on success.

Returns -1 on error, and sets errno.

Errors

EPERM The filesystem where cmd resides is mounted nosuid and the program is suid or sgid

ENOMEM Out of memory

EBUSY No Master

EFAULT cmd, envp, or argv points to memory that is not accessible by the program.

EACCES The program does not have execute permission on cmd

E2BIG Argument list is too big

ENOEXEC `cmd` is not in a recognized executable format or is for the wrong architecture

ENAMETOOLONG `cmd` is too long

ENOENT `cmd` does not exist.

ENOTDIR Part of the path to `cmd` is not a directory.

ELOOP Too many symbolic links were encountered when resolving `cmd`.

ETXTBSY `cmd` is open for writing by another program.

EIO An I/O error occurred.

ENFILE The limit on open files has been reached.

EINVAL An ELF executable had more than one `PT_INTERP` segment.

7.6.16 bproc_rfork

Name

bproc_rfork – fork, with the child ending up on a remote node.

Synopsis

```
#include <sys/bproc.h>
int _bproc_rfork_io (int node, int flags, int port);
int _bproc_rfork (int node, int flags);
int bproc_rfork (int node);
```

Arguments

`node` The node the child should be on.

`flags` Flags for `VMAdump`.

`port` The port `BProc` should connect back to for I/O forwarding.

Description

The semantics of this function are designed to mimic `fork`, except that the child process created will end up on the node given by the node argument. The process forks a child and that child performs a `bproc_move` to move itself to the remote node. Combining these two operations in a system call prevents zombies and `SIGCHLDs` in the case that the fork is successful but the move is not.

On success, this function returns the process ID of the new child process to the parent and 0 to the child. On failure it returns -1, and `errno` is set appropriately.

`node` is the node the child should be on.

`flags` can be one of the following: `BPROC_DUMP_LIBS`, `BPROC_DUMP_EXEC`, `BPROC_DUMP_OTHER` or any combination of them binary OR'd together. If you with to use all of them, you can also use `BPROC_DUMP_ALL` as a shortcut. These flags tell `VMAdump` how much of the running process to dump and send to the compute node.

`port` is the port `BProc` should connect back to for I/O forwarding. A port value of zero means it assumes I/O forwarding is being done on the existing socket for `stdout` and `stderr` only. Any other value and it will try to connect back to that port and open three connections, one for `stdout`, one for `stderr`, and one for `stdin`.

If you use `_bproc_rfork` or `bproc_rfork`, port has a default value of 0. If you use `bproc_rfork`, `flags` takes a default value that is `BPROC_DUMP_EXEC|BPROC_DUMP_OTHER`, if you are trying to move to an up node or the master, otherwise it is `BPROC_DUMP_EXEC|BPROC_DUMP_LIBS|BPROC_DUMP_OTHER`.

Return Value

For the parent process, this will return the PID of the child process.

For the child process, this will return 0.

If there is an error, -1 will be returned to the parent process and there will be no child process.

Errors

EBUSY No Master

7.6.17 bproc_setnodestatus

Name

bproc_setnodestatus – Change the status of a node

Synopsis

```
#include <sys/bproc.h>
int bproc_setnodestatus (int node, int status);
```

Arguments

`node` The node to change the status of

`status` The new status for the node

Description

This call sets the status of a node. Note that it is not possible to change the status of a node that is marked as "down", "pwroff", or "halt".

`bproc_node_down` The node is not connected to the master daemon. It may be off or crashed or not far enough along in its boot process to connect to the master daemon.

`bproc_node_unavailable` The node is running but is currently unavailable to users. Nodes are only in this state if set that way explicitly by the administrator.

`bproc_node_error` There is a problem with the node. Nodes are assigned this state if booting is unsuccessful.

`bproc_node_up` The node is up and ready to accept processes. This is the only state in which non-root users can send jobs to the node.

`bproc_node_reboot` Setting a node to this state will tell it to reboot.

bproc_node_halt Setting a node to this state will tell it to halt.

bproc_node_pwroff Setting a node to this state will tell it to power off.

bproc_node_boot The node is in the process of coming up (running the node_up script). A node should only be put in this state by the BProc master daemon.

Return Value

Returns 0 on success.

Returns -1 on error, and sets errno.

Errors

EPERM You do not have root access

ENOMEM Out of memory

EIO I/O error

CHAPTER

EIGHT

FEEDBACK

We welcome any reports on errors or difficulties that you may find. We also would like your suggestions on improving this document. Please direct all comments and problems to support@penguincomputing.com.

When writing your email, please be as specific as possible, especially with errors in the text. Please include the chapter and section information. Also, please mention in which version of the manual you found the error. This version is Scyld ClusterWare Release v6.10.14-61014g0000.