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.

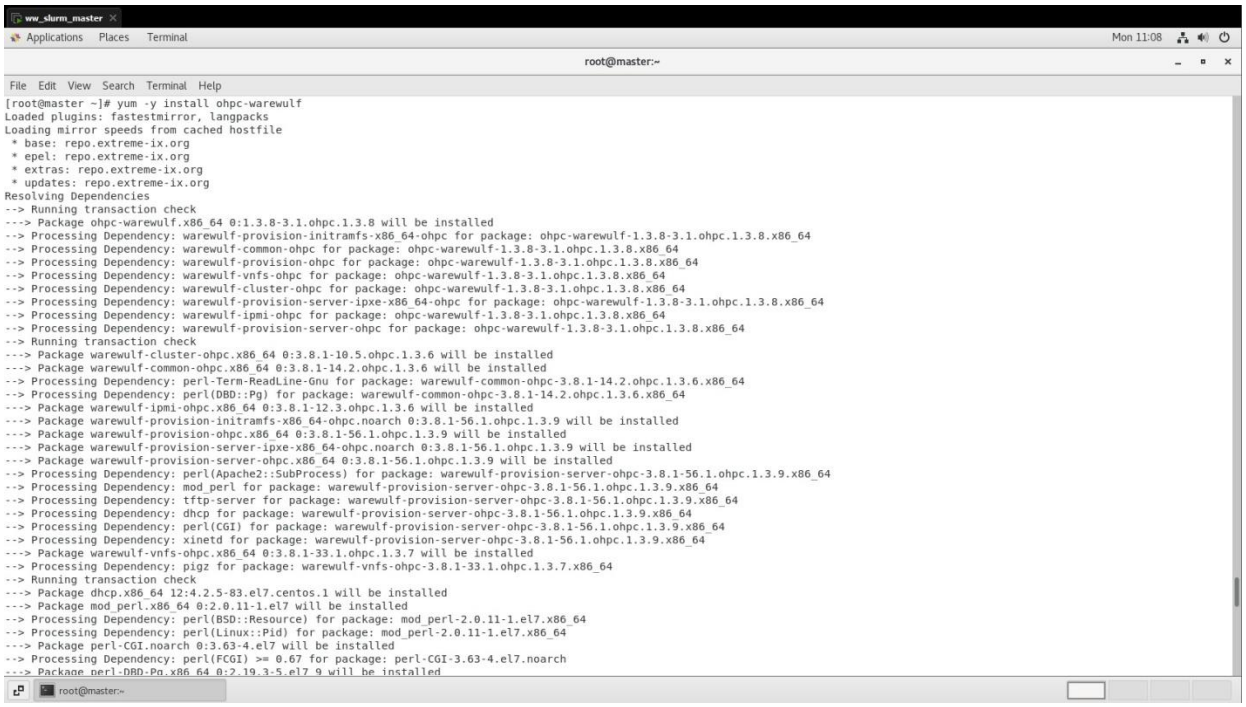
After that we will make installation of Warewulf on master with Slurm which will be used for Resource Management, Chrony which will be used for Time Date Synchronization, Nagios and Ganglia for Monitoring Purpose of Cluster.

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.

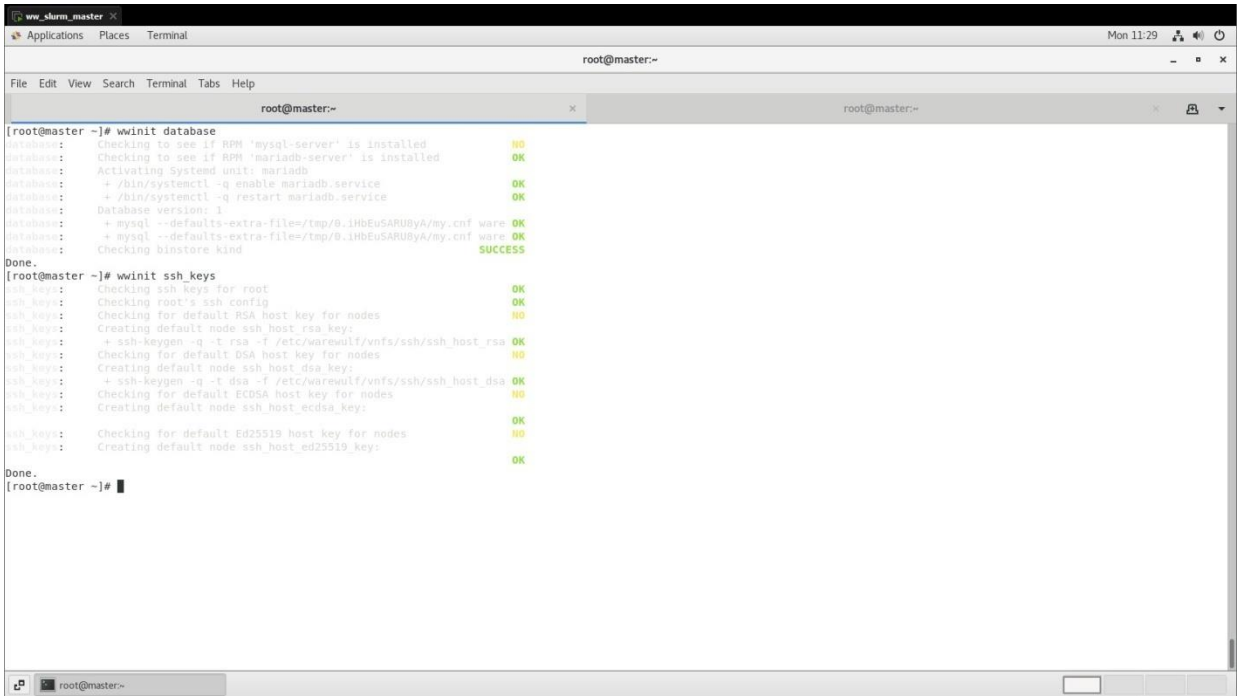
After the successful installation of all the nodes of Cluster we will perform a Benchmark test using HPL Benchmarking.

Snapshot 1: Install RPMS from OpenHPC community

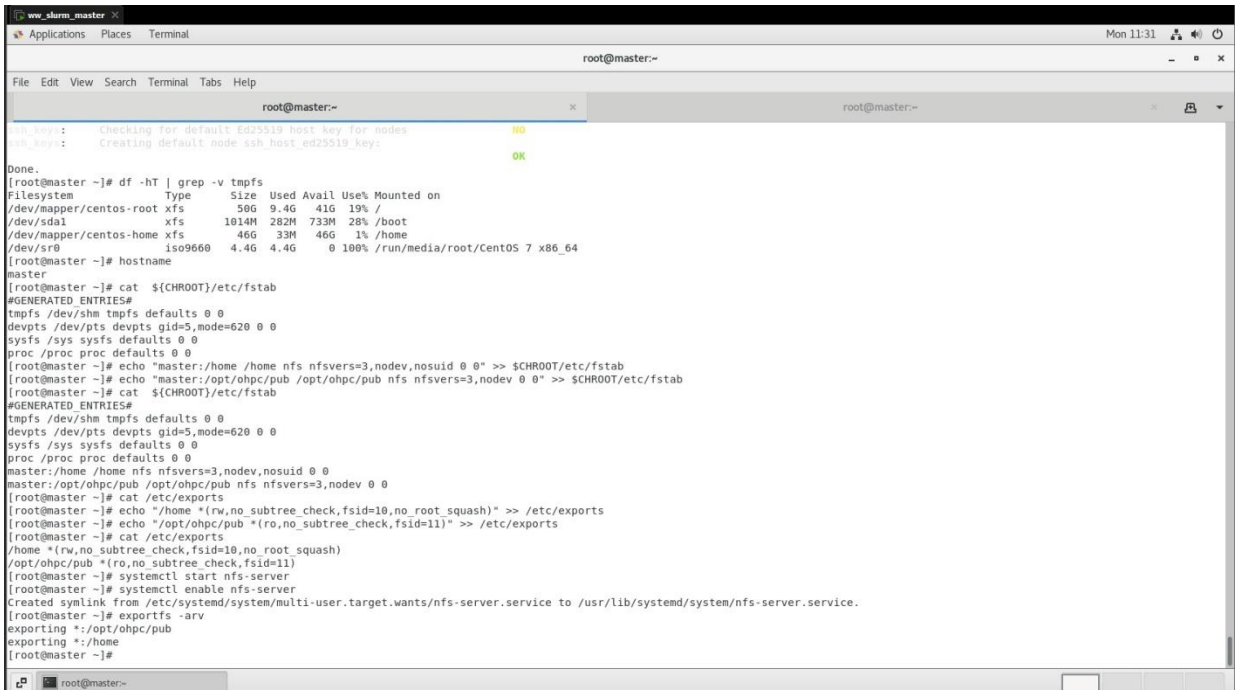
Snapshot 2: Install Ohpc-warewulf



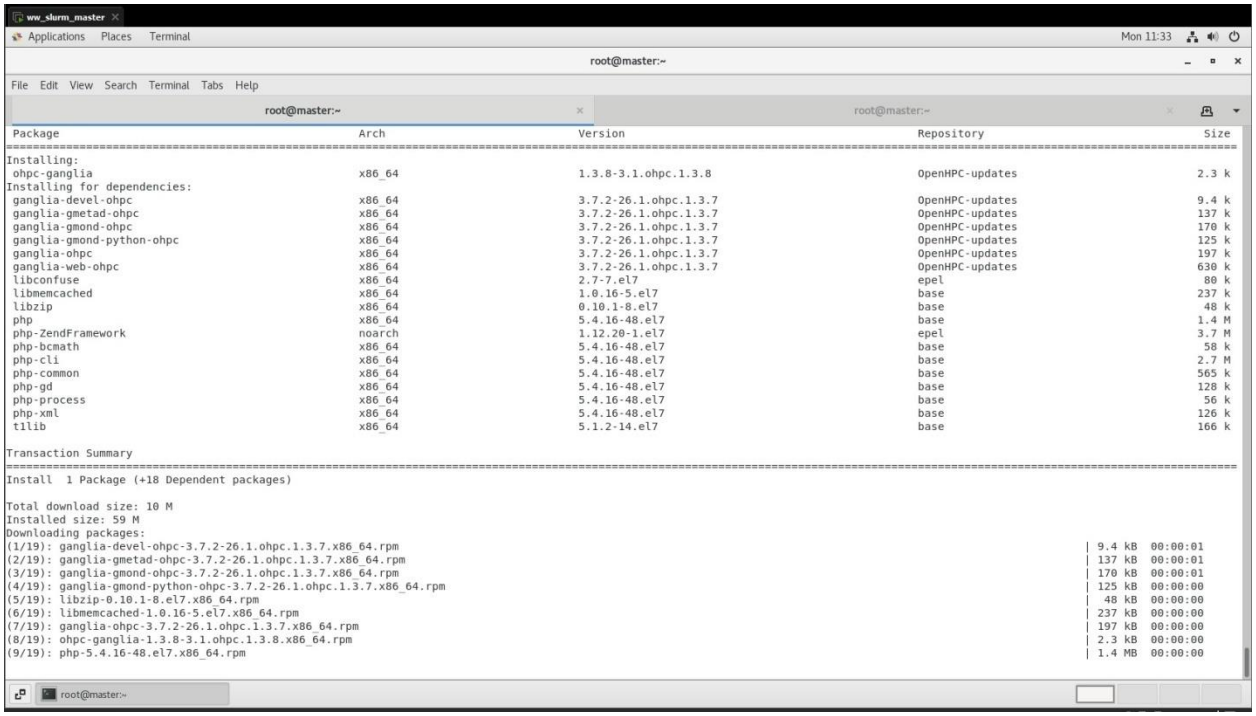
Snapshot 3: Initializing Database of Warewulf and Generating ssh_keys



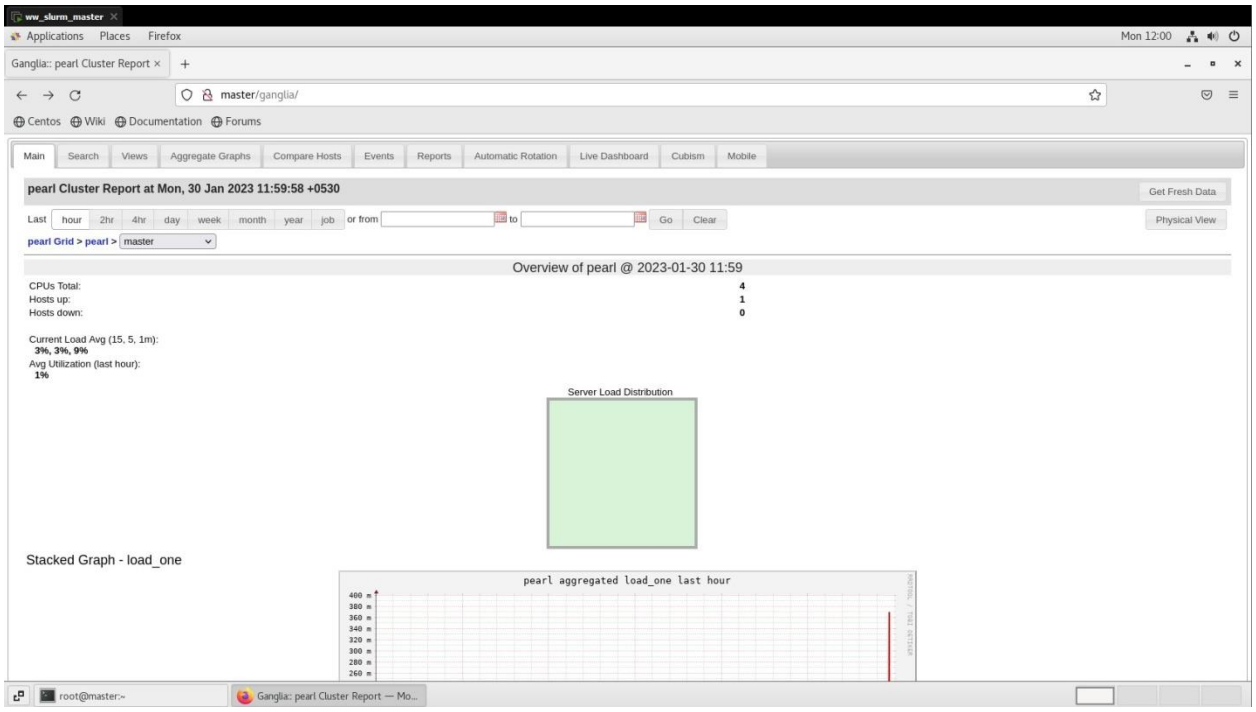
Snapshot 4: Starting and Enabling NFS-service



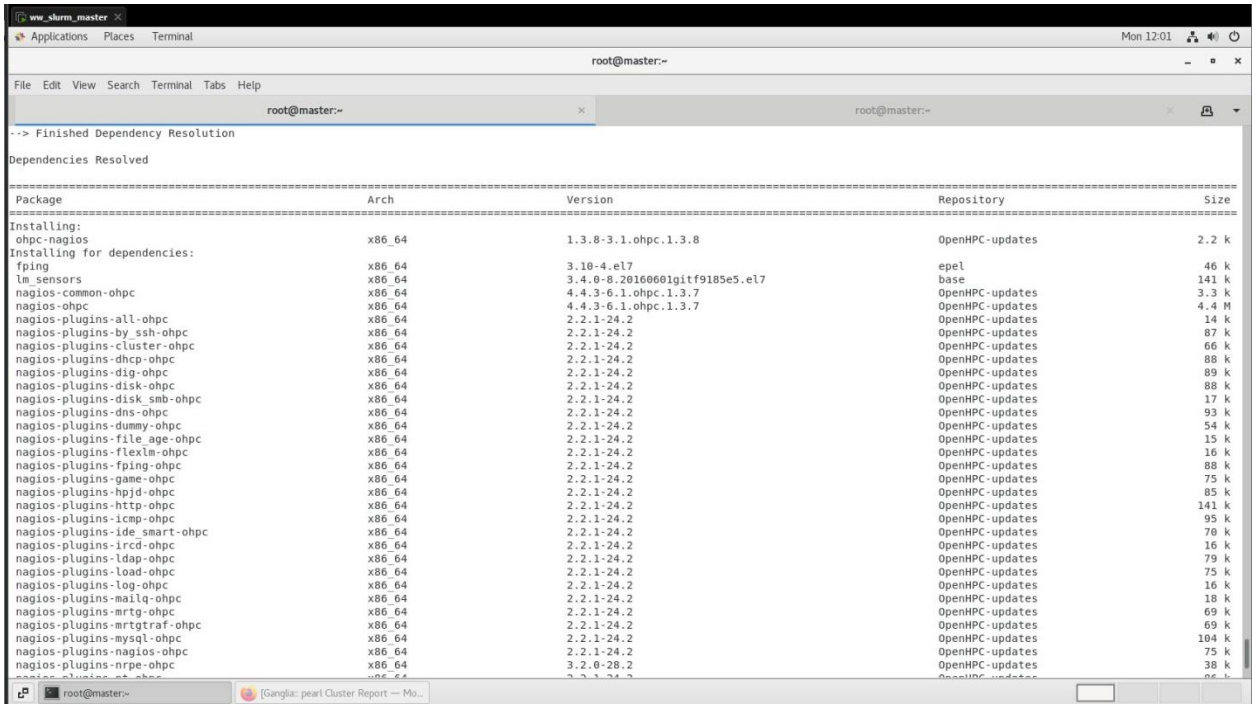
Snapshot 5: Installation of Ganglia



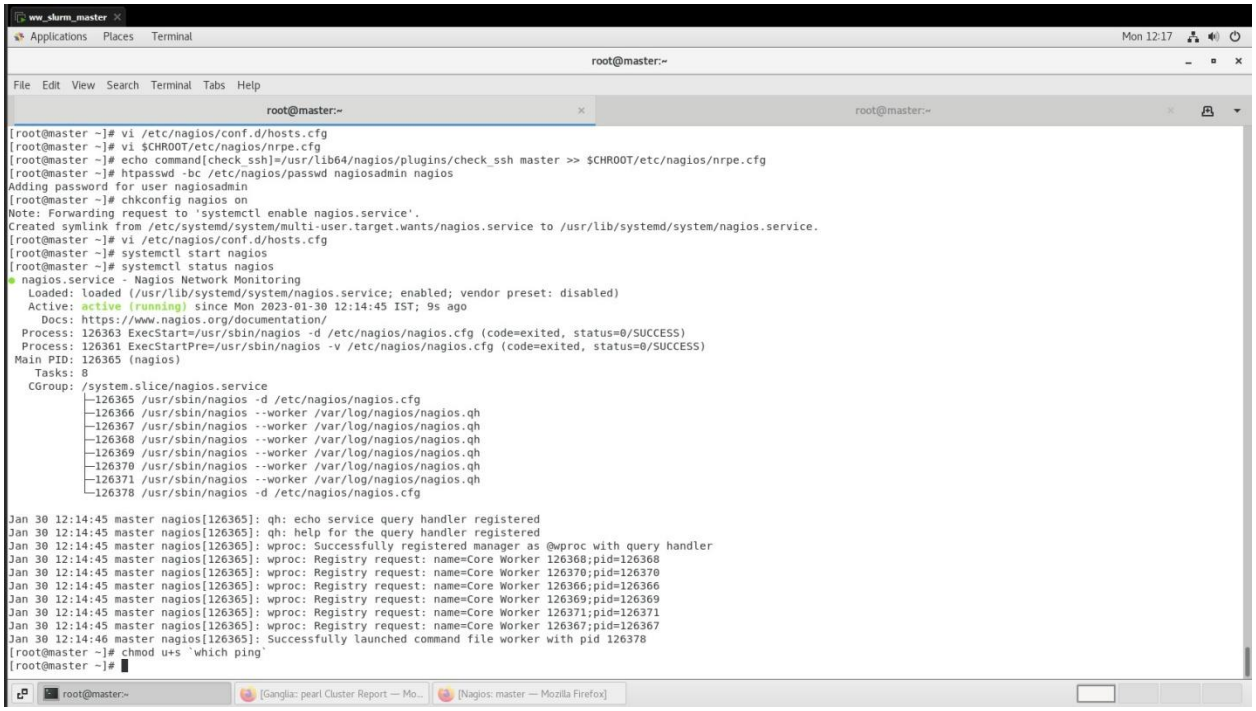
Snapshot 6: Ganglia Interface on Browser



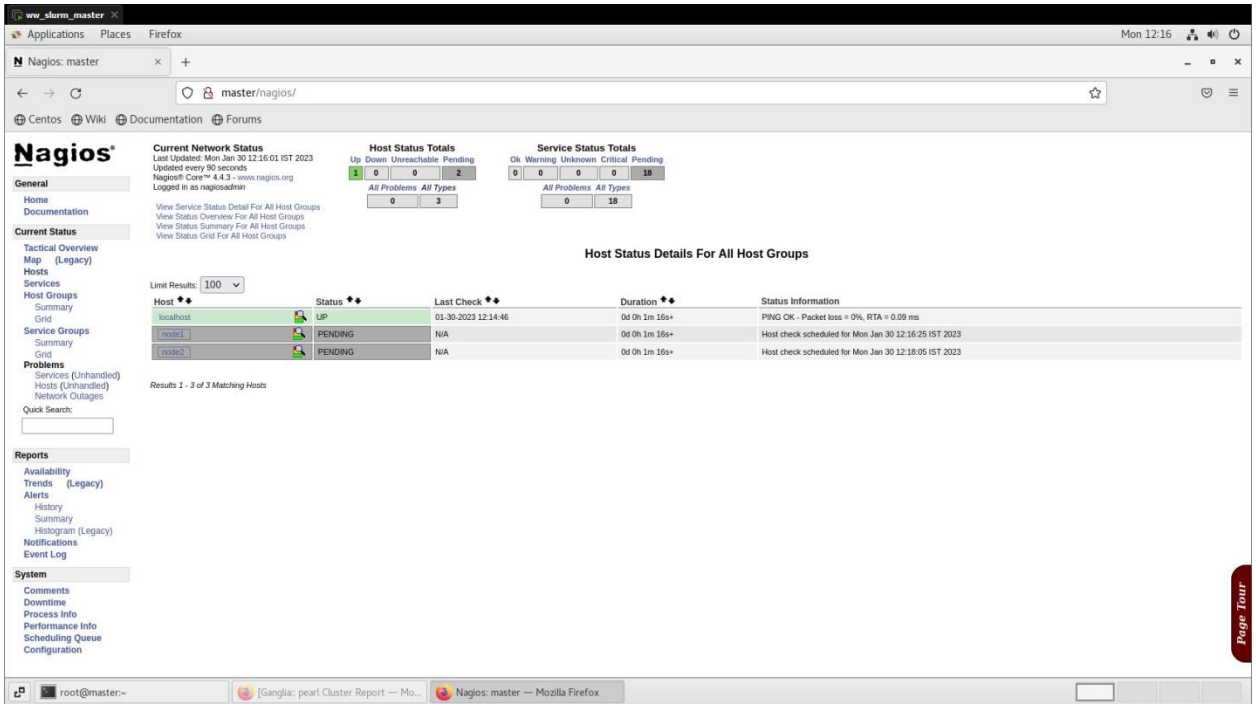
Snapshot 7: Installation of Nagios



Snapshot 8: Setting up of Username and Password for Nagios



Snapshot 9: Nagios Interface on Browser



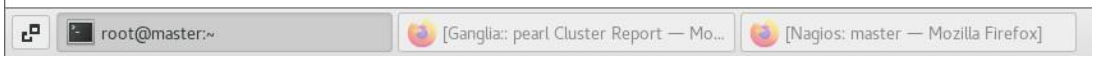
Snapshot 10: User Synchronization

```
[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 ~]#
```

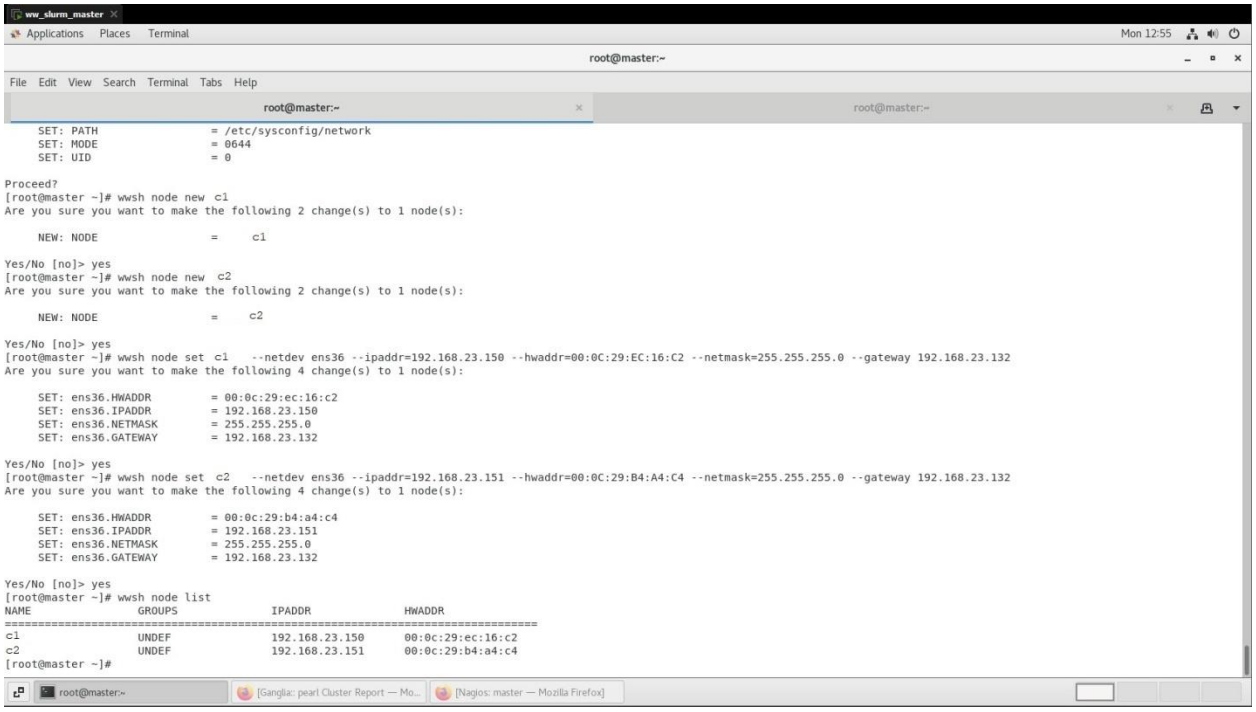
Snapshot 11: Kernel of Bootstrap image

```
[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 ~]#
```

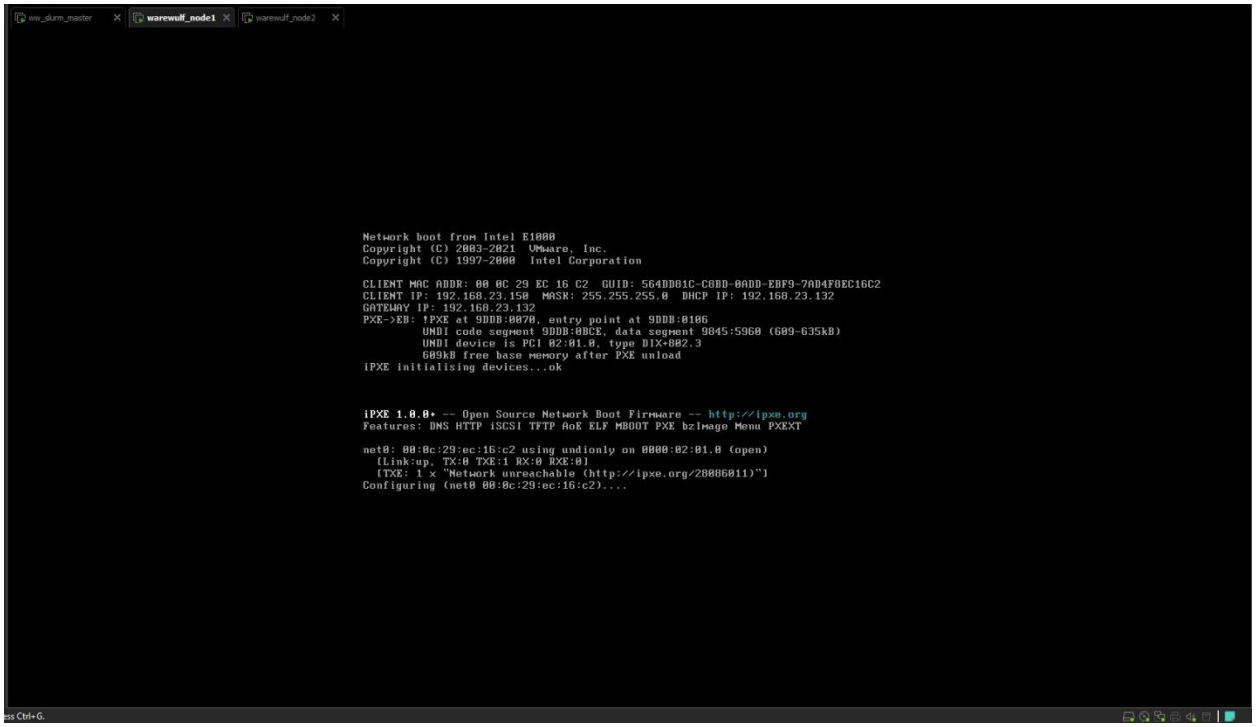

```
[root@master ~]# echo ${CHROOT}
/opt/ohpc/admin/images/centos7.7
[root@master ~]# wwvnfs --chroot $CHROOT
Using 'centos7.7' as the VNFS name
Creating VNFS image from centos7.7
Compiling hybridization link tree                          : 0.19 s
Building file list                                         : 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 ~]#
```



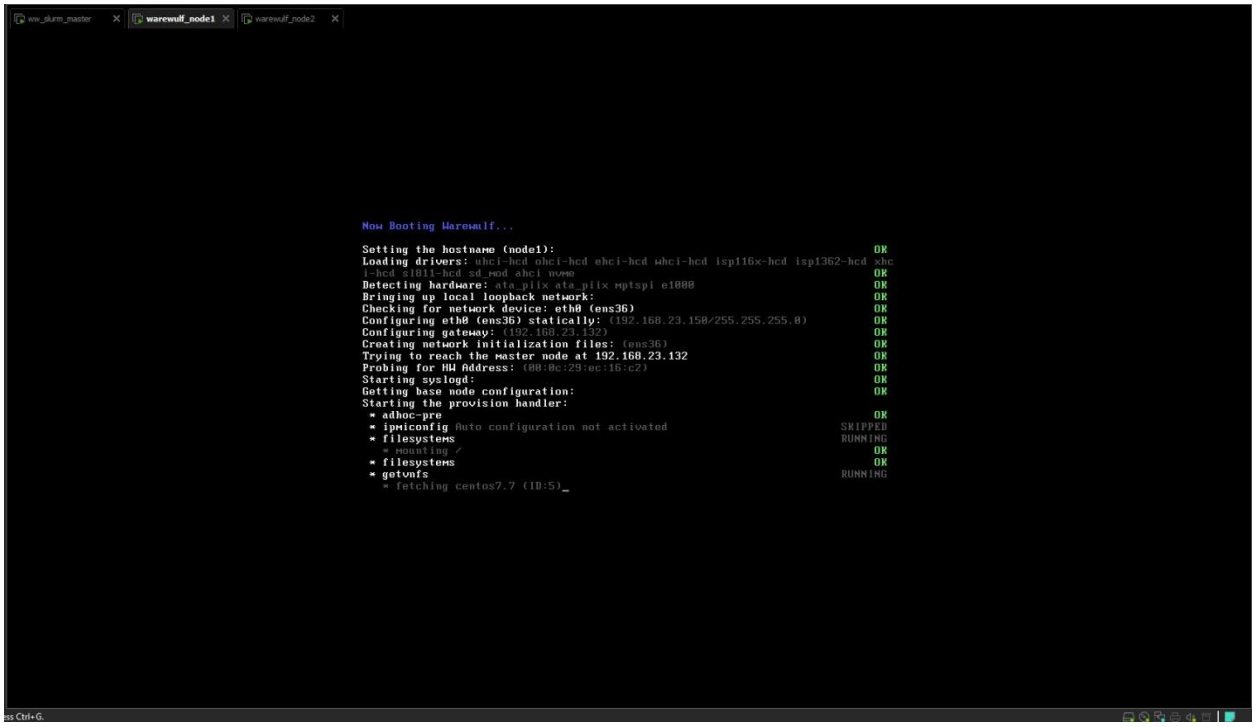
Snapshot 12: Adding Node List



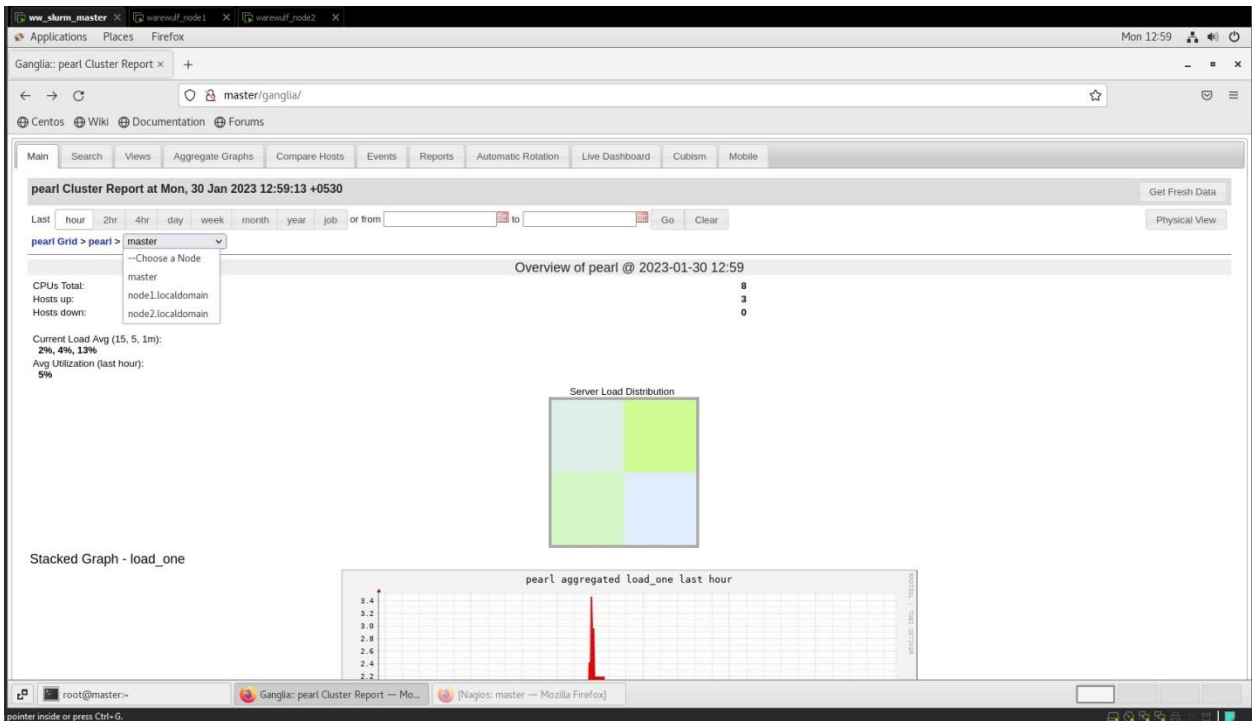
Snapshot 13: Starting Nodes Using Bootstrap image through warewulf



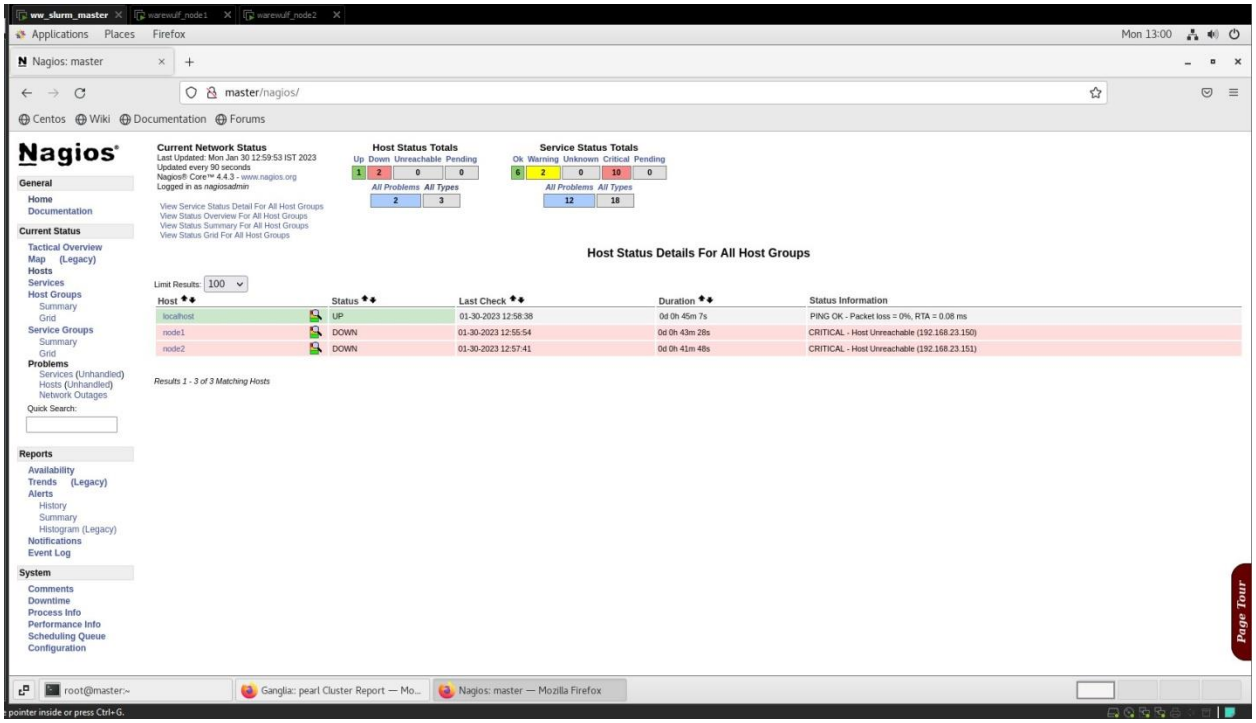
Snapshot 14: Booting using Warewulf Started



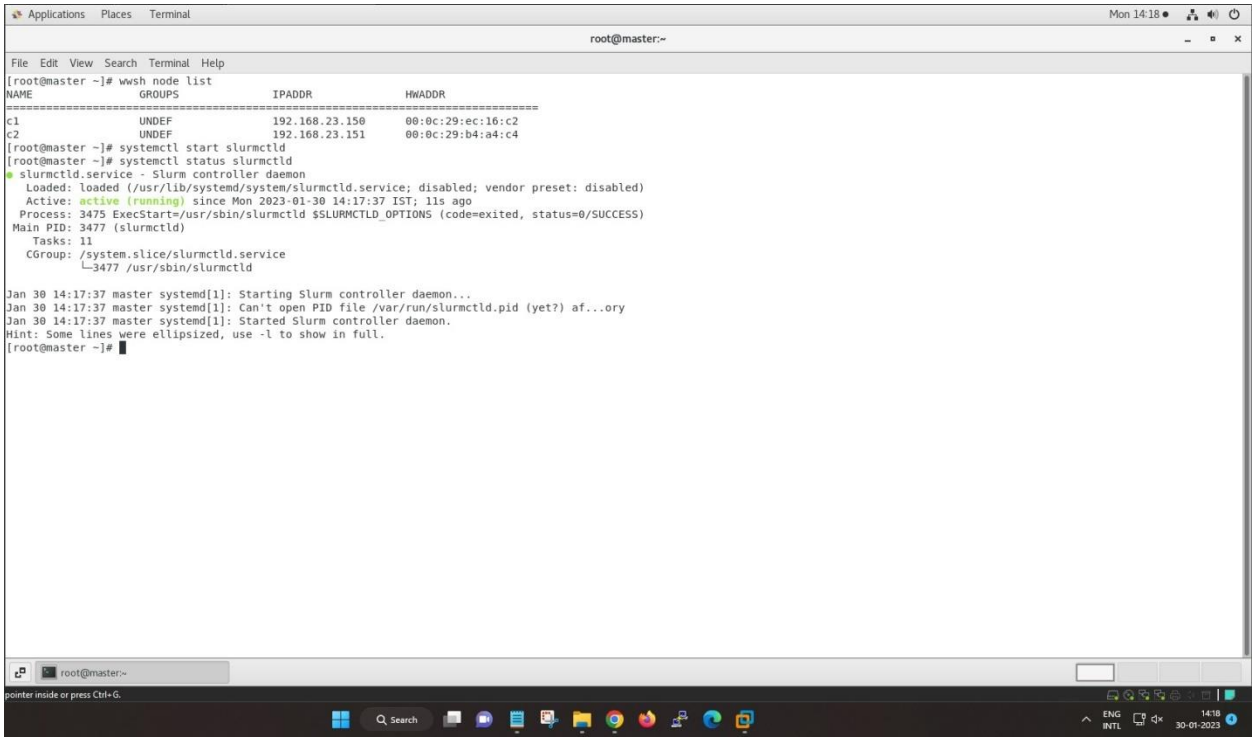
Snapshot 15: Ganglia Interface with Confirmation of addition of two nodes



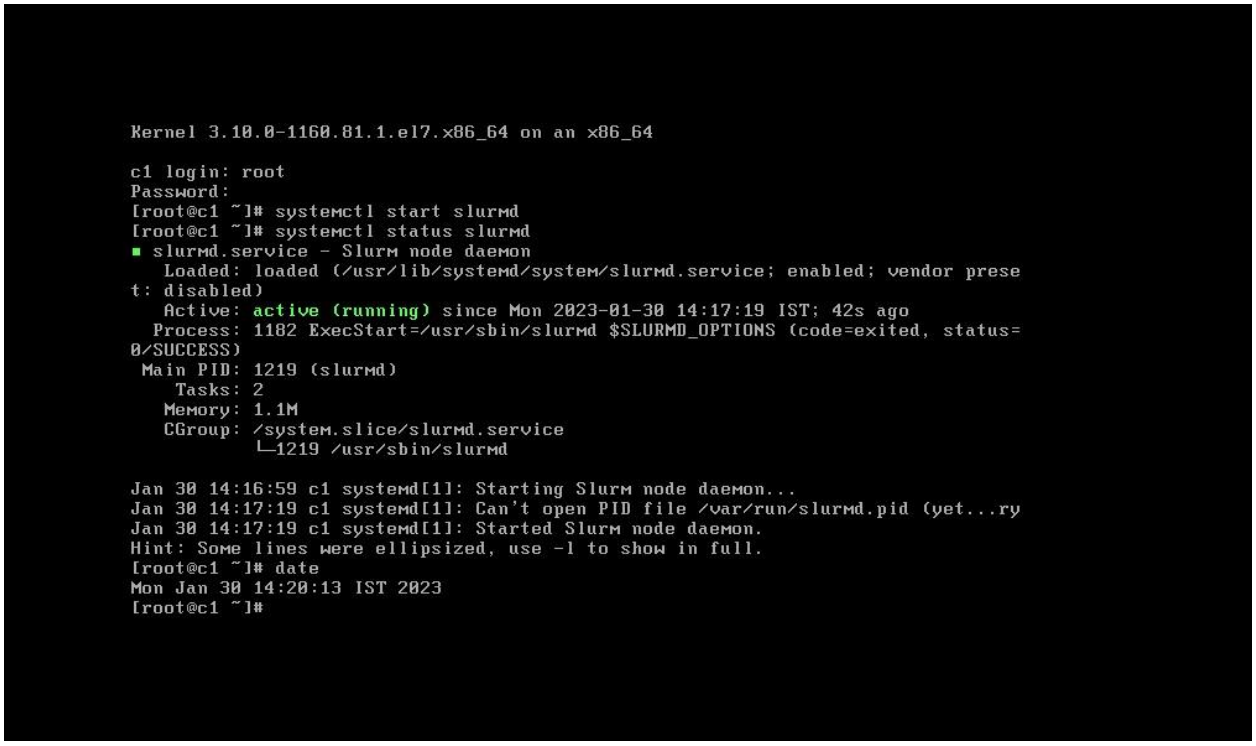
Snapshot 16: Nagios Confirmation of Addition of two nodes in Cluster

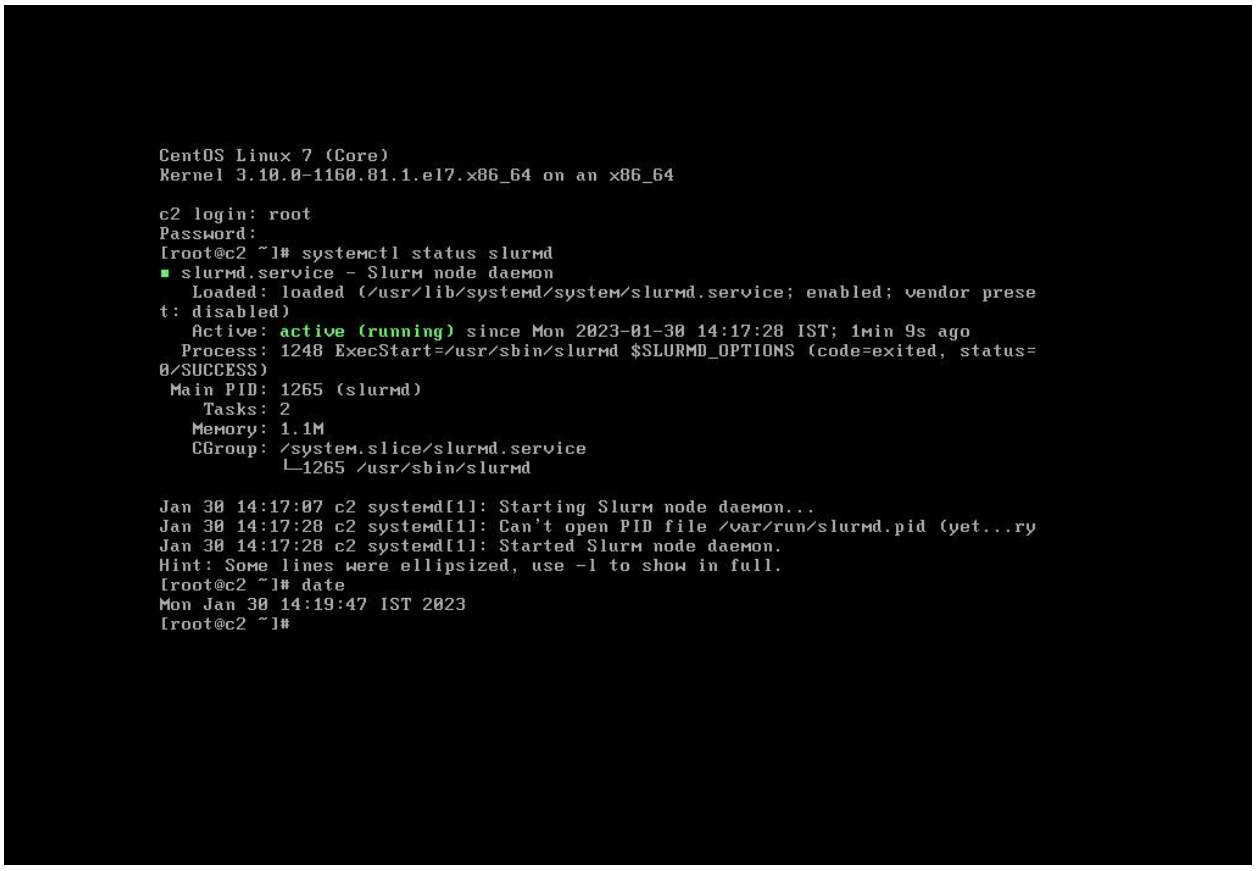


Snapshot 17: Slurmctld Service Status Confirmation

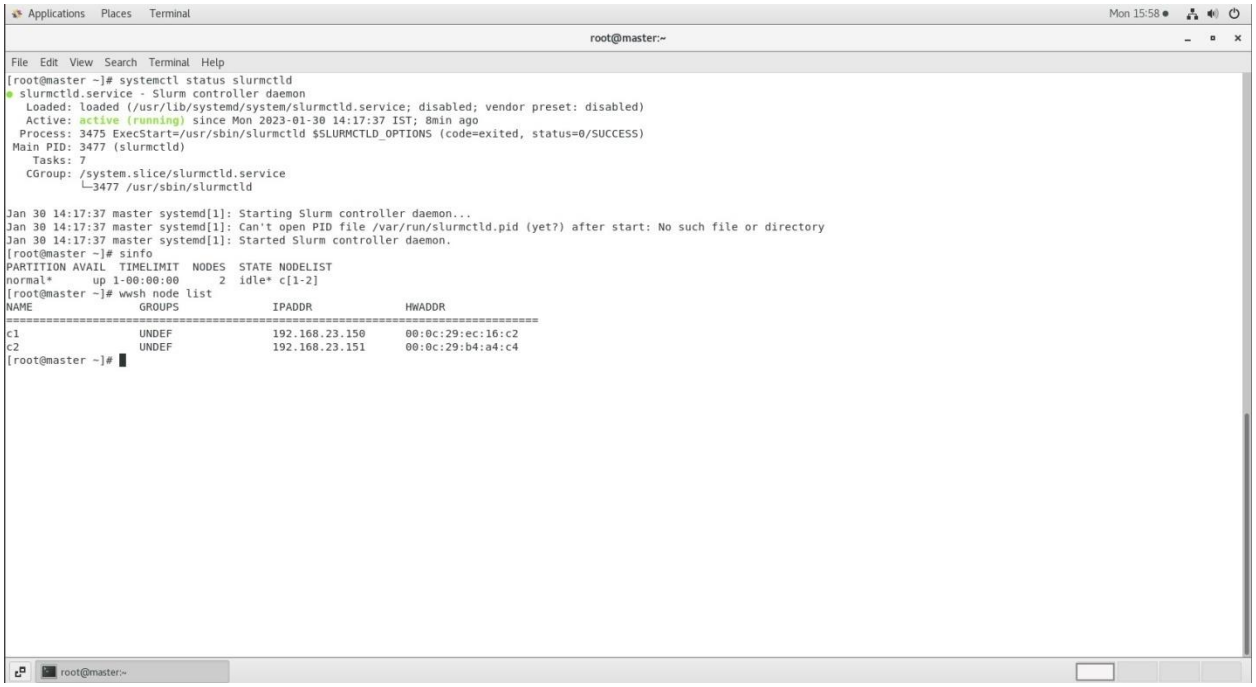


Snapshot 18: Slurmd Daemon on c1 node and c2 node

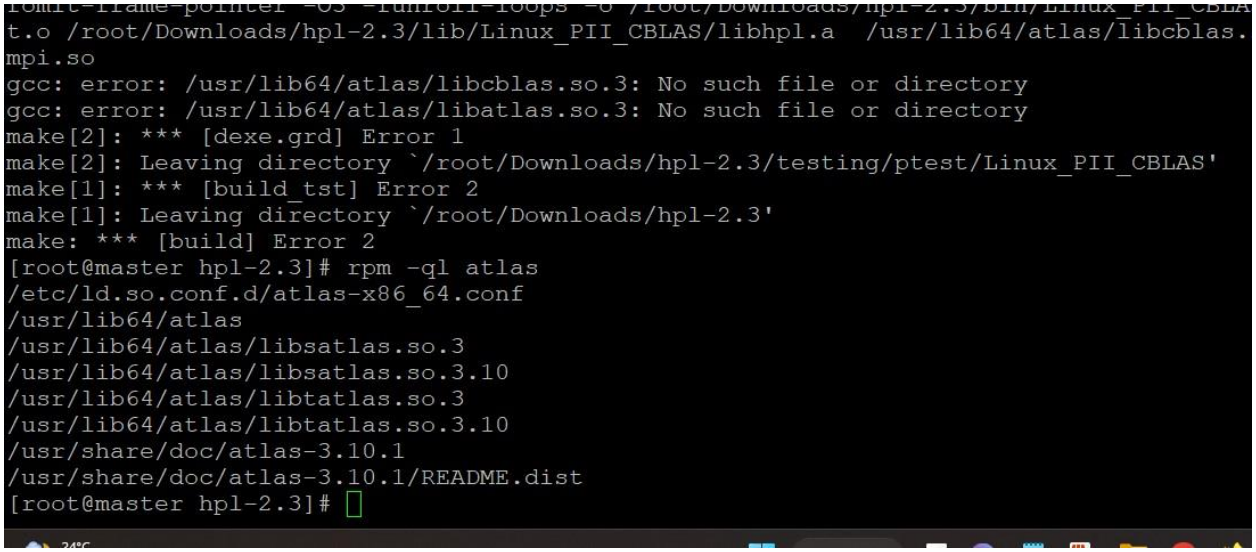




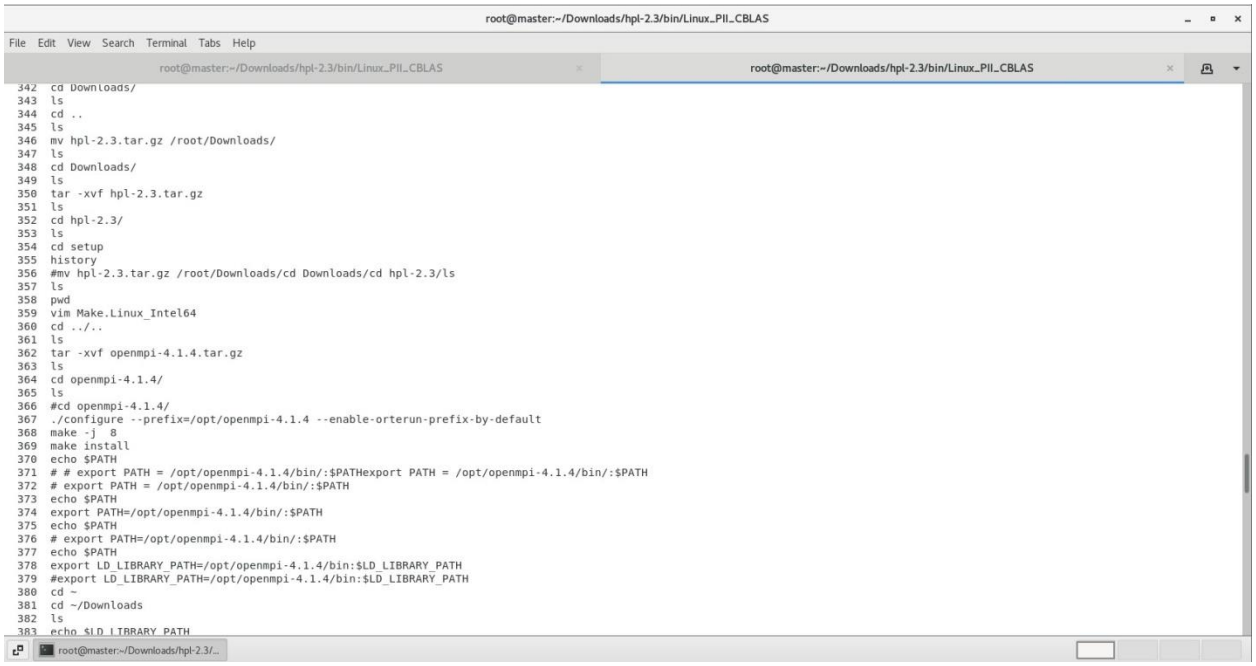
Snapshot 19: sinfo and state of nodes



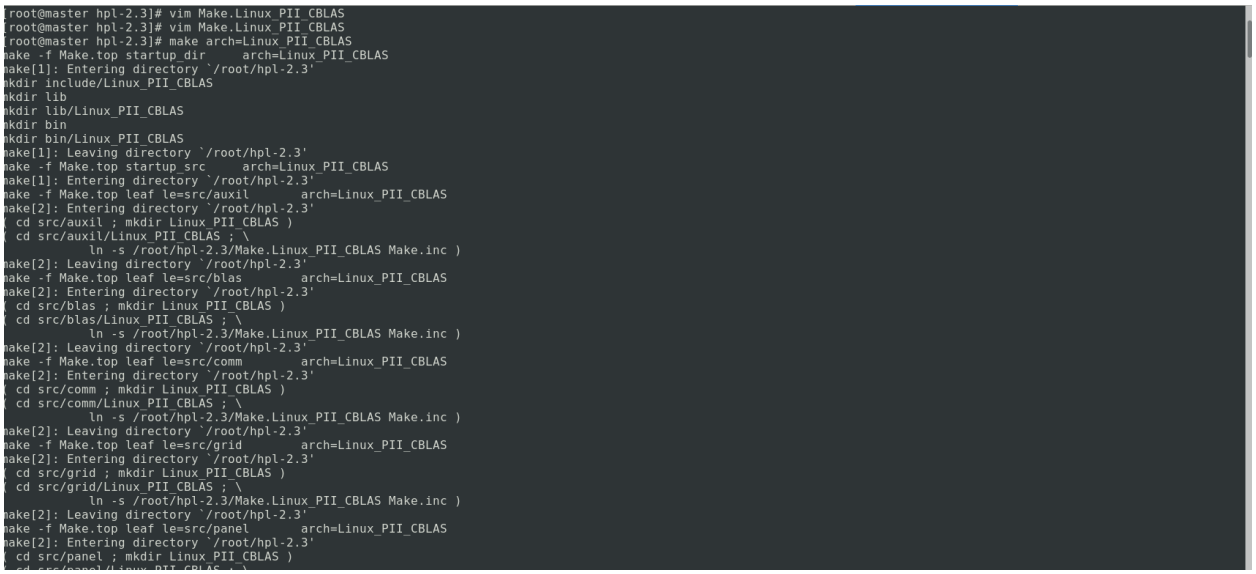
Snapshot 20: HPL Benchmarking (atlas rpm)



Snapshot 21: HPL Installation Commands



Snapshot 22: make arch=Linux_PII_CBLAS command



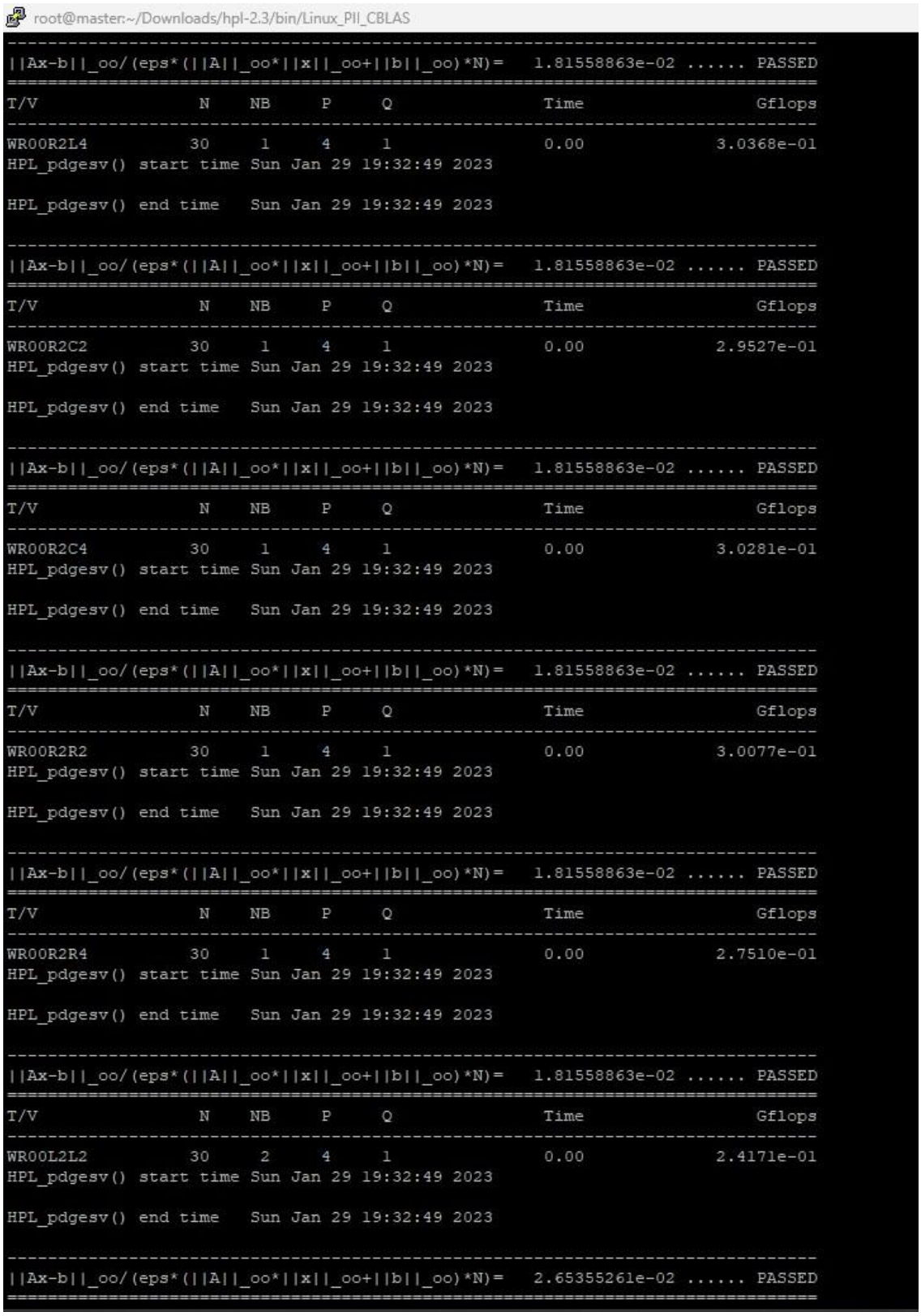
Snapshot 23: Listing of HPL.dat File and xhpl

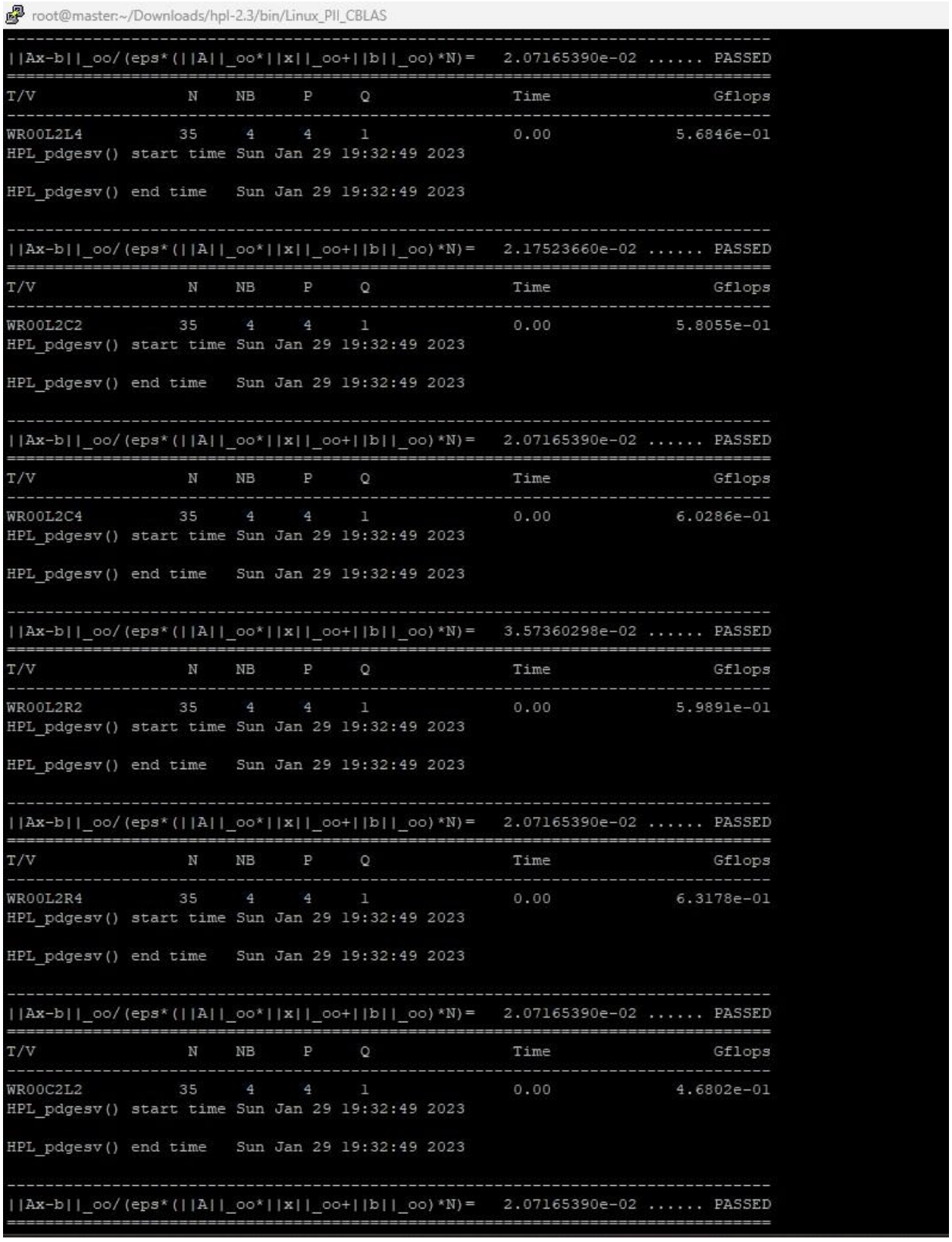
```
[root@master hpl-2.3]# cd bin/
[root@master bin]# ls
Linux_PII_CBLAS
[root@master bin]# cd Linux_PII_CBLAS/
[root@master Linux_PII_CBLAS]# ls
HPL.dat  xhpl
[root@master Linux_PII_CBLAS]# vim HPL.dat
[root@master Linux_PII_CBLAS]# mpirun --allow-run-as-root -np 4 ./xhpl HPL.dat
bash: mpirun: command 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]#
```

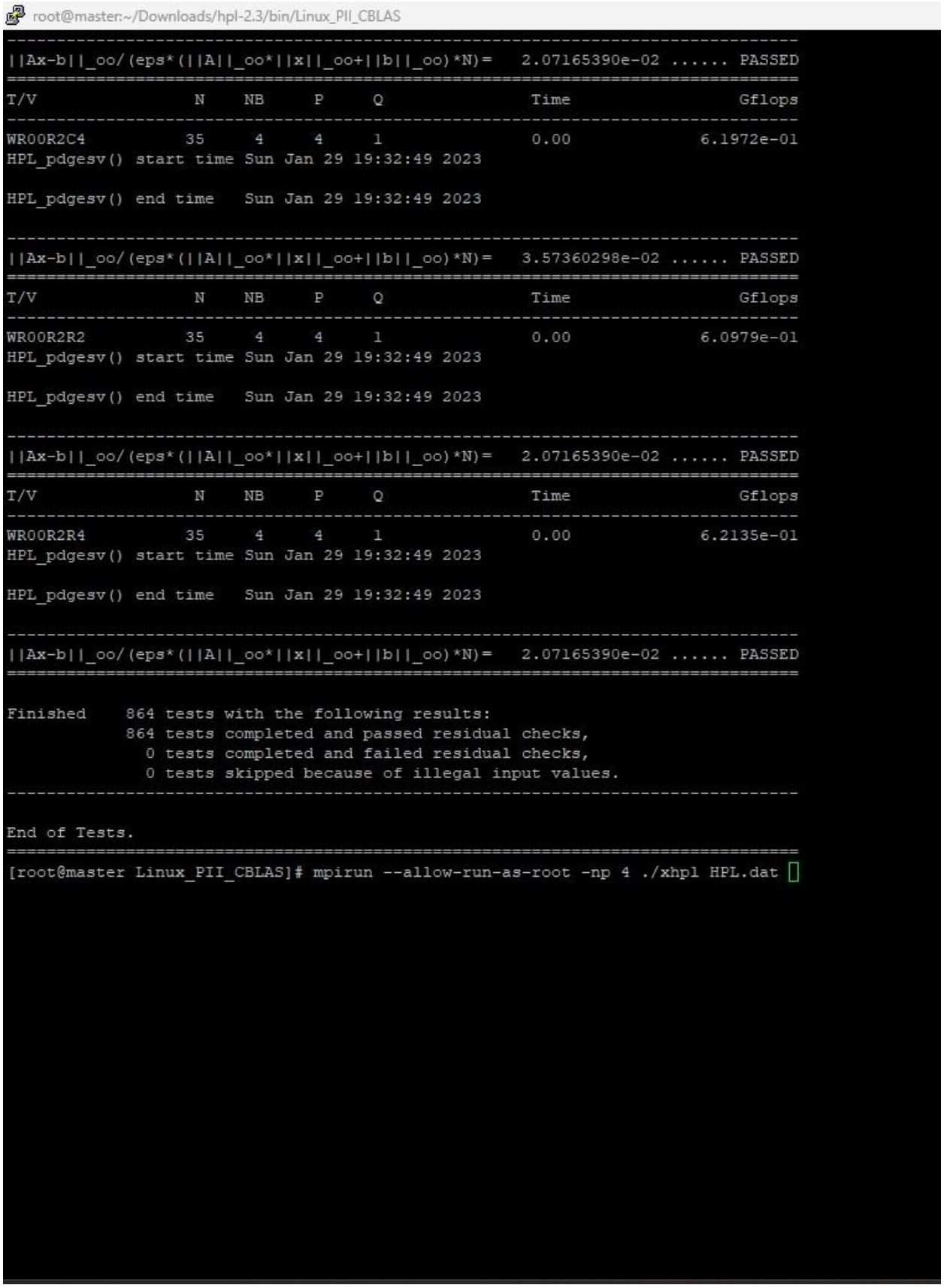
Snapshot 24: HPL.dat file

```
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          NBMINs (>= 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=lrg,1=lrM,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)= 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

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 htop 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
2. https://github.com/AnkushKapoor-97/HPL-Benchmarking.git