

# High Performance Computing System Administration



## CASE STUDY

### OpenHPC - Warewulf

Submitted by:

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## **Case Study Group Members**

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**Aim:**

Build a two node Disk-less HPC-Cluster using OpenHPC with Warewulf, Slurm, Nagios and Ganglia and perform a HPL Benchmarking test.

**Requirement:****Hardware Requirement:**

1. RAM - 32 GB
2. Processor - i7

**Software Requirement**

1. Operating System - Window 11 , CentOS 7
2. Vmware Pro 17
3. Putty

**Procedure:**

In the initial step we installed a CentOS VM with 12 GB RAM and 4 Processors and installed 2 Network Adapters: 1 on NAT or Bridge and Another on Host-only. Host-only adapter will be used for Cluster Communication and for pxe-booting with Warewulf.

After that we will make installation of Warewulf on master with Slurm which will be used for Resource Management, Chrony which will be used for Time Date Synchronization, Nagios and Ganglia for Monitoring Purpose of Cluster.

Then we will start booting two nodes having 8 GB RAM and 1 Network Adapter on Host-Only with the image from master using Warewulf.

After the successful installation of all the nodes of Cluster we will perform a Benchmark test using HPL Benchmarking.

## Snapshot 1: Install RPMS from OpenHPC community

```
vw_slurm_master x
Applications Places Terminal
root@master:~
Mon 11:05

File Edit View Search Terminal Help
[root@master ~]# yum install http://build.openhpc.community/OpenHPC/1.3/CentOS_7/x86_64/ohpc-release-1.3-1.el7.x86_64.rpm
Loaded plugins: fastestmirror, langpacks
ohpc-release-1.3-1.el7.x86_64.rpm
Examining /var/tmp/yum-root-0wrHtg/ohpc-release-1.3-1.el7.x86_64.rpm: ohpc-release-1.3-1.el7.x86_64
Marking /var/tmp/yum-root-0wrHtg/ohpc-release-1.3-1.el7.x86_64.rpm to be installed
Resolving Dependencies
--> Running transaction check
--> Package ohpc-release.x86_64 0:1.3-1.el7 will be installed
--> Processing Dependency: epel-release for package: ohpc-release-1.3-1.el7.x86_64
Loading mirror speeds from cached hostfile
* base: repo.extreme-ix.org
* extras: repo.extreme-ix.org
* updates: repo.extreme-ix.org
--> Running transaction check
--> Package epel-release.noarch 0:7-11 will be installed
--> Finished Dependency Resolution

Dependencies Resolved

=====
Package Arch Version Repository Size
=====
Installing:
ohpc-release x86_64 1.3-1.el7 /ohpc-release-1.3-1.el7.x86_64 1.4 k
Installing for dependencies:
epel-release noarch 7-11 extras 15 k
=====

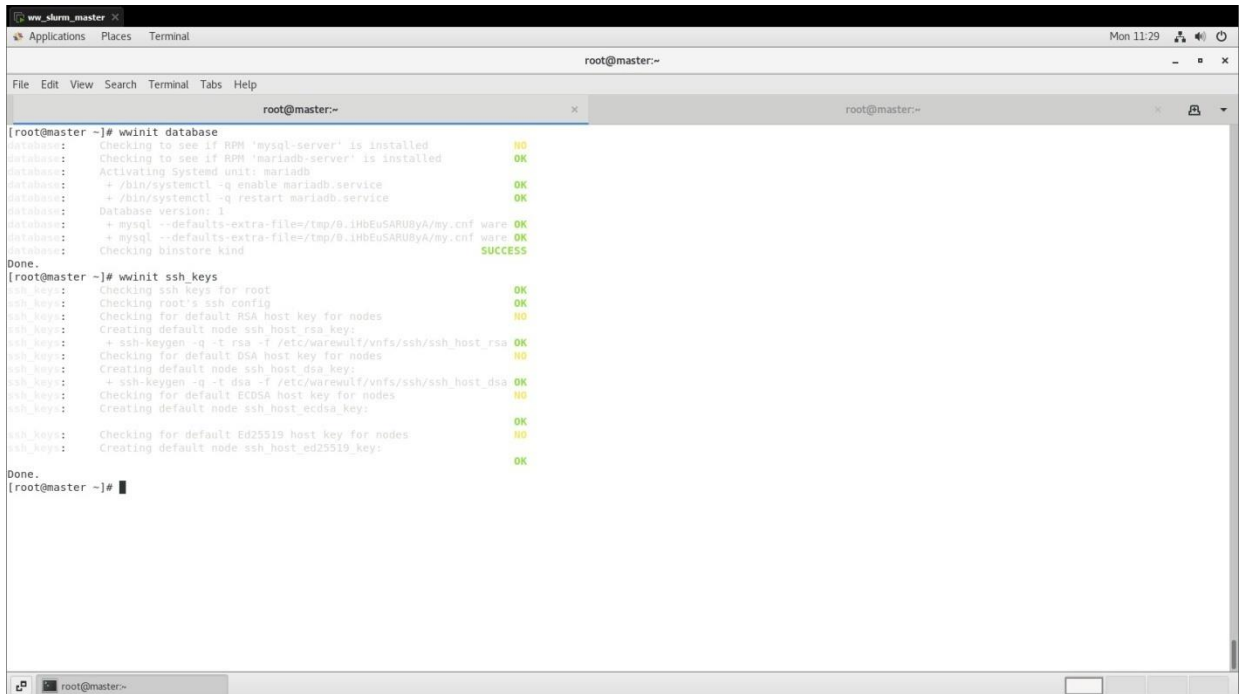
Transaction Summary
=====
Install 1 Package (+1 Dependent package)
Total size: 16 k
Total download size: 15 k
Installed size: 26 k
Is this ok [y/d/N]: y
Downloading packages:
epel-release-7-11.noarch.rpm | 15 kB 00:00:00
Running transaction check
Running transaction test
Transaction test succeeded
Running transaction
Installing : epel-release-7-11.noarch
Installing : ohpc-release-1.3-1.el7.x86_64
Verifying : ohpc-release-1.3-1.el7.x86_64
1/2
2/2
1/2
root@master:~
```

## Snapshot 2: Install Ohpc-warewulf

```
vw_slurm_master x
Applications Places Terminal
root@master:~
Mon 11:08

File Edit View Search Terminal Help
[root@master ~]# yum -y install ohpc-warewulf
Loaded plugins: fastestmirror, langpacks
Loading mirror speeds from cached hostfile
* base: repo.extreme-ix.org
* epel: repo.extreme-ix.org
* extras: repo.extreme-ix.org
* updates: repo.extreme-ix.org
Resolving Dependencies
--> Running transaction check
--> Package ohpc-warewulf.x86_64 0:1.3.8-3.1.ohpc.1.3.8 will be installed
--> Processing Dependency: warewulf-provision-initramfs-x86_64-ohpc for package: ohpc-warewulf-1.3.8-3.1.ohpc.1.3.8.x86_64
--> Processing Dependency: warewulf-common-ohpc for package: ohpc-warewulf-1.3.8-3.1.ohpc.1.3.8.x86_64
--> Processing Dependency: warewulf-provision-ohpc for package: ohpc-warewulf-1.3.8-3.1.ohpc.1.3.8.x86_64
--> Processing Dependency: warewulf-vnfs-ohpc for package: ohpc-warewulf-1.3.8-3.1.ohpc.1.3.8.x86_64
--> Processing Dependency: warewulf-cluster-ohpc for package: ohpc-warewulf-1.3.8-3.1.ohpc.1.3.8.x86_64
--> Processing Dependency: warewulf-provision-server-ipxe-x86_64-ohpc for package: ohpc-warewulf-1.3.8-3.1.ohpc.1.3.8.x86_64
--> Processing Dependency: warewulf-ipmi-ohpc for package: ohpc-warewulf-1.3.8-3.1.ohpc.1.3.8.x86_64
--> Processing Dependency: warewulf-provision-server-ohpc for package: ohpc-warewulf-1.3.8-3.1.ohpc.1.3.8.x86_64
--> Running transaction check
--> Package warewulf-cluster-ohpc.x86_64 0:3.8.1-10.5.ohpc.1.3.6 will be installed
--> Package warewulf-common-ohpc.x86_64 0:3.8.1-14.2.ohpc.1.3.6 will be installed
--> Processing Dependency: perl-Term-ReadLine-Gnu for package: warewulf-common-ohpc-3.8.1-14.2.ohpc.1.3.6.x86_64
--> Processing Dependency: perl(DBD:Pg) for package: warewulf-common-ohpc-3.8.1-14.2.ohpc.1.3.6.x86_64
--> Package warewulf-ipmi-ohpc.x86_64 0:3.8.1-12.3.ohpc.1.3.6 will be installed
--> Package warewulf-provision-initramfs-x86_64-ohpc.noarch 0:3.8.1-56.1.ohpc.1.3.9 will be installed
--> Package warewulf-provision-ohpc.x86_64 0:3.8.1-56.1.ohpc.1.3.9 will be installed
--> Package warewulf-provision-server-ipxe-x86_64-ohpc.noarch 0:3.8.1-56.1.ohpc.1.3.9 will be installed
--> Processing Dependency: perl(Apache2:SubProcess) for package: warewulf-provision-server-ohpc-3.8.1-56.1.ohpc.1.3.9.x86_64
--> Processing Dependency: mod_perl for package: warewulf-provision-server-ohpc-3.8.1-56.1.ohpc.1.3.9.x86_64
--> Processing Dependency: tftp-server for package: warewulf-provision-server-ohpc-3.8.1-56.1.ohpc.1.3.9.x86_64
--> Processing Dependency: dhcp for package: warewulf-provision-server-ohpc-3.8.1-56.1.ohpc.1.3.9.x86_64
--> Processing Dependency: perl(CGI) for package: warewulf-provision-server-ohpc-3.8.1-56.1.ohpc.1.3.9.x86_64
--> Processing Dependency: xinetd for package: warewulf-provision-server-ohpc-3.8.1-56.1.ohpc.1.3.9.x86_64
--> Package warewulf-vnfs-ohpc.x86_64 0:3.8.1-33.1.ohpc.1.3.7 will be installed
--> Processing Dependency: pigz for package: warewulf-vnfs-ohpc-3.8.1-33.1.ohpc.1.3.7.x86_64
--> Running transaction check
--> Package dhcp.x86_64 12:4.2.5-83.el7.centos.1 will be installed
--> Package mod_perl.x86_64 0:2.0.11-1.el7 will be installed
--> Processing Dependency: perl(BSD:Resource) for package: mod_perl-2.0.11-1.el7.x86_64
--> Processing Dependency: perl(Linux:Pld) for package: mod_perl-2.0.11-1.el7.x86_64
--> Package perl-CGI.noarch 0:3.63-4.el7 will be installed
--> Processing Dependency: perl(FCGI) >= 0.67 for package: perl-CGI-3.63-4.el7.noarch
--> Package perl-BDB-Pg.x86_64 0:2.19.3-5.el7.9 will be installed
root@master:~
```

## Snapshot 3: Initializing Database of Warewulf and Generating ssh\_keys

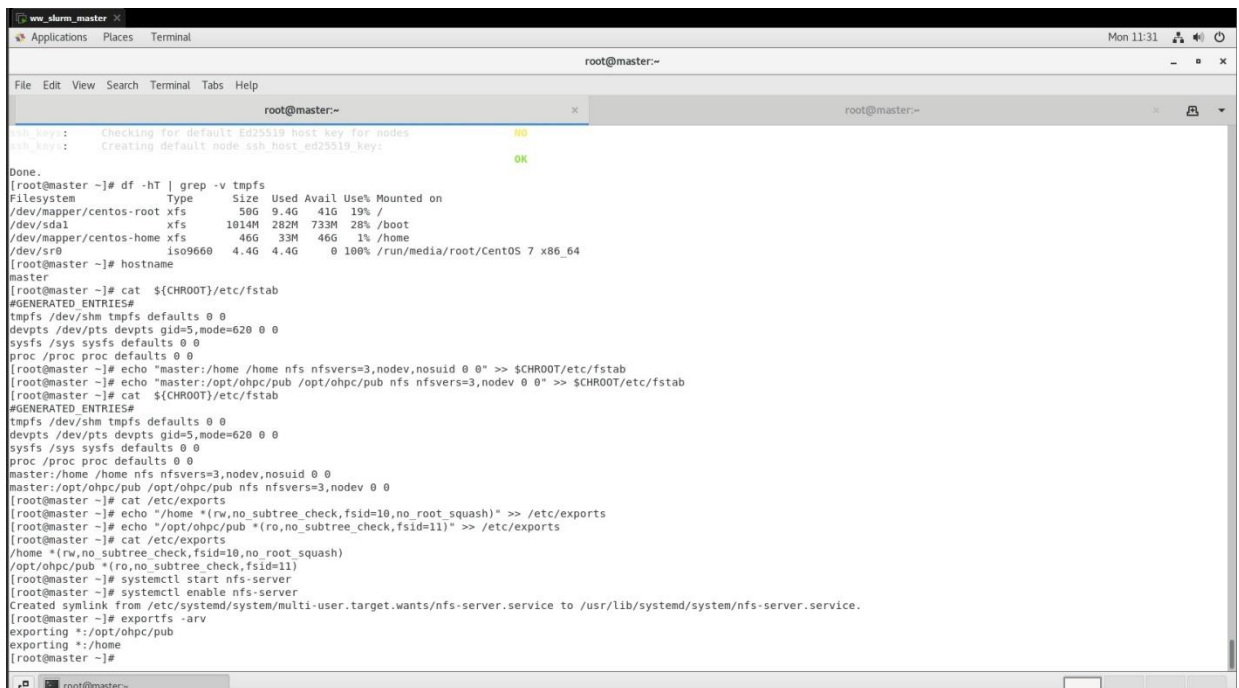


```
ww_shum_master x
Applications Places Terminal
root@master:~
Mon 11:29

File Edit View Search Terminal Tabs Help

root@master:~
[root@master ~]# winit database
database: Checking to see if RPM 'mysql-server' is installed NO
database: Checking to see if RPM 'mariadb-server' is installed OK
database: Activating systemd unit: mariadb
database: + /bin/systemctl -q enable mariadb.service OK
database: + /bin/systemctl -q restart mariadb.service OK
database: Database version: 1
database: + mysql --defaults-extra-file=/tmp/0.IHbEuSARU8yh/my.cnf ware OK
database: + mysql --defaults-extra-file=/tmp/0.IHbEuSARU8yh/my.cnf ware OK
database: Checking binstore kind SUCCESS
Done.
[root@master ~]# winit ssh_keys
ssh_key: Checking ssh keys for root OK
ssh_key: Checking root's ssh config OK
ssh_key: Checking for default RSA host key for nodes NO
ssh_key: Creating default node ssh host rsa keys
ssh_key: + ssh-keygen -q -t rsa -f /etc/warewulf/vnfs/ssh/ssh_host_rsa OK
ssh_key: Checking for default DSA host key for nodes NO
ssh_key: Creating default node ssh host dsa keys
ssh_key: + ssh-keygen -q -t dsa -f /etc/warewulf/vnfs/ssh/ssh_host_dsa OK
ssh_key: Checking for default ECDSA host key for nodes NO
ssh_key: Creating default node ssh host_ecdsa_keys OK
ssh_key: Checking for default Ed25519 host key for nodes NO
ssh_key: Creating default node ssh host_ed25519_keys OK
Done.
[root@master ~]#
```

## Snapshot 4: Starting and Enabling NFS-service

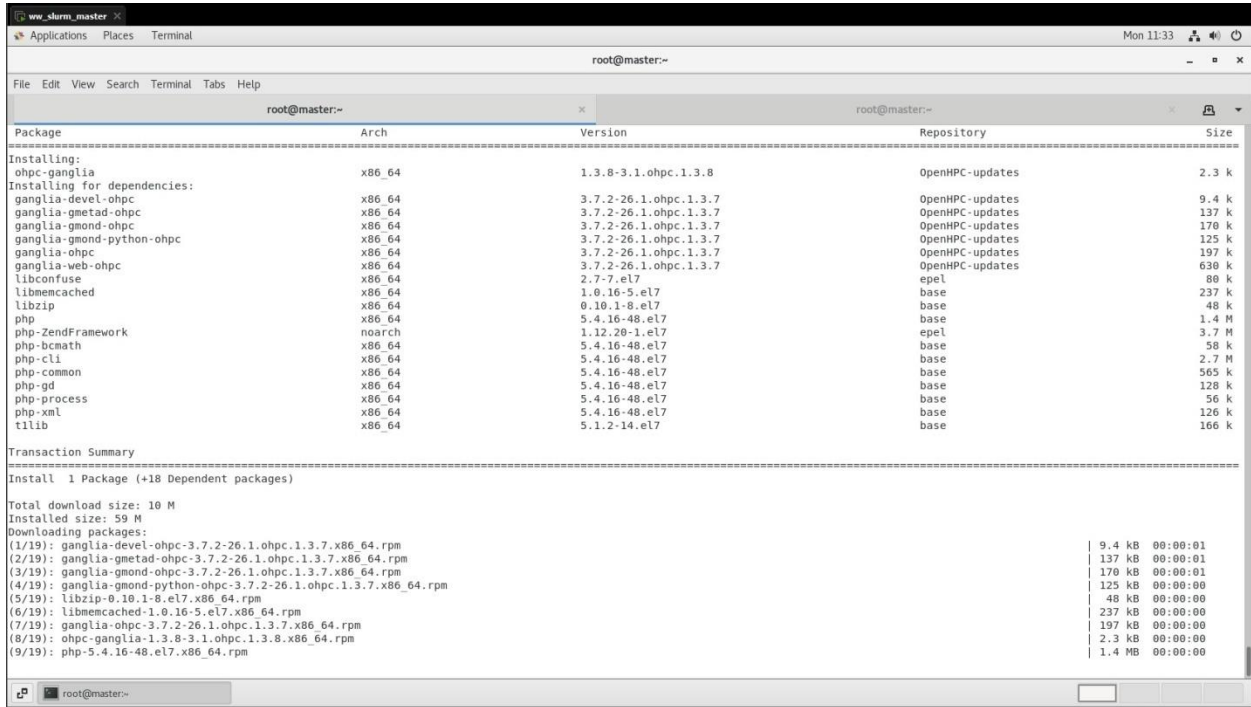


```
ww_shum_master x
Applications Places Terminal
root@master:~
Mon 11:31

File Edit View Search Terminal Tabs Help

root@master:~
ssh_key: Checking for default Ed25519 host key for nodes NO
ssh_key: Creating default node ssh host_ed25519_keys OK
Done.
[root@master ~]# df -HT | grep -v tmpfs
Filesystem Type Size Used Avail Use% Mounted on
/dev/mapper/centos-root xfs 50G 9.4G 41G 19% /
/dev/sdal xfs 1014M 282M 733M 28% /boot
/dev/mapper/centos-home xfs 46G 33M 46G 1% /home
/dev/sr0 iso9660 4.4G 4.4G 0 100% /run/media/root/CentOS 7 x86_64
[root@master ~]# hostname
master
[root@master ~]# cat ${CHROOT}/etc/fstab
#GENERATED ENTRIES#
tmpfs /dev/shm tmpfs defaults 0 0
devpts /dev/pts devpts gid=5,mode=620 0 0
sysfs /sys sysfs defaults 0 0
proc /proc proc defaults 0 0
[root@master ~]# echo "master:/home /home nfs nfsvers=3,nodew,nosuid 0 0" >> ${CHROOT}/etc/fstab
[root@master ~]# echo "master:/opt/ohpc/pub /opt/ohpc/pub nfs nfsvers=3,nodew 0 0" >> ${CHROOT}/etc/fstab
[root@master ~]# cat ${CHROOT}/etc/fstab
#GENERATED ENTRIES#
tmpfs /dev/shm tmpfs defaults 0 0
devpts /dev/pts devpts gid=5,mode=620 0 0
sysfs /sys sysfs defaults 0 0
proc /proc proc defaults 0 0
master:/home /home nfs nfsvers=3,nodew,nosuid 0 0
master:/opt/ohpc/pub /opt/ohpc/pub nfs nfsvers=3,nodew 0 0
[root@master ~]# cat /etc/exports
[root@master ~]# echo "/home *(rw,no_subtree_check,fsid=10,no_root_squash)" >> /etc/exports
[root@master ~]# echo "/opt/ohpc/pub *(ro,no_subtree_check,fsid=11)" >> /etc/exports
[root@master ~]# cat /etc/exports
/home *(rw,no_subtree_check,fsid=10,no_root_squash)
/opt/ohpc/pub *(ro,no_subtree_check,fsid=11)
[root@master ~]# systemctl start nfs-server
[root@master ~]# systemctl enable nfs-server
Created symlink from /etc/systemd/system/multi-user.target.wants/nfs-server.service to /usr/lib/systemd/system/nfs-server.service.
[root@master ~]# exportfs -arv
exporting *:opt/ohpc/pub
exporting *:home
[root@master ~]#
```

## Snapshot 5: Installation of Ganglia

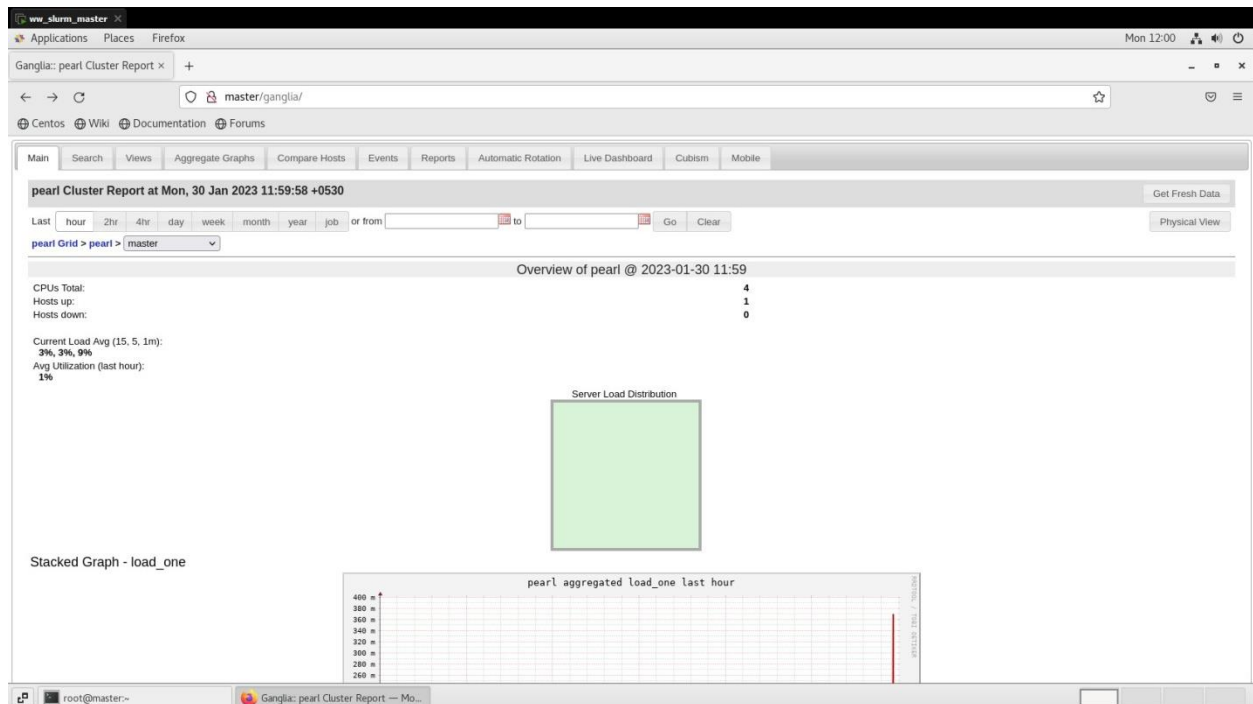


```
root@master:~# dnf install ohpc-ganglia
Installing:
ohpc-ganglia                                x86_64                                1.3.8-3.1.ohpc.1.3.8                                OpenHPC-updates                                2.3 k
Installing for dependencies:
ganglia-devel-ohpc                          x86_64                                3.7.2-26.1.ohpc.1.3.7                                OpenHPC-updates                                9.4 k
ganglia-gmetad-ohpc                        x86_64                                3.7.2-26.1.ohpc.1.3.7                                OpenHPC-updates                                137 k
ganglia-gmond-ohpc                         x86_64                                3.7.2-26.1.ohpc.1.3.7                                OpenHPC-updates                                170 k
ganglia-gmond-python-ohpc                  x86_64                                3.7.2-26.1.ohpc.1.3.7                                OpenHPC-updates                                125 k
ganglia-ohpc                               x86_64                                3.7.2-26.1.ohpc.1.3.7                                OpenHPC-updates                                197 k
ganglia-web-ohpc                           x86_64                                3.7.2-26.1.ohpc.1.3.7                                OpenHPC-updates                                638 k
libconfuse                                 x86_64                                2.7-7.el7                                             epel                                             86 k
libmemcached                              x86_64                                1.0.16-5.el7                                         base                                            237 k
libzip                                    x86_64                                0.10.1-8.el7                                         base                                            48 k
php                                         x86_64                                5.4.16-48.el7                                        base                                            1.4 M
php-ZendFramework                          noarch                                  1.12.20-1.el7                                        epel                                            3.7 M
php-bcmath                                 x86_64                                5.4.16-48.el7                                        base                                            58 k
php-cli                                    x86_64                                5.4.16-48.el7                                        base                                            2.7 M
php-common                                 x86_64                                5.4.16-48.el7                                        base                                            565 k
php-gd                                     x86_64                                5.4.16-48.el7                                        base                                            128 k
php-process                                x86_64                                5.4.16-48.el7                                        base                                            56 k
php-xml                                    x86_64                                5.4.16-48.el7                                        base                                            126 k
tidlib                                     x86_64                                5.1.2-14.el7                                         base                                            166 k

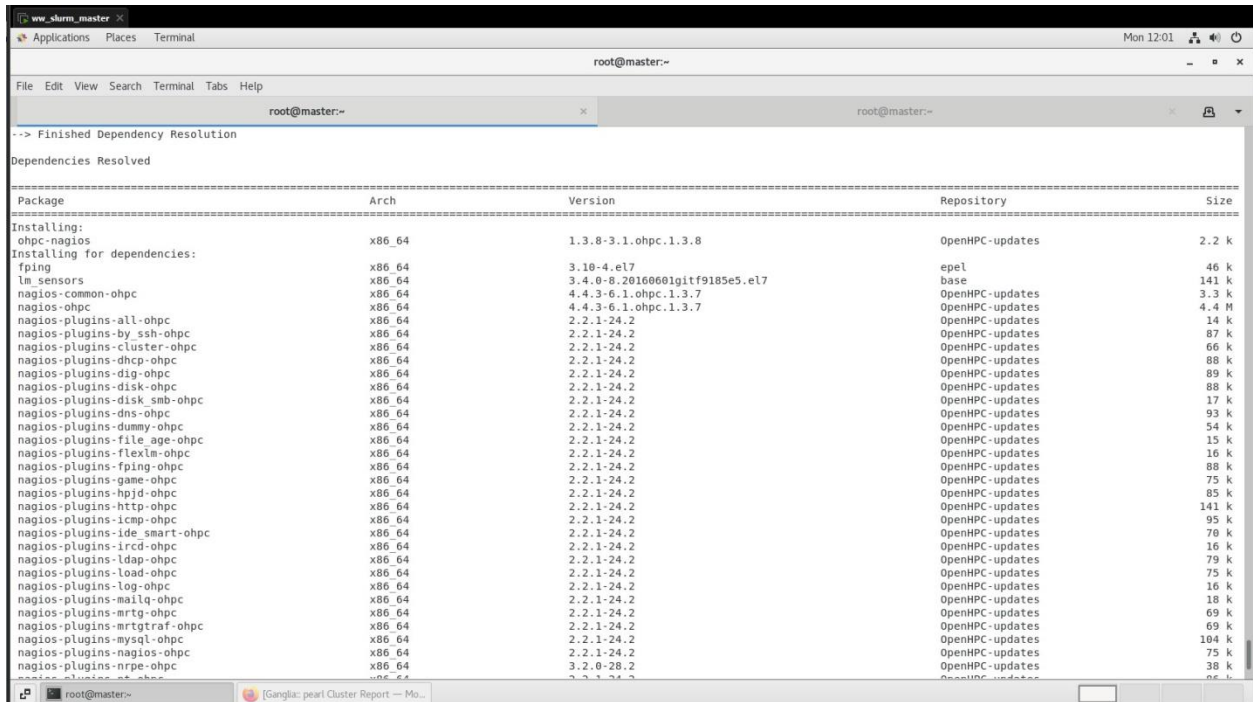
Transaction Summary
-----
Install 1 Package (+18 Dependent packages)

Total download size: 10 M
Installed size: 59 M
Downloading packages:
(1/19): ganglia-devel-ohpc-3.7.2-26.1.ohpc.1.3.7.x86_64.rpm | 9.4 kB 00:00:01
(2/19): ganglia-gmetad-ohpc-3.7.2-26.1.ohpc.1.3.7.x86_64.rpm | 137 kB 00:00:01
(3/19): ganglia-gmond-ohpc-3.7.2-26.1.ohpc.1.3.7.x86_64.rpm | 170 kB 00:00:01
(4/19): ganglia-gmond-python-ohpc-3.7.2-26.1.ohpc.1.3.7.x86_64.rpm | 125 kB 00:00:00
(5/19): libzip-0.10.1-8.el7.x86_64.rpm | 48 kB 00:00:00
(6/19): libmemcached-1.0.16-5.el7.x86_64.rpm | 237 kB 00:00:00
(7/19): ganglia-ohpc-3.7.2-26.1.ohpc.1.3.7.x86_64.rpm | 197 kB 00:00:00
(8/19): ohpc-ganglia-1.3.8-3.1.ohpc.1.3.8.x86_64.rpm | 2.3 kB 00:00:00
(9/19): php-5.4.16-48.el7.x86_64.rpm | 1.4 MB 00:00:00
```

## Snapshot 6: Ganglia Interface on Browser

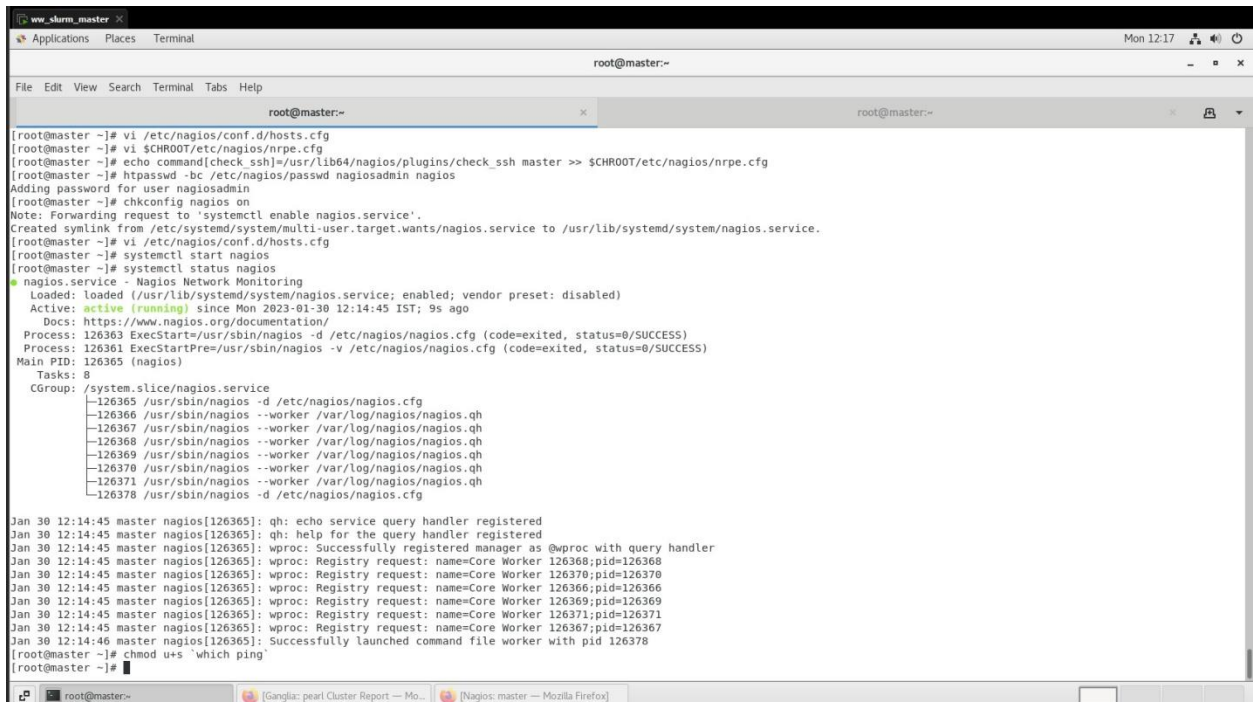


## Snapshot 7: Installation of Nagios



```
root@master:~# dpkg --get-selections | grep nagios
root@master:~# dpkg-query -f='${Package} ${Architecture} ${Version} ${Repository} ${Size}\n' -W -f='${Package} ${Architecture} ${Version} ${Repository} ${Size}\n'
Package Architecture Version Repository Size
Installing:
ohpc-nagios x86_64 1.3.8-3.1.ohpc.1.3.8 OpenHPC-updates 2.2 k
Installing for dependencies:
fping x86_64 3.10-4.el7 epel 46 k
lm_sensors x86_64 3.4.0-8.20160601gitf9185e5.el7 base 141 k
nagios-common-ohpc x86_64 4.4.3-6.1.ohpc.1.3.7 OpenHPC-updates 3.3 k
nagios-ohpc x86_64 4.4.3-6.1.ohpc.1.3.7 OpenHPC-updates 4.4 M
nagios-plugins-all-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 14 k
nagios-plugins-by_ssh-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 87 k
nagios-plugins-cluster-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 66 k
nagios-plugins-dhcp-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 88 k
nagios-plugins-dig-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 89 k
nagios-plugins-disk-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 88 k
nagios-plugins-disk_smb-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 17 k
nagios-plugins-dns-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 93 k
nagios-plugins-dummy-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 54 k
nagios-plugins-file_age-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 15 k
nagios-plugins-flexlm-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 16 k
nagios-plugins-fping-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 88 k
nagios-plugins-game-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 75 k
nagios-plugins-hpjd-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 85 k
nagios-plugins-http-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 141 k
nagios-plugins-icmp-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 95 k
nagios-plugins-ide_smart-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 70 k
nagios-plugins-ircd-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 16 k
nagios-plugins-ldap-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 79 k
nagios-plugins-load-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 75 k
nagios-plugins-log-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 16 k
nagios-plugins-mailq-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 18 k
nagios-plugins-mrtg-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 69 k
nagios-plugins-mrtgtraf-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 69 k
nagios-plugins-mysql-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 104 k
nagios-plugins-nagios-ohpc x86_64 2.2.1-24.2 OpenHPC-updates 75 k
nagios-plugins-nrpe-ohpc x86_64 3.2.0-28.2 OpenHPC-updates 38 k
```

## Snapshot 8: Setting up of Username and Password for Nagios



```
root@master:~# vi /etc/nagios/conf.d/hosts.cfg
root@master:~# vi $CHR00T/etc/nagios/nrpe.cfg
root@master:~# echo command[check_ssh]=usr/lib64/nagios/plugins/check_ssh master >> $CHR00T/etc/nagios/nrpe.cfg
root@master:~# htpasswd -bc /etc/nagios/passwd nagiosadmin nagios
Adding password for user nagiosadmin
root@master:~# chkconfig nagios on
Note: Forwarding request to 'systemctl enable nagios.service'.
Created symlink from /etc/systemd/system/multi-user.target.wants/nagios.service to /usr/lib/systemd/system/nagios.service.
root@master:~# vi /etc/nagios/conf.d/hosts.cfg
root@master:~# systemctl start nagios
root@master:~# systemctl status nagios
nagios.service - Nagios Network Monitoring
Loaded: loaded (/usr/lib/systemd/system/nagios.service; enabled; vendor preset: disabled)
Active: active (running) since Mon 2023-01-30 12:14:45 IST; 9s ago
Docs: https://www.nagios.org/documentation/
Process: 126363 ExecStartPre=usr/sbin/nagios -d /etc/nagios/nagios.cfg (code=exited, status=0/SUCCESS)
Process: 126361 ExecStartPre=usr/sbin/nagios -v /etc/nagios/nagios.cfg (code=exited, status=0/SUCCESS)
Main PID: 126365 (nagios)
Tasks: 8
CGroup: /system.slice/nagios.service
├─126365 /usr/sbin/nagios -d /etc/nagios/nagios.cfg
├─126366 /usr/sbin/nagios --worker /var/log/nagios/nagios.qh
├─126367 /usr/sbin/nagios --worker /var/log/nagios/nagios.qh
├─126368 /usr/sbin/nagios --worker /var/log/nagios/nagios.qh
├─126369 /usr/sbin/nagios --worker /var/log/nagios/nagios.qh
├─126370 /usr/sbin/nagios --worker /var/log/nagios/nagios.qh
├─126371 /usr/sbin/nagios --worker /var/log/nagios/nagios.qh
└─126378 /usr/sbin/nagios -d /etc/nagios/nagios.cfg
Jan 30 12:14:45 master nagios[126365]: qh: echo service query handler registered
Jan 30 12:14:45 master nagios[126365]: qh: help for the query handler registered
Jan 30 12:14:45 master nagios[126365]: wproc: Successfully registered manager as @wproc with query handler
Jan 30 12:14:45 master nagios[126365]: wproc: Registry request: name=Core Worker 126368;pid=126368
Jan 30 12:14:45 master nagios[126365]: wproc: Registry request: name=Core Worker 126370;pid=126370
Jan 30 12:14:45 master nagios[126365]: wproc: Registry request: name=Core Worker 126366;pid=126366
Jan 30 12:14:45 master nagios[126365]: wproc: Registry request: name=Core Worker 126369;pid=126369
Jan 30 12:14:45 master nagios[126365]: wproc: Registry request: name=Core Worker 126371;pid=126371
Jan 30 12:14:45 master nagios[126365]: wproc: Registry request: name=Core Worker 126367;pid=126367
Jan 30 12:14:46 master nagios[126365]: Successfully launched command file worker with pid 126378
root@master:~# chmod u+s `which ping`
root@master:~#
```



## Snapshot 9: Nagios Interface on Browser

The screenshot shows the Nagios web interface in a Mozilla Firefox browser window. The address bar shows 'master/nagios/'. The interface includes a sidebar with navigation links like 'General', 'Current Status', 'Problems', 'Reports', and 'System'. The main content area displays 'Current Network Status' with a last update of 'Mon Jan 30 12:16:01 IST 2023'. It also shows 'Host Status Totals' and 'Service Status Totals' with various status counts. A table titled 'Host Status Details For All Host Groups' lists hosts like 'localhost', 'node1', and 'node2' with their status (UP, PENDING) and last check times. A 'Page Tour' button is visible on the right side.

## Snapshot 10: User Synchronization

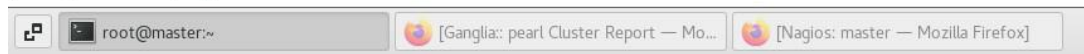
```
[root@master ~]# wwsh file list
No objects found
[root@master ~]# wwsh file import /etc/passwd
[root@master ~]# wwsh file import /etc/group
[root@master ~]# wwsh file import /etc/shadow
[root@master ~]# wwsh file list
group           : rw-r--r-- 1 root root      1374 /etc/group
passwd          : rw-r--r-- 1 root root      3902 /etc/passwd
shadow          : rw-r----- 1 root root      1826 /etc/shadow
[root@master ~]#
```

The terminal window shows the command prompt '[root@master ~]#'. Below the terminal, there are two open browser windows: '[Ganglia: pearl Cluster Report — Mo...]' and '[Nagios: master — Mozilla Firefox]'. A 'Page Tour' button is also visible on the right side of the Nagios window.

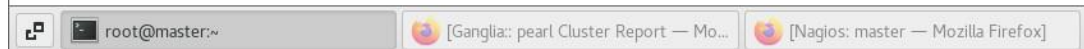


## Snapshot 11: Kernel of Bootstrap image

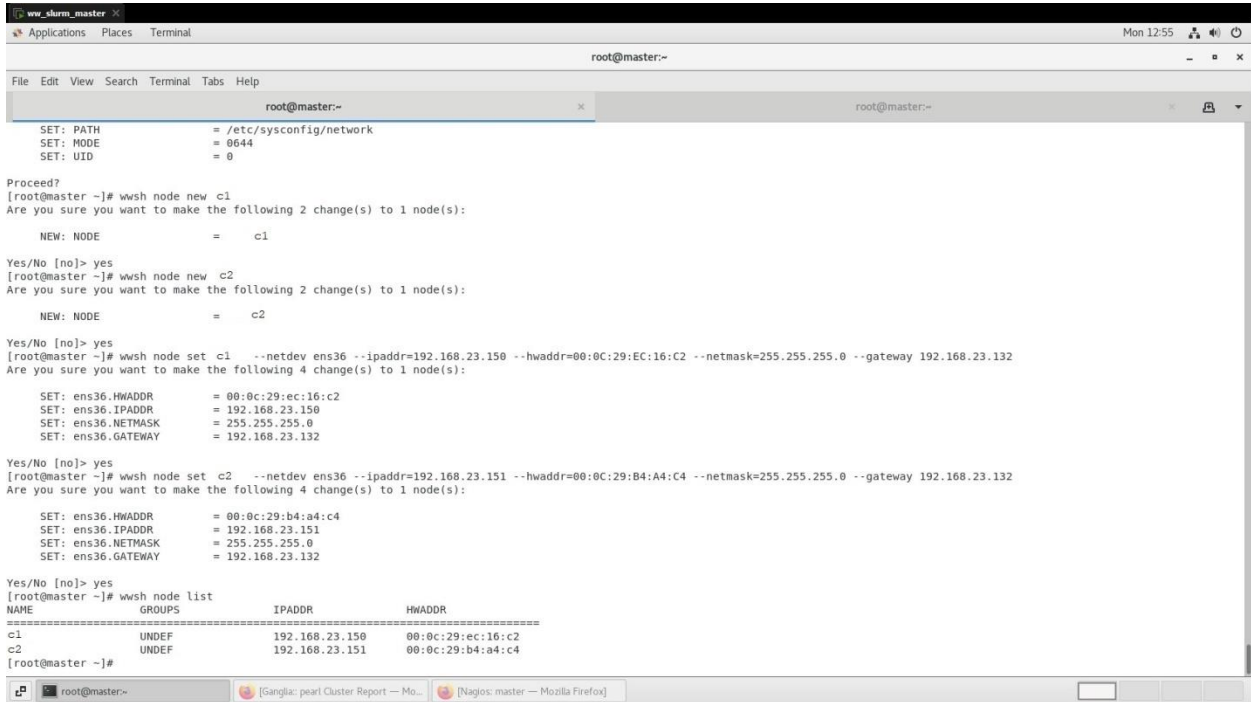
```
[root@master ~]# export WW_CONF=/etc/warewulf/bootstrap.conf
[root@master ~]# echo "drivers += updates/kernel/" >> $WW_CONF
[root@master ~]# echo "modprobe += ahci, nvme" >> $WW_CONF
[root@master ~]# echo "drivers += overlay" >> $WW_CONF
[root@master ~]# wwbootstrap `uname -r`
Number of drivers included in bootstrap: 543
Number of firmware images included in bootstrap: 102
Building and compressing bootstrap
Integrating the Warewulf bootstrap: 3.10.0-1160.81.1.el7.x86_64
Including capability: provision-adhoc
Including capability: provision-files
Including capability: provision-selinux
Including capability: provision-vnfs
Including capability: setup-filesystems
Including capability: setup-ipmi
Including capability: transport-http
Compressing the initramfs
Locating the kernel object
Bootstrap image '3.10.0-1160.81.1.el7.x86_64' is ready
Done.
You have mail in /var/spool/mail/root
[root@master ~]#
```



```
[root@master ~]# echo ${CHROOT}
/opt/ohpc/admin/images/centos7.7
[root@master ~]# wwnfs --chroot $CHROOT
Using 'centos7.7' as the VNFS name
Creating VNFS image from centos7.7
Compiling hybridization link tree           : 0.19 s
Building file list                          : 0.38 s
Compiling and compressing VNFS              : 43.97 s
Adding image to datastore                   : 17.48 s
Wrote a new configuration file at: /etc/warewulf/vnfs/centos7.7.conf
Total elapsed time                          : 62.02 s
[root@master ~]#
```



## Snapshot 12: Adding Node List



```
root@master:~# wwsd node new c1
Are you sure you want to make the following 2 change(s) to 1 node(s):

NEW: NODE           = c1

Yes/No [no]> yes
root@master:~# wwsd node new c2
Are you sure you want to make the following 2 change(s) to 1 node(s):

NEW: NODE           = c2

Yes/No [no]> yes
root@master:~# wwsd node set c1 --netdev ens36 --ipaddr=192.168.23.150 --hwaddr=00:0c:29:ec:16:c2 --netmask=255.255.255.0 --gateway 192.168.23.132
Are you sure you want to make the following 4 change(s) to 1 node(s):

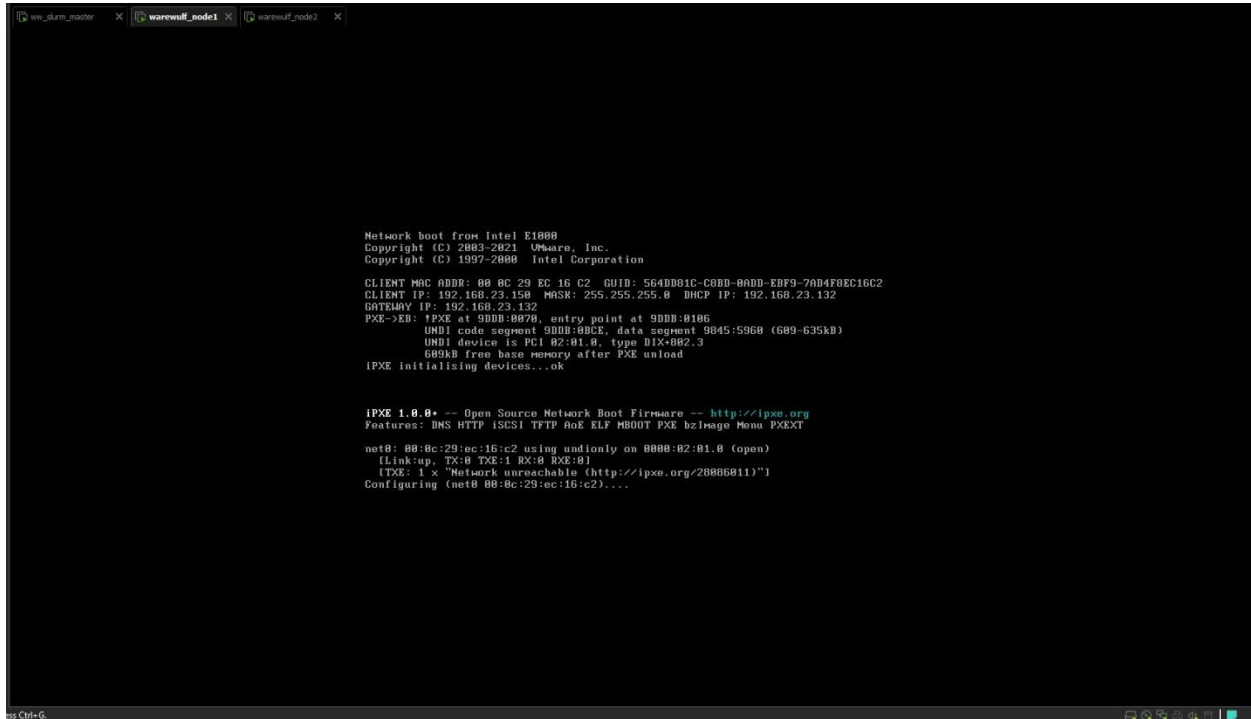
SET: ens36.HWADDR    = 00:0c:29:ec:16:c2
SET: ens36.IPADDR     = 192.168.23.150
SET: ens36.NETMASK    = 255.255.255.0
SET: ens36.GATEWAY    = 192.168.23.132

Yes/No [no]> yes
root@master:~# wwsd node set c2 --netdev ens36 --ipaddr=192.168.23.151 --hwaddr=00:0c:29:b4:a4:c4 --netmask=255.255.255.0 --gateway 192.168.23.132
Are you sure you want to make the following 4 change(s) to 1 node(s):

SET: ens36.HWADDR    = 00:0c:29:b4:a4:c4
SET: ens36.IPADDR     = 192.168.23.151
SET: ens36.NETMASK    = 255.255.255.0
SET: ens36.GATEWAY    = 192.168.23.132

Yes/No [no]> yes
root@master:~# wwsd node list
=====
NAME      GROUPS      IPADDR      HWADDR
=====
c1        UNDEF      192.168.23.150  00:0c:29:ec:16:c2
c2        UNDEF      192.168.23.151  00:0c:29:b4:a4:c4
root@master:~#
```

## Snapshot 13: Starting Nodes Using Bootstrap image through warewulf



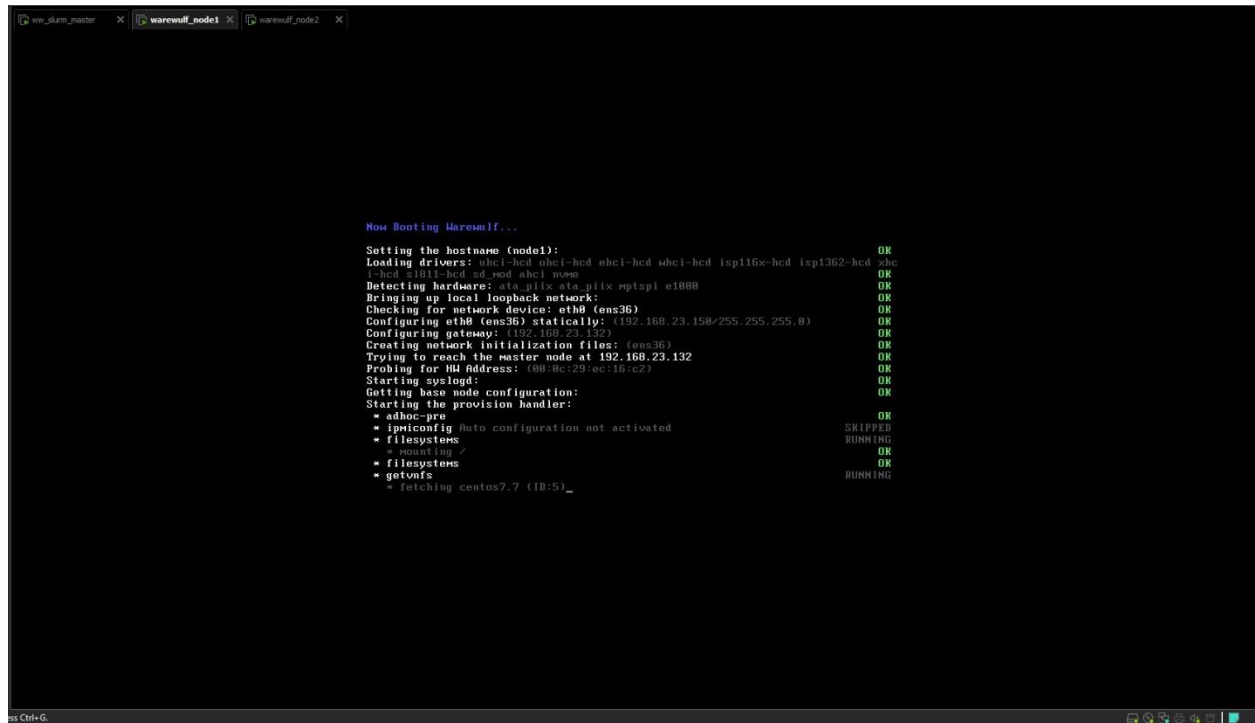
```
Network boot from Intel E1000
Copyright (C) 2003-2021 VMware, Inc.
Copyright (C) 1997-2000 Intel Corporation

CLIENT MAC ADDR: 00:0c:29:ec:16:c2  GUID: 5640d01c-c0bd-0add-ebf9-70d4f0ec16c2
CLIENT IP: 192.168.23.150  MASK: 255.255.255.0  DHCP IP: 192.168.23.132
GATEWAY IP: 192.168.23.132
PXE->EB: IPXE at 900b:0070, entry point at 900b:0106
UNDI code segment 000b:000e, data segment 9045:5960 (689-635kB)
UNDI device is PCI 02:01.0, type DIX-902.3
689kB free base memory after PXE unload
IPXE initialising devices...ok

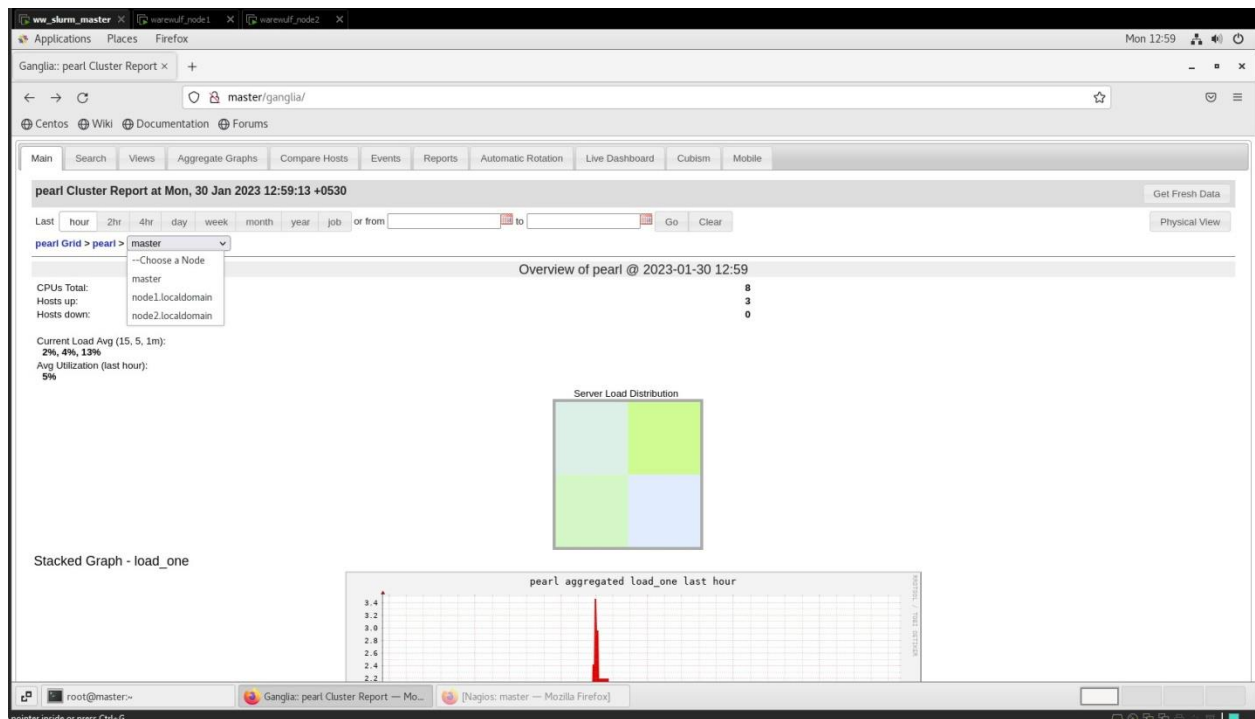
IPXE 1.0.0+ -- Open Source Network Boot Firmware -- http://ipxe.org
Features: DNS HTTP iSCSI TFTP ROK ELF MBOOT PXE bzImage Menu PXEXT

net0: 00:0c:29:ec:16:c2 using undionly on 0000:02:01.0 (open)
(Link:up, TX:0 PXE:1 RX:0 PXE:0)
[TXE: 1 x "Network unreachable (http://ipxe.org/20080811)"]
Configuring (net0 00:0c:29:ec:16:c2)...
```

## Snapshot 14: Booting using Warewulf Started



## Snapshot 15: Ganglia Interface with Confirmation of addition of two nodes



## Snapshot 16: Nagios Confirmation of Addition of two nodes in Cluster

The screenshot shows the Nagios web interface in a Firefox browser window. The address bar shows 'master/nagios/'. The interface includes a sidebar with navigation links like 'Home', 'Documentation', 'Current Status', 'Problems', 'Reports', and 'System'. The main content area displays 'Current Network Status' with a last update of 'Mon Jan 30 12:59:53 IST 2023'. It also shows 'Host Status Totals' and 'Service Status Totals'. A table titled 'Host Status Details For All Host Groups' lists the following hosts:

Host	Status	Last Check	Duration	Status Information
localhost	UP	01-30-2023 12:58:38	0d 0h 45m 7s	PING OK - Packet loss = 0%, RTA = 0.08 ms
node1	DOWN	01-30-2023 12:55:54	0d 0h 43m 28s	CRITICAL - Host Unreachable (192.168.23.150)
node2	DOWN	01-30-2023 12:57:41	0d 0h 41m 48s	CRITICAL - Host Unreachable (192.168.23.151)

Results 1 - 3 of 3 Matching Hosts

## Snapshot 17: Slurmctld Service Status Confirmation

The screenshot shows a terminal window with the following commands and output:

```
root@master ~# wssh node list
NAME      GROUPS      IPADDR      HWADDR
-----
c1        UNDEF      192.168.23.150  08:0c:29:ec:16:c2
c2        UNDEF      192.168.23.151  08:0c:29:b4:a4:c4

root@master ~# systemctl start slurmctld
root@master ~# systemctl status slurmctld
slurmctld.service - Slurm controller daemon
Loaded: loaded (/usr/lib/systemd/system/slurmctld.service; disabled; vendor preset: disabled)
Active: active (running) since Mon 2023-01-30 14:17:37 IST; 11s ago
Process: 3475 ExecStart=/usr/sbin/slurmctld $SLURMCTLD_OPTIONS (code=exited, status=0/SUCCESS)
Main PID: 3477 (slurmctld)
Tasks: 11
CGroup: /system.slice/slurmctld.service
        └─3477 /usr/sbin/slurmctld

Jan 30 14:17:37 master systemd[1]: Starting Slurm controller daemon...
Jan 30 14:17:37 master systemd[1]: Can't open PID file /var/run/slurmctld.pid (yet?) af...ory
Jan 30 14:17:37 master systemd[1]: Started Slurm controller daemon.
Hint: Some lines were ellipsized, use -l to show in full.
root@master ~#
```

## Snapshot 18: Slurmd Daemon on c1 node and c2 node

```
Kernel 3.10.0-1160.81.1.el7.x86_64 on an x86_64

c1 login: root
Password:
[root@c1 ~]# systemctl start slurmd
[root@c1 ~]# systemctl status slurmd
■ slurmd.service - Slurm node daemon
   Loaded: loaded (/usr/lib/systemd/system/slurmd.service; enabled; vendor prese
t: disabled)
   Active: active (running) since Mon 2023-01-30 14:17:19 IST; 42s ago
     Process: 1182 ExecStart=/usr/sbin/slurmd $SLURMD_OPTIONS (code=exited, status=
0/SUCCESS)
    Main PID: 1219 (slurmd)
       Tasks: 2
      Memory: 1.1M
      CGroup: /system.slice/slurmd.service
              └─1219 /usr/sbin/slurmd

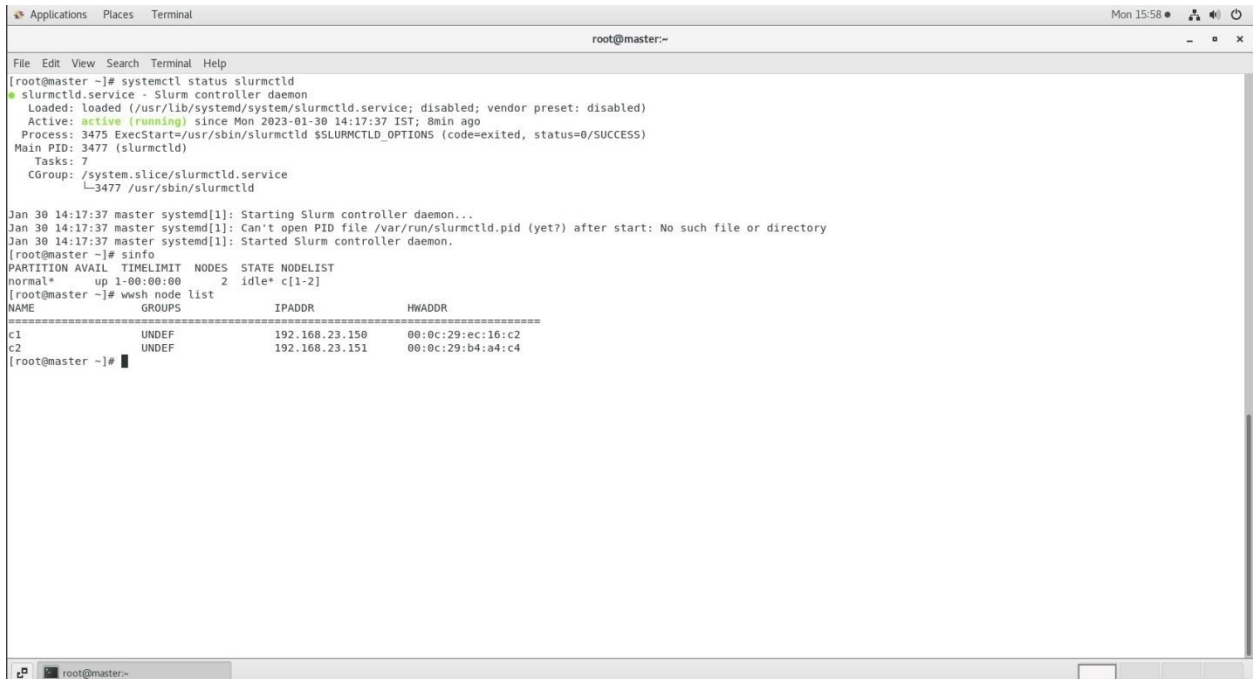
Jan 30 14:16:59 c1 systemd[1]: Starting Slurm node daemon...
Jan 30 14:17:19 c1 systemd[1]: Can't open PID file /var/run/slurmd.pid (yet...ry
Jan 30 14:17:19 c1 systemd[1]: Started Slurm node daemon.
Hint: Some lines were ellipsized, use -l to show in full.
[root@c1 ~]# date
Mon Jan 30 14:20:13 IST 2023
[root@c1 ~]#
```

```
CentOS Linux 7 (Core)
Kernel 3.10.0-1160.81.1.el7.x86_64 on an x86_64

c2 login: root
Password:
[root@c2 ~]# systemctl status slurmd
■ slurmd.service - Slurm node daemon
   Loaded: loaded (/usr/lib/systemd/system/slurmd.service; enabled; vendor prese
t: disabled)
   Active: active (running) since Mon 2023-01-30 14:17:28 IST; 1min 9s ago
     Process: 1248 ExecStart=/usr/sbin/slurmd $SLURMD_OPTIONS (code=exited, status=
0/SUCCESS)
    Main PID: 1265 (slurmd)
       Tasks: 2
      Memory: 1.1M
      CGroup: /system.slice/slurmd.service
              └─1265 /usr/sbin/slurmd

Jan 30 14:17:07 c2 systemd[1]: Starting Slurm node daemon...
Jan 30 14:17:28 c2 systemd[1]: Can't open PID file /var/run/slurmd.pid (yet...ry
Jan 30 14:17:28 c2 systemd[1]: Started Slurm node daemon.
Hint: Some lines were ellipsized, use -l to show in full.
[root@c2 ~]# date
Mon Jan 30 14:19:47 IST 2023
[root@c2 ~]#
```

## Snapshot 19: sinfo and state of nodes



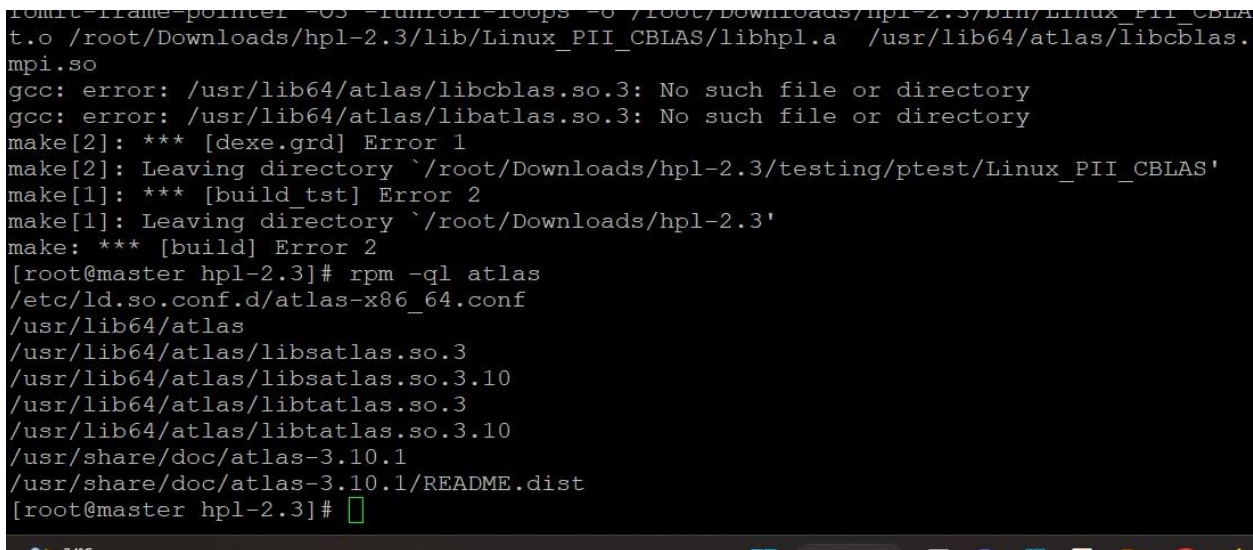
A terminal window titled 'root@master:~' showing the output of several commands. The first command is 'systemctl status slurmctld', which shows the service is loaded and active. The second command is 'sinfo', which shows the state of the nodes. The output of 'sinfo' is as follows:

```

[root@master ~]# systemctl status slurmctld
slurmctld.service - Slurm controller daemon
Loaded: loaded (/usr/lib/systemd/system/slurmctld.service; disabled; vendor preset: disabled)
Active: active (running) since Mon 2023-01-30 14:17:37 IST; 8min ago
Process: 3475 ExecStart=/usr/sbin/slurmctld $SLURMCTLD_OPTIONS (code=exited, status=0/SUCCESS)
Main PID: 3477 (slurmctld)
Tasks: 7
CGroup: /system.slice/slurmctld.service
        └─3477 /usr/sbin/slurmctld

Jan 30 14:17:37 master systemd[1]: Starting Slurm controller daemon...
Jan 30 14:17:37 master systemd[1]: Can't open PID file /var/run/slurmctld.pid (yet?) after start: No such file or directory
Jan 30 14:17:37 master systemd[1]: Started Slurm controller daemon.
[root@master ~]# sinfo
PARTITION AVAIL  TIMELIMIT  NODES  STATE MODELIST
normal*    up 1-00:00:00    2    idle* c[1-2]
[root@master ~]# wsh node list
NAME      GROUPS      IPADDR      HWADDR
=====
c1        UNDEF      192.168.23.150  00:0c:29:ec:16:c2
c2        UNDEF      192.168.23.151  00:0c:29:b4:a4:c4
[root@master ~]#
```

## Snapshot 20: HPL Benchmarking (atlas rpm)

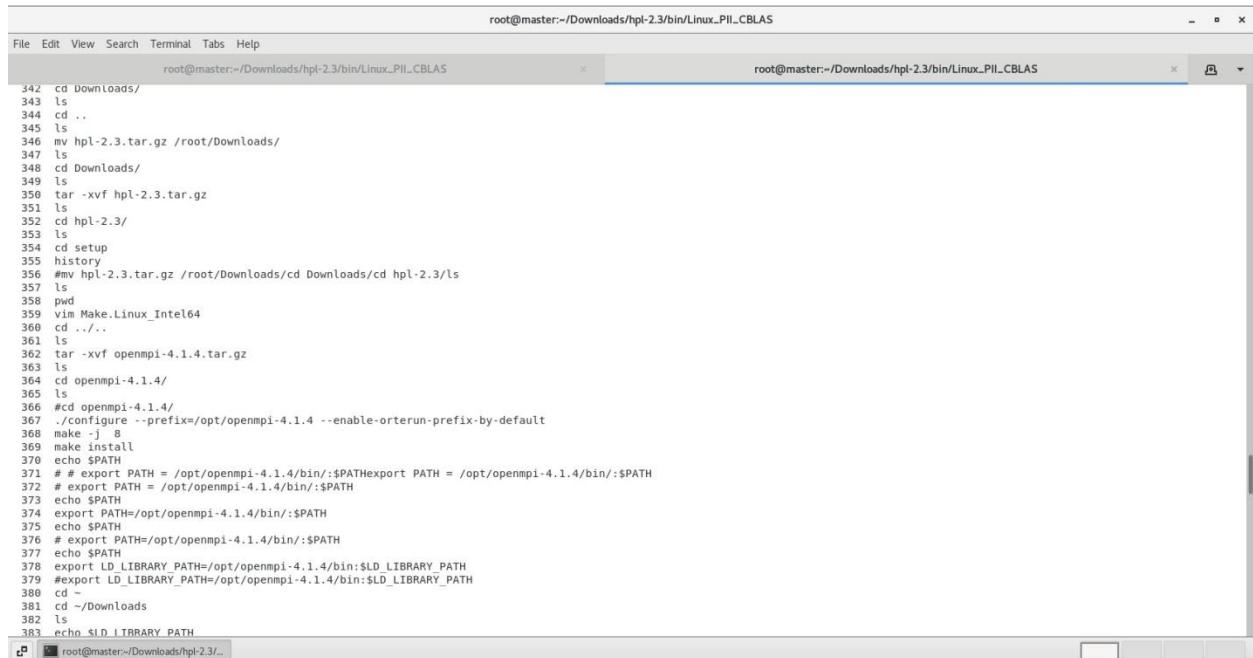


A terminal window showing the output of a build process for HPL. The first part shows errors from 'make' and 'gcc' due to missing files. The second part shows the output of 'rpm -ql atlas', which lists the files installed by the atlas rpm.

```

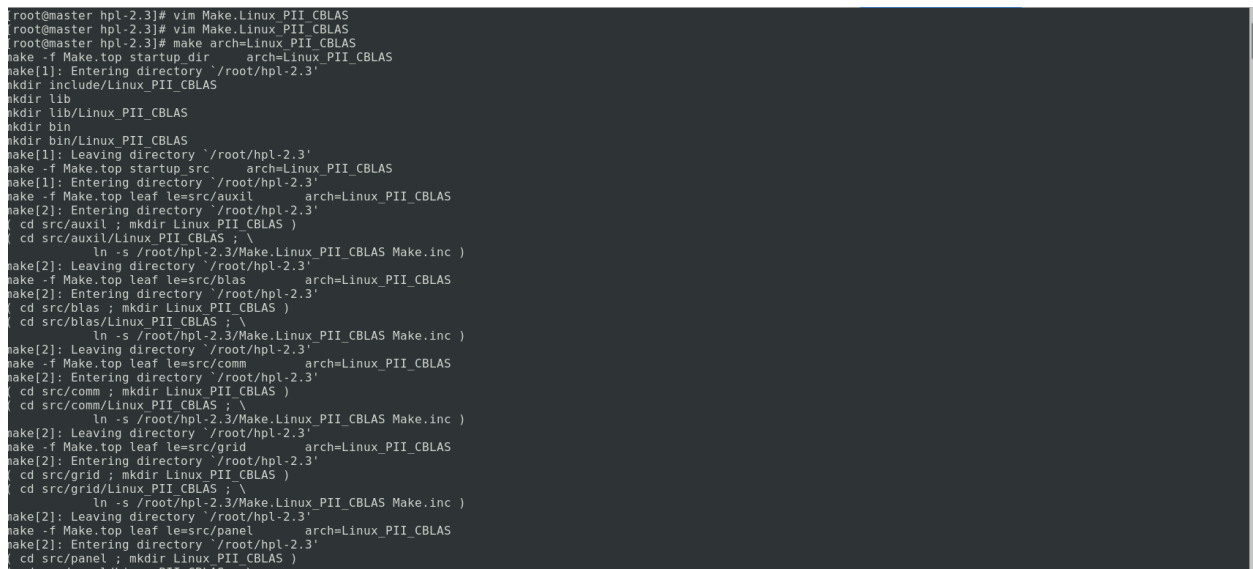
[root@master hpl-2.3]# make
make[2]: *** [dexe.grd] Error 1
make[2]: Leaving directory `/root/Downloads/hpl-2.3/testing/ptest/Linux_PII_CBLAS'
make[1]: *** [build_tst] Error 2
make[1]: Leaving directory `/root/Downloads/hpl-2.3'
make: *** [build] Error 2
[root@master hpl-2.3]# rpm -ql atlas
/etc/ld.so.conf.d/atlas-x86_64.conf
/usr/lib64/atlas
/usr/lib64/atlas/libsatlas.so.3
/usr/lib64/atlas/libsatlas.so.3.10
/usr/lib64/atlas/libtatlas.so.3
/usr/lib64/atlas/libtatlas.so.3.10
/usr/share/doc/atlas-3.10.1
/usr/share/doc/atlas-3.10.1/README.dist
[root@master hpl-2.3]#
```

## Snapshot 21: HPL Installation Commands

A terminal window titled 'root@master:~/Downloads/hpl-2.3/bin/Linux\_PII\_CBLAS' showing a series of commands for installing HPL. The commands include navigating directories, extracting tarballs, setting up the environment, and installing OpenMPI. The terminal output shows the execution of these commands, with some lines being commented out or skipped.

```
root@master:~/Downloads/hpl-2.3/bin/Linux_PII_CBLAS
File Edit View Search Terminal Tabs Help
root@master:~/Downloads/hpl-2.3/bin/Linux_PII_CBLAS
342 cd Downloads/
343 ls
344 cd ..
345 ls
346 mv hpl-2.3.tar.gz /root/Downloads/
347 ls
348 cd Downloads/
349 ls
350 tar -xvf hpl-2.3.tar.gz
351 ls
352 cd hpl-2.3/
353 ls
354 cd setup
355 history
356 #mv hpl-2.3.tar.gz /root/Downloads/cd Downloads/cd hpl-2.3/ls
357 ls
358 pwd
359 vim Make.Linux_Intel64
360 cd ../..
361 ls
362 tar -xvf openmpi-4.1.4.tar.gz
363 ls
364 cd openmpi-4.1.4/
365 ls
366 #cd openmpi-4.1.4/
367 ./configure --prefix=/opt/openmpi-4.1.4 --enable-orterun-prefix-by-default
368 make -j 8
369 make install
370 echo $PATH
371 # export PATH = /opt/openmpi-4.1.4/bin/:$PATHexport PATH = /opt/openmpi-4.1.4/bin/:$PATH
372 # export PATH = /opt/openmpi-4.1.4/bin/:$PATH
373 echo $PATH
374 export PATH=/opt/openmpi-4.1.4/bin/:$PATH
375 echo $PATH
376 # export PATH=/opt/openmpi-4.1.4/bin/:$PATH
377 echo $PATH
378 export LD_LIBRARY_PATH=/opt/openmpi-4.1.4/bin:$LD_LIBRARY_PATH
379 #export LD_LIBRARY_PATH=/opt/openmpi-4.1.4/bin:$LD_LIBRARY_PATH
380 cd ~
381 cd ~/Downloads
382 ls
383 echo $LD_LIBRARY_PATH
```

## Snapshot 22: make arch=Linux\_PII\_CBLAS command

A terminal window showing the execution of the 'make arch=Linux\_PII\_CBLAS' command. The output shows the make process creating directories and compiling source files. The terminal output is as follows:

```
root@master hpl-2.3]# vim Make.Linux_PII_CBLAS
root@master hpl-2.3]# vim Make.Linux_PII_CBLAS
root@master hpl-2.3]# make arch=Linux_PII_CBLAS
make -f Make.top startup_dir arch=Linux_PII_CBLAS
make[1]: Entering directory '/root/hpl-2.3'
mkdir include/Linux_PII_CBLAS
mkdir lib
mkdir lib/Linux_PII_CBLAS
mkdir bin
mkdir bin/Linux_PII_CBLAS
make[1]: Leaving directory '/root/hpl-2.3'
make -f Make.top startup_src arch=Linux_PII_CBLAS
make[1]: Entering directory '/root/hpl-2.3'
make -f Make.top leaf le=src/auxil arch=Linux_PII_CBLAS
make[2]: Entering directory '/root/hpl-2.3'
cd src/auxil ; mkdir Linux_PII_CBLAS )
cd src/auxil/Linux_PII_CBLAS ; \
ln -s /root/hpl-2.3/Make.Linux_PII_CBLAS Make.inc )
make[2]: Leaving directory '/root/hpl-2.3'
make -f Make.top leaf le=src/blas arch=Linux_PII_CBLAS
make[2]: Entering directory '/root/hpl-2.3'
cd src/blas ; mkdir Linux_PII_CBLAS )
cd src/blas/Linux_PII_CBLAS ; \
ln -s /root/hpl-2.3/Make.Linux_PII_CBLAS Make.inc )
make[2]: Leaving directory '/root/hpl-2.3'
make -f Make.top leaf le=src/comm arch=Linux_PII_CBLAS
make[2]: Entering directory '/root/hpl-2.3'
cd src/comm ; mkdir Linux_PII_CBLAS )
cd src/comm/Linux_PII_CBLAS ; \
ln -s /root/hpl-2.3/Make.Linux_PII_CBLAS Make.inc )
make[2]: Leaving directory '/root/hpl-2.3'
make -f Make.top leaf le=src/grid arch=Linux_PII_CBLAS
make[2]: Entering directory '/root/hpl-2.3'
cd src/grid ; mkdir Linux_PII_CBLAS )
cd src/grid/Linux_PII_CBLAS ; \
ln -s /root/hpl-2.3/Make.Linux_PII_CBLAS Make.inc )
make[2]: Leaving directory '/root/hpl-2.3'
make -f Make.top leaf le=src/panel arch=Linux_PII_CBLAS
make[2]: Entering directory '/root/hpl-2.3'
cd src/panel ; mkdir Linux_PII_CBLAS )
cd src/panel/Linux_PII_CBLAS ; \
ln -s /root/hpl-2.3/Make.Linux_PII_CBLAS Make.inc )
```



## Snapshot 23: Listing of HPL.dat File and xhpl

```
[root@master hpl-2.3]# cd bin/
[root@master bin]# ls
Linux_PII_CBLAS
[root@master bin]# cd Linux_PII_CBLAS/
[root@master Linux_PII_CBLAS]# ls
HPL.dat  xhpl
[root@master Linux_PII_CBLAS]# vim HPL.dat
[root@master Linux_PII_CBLAS]# mpirun --allow-run-as-root -np 4 ./xhpl HPL.dat
bash: mpirun: command not found...
[root@master Linux_PII_CBLAS]# mpirun --allow-run-as-root -np 4 ./xhpl HPL.dat
bash: mpirun: command not found...
You have new mail in /var/spool/mail/root
[root@master Linux_PII_CBLAS]# mpirun --allow-run-as-root -np 4 ./xhpl HPL.dat
bash: mpirun: command not found...
[root@master Linux_PII_CBLAS]# ls
HPL.dat  xhpl
You have new mail in /var/spool/mail/root
[root@master Linux_PII_CBLAS]# ls
HPL.dat  xhpl
[root@master Linux_PII_CBLAS]#
```

## Snapshot 24: HPL.dat file

```
root@master:~/Downloads/hpl-2.3/bin/Linux_PII_CBLAS
HPLInpack benchmark input file
Innovative Computing Laboratory, University of Tennessee
HPL.out      output file name (if any)
6            device out (6=stdout,7=stderr,file)
4            # of problems sizes (N)
29 30 34 35  Ns
4            # of NBs
1 2 3 4      NBs
0            PMAP process mapping (0=Row-,1=Column-major)
3            # of process grids (P x Q)
2 1 4        Ps
2 4 1        Qs
16.0         threshold
3            # of panel fact
0 1 2        PFACTs (0=left, 1=Crout, 2=Right)
2            # of recursive stopping criterium
2 4          NEMINs (>= 1)
1            # of panels in recursion
2            NDIVs
3            # of recursive panel fact.
0 1 2        RFACTs (0=left, 1=Crout, 2=Right)
1            # of broadcast
0            BCASTs (0=1rg,1=1rM,2=2rg,3=2rM,4=Lng,5=LnM)
1            # of lookahead depth
0            DEPTHS (>=0)
2            SWAP (0=bin-exch,1=long,2=mix)
64           swapping threshold
0            L1 in (0=transposed,1=no-transposed) form
0            U  in (0=transposed,1=no-transposed) form
1            Equilibration (0=no,1=yes)
8            memory alignment in double (> 0)

...

...

"HPL.dat" 31L, 1133C
```

## Snapshot 25: Result of HPL Benchmarking Test

```

root@master:~/Downloads/hpl-2.3/bin/Linux_PII_CBLAS

=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 1.81558863e-02 ..... PASSED
=====
T/V          N    NB    P    Q          Time          Gflops
-----
WR00R2L4      30     1     4     1          0.00          3.0368e-01
HPL_pdgesv() start time Sun Jan 29 19:32:49 2023
HPL_pdgesv() end time   Sun Jan 29 19:32:49 2023

=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 1.81558863e-02 ..... PASSED
=====
T/V          N    NB    P    Q          Time          Gflops
-----
WR00R2C2      30     1     4     1          0.00          2.9527e-01
HPL_pdgesv() start time Sun Jan 29 19:32:49 2023
HPL_pdgesv() end time   Sun Jan 29 19:32:49 2023

=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 1.81558863e-02 ..... PASSED
=====
T/V          N    NB    P    Q          Time          Gflops
-----
WR00R2C4      30     1     4     1          0.00          3.0281e-01
HPL_pdgesv() start time Sun Jan 29 19:32:49 2023
HPL_pdgesv() end time   Sun Jan 29 19:32:49 2023

=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 1.81558863e-02 ..... PASSED
=====
T/V          N    NB    P    Q          Time          Gflops
-----
WR00R2R2      30     1     4     1          0.00          3.0077e-01
HPL_pdgesv() start time Sun Jan 29 19:32:49 2023
HPL_pdgesv() end time   Sun Jan 29 19:32:49 2023

=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 1.81558863e-02 ..... PASSED
=====
T/V          N    NB    P    Q          Time          Gflops
-----
WR00R2R4      30     1     4     1          0.00          2.7510e-01
HPL_pdgesv() start time Sun Jan 29 19:32:49 2023
HPL_pdgesv() end time   Sun Jan 29 19:32:49 2023

=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 1.81558863e-02 ..... PASSED
=====
T/V          N    NB    P    Q          Time          Gflops
-----
WR00L2L2      30     2     4     1          0.00          2.4171e-01
HPL_pdgesv() start time Sun Jan 29 19:32:49 2023
HPL_pdgesv() end time   Sun Jan 29 19:32:49 2023

=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 2.65355261e-02 ..... PASSED
=====

```

root@master:~/Downloads/hpl-2.3/bin/Linux\_PII\_CBLAS

```
=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 2.07165390e-02 ..... PASSED
=====
T/V          N    NB    P    Q          Time          Gflops
-----
WR00L2L4      35    4    4    1          0.00          5.6846e-01
HPL_pdgesv() start time Sun Jan 29 19:32:49 2023

HPL_pdgesv() end time   Sun Jan 29 19:32:49 2023

=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 2.17523660e-02 ..... PASSED
=====
T/V          N    NB    P    Q          Time          Gflops
-----
WR00L2C2      35    4    4    1          0.00          5.8055e-01
HPL_pdgesv() start time Sun Jan 29 19:32:49 2023

HPL_pdgesv() end time   Sun Jan 29 19:32:49 2023

=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 2.07165390e-02 ..... PASSED
=====
T/V          N    NB    P    Q          Time          Gflops
-----
WR00L2C4      35    4    4    1          0.00          6.0286e-01
HPL_pdgesv() start time Sun Jan 29 19:32:49 2023

HPL_pdgesv() end time   Sun Jan 29 19:32:49 2023

=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 3.57360298e-02 ..... PASSED
=====
T/V          N    NB    P    Q          Time          Gflops
-----
WR00L2R2      35    4    4    1          0.00          5.9891e-01
HPL_pdgesv() start time Sun Jan 29 19:32:49 2023

HPL_pdgesv() end time   Sun Jan 29 19:32:49 2023

=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 2.07165390e-02 ..... PASSED
=====
T/V          N    NB    P    Q          Time          Gflops
-----
WR00L2R4      35    4    4    1          0.00          6.3178e-01
HPL_pdgesv() start time Sun Jan 29 19:32:49 2023

HPL_pdgesv() end time   Sun Jan 29 19:32:49 2023

=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 2.07165390e-02 ..... PASSED
=====
T/V          N    NB    P    Q          Time          Gflops
-----
WR00C2L2      35    4    4    1          0.00          4.6802e-01
HPL_pdgesv() start time Sun Jan 29 19:32:49 2023

HPL_pdgesv() end time   Sun Jan 29 19:32:49 2023

=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 2.07165390e-02 ..... PASSED
=====
```

root@master:~/Downloads/hpl-2.3/bin/Linux\_PII\_CBLAS

```
=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 2.07165390e-02 ..... PASSED
=====
```

T/V	N	NB	P	Q	Time	Gflops
-----	---	----	---	---	------	--------

WR00R2C4	35	4	4	1	0.00	6.1972e-01
----------	----	---	---	---	------	------------

HPL\_pdgesv() start time Sun Jan 29 19:32:49 2023

HPL\_pdgesv() end time Sun Jan 29 19:32:49 2023

```
=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 3.57360298e-02 ..... PASSED
=====
```

T/V	N	NB	P	Q	Time	Gflops
-----	---	----	---	---	------	--------

WR00R2R2	35	4	4	1	0.00	6.0979e-01
----------	----	---	---	---	------	------------

HPL\_pdgesv() start time Sun Jan 29 19:32:49 2023

HPL\_pdgesv() end time Sun Jan 29 19:32:49 2023

```
=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 2.07165390e-02 ..... PASSED
=====
```

T/V	N	NB	P	Q	Time	Gflops
-----	---	----	---	---	------	--------

WR00R2R4	35	4	4	1	0.00	6.2135e-01
----------	----	---	---	---	------	------------

HPL\_pdgesv() start time Sun Jan 29 19:32:49 2023

HPL\_pdgesv() end time Sun Jan 29 19:32:49 2023

```
=====
||Ax-b||_oo/(eps*(||A||_oo*||x||_oo+||b||_oo)*N)= 2.07165390e-02 ..... PASSED
=====
```

```
Finished      864 tests with the following results:
              864 tests completed and passed residual checks,
                0 tests completed and failed residual checks,
                0 tests skipped because of illegal input values.
=====
```

End of Tests.

```
=====
[root@master Linux_PII_CBLAS]# mpirun --allow-run-as-root -np 4 ./xhpl HPL.dat
```

## **Commands Used :**

### **1. OpenHPC Warewulf + Slurm + Ganglia + Nagios Commands**

Create one Master VM with two Network adapters (ens33[NAT],ens36[Host-only for cluster communication])

x86 -> Processor : 4 RAM - 8GB Secondary Storage - 100 GB

-----  
Warewulf installation (Network Boot in HPC Cluster) Centos-7

-----  
Pre-requisite:

-----  
We have to stop and disable firewall and disable selinux

sethostname of machine as master

# hostnamectl set-hostname master

-----  
Check for the file of ens36 (if not there use #nmtui command and edit Wired Connection 1 to ens36)

# cat /etc/sysconfig/network-scripts/ifcfg-ens36

# ifconfig ens36

Output -> ens36:192.168.23.130

# vi /etc/hosts

-> edit -> 192.168.23.130 master

# yum -y install yum-utils

# yum install [http://build.openhpc.community/OpenHPC:/1.3/CentOS\\_7/x86\\_64/ohpc-release-1.3-1.el7.x86\\_64.rpm](http://build.openhpc.community/OpenHPC:/1.3/CentOS_7/x86_64/ohpc-release-1.3-1.el7.x86_64.rpm)

# yum repolist

# yum -y install ohpc-base

# yum -y install ohpc-warewulf

```
# yum -y install chrony
```

```
# vi /etc/chrony.conf
```

```
-> Edit this Conf. file -> server 192.168.23.130 iburst
                                -> allow 192.168.23.0/24 (uncomment and edit
network address)
                                -> local stratum 10 (uncomment)
                                -> SAVE and Exit
```

```
# systemctl start chronyd
```

```
# systemctl enable chronyd
```

```
# yum install ntpdate
```

```
# ntpdate -q 192.168.23.130
```

```
# vi /etc/warewulf/provision.conf
```

```
edit -> change network device = ens36
```

```
# grep device /etc/warewulf/provision.conf
```

```
# vi /etc/xinetd.d/tftp
```

```
edit -> disable = no
```

```
# grep disable /etc/xinetd.d/tftp
```

```
*****
Resource Manager Installation
```

---

```
# yum -y install ohpc-slurm-server
```

```
# yum -y install slurm-sview-ohpc slurm-torque-ohpc
```

```
# vi /etc/slurm/slurm.conf
```

```
edit -> ClusterName=pearl
-> ControlMachine=master
    -> NodeName=c[1-2]
    -> Nodes=c[1-2]          --> This is my nodename
```

```

# grep NodeName= /etc/slurm/slurm.conf

# echo ens36

# ifconfig ens36


# systemctl restart xinetd
# systemctl enable mariadb.service
# systemctl restart mariadb
# systemctl enable httpd.service
# systemctl restart httpd
# systemctl enable dhcpd.service


*****

# echo ${CHROOT}

# export CHROOT=/opt/ohpc/admin/images/centos7.7

# echo ${CHROOT}

# wwmkchroot centos-7 ${CHROOT}                -> Building initial BOS image

# uname -r

# chroot ${CHROOT} uname -r


*****

# yum -y --installroot=${CHROOT} update

# yum -y --installroot=${CHROOT} install \
ohpc-base-compute kernel kernel-headers kernel-devel kernel-tools parted \
xfsprogs python-devel yum httpd ipmitool glibc* perl perl-CPAN perl-CPAN \
sysstat gcc make xauth firefox squashfs-tools

# cat /etc/resolv.conf

# vi /etc/resolv.conf

    add -> master 192.168.23.130

# cp -p /etc/resolv.conf ${CHROOT}/etc/resolv.conf

```



```

# yum -y --installroot=${CHROOT} install ohpc-slurm-client

# chroot ${CHROOT} systemctl enable slurmd

# yum -y --installroot=${CHROOT} install chrony

# yum -y --installroot=${CHROOT} install kernel lmod-ohpc

*****

# # Initialize warewulf database and ssh_keys



---



# wwinit database

# wwinit ssh_keys

# df -hT | grep -v tmpfs

# hostname

# cat ${CHROOT}/etc/fstab

# echo "master:/home /home nfs nfsvers=3,nodev,nosuid 0 0" >> ${CHROOT}/etc/fstab

# echo "master:/opt/ohpc/pub /opt/ohpc/pub nfs nfsvers=3,nodev 0 0" >>
${CHROOT}/etc/fstab

# cat ${CHROOT}/etc/fstab

# cat /etc/exports

# echo "/home *(rw,no_subtree_check,fsid=10,no_root_squash)" >> /etc/exports

# echo "/opt/ohpc/pub *(ro,no_subtree_check,fsid=11)" >> /etc/exports

# cat /etc/exports

# systemctl start nfs-server

# systemctl status nfs-server

# systemctl enable nfs-server

# exportfs -arv

```

```
# chroot ${CHROOT} systemctl enable chronyd
```

```
# echo "server 192.168.23.130 iburst" >> ${CHROOT}/etc/chrony.conf
```

```
*****
```

### Add Ganglia monitoring

---

```
# yum -y install ohpc-ganglia -> # Install
Ganglia meta-package on master
```

```
# yum -y --installroot=${CHROOT} install ganglia-gmond-ohpc ->
Install Ganglia compute node daemon
```

```
# Use example configuration script to enable unicast receiver on master host
```

```
-----
# cp /opt/ohpc/pub/examples/ganglia/gmond.conf /etc/ganglia/gmond.conf -> yes
```

```
# grep 'host =' /etc/ganglia/gmond.conf
```

```
# sed -i "s/<sms>/master/" /etc/ganglia/gmond.conf
```

```
# grep 'host =' /etc/ganglia/gmond.conf
```

```
# grep OpenHPC /etc/ganglia/gmond.conf
```

```
# sed -i "s/OpenHPC/pearl/" /etc/ganglia/gmond.conf
```

```
# grep pearl /etc/ganglia/gmond.conf
```

```
# cp /etc/ganglia/gmond.conf ${CHROOT}/etc/ganglia/gmond.conf -> yes
```

```
# echo "gridname pearl" >> /etc/ganglia/gmetad.conf
```

```
# grep gridname /etc/ganglia/gmetad.conf
```

```
# echo "
systemctl enable gmond
systemctl enable gmetad
systemctl start gmond
systemctl start gmetad
chroot ${CHROOT} systemctl enable gmond
" > /tmp/start_ganglia_service.sh
```

```
# bash /tmp/start_ganglia_service.sh

# grep "^date.timezone =" /etc/php.ini

# echo "date.timezone = Asia/Kolkata" >> /etc/php.ini

# grep "^date.timezone =" /etc/php.ini

# systemctl try-restart httpd
```

Go to browser : <http://master/ganglia>

\*\*\*\*\*

Add Nagios monitoring

---

```
# yum -y install ohpc-nagios -> Install Nagios meta-package on master host

# yum -y --installroot=$CHROOT install nagios-plugins-all-ohpc nrpe-ohpc -> Install
plugins into compute node image

# chroot $CHROOT systemctl enable nrpe

# touch /var/log/nagios/nrpe.pid

# chown -R nrpe:nrpe /var/log/nagios/nrpe.pid

# perl -pi -e "s/^allowed_hosts=/# allowed_hosts=/" $CHROOT/etc/nagios/nrpe.cfg

# echo "nrpe 5666/tcp # NRPE" >> $CHROOT/etc/services

# echo "nrpe : 192.168.23.130 : ALLOW" >> $CHROOT/etc/hosts.allow

# echo "nrpe : ALL : DENY" >> $CHROOT/etc/hosts.allow

# chroot $CHROOT /usr/sbin/useradd -c "NRPE user for the NRPE service" -d
/var/run/nrpe \
-r -g nrpe -s /sbin/nologin nrpe

# chroot $CHROOT /usr/sbin/groupadd -r nrpe

****

# # Configure remote services to test on compute nodes
```

```

-----

# mv /etc/nagios/conf.d/services.cfg.example /etc/nagios/conf.d/services.cfg

# mv /etc/nagios/conf.d/hosts.cfg.example /etc/nagios/conf.d/hosts.cfg

# for ((i=0; i<2; i++)) ; do perl -pi -e "s/HOSTNAME$((i+1))/${c[$i]}/ ||
s/HOST$((i+1))_IP/${c_ip[$i]}/" /etc/nagios/conf.d/hosts.cfg; done

# perl -pi -e "s/ \bin\mail/ \usr\bin\mailx/g" /etc/nagios/objects/commands.cfg

# perl -pi -e "s/nagios\@localhost/root\@master/" /etc/nagios/objects/contacts.cfg

# echo command[check_ssh]=usr/lib64/nagios/plugins/check_ssh master >>
$CHROOT/etc/nagios/nrpe.cfg

# htpasswd -bc /etc/nagios/passwd nagiosadmin nagios -> username : nagiosadmin |
password: nagios

# chkconfig nagios on

# vi /etc/nagios/conf.d/hosts.cfg -> Add clients and hostname

# systemctl start nagios

# chmod u+s `which ping`

```

Go to browser : <http://master/nagios>

```

username : nagiosadmin
password : nagios

```

```

*****

```

```

# wwsh file list

# wwsh file import /etc/passwd

# wwsh file import /etc/group

# wwsh file import /etc/shadow

# wwsh file list

```

```

# export WW_CONF=/etc/warewulf/bootstrap.conf

# echo "drivers += updates/kernel/" >> $WW_CONF

# echo "modprobe += ahci, nvme" >> $WW_CONF

# echo "drivers += overlay" >> $WW_CONF


# wwbootstrap `uname -r`

# echo ${CHROOT}

# wwvnfs --chroot $CHROOT
or
# wwvnfs --chroot /opt/ohpc/admin/images/centos7.7

# wwsh vnfs list


*****

# echo "GATEWAYDEV=ens36" > /tmp/network.wwsh

# wwsh -y file import /tmp/network.wwsh --name network

# wwsh -y file set network --path /etc/sysconfig/network --mode=0644 --uid=0

# wwsh node new c1

#   wwsh   node   set   c1   --netdev   ens36   --ipaddr=192.168.23.150   --
hwaddr=00:0C:29:EC:16:C2 --netmask=255.255.255.0 --gateway 192.168.23.130

# wwsh node new c2

#   wwsh   node   set   c2   --netdev   ens36   --ipaddr=192.168.23.151   --
hwaddr=00:0C:29:B4:A4:C4 --netmask=255.255.255.0 --gateway 192.168.23.130

```

---

```

# wwsh node list

```

```
# wwsh -y provision set c1 --vnfs=centos7.7 --bootstrap=`uname -r` --  
files=dynamic_hosts,passwd,group,shadow,network  
  
# wwsh -y provision set c2 --vnfs=centos7.7 --bootstrap=`uname -r` --  
files=dynamic_hosts,passwd,group,shadow,network  
  
# systemctl restart dhcpd && wwsh pxe update
```

## 2. HPL Benchmarking Commands

```
*****  
Installation of HPL Benchmarking (HPC-Cluster)
```

```
*****
```

```
# yum install epel-release -y  
  
# yum install atlas -y  
  
# rpm -ql atlas  
  
# wget https://netlib.org/benchmark/hpl/hpl-2.3.tar.gz  
  
# mv hpl-2.3.tar.gz /root/Downloads/  
  
# cd /root/Downloads  
  
# tar -zxvf hpl-2.3.tar.gz  
  
# ls  
  
# cd hpl-2.3/  
  
# ls  
  
# cd setup  
  
# vim Make.Linux_Intel64  
  
# wget https://download.open-mpi.org/release/open-mpi/v4.1/openmpi-4.1.4.tar.gz  
  
# mv openmpi-4.1.4.tar.gz /root/Downloads/
```

```

# tar -xvf openmpi-4.1.4.tar.gz

# ls

# cd openmpi-4.1.4/

# ./configure --prefix=/opt/openmpi-4.1.4 --enable-orterun-prefix-by-default

# make -j 8

# make install

# echo $PATH

# export PATH=/opt/openmpi-4.1.4/bin:$PATH

# mp <Press TAB KEY>

# export LD_LIBRARY_PATH=/opt/openmpi-4.1.4/bin:$LD_LIBRARY_PATH

# echo $LD_LIBRARY_PATH

# cd ~/Downloads/hpl-2.3/setup

# cp Make.Linux_PII_CBLAS /root/Downloads/hpl-2.3

# cd /root/Downloads/hpl-2.3/

# ls

# rpm -ql atlas

# vim Make.Linux_PII_CBLAS

    >> edit  # -----
              # - HPL Directory Structure / HPL library -----
-
              # -----
              #
              TOPdir    = /root/Downloads/hpl-2.3

              # -----
              # - Message Passing library (MPI) -----
              # -----

```



```

MPdir    = /opt/openmpi-4.1.4

MPlib    = $(MPdir)/lib/libmpi.so
# -----
# - Compilers / linkers - Optimization flags -----
--

# -----
#
CC        = /usr/bin/gcc

LINKER    = /usr/bin/gcc
#
# -----
# - Linear Algebra library (BLAS or VSIPL) -----
---

# -----

LAlib    = $(LAdir)/libsatlas.so.3 $(LAdir)/libtatlas.so.3

>> <Escape Key> : wq

# make arch=Linux_PII_CBLAS

# cd /root/Downloads/hpl-2.3/bin/Linux_PII_CBLAS/

# ls

# vi HPL.dat

# mpirun --allow-run-as-root -np 4 ./xhpl HPL.dat

```

### **CASE-STUDY GitHub Links:**

1. [https://github.com/AnkushKapoor-97/openhpc\\_warewulf.git](https://github.com/AnkushKapoor-97/openhpc_warewulf.git)
2. <https://github.com/AnkushKapoor-97/HPL-Benchmarking.git>