Road to Building a Linux Cluster

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Introduction:

Computer clusters consist of connected computers that work together so that it can be viewed as one system. Each node (CPU) is set to perform the same task for speed and efficiency. The components of a computer cluster are usually connected to each other through fast local area networks, which each node running its own instance of an operating system. In most cases, the nodes use the same hardware with the same operating systems but you can also install different operating systems on each compute node. In this manual we will be guiding you on how to build a Linux cluster from scratch using multiple compute nodes (CPU) and each of them will be using Debian 7.11 as the operating system.

Getting Started:

Before starting to build your Linux Cluster, you should know some basic information on Linux so here are some Linux commands you should be familiar with:

Commands

- cd - used to change the current working directory in the operating system
- ls - used for listing files in the current working directory and subdirectories
- mkdir - used to create new directories
- apt-get - tool used for working with APT (the Advanced Packaging Tool) software packages. A rapid, practical, and efficient way to install packages on your system
- chmod - used to change the permissions of files or directories
- su - makes it possible to change a login session's owner without the owner having to first log out of that session. This command is short for "substitute user"
- wget - stands for "web get." Used for downloading files over a network
- ssh - used to start a SSH client program that enables secure connection to a SSH server on a remote machine
- vi - a screen-oriented text editor originally created for the Unix operating system
- nano - a text editor for Unix-like computing systems or operating environments using a command line interface
- cp - used to make copies of files and directories

- chroot - runs a command or an interactive shell from another directory, and treats that directory as root
- tar - used to create, maintain, modify, and extract files that are archived in the tar format
- dd - enables you to create a bootable USB drive

Also some hardware components you will be using for your build. Creating ethernet cables, installing the hard drive and network drive into your compute nodes. Here are some definitions of hardware and software components:

Definitions

- RAM (Random Access Memory) - alternatively referred to as main memory, primary memory, or system memory, RAM is a hardware device that allows info to be stored and retrieved on a computer.
- USB Drive - alternatively referred to as a flash drive, data stick, pen drive, memory unit, or key chain drive. This is simply a portable storage device.
- Debian - a free, open-source operating system developed with tools from the GNU project
- Ethernet - a widely used local-area network (LAN) protocol originally created by Xerox PARC in 1973 by Robert Metcalfe and others
- CPU (Central Processing Unit) - alternatively referred to as a processor, central processor, or microprocessor. The CPU handles all instructions it receives from hardware and software running on the computer.
- TCP (Transmission Control Protocol) - a standard that dictates how to establish and maintain a connection through which two programs may exchange data.
- Network File System- allows network users to access shared files over TCP/IP.
- NTP (Network Time Protocol) - a protocol introduced in 1988 that is used on computer networks to synchronize the time of computers and network devices.
- Warewulf - a computer cluster implementation toolkit that facilitates the process of installing a cluster and long term administration
- MariaDB - one of the most popular database servers in the world. It’s made by the original developers of MySQL.

Beginning your Build

Hardware

In order to begin working on your linux cluster, you will first need a master node. This node will need a CPU, hard drive, cpu cooler, network card, motherboard, RAM and the peripherals needed will consist of a monitor, mouse, keyboard, ethernet cables, and power cables. Once the master node's hardware has been set up, you will need a bootable USB drive to install an OS (in this case Debain 7.11). Using Debian 7 is more stable than using Debian 9!

How to make a network cable:

Supplies

1. Cable
2. Crimp tool
3. Box of cat 5 plugs.

Three steps: Strip, Arrange, Crimp

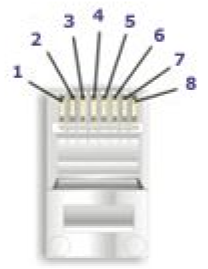
Step 1: Strip

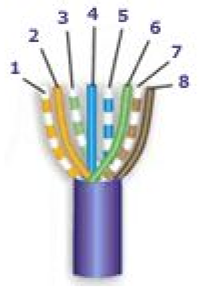
Using the razor on the crimp tool, strip off the amount you want off the sheath at the end of the cable. If you somehow cut the internal wires, just cut the wire an inch down and strip again. After the strip you will find 8 color-codes internal wires.

Step 2: Arrange

For making a standard network cable, you'll want to arrange the colors in the same order on both ends:

1. White/Orange striped
2. Orange solid
3. White/Green striped
4. Blue solid
5. White/Blue striped
6. Green solid
7. White/Brown striped
8. Brown solid





Step 3: Crimp

Insert the colored wires in that order into the cat 5 plug.

After you have done that, double check to see if they stayed in the correct order. It may take a couple tries to get it right. Once it's correctly placed into the plug, insert it into the crimp tool and squeeze. But do not squeeze too hard because you might end up cutting one of the internal wires. Repeat these 3 steps for the other end, and then you are done!!

Software

To create a bootable USB you will need to download Debian Wheezy from a separate computer, and use a program which will create a bootable USB drive such as the dd command in linux or LinuxLive USB creator in windows. With a bootable USB drive in hand, plug it into the master node and power on the node. If necessary, enter the BIOS and change the boot sequence to start with the USB drive and if the USB drive is not detected reset the BIOS to its defaults and try again. Once you are able to boot off the USB, complete OS installation and remove USB. Be sure to install the desktop environment, the ssh server, and the needed system software. When partitioning, allocate 10 GB of memory to /boot, 2x Physical Memory to swap and the rest to / (root). With multiple drives we will partition differently. Our build had three drives which were partitioned:

Drive one: 50-100GB for **/Boo**t, 10GB **/swap**, 50GB **/usr/local** and rest to **/** (root)
Drive two: 50GB **/var**, **/home**
Drive three: **/scratch**

Configuring the Master Node

This section will set up your master node in order to communicate with the other compute nodes. We will setup the network so that the compute node has access to the outside world or the internet through the PCI network card, and will communicate with the compute nodes through the motherboards network card. We will also create a chrooted environment for the nodes and a network file system to be shared to the compute nodes. As well as installing any necessary software.

With a working computer, first thing we will need to do is set up the network. To set up networking connections, edit the **/etc/network/interfaces** file, this file describes the network interfaces available on your system.

```
# The loopback network interface
auto lo
iface lo inet loopback
```

```
#Use DHCP for public interface
auto eth0
iface eth0 inet dhcp

#setup static for mobo
auto eth1
iface eth1 inet static

     address 10.253.1.254
     netmask 255.255.255.0
     gateway 10.253.1.254
```

Afterwards reboot the node and check your network using:

```
ip route
```

The output should look something along the lines of:

```
default via 136.160.116.1 dev eth0 proto static
10.253.1.0/24 dev eth1 proto kernel scope link src 10.253.1.254
136.160.116.0/22 dev eth0 proto kernel scope link src 136.160.119.40
```

Once everything checks out, you will need to install the essential build tools:

```
apt-get install build-essential
```

Then install the new updated mysql (mariaDB), and other important packages:

```
apt-get install mysql-server mysql-client

apt-get install ssh ntp qt-sdk pkg-config ncurses-dev nfs-server
libselinux1-dev pdsh tftp gfortran libxml2-dev tk-dev apache2
libapache2-mod-perl2 tftp-hpa debootstrap tcpdump isc-dhcp-server curl
libterm-readline-gnu-perl
```

Then reboot master node either using the reboot command or the GUI shutdown and reboot. If problems occur you may need to turn off selinux by editing the **/etc/selinux/config** file and setting the flag:

```
vi /etc/selinux/config

SELINUX=permissive
```

Note: when you exit vi editor (saving upon exit): Hit the (esc) key followed by :exit

If everything is fine up to this point then you will work on installing warewulf:

```
mkdir ~/src

cd ~/src

wget --no-check-certificate
https://warewulf.lbl.gov/svn/trunk/platform/deb/install-wwdebsystem

chmod +x install-wwdebsystem3.6

./install-wwdebsystem3.6
```

It should be noted that this will and should only fail on the VNFS with an invalid chroot path. Therefore, you will need to eliminate the SSHD root login for security purposes:

```
nano /etc/ssh/sshd_config

change the line ‘#PermitRootLogin yes’ to ‘PermitRootLogin no’
/etc/init.d/ssh restart
```

Then edit **/etc/exports** to contain the following. Be careful to note the rw flag in /opt and the ‘no_subtree_check’. This is changing the default settings from warewulf.

```
vi /etc/exports

/home 10.253.1.0/255.255.255.0(rw,no_root_squash,no_subtree_check)
/srv/chroots 10.253.1.0/255.255.255.0(ro,no_root_squash,no_subtree_check)
/srv/chroots/debian7/vnfs
10.253.1.0/255.255.255.0(ro,no_root_squash,no_subtree_check)
/usr/local 10.253.1.0/255.255.255.0(rw,no_root_squash,no_subtree_check)
/opt 1 0.253.1 .0/255.255.255.0(rw,no_root_squash,no_subtree_check)
```

Afterwards edit **/usr/local/libexec/warewulf/wwmkchroot/include-deb** to replace/root:

```
vi /usr/local/libexec/warewulf/wwmkchroot/include-deb

DEB_CONF="/etc/apt-ww.conf"
DEB_CONF_FULL="$CHROOTDIR/etc/apt-ww.conf"
DEB_SRC="/etc/apt/sources.list"
DEB_SRC_FULL="$CHROOTDIR/etc/apt/sources.list"
```

Then edit **/usr/local/etc/warewulf/vnfs.conf** to include or read:

```
vi /usr/local/etc/warewulf/vnfs.conf

hybridpath = /srv/chroots/%{name}
```

Once finished, create a file in **/usr/local/libexec/warewulf/wwmkchroot/** named **debian7.tmpl** containing:

```
vi /usr/local/libexec/warewulf/wwmkchroot/debian7.tmpl

# Start debian7.tmpl
# DESC: A base 64 bit Debian wheezy chroot
# The general Deb include has all of the necessary functions, but #requires
# some basic variables specific to each chroot type to be defined.
. include-deb
ARCH="amd64"
SUITE="wheezy"
DEB_MIRROR="http://http.us.debian.org/debian/"
# Install additional packages with debootstrap.
PKGLIST="openssh-server,openssh-client,isc-dhcp-client,pciutils,strace,nfs-com
mon,ethtool,iproute,iputils-ping,iputils-arping,net-tools,linux-image-amd64,km
od,ntp,python-dev,libxml2,gfortran"

# End debian7.tmpl file
```

Once done create directories using mkdir command:

```
mkdir /srv/chroots
mkdir /srv/chroots/debian7
mkdir /srv/chroots/debian7/vnfs
mkdir /srv/chroots/debian7/srv
mkdir /srv/chroots/debian7/srv/chroots
```

Then create the warewulf chroot:

```
wwmkchroot debian7 /srv/chroots/debian7
```

Then edit the files (on the master node) **/etc/idmapd.conf** & **/srv/chroots/debian7/etc/idmapd.conf** to read:

```
[General]
Verbosity = 0
Pipefs-Directory = /var/lib/nfs/rpc_pipefs
#set your own domain here. If ID differs from FQDN minus hostname
Domain = tier1.cluster

[Mapping]
```

```
Nobody-User = nobody
Nobody-Group = nogroup
```

Nobody and nogroup may need to be changed to the non-root username.

Next edit the **/usr/local/etc/warewulf/defaults/node.conf** to read:

```
#groups = maingroup
cluster = teir1
domain = cluster
unique hwaddrs = yes
```

Also edit the **/usr/local/etc/warewulf/defaults/provision.conf** to read:

```
vnfs = debian7
files = dynamic_hosts, passwd, group, shadow
```

Next you should comment out the infiniband drivers in **/usr/local/etc/warewulf/bootstrap.conf.** Simply add a '#' in front of the lines with drivers. The next step is to edit the **/srv/chroots/debian7/etc/fstab** file to read under the infiniband section:

```
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
10.253.1.254 /home /home nfs defaults 0 0
10.253.1.254 /srv/chroots /srv/chroots nfs defaults 0 0
10.253.1.254 /srv/chroots/debian7/vnfs /vnfs nfs defaults 0 0
10.253.1.254 /usr/local /usr/local/ nfs defaults 0 0
10.253.1.254 /opt/opt nfs defaults 0 0
```

After editing these files, restart the nfs on the master node:

```
/etc/init.d/nfs-kernel-server restart
/etc/init.d/nfs-common restart
```

In the chroot directory you will need to edit the **/srv/chroots/debian7/etc/rc.local** file to look like:

```
#mount all nfs shares
/bin/mount -a
exit 0
```

Then we will need to verify that the network file system is being exported by the master node, using the command:

```
showmount -e 10.253.1.254
```

With the nfs being correctly exported, next we will check to see if the tftp config file is using the correct address **/etc/default/tftpd-hpa**:

```
TFTP_ADDRESS="10.253.1.254:69"
```

Restart the tftp server:

```
/etc/init.d/tftpd-hpa restart
```

With all of the above completed we will now build our chroot environment and install it using the warewulf commands which all start with "ww" then add our first compute node. As a side note the compute node will not need a hard drive because it will be using the master node for any information:

```
wwvnfs --chroot /srv/chroots/debian7 --hybridpath=/vnfs
wwsh dhcp update
wwsh node new n0001 --hwaddr=YourComputeNodesADDR --ipaddr=10.253.1.1
```

If you're having trouble finding your compute nodes hardware address just enter the BIOS and look in the settings, it is also known as the MAC address. At this point you should have another computer ready to go, this pc should have everything your master node has hardware wise except for the PCI network card and the hard drive. Connect the two nodes (computers) together with a network cable which you have created. The nodes should be connected through the motherboards network, not the master nodes PCI network card. Turn on the second computer which we will now reference as n0001 or compute node1. Once n0001 has been turned on you may attach the display cord (VGA, HDMI, etc) to it in order to see what it is doing and to verify that it is performing as a compute node and not failing. Once you are sure that it is working continue to the next section. Any issue will need to be fixed, some helpful commands are wwsh, wwinit ALL, and you should go through each of the files which were edited and examine any spelling or syntax mistakes which could be causing an issue.

Working with the Compute Nodes

With n0001 running and acting like a compute node, we will need to check that the nfs mounts are working on it and are keeping the correct permissions. To do this we will do:

```
ssh n0001
df -k
```

```
ls -ltra /home
```

Examine the output and of the ownership and permissions of the mount. Next we will work of the non-root user setup of ssh and passwordless login.

```
su (non-root user)
ssh (name of node)
cd
ssh-keygen -t rsa #(do not enter a passphrase)
Cd ~/.ssh
cp id_rsa pub authorized_keys
cd
ssh n0001 (answer yes)
exit
ssh n0001
```

If you run into any issues, **BE VERY CAREFUL WITH THIS STEP**, but you can remove the files created by:

```
cd ~
rm -rf .ssh/
```

The second ssh into n0001 should not prompt for a password. If any issue occurs with ssh (non root user) then you may have an issue with exporting the shadow file from the master node. If this is the case:

```
sudo wwsh file import /etc/shadow

sudo wwsh provision set n0001 --fileadd shadow
```

After that works, we will then make sure the vnfs system stays up to date, patched and secure. On the master node, as root, edit **/srv/chroots/debian7/etc/apt/sources.list** to include the following lines to the beginning:

```
deb http://security.debian.org/ wheezy/updates main
deb-src http://security.debian.org/ wheezy/updates main
```

Optionaly, you can copy the sources.list file from the master to the chroot if any problems occur:

```
cp /etc/apt/sources.list /srv/chroots/debian7/etc/apt/sources.list
```

Then update, install, rebuild chroot and reboot compute nodes:

```
chroot /srv/chroots/debian7
mount -t proc proc proc/
```

```
apt-get update && apt-get upgrade
exit
wwvnfs --chroot /srv/chroots/debian7 --hybridpath=/vnfs
(while in the compute node ssh)
reboot
```

After restarting your compute nodes, you may need to update the bootstrap image (only if you have a kernel upgrade in this) by executing the following commands:

```
wwbootstrap 3.21.6
wwsh provision set n0001 --vnfs=debian7 --bootstrap=3.21.6-4-amd64
```

After that works, we want the clocks to be the same on all nodes (synchronized with each other). Edit the **/srv/chroots/debian7/etc/ntp.conf** file for compute nodes to read as follows:

```
#driftfile /var/lib/ntp/drift

#Permit all access over the loopback interface. This could be tightened as
#well, but to do so would #effect some of the administrative functions.
#restrict 127.0.0.1
#restrict default ignore
server 10.253.1.254
#restrict 10.253.1.254 nomodify
```

Rebuild vnfs to incorporate the changes:

```
wwvnfs --chroot /srv/chroots/debian7 --hybridpath=/vnfs
```

Reboot your compute node **n0001**, ssh into **n0001** and check that ntp info is being picked up by the compute nodes.Type “**ntpq**” in the command prompt then “**peers**”:

```
ntpq
ntpq> peers
```

SAMPLE OUTPUT FOR PEERS COMMAND

```
 remote      refid            st  t when poll  reach  delay   offset      jitter
==========================================================================
debian      12.167.151.1  3  u  58  64    1     0.207  -4972.7     0.000
```

Now you can manually add new nodes by individually executing each of the following commands:

```
wwsh node new n0002 --hwaddr="MAC ADDRESS OF NODE" --ipaddr=10.253.1.2
wwsh node new n0003 --hwaddr="MAC ADDRESS OF NODE" --ipaddr=10.253.1.3
```

Make sure each ip address is unique for each node.

After adding another compute node, go back to Page 9 and follow through the steps of **Working with Compute Nodes** again up till synchronizing their clocks.
Then after that update the files.

```
wwsh file sync
wwsh dhcp update
wwsh pxe update
```

Make sure that all of your nodes have their hostnames added to the ssh config files by logging into them manually over ssh, which should prompt for their addition to the files.
Then confirm that pdsh will execute a command in parallel across as a root user and a normal user.

```
pdsh -R ssh -w (masternodename), n0001 hostname
pdsh -R ssh -w (masternodename), n0001 uname -a
```

Optionally, if rsyslog needs to be installed on compute nodes:

```
chroot /srv/chroots/debian7
mount -t proc proc proc/
apt-get install rsyslog
wwvnfs --chroot /srv/chroots/debian7 --hybridpath=/vnfs
wsh dhcp update
(restart compute nodes)
```

Next, you have to build and install MPICH as root from this source (https://www.mpich.org/):
Click on the Green button (Download MPICH).

```
cd ~/src
cp (Path)/Downloads/mpich-3.2.tar.gz ~/src
tar zxvf mpich-3.2.tar.gz
cd mpich-3.2
./configure --enable-fc --enable-f77 --enable-romio --enable-mpe
--with-pm=hydra
make
make install
```

If problems occur during configuration you may need to also add **--disable-fortran** to the **./configure...** line. Also don't forget to make sure that **/usr/local/lib** is in library path on all nodes. Addition of **/usr/local/lib** to the file **/srv/chroots/debian7/etc/ld.so.conf.d/libc.conf** file.

Reboot each node:

```
pdsh -R ssh -w n0001,n0002,n0003 reboot
```

Installing Ganglia

Ganglia is a scalable monitoring tool for high-performance computing systems, cluster and networks. The software is used to record live statistics covering metrics such as CPU loads. You can monitor your master node and also the nodes you add to your cluster. You will have to edit the ganglia monitoring daemon (gmond) file which basically runs on each compute node you want to monitor (including the master node). The ganglia meta daemon (gmetad) file you will also edit, will collect information from each node periodically. Using data sources such as IP addresses for access control over the compute nodes. And the ganglia web interface, which of course will let you interact with ganglia and allow you to easily monitor and control your cluster.

On the master node, install Ganglia monitor, RDDtool, Gmetad, and the Ganglia web front end.

```
sudo apt-get install -y ganglia-monitor rrdtool gmetad ganglia-webfrontend
```

During the installation, you will be asked to restart Apache. Select yes. Then set up the online dashboard by copying the Ganglia web front end configuration file to the Apache **sites-enabled** folder.

```
sudo cp /etc/ganglia-webfrontend/apache.conf    (continued on next line)
/etc/apache2/sites-enabled/ganglia.conf
```

Then edit the **Gmetad** configuration file to set up your cluster. This file configures where and how the **Getad** daemon will collect data.

```
sudo vi /etc/ganglia/gmetad.conf
```

Find the line in the file that begins with “data_source”:

```
data_source “my cluster” localhost
```

And edit the line to:

```
data_source “my cluster” 60 localhost
```

Save file.

Next, edit the Gmond configuration file. We are setting it up for monitoring as the first node in the "my cluster" cluster. The **gmond.conf** file configures where the node sends its information.

```
sudo vi /etc/ganglia/gmond.conf
```

In the cluster section in this file, make sure you set the name to the same one you set in the **gmetad.conf** file

```
cluster {
     name = "my cluster" #use the name from gmetad.conf file
     owner = "unspecified"
     latlong = "unspecified"
     url = "unspecified"
}
```

In the **udp_send_channel** section, insert a new **host** line with the value **localhost**, which is the server where you're sending the information. Comment out the **mcast_join** line.
For reference, the **mcast_join** value provides a multicast address, but we need to send the data to only one host, so this is unnecessary.

```
udp_send_channel {
      #mcast_join = 239.2.11.71 #comment out
      host = localhost
      port = 8649
      ttl = 1
}
```

In the **upd_recv_channel** section, comment out the **mcast_join** and **bind** lines.
The bind value provides a local address to bind to, but since the cluster will only be sending information, this is unnecessary.

```
udp_recv_channel {
      #mcast_join = 239.2.11.71 #comment out
      port = 8649
      #bind = 239.2.11.71 #comment out
}

tcp_accept_channel {
    port = 8649
}
```

Restart Ganglia-monitor, Gmetad and Apache.

```
sudo service ganglia-monitor restart && sudo service gmetad restart && sudo
service apache2 restart
```

Web Interface

Ganglia should now be set up on your master node and accessed by typing **localhost/ganglia** in your address bar.

Client Installation

For installing ganglia on your compute nodes you will need to go in your **chroot** environment.

```
sudo chroot /srv/chroots/debian7/
```

On the second node you want to monitor, install the ganglia monitor.

```
sudo apt-get install -y ganglia-monitor
```

Edit the **gmond** configuration file for monitoring the node.

```
sudo nano /etc/ganglia/gmond.conf
```

In the file you want to edit it so your node can match up with the master node files.

```
Cluster {
     Name = “my cluster”  #cluster name
     Owner = “unspecified”
     Laglong = “unspecified”
     Url = “unspecified”
}

Udp_send_channel {
      #mcast_join = 239.2.11.71
      Host = localhost    #IP address of master node
      Port = 8649
      Ttl = 1
}

/* udp_recv_channel {
       Mcast_join = 239.2.11.71
       Port = 8649
       Bind = 239.2.11.71
} */
```

If you run into an issue where the compute nodes are not being picked up by ganglia monitor then:

```
globals {
  daemonize = yes
  setuid = no
  user = ganglia
  debug_level = 1
  max_udp_msg_len = 1472
  mute = no
  deaf = no
  host_dmax = 0 /*secs */
  cleanup_threshold = 300 /*secs */
  gexec = no
  send_metadata_interval = 0
}
```

Pay special attention to debug_level = 1 as well as setuid = no. These configurations should resolve or help resolve any issues.

After making these changes in the **/etc/ganglia/gmond.conf** file you would want to restart the monitor service.

```
sudo service ganglia-monitor restart
```

After restarting the service, wait between 2-3 minutes and then reload the web interface. The new node you just added should appear in the cluster. Repeat these steps if you want to add more compute nodes.

Link to our blog: http://carloshernandezsalisburycompsci420.blogspot.com/2017/

BRAINBLAST