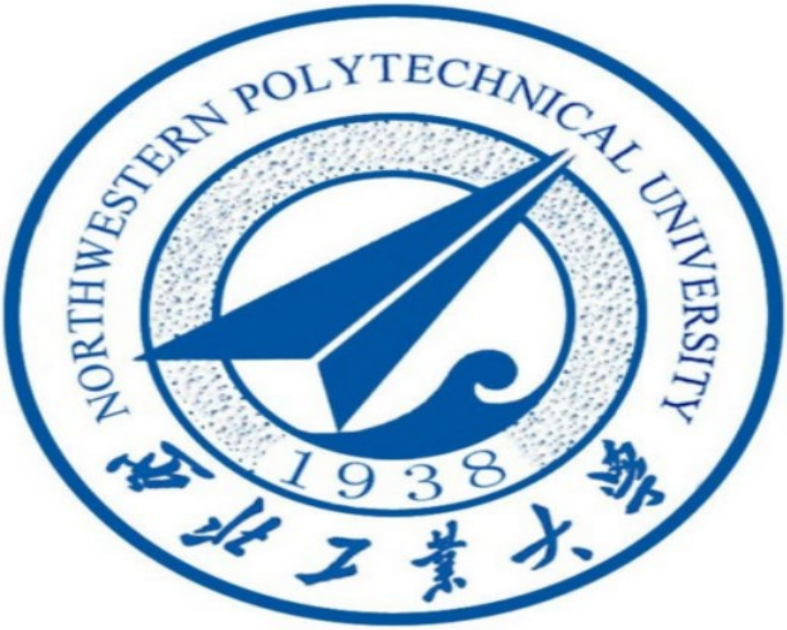

Parallel Programming

Homework 1

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Lecture : Professor Zhengxiong Hou
Submission : 12/30/2022
Submitted Email : houzhx@nwpu.edu.cn

Contents

1. Principle

In this experiment, you will learn how to build a Linux cluster for parallel programming and parallel computing using 2-3 physical machines or virtual machines. One of them is acting as a management node, the other nodes are computing nodes. The computing nodes should be accessed using SSH without requiring password. And you can install MPI and run MPI programs based on the basic services such as SSH, NFS and NIS.

2. Goal

- Master virtualization technology , to create 2-3 virtual machines (optional)；
- Master some common Linux commands, such as useradd etc.
- Master some basic configurations and services for a Linux cluster, such as SSH,NIS,NFS；
- Master the installation and usage of gcc or Intel compilers (optional);
- Master the installation of MPI and running of MPI programs.

3. Software used

(a) Virtual Box
(b) Linux Ubuntu Distro -20.04.3-
(c)

4. Building Linux Cluster

#Structure:

This is how our cluster will run. The work machine is our main machine(client) and can talk to both nodes while the nodes can talk to the work machine as well. Alongside the nodes will be able to contact each other and every machine can individually connect to internet.

4.1 Linux Cluster Structure

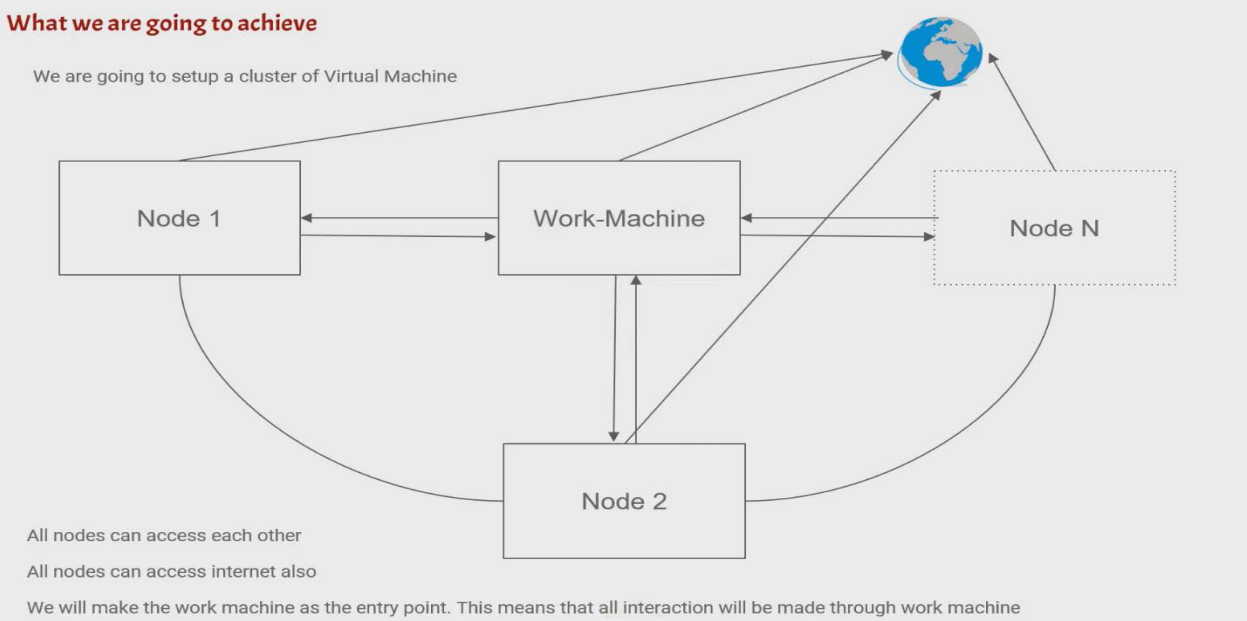


Figure: Linux Cluster Structure

4.2 Oracle VM VirtualBox Manager

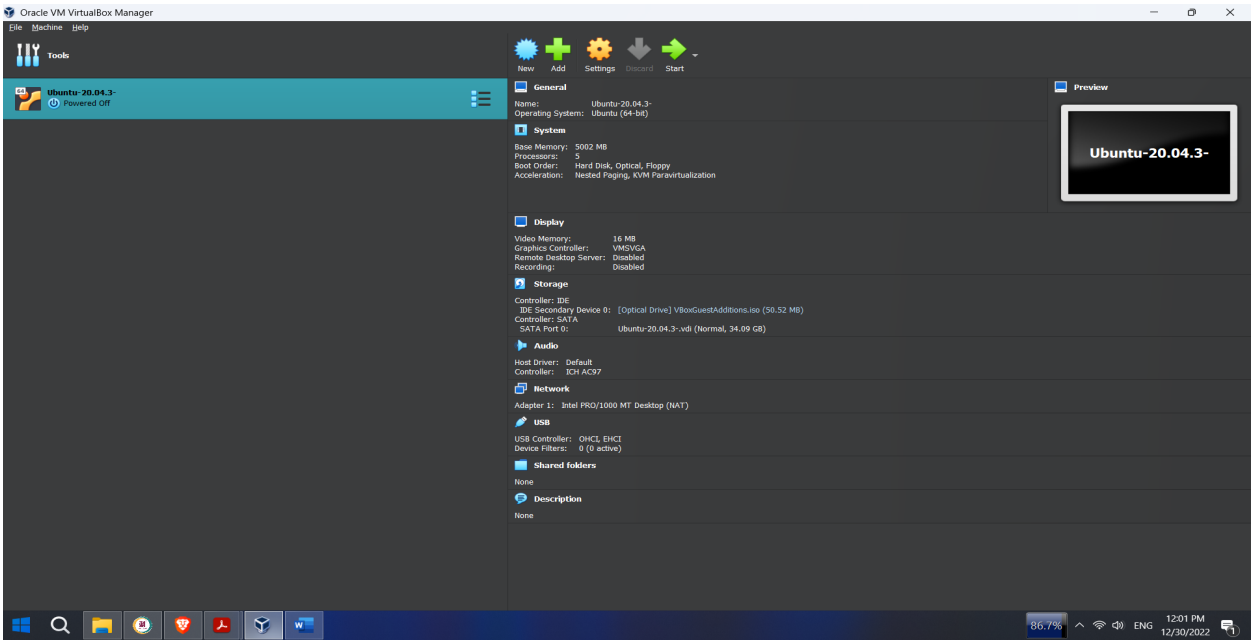


Figure: Oracle VM VirtualBox Manager Interface

4.3 Downloading Ubuntu 22.04.3

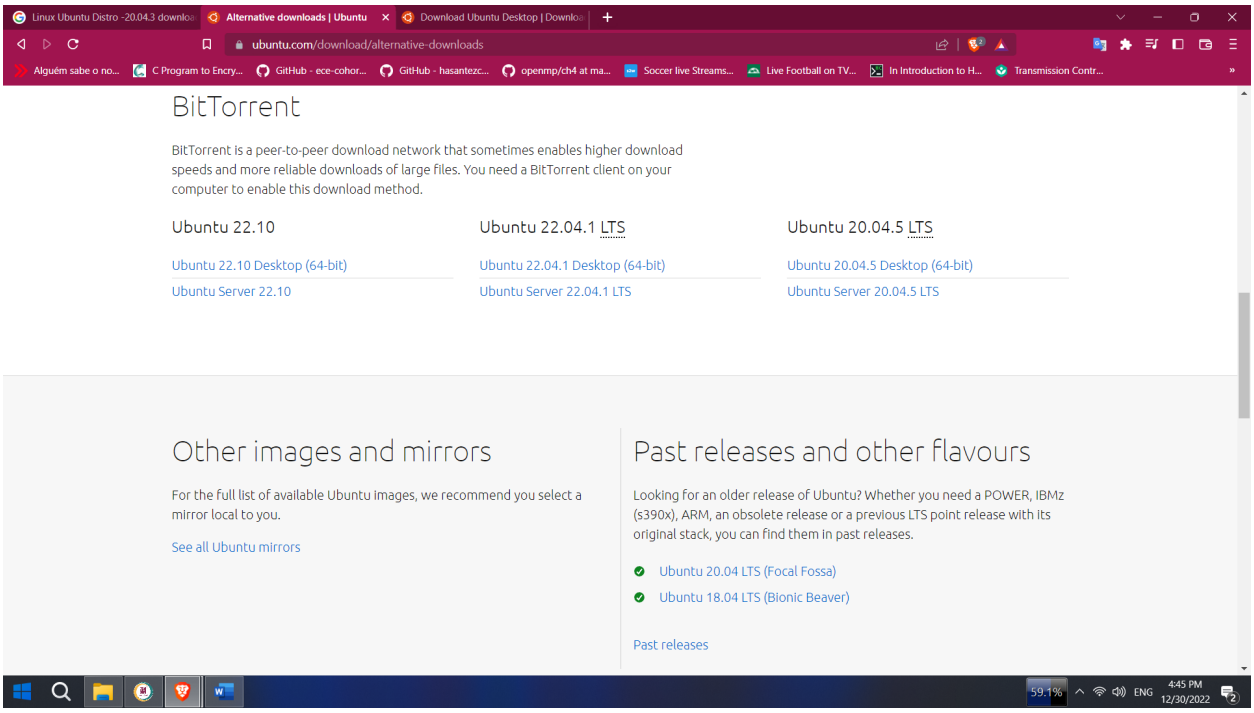


Figure: Downloading Ubuntu 22.04.3

4.4 Creating Workmachine

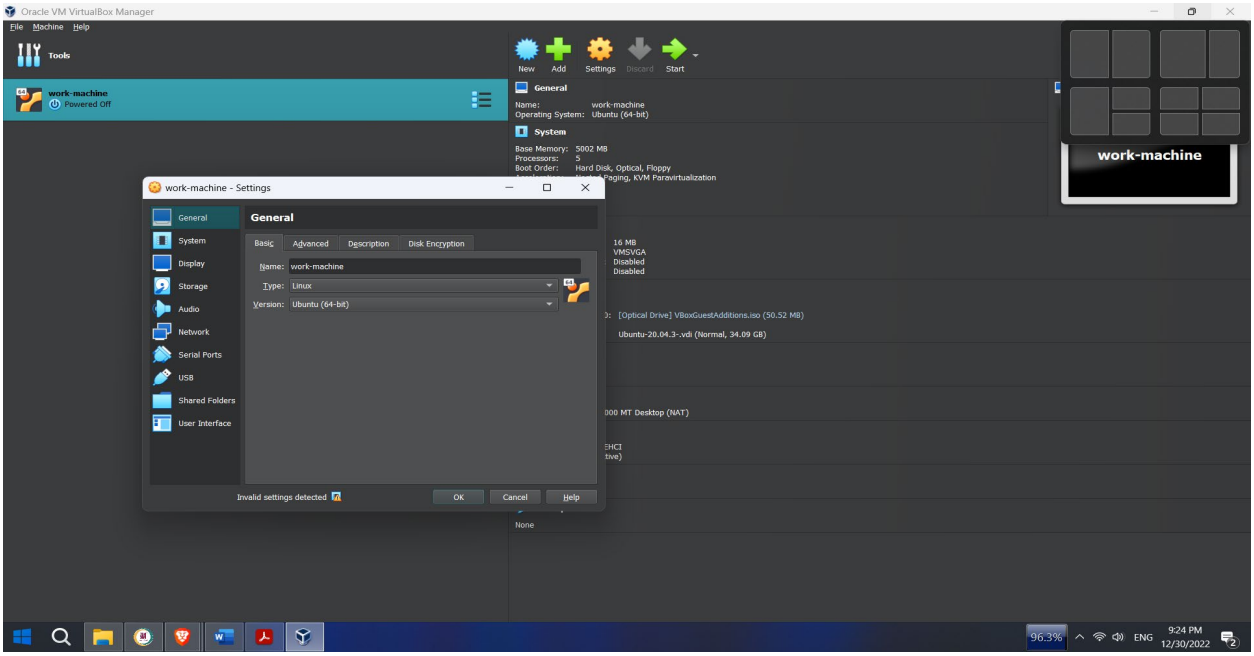


Figure: Created Workmachine

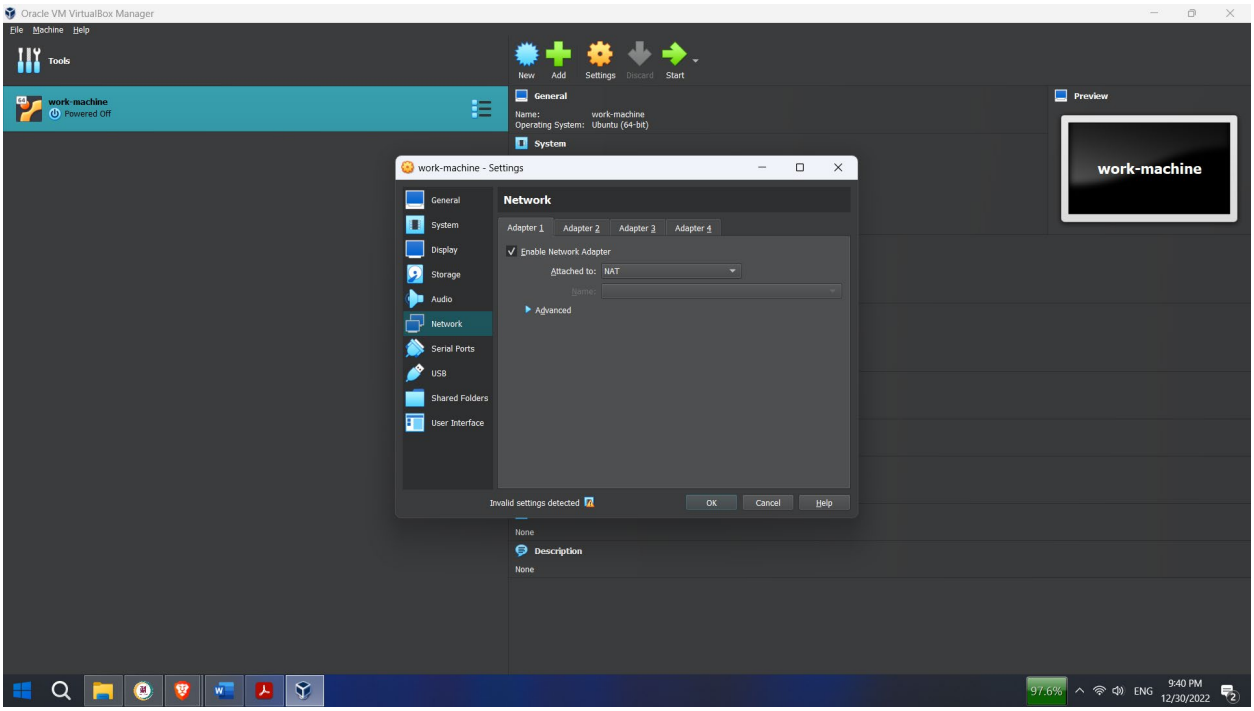


Figure: Created Workmachine (1)

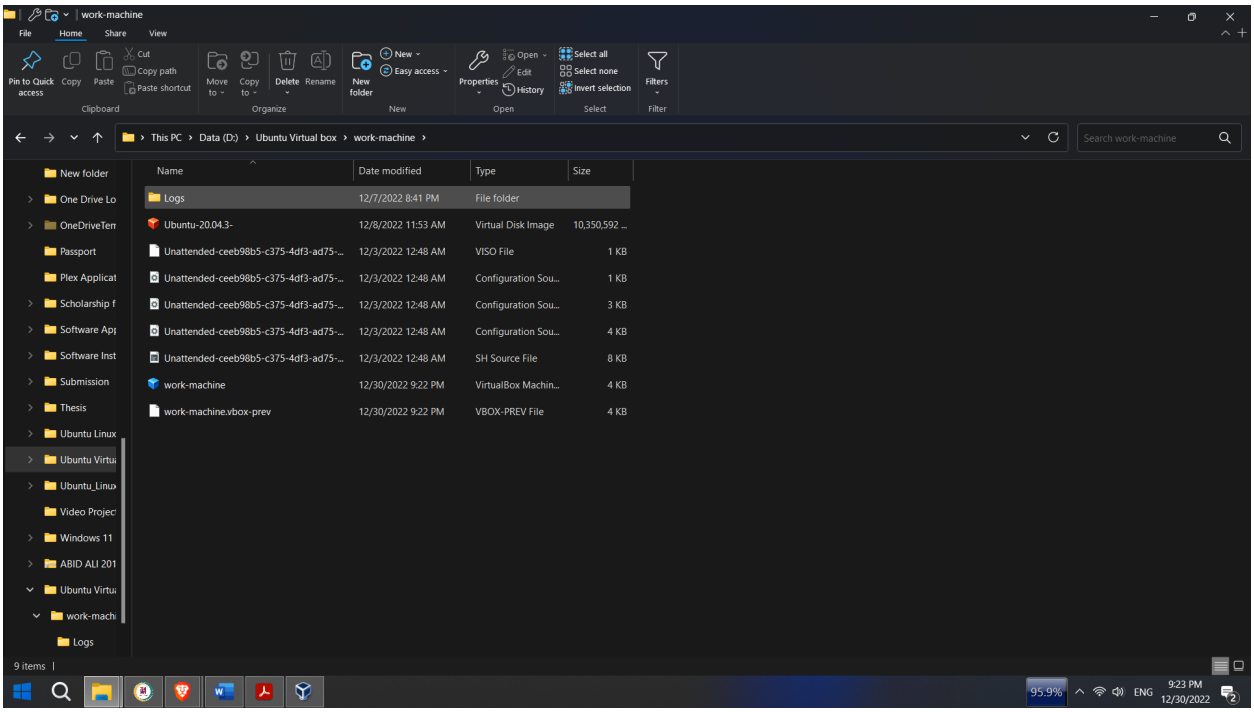


Figure: Created Workmachine (2)

4.5 Adding User In System

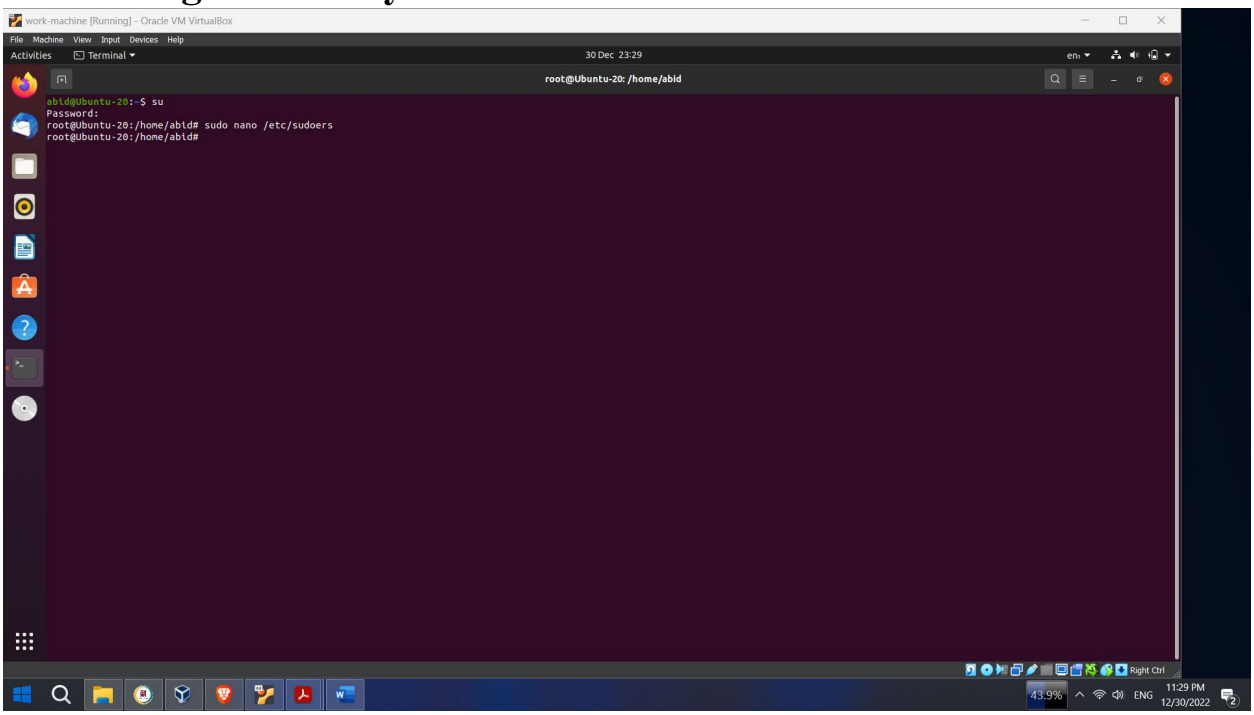


Figure: Added User In The System

4.6 Giving Permission To Other User

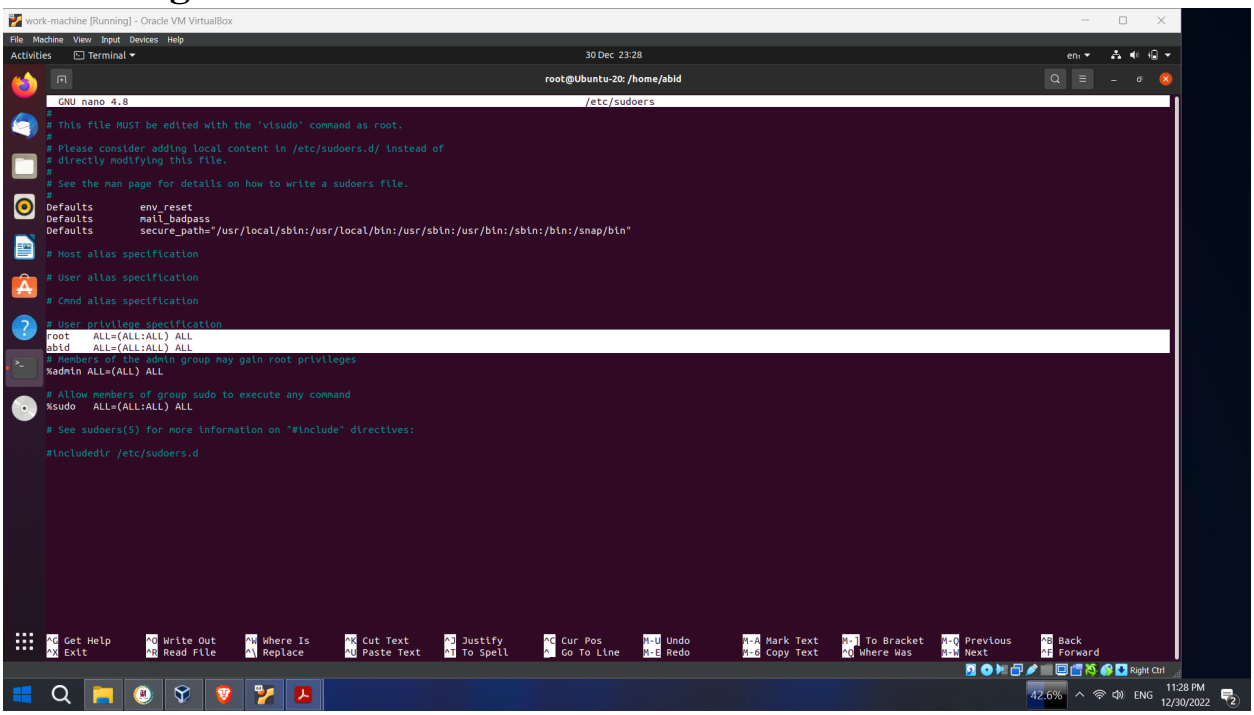


Figure: Permission To Other User

5. Basic configurations and services for a Linux Cluster

5.1 Downloading Ubuntu Server

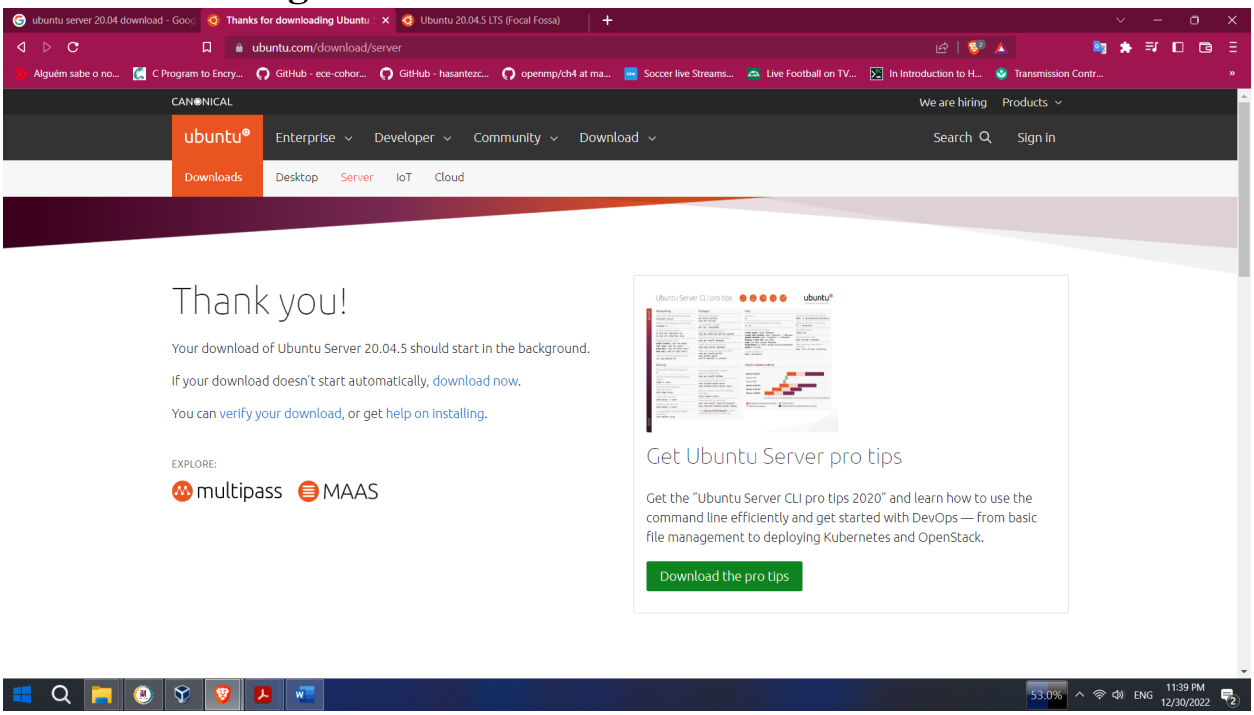


Figure: Downloading Ubuntu Server

5.2 Install Ubuntu Server For Linux Cluster

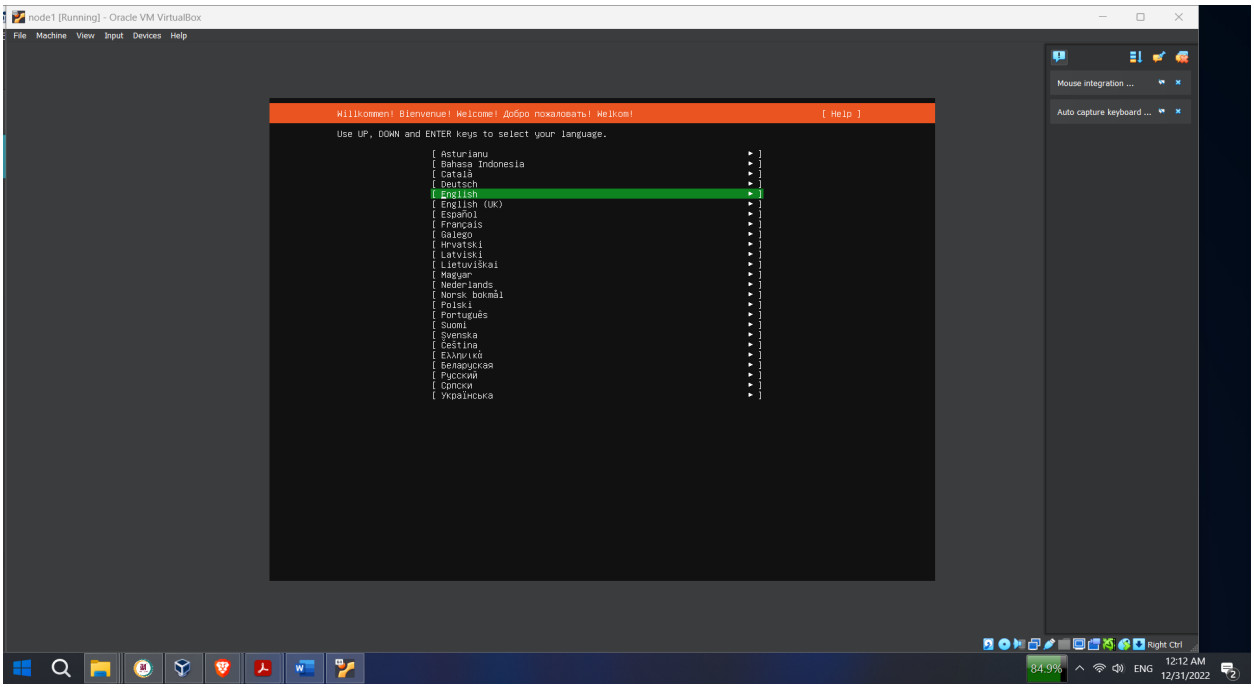


Figure: Installing Ubuntu Server For Linux Cluster

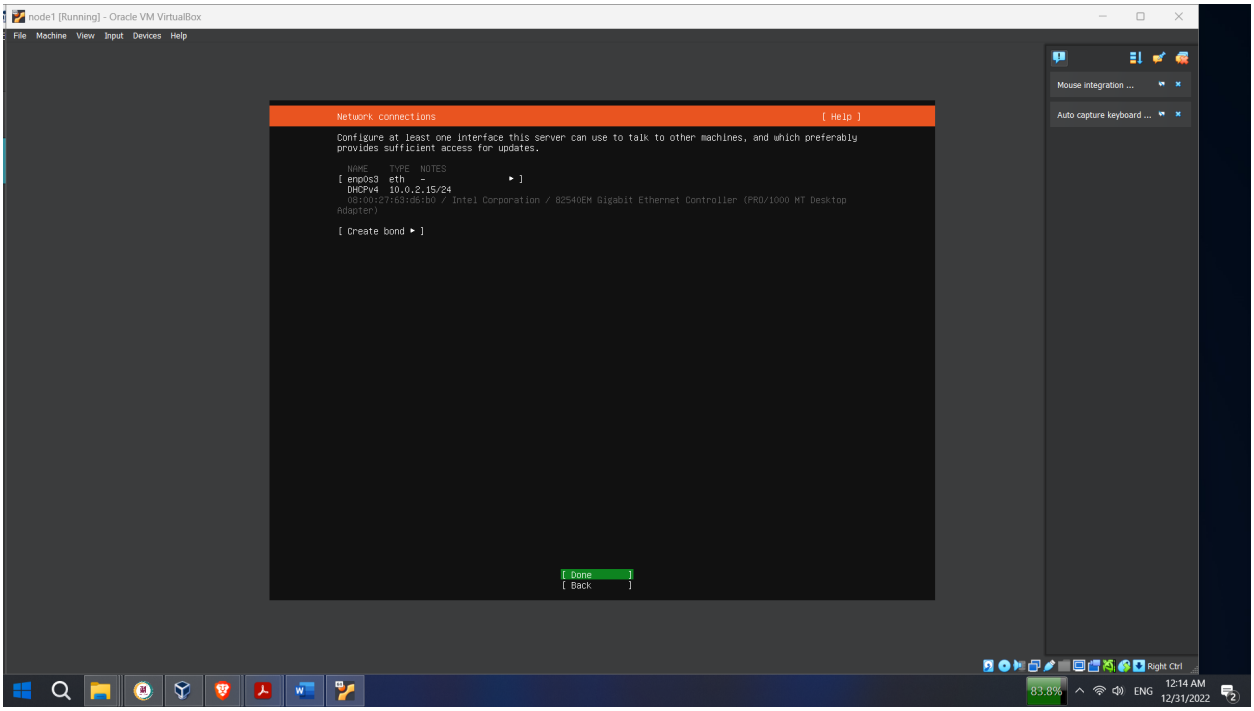


Figure: Installing Ubuntu Server For Linux Cluster (1)

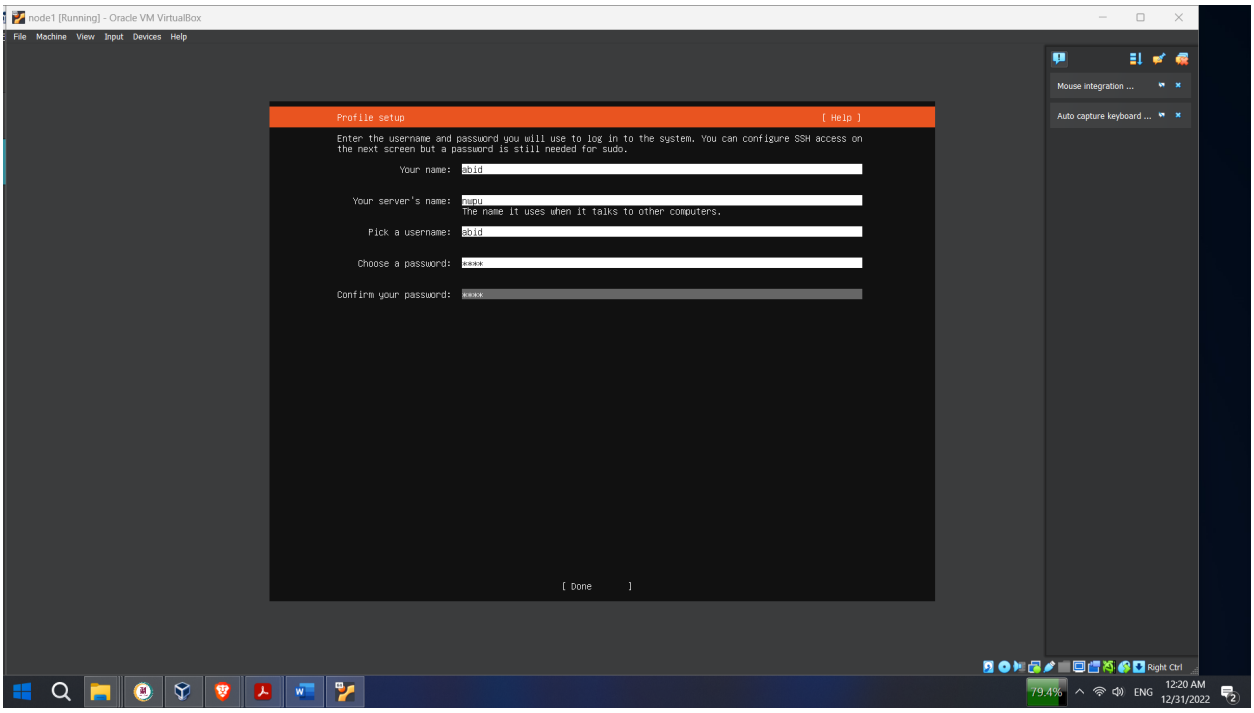


Figure: Installing Ubuntu Server For Linux Cluster (2)

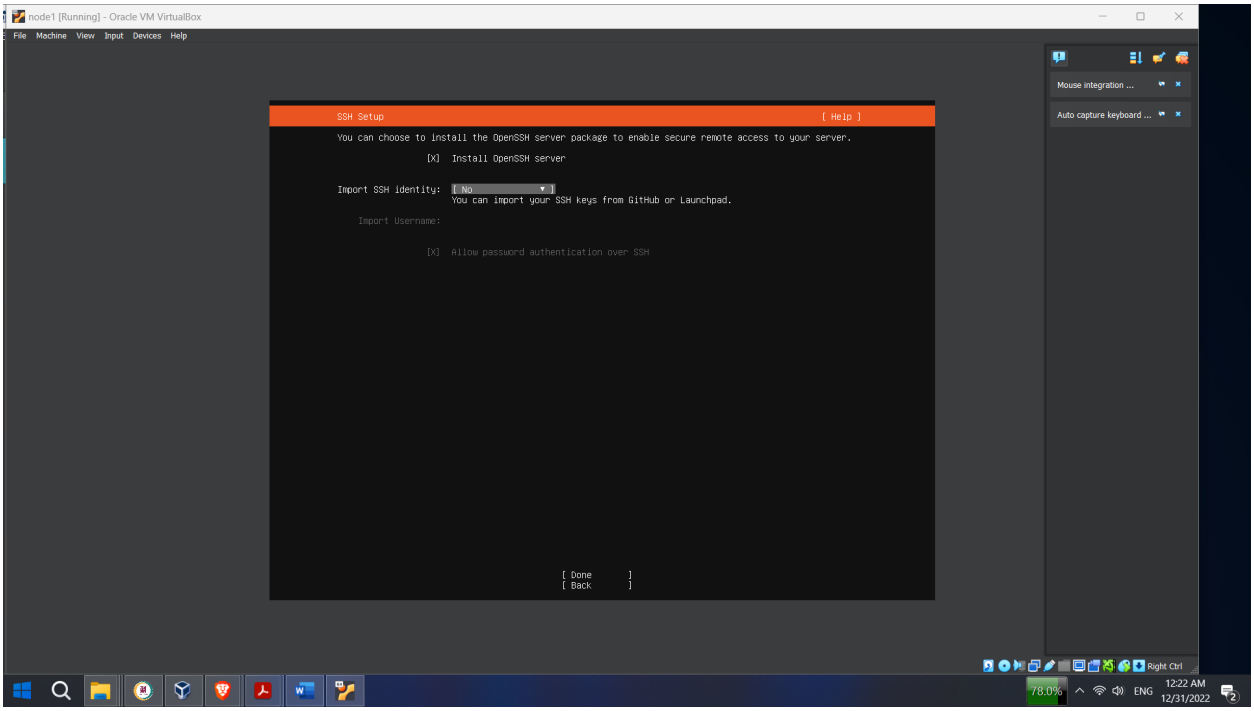


Figure: Installing Ubuntu Server For Linux Cluster (3)

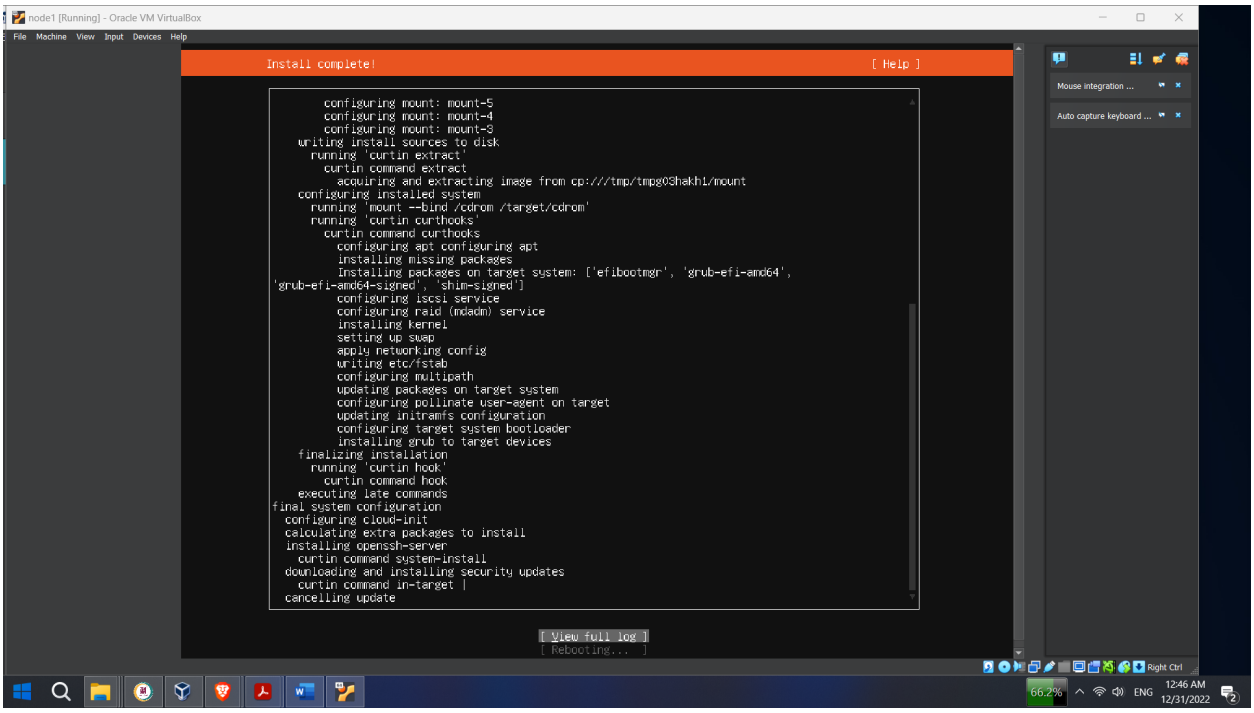


Figure: Installing Ubuntu Server For Linux Cluster (4)

5.3 Node 1 and Node 2 Created

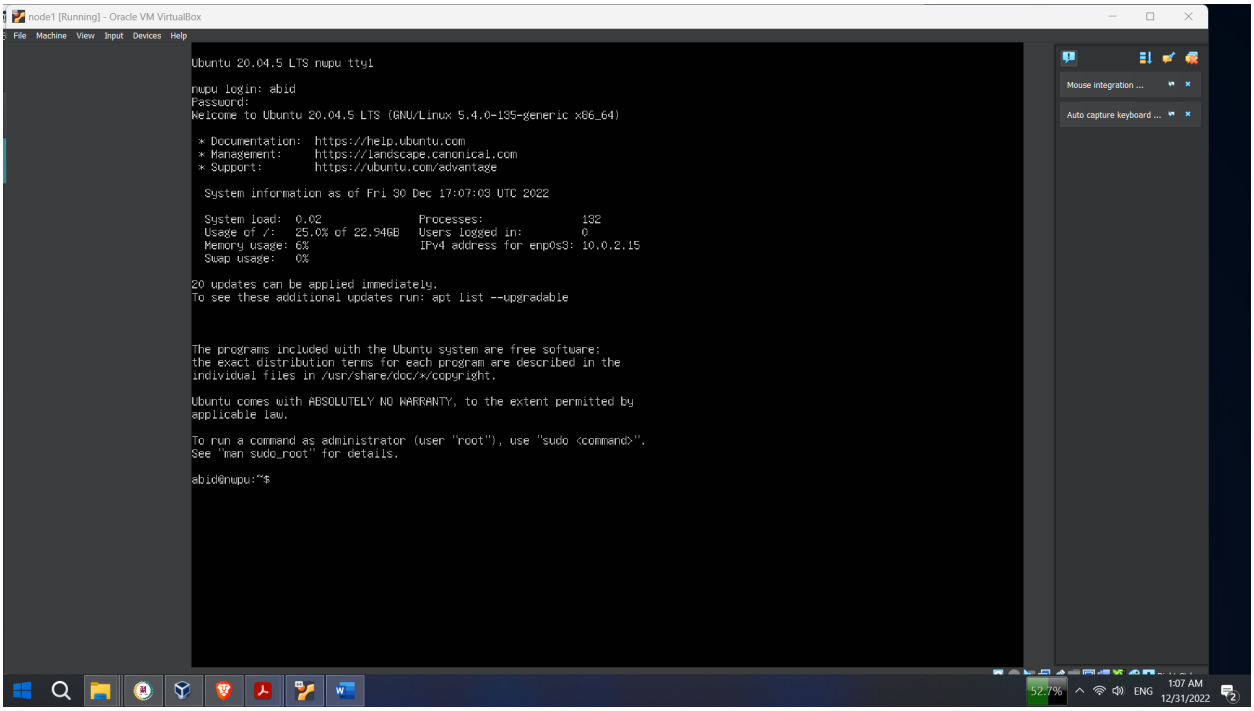
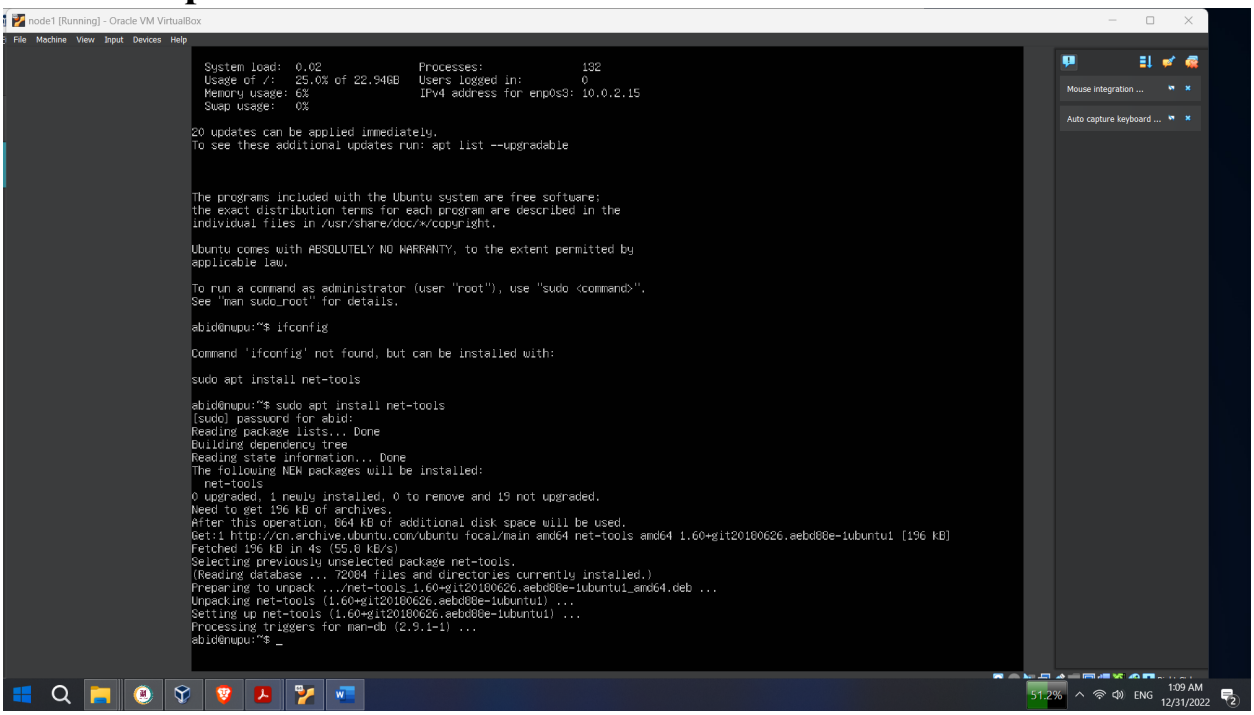


Figure: Node 1 and Node 2

5.4 sudo apt install net-tools

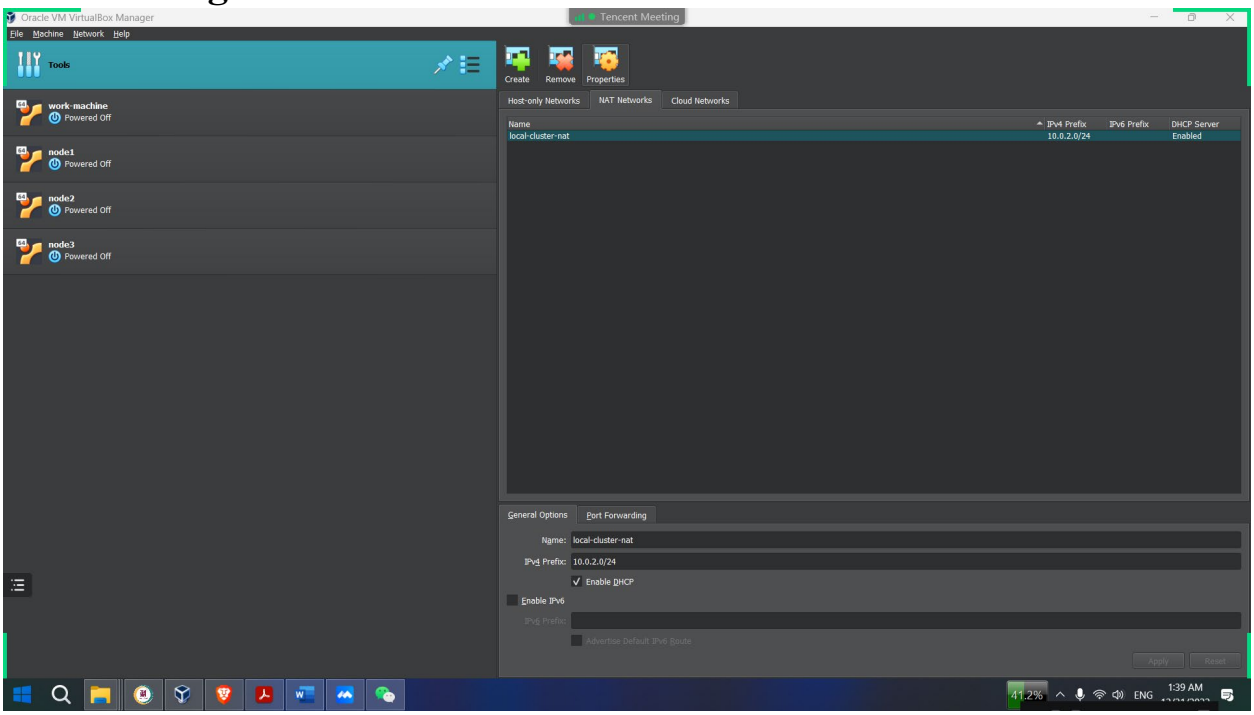


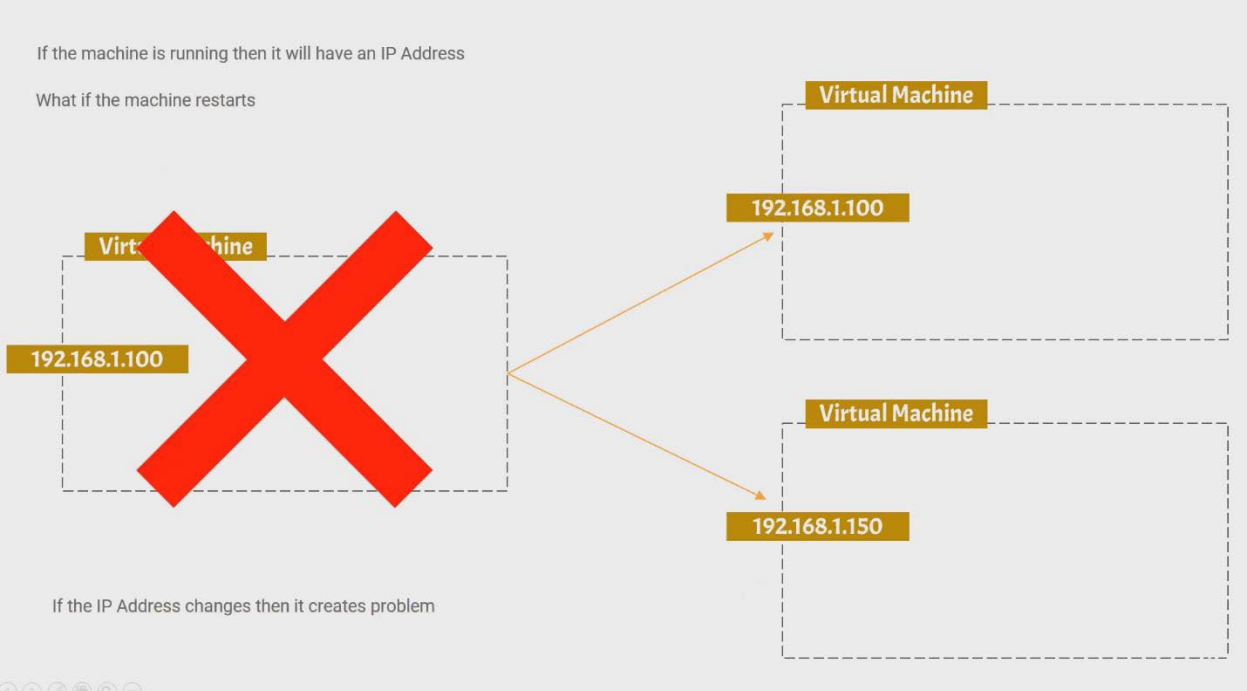
sudo apt install net-tools

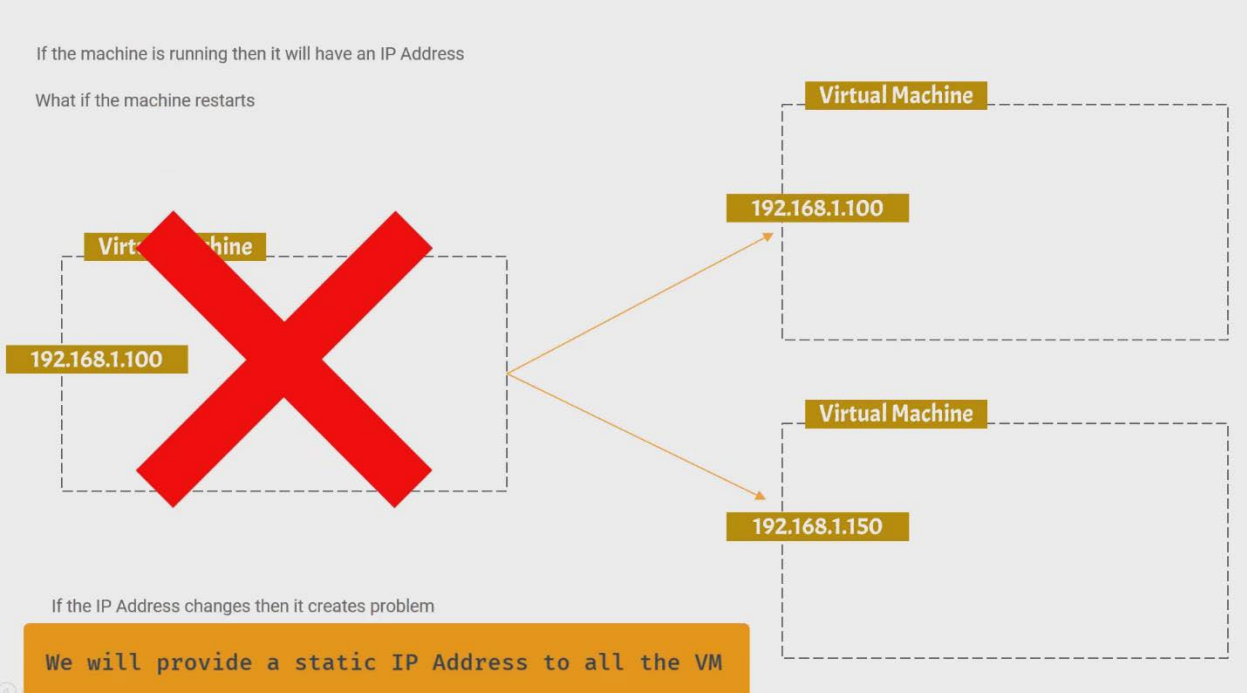
5.5 Checking Network Setting

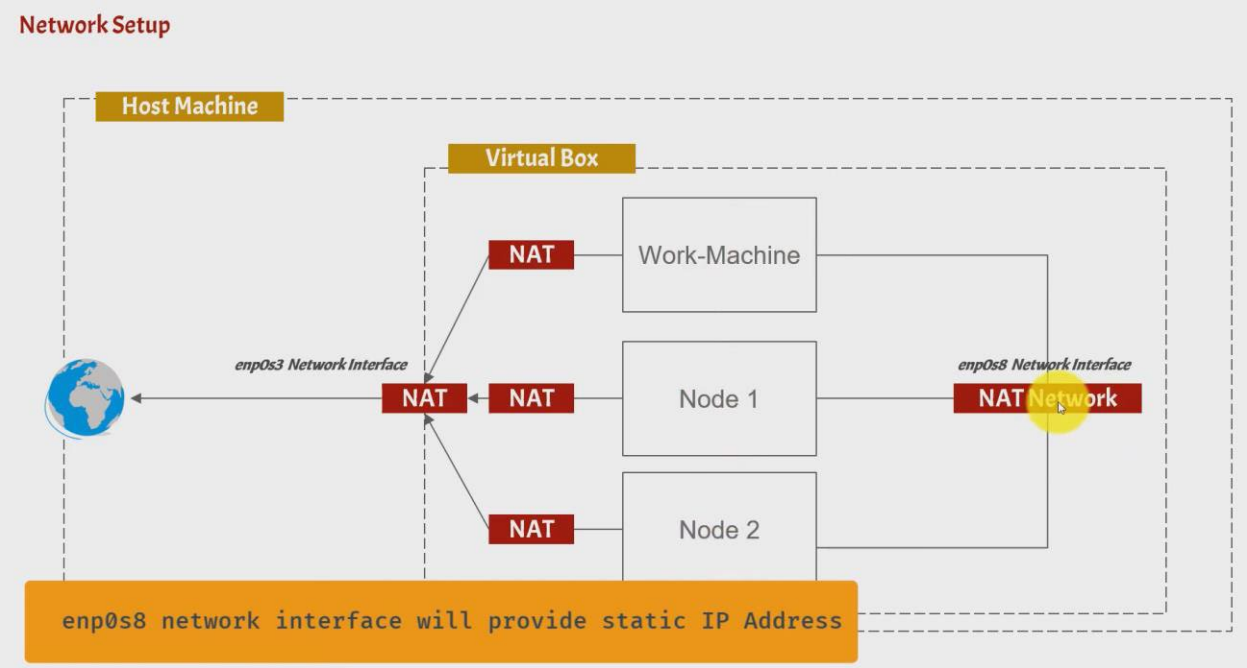
```
abid@nwpu:~$ ifconfig
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 10.0.2.15  netmask 255.255.255.0  broadcast 10.0.2.255
        inet6 fe80::a00:27ff:fe63:d6b0  prefixlen 64  scopeid 0x20<link>
        ether 08:00:27:63:d6:b0  txqueuelen 1000  (Ethernet)
        RX packets 414  bytes 479622 (479.6 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 172  bytes 19916 (19.9 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING>  mtu 65536
        inet 127.0.0.1  netmask 255.0.0.0
        inet6 ::1  prefixlen 128  scopeid 0x10<host>
        loop  txqueuelen 1000  (Local Loopback)
        RX packets 114  bytes 9224 (9.2 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 114  bytes 9224 (9.2 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

5.6 Creating Nat Network

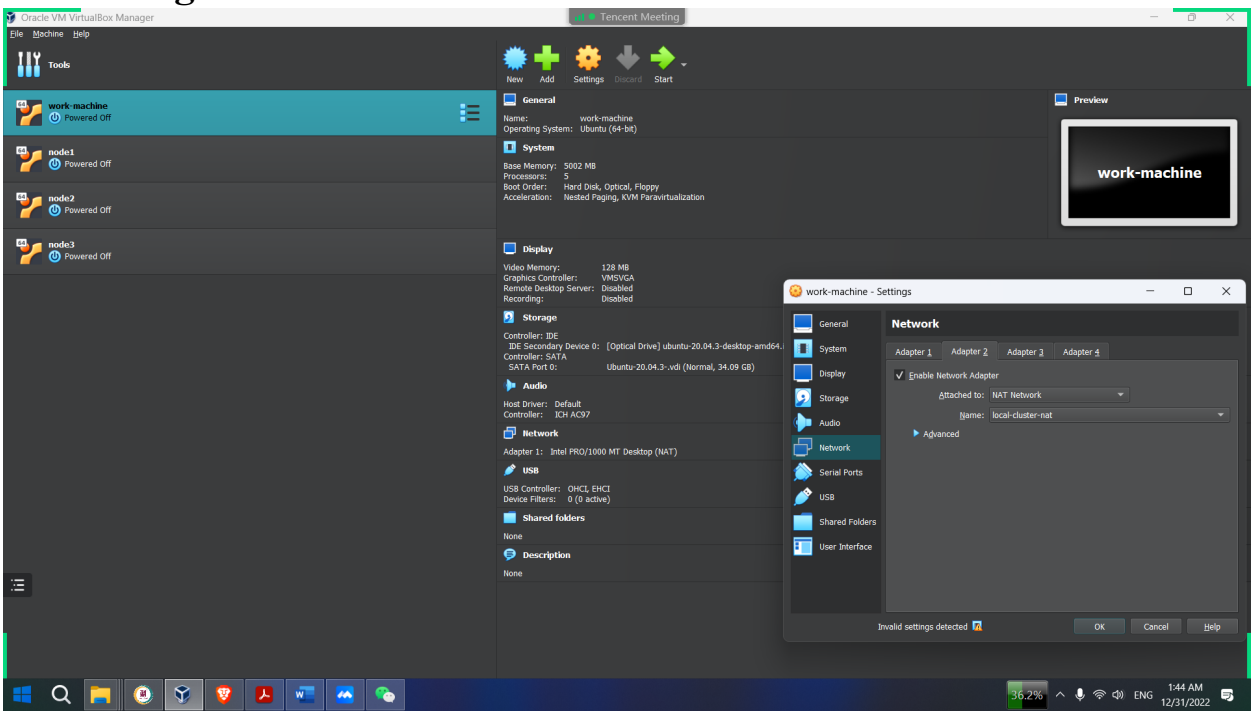



If the machine is running then it will have an IP Address
What if the machine restarts
Virtual Machine
192.168.1.100
192.168.1.100
Virtual Machine
192.168.1.150
If the IP Address changes then it creates problem

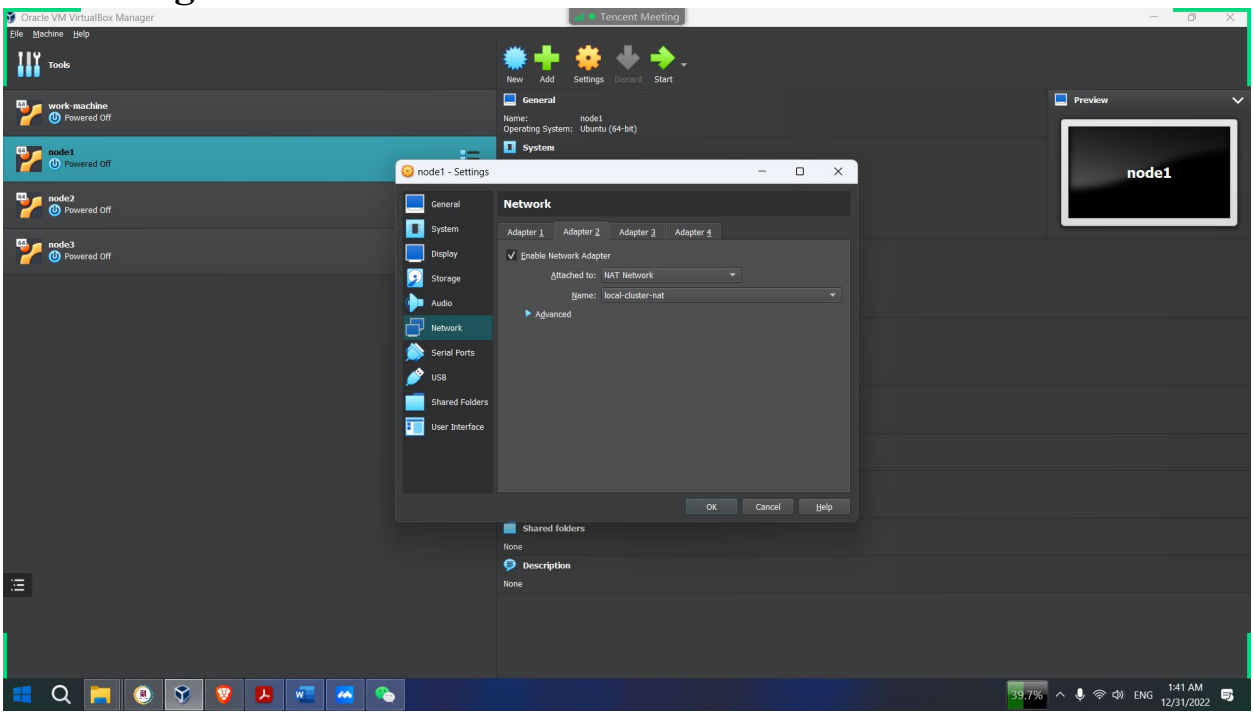

If the machine is running then it will have an IP Address
What if the machine restarts
Virtual Machine
192.168.1.100
192.168.1.100
Virtual Machine
192.168.1.150
If the IP Address changes then it creates problem
We will provide a static IP Address to all the VM



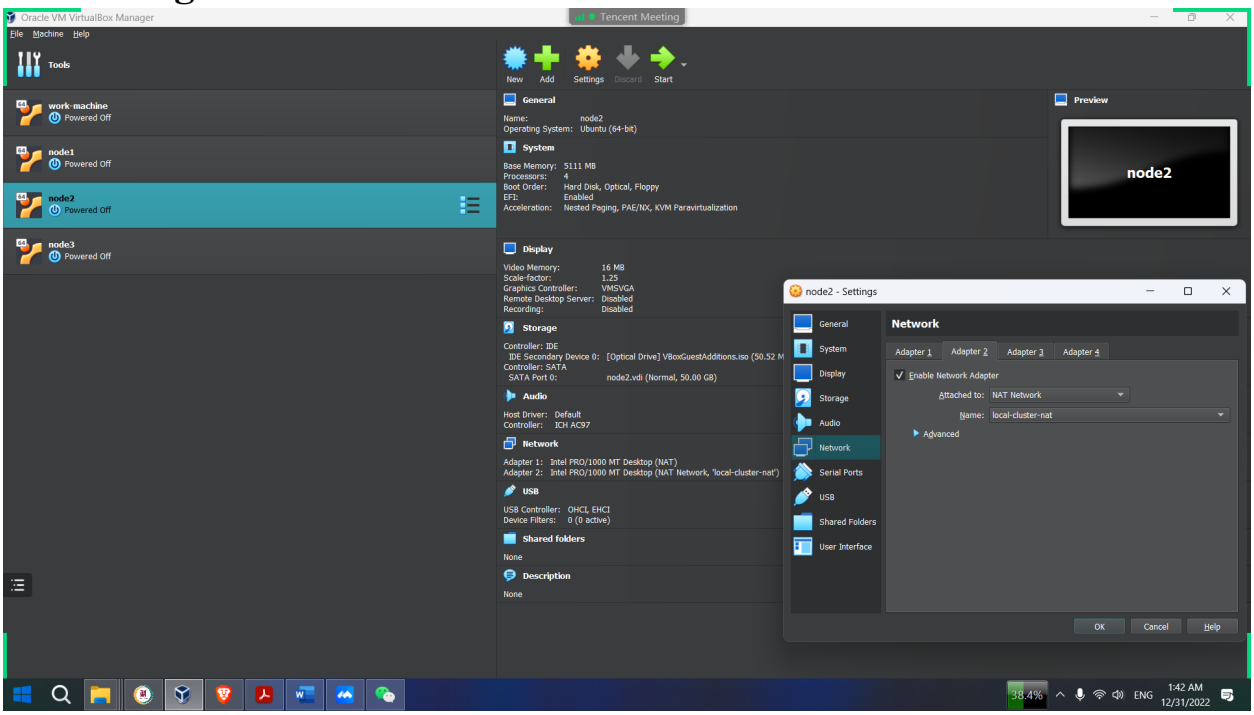
5.7 Setting Nat Network For Work Machine

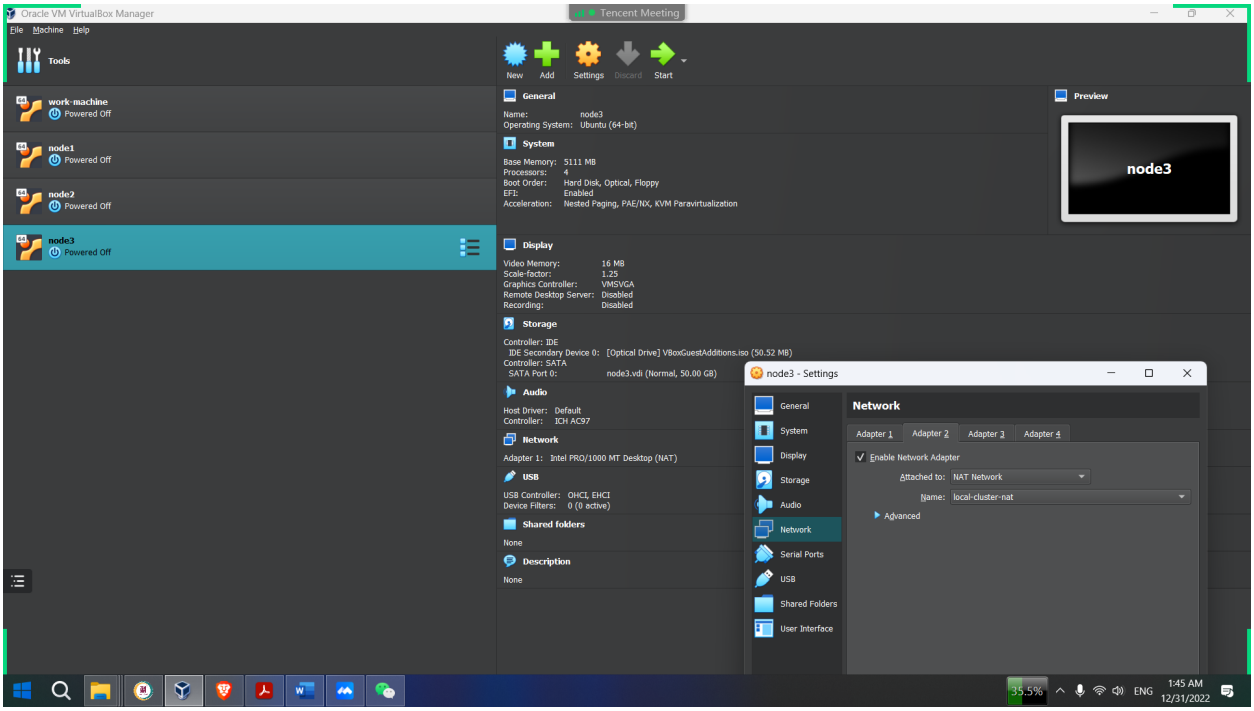


5.8 Setting Nat Network For Node1



5.9 Setting Nat Network For Node 2





5.10 Demonstration of Linux Cluster

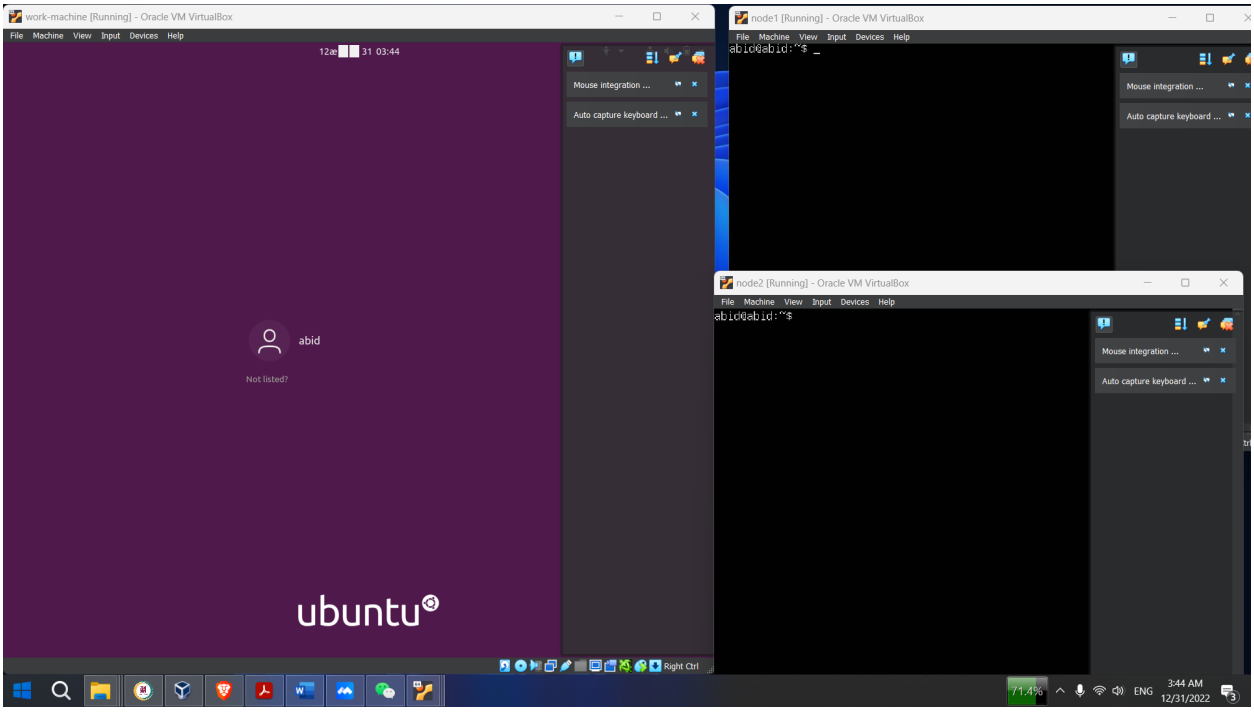


Figure: Demonstration of Linux Cluster

5.11 Creating enp0s8

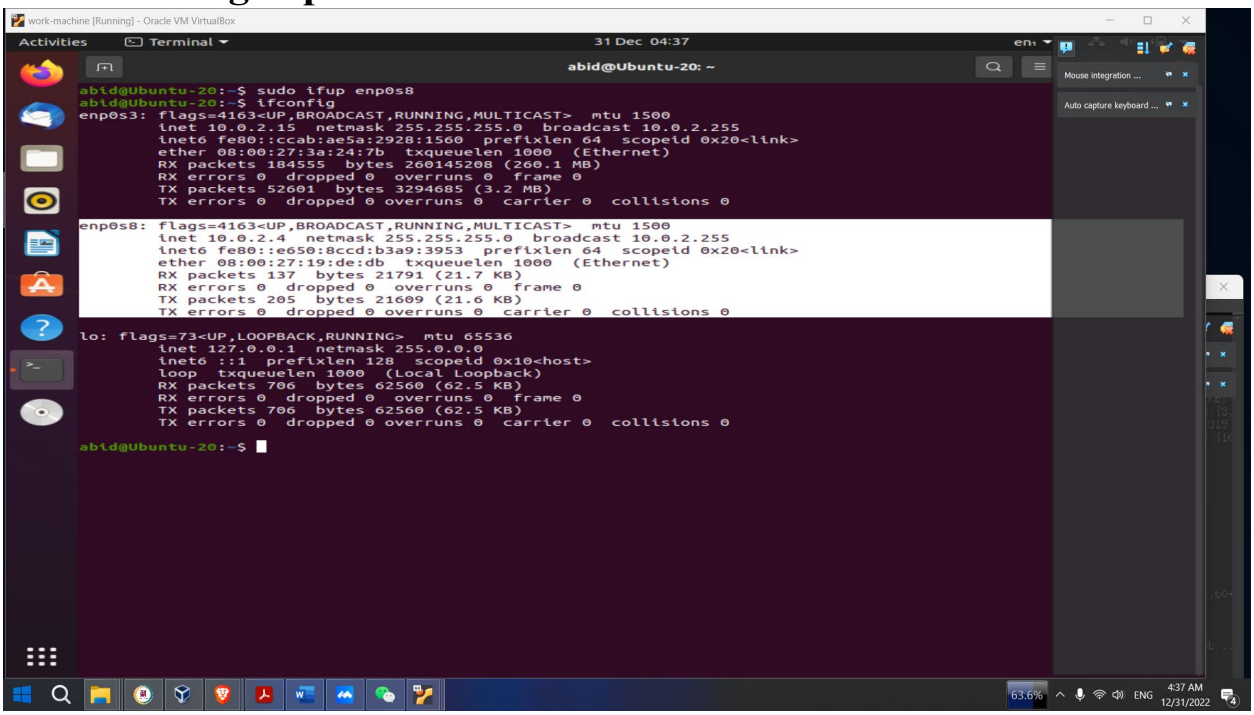


Figure: Creating enp0s8

5.12 Setting Up enp0s8 Network

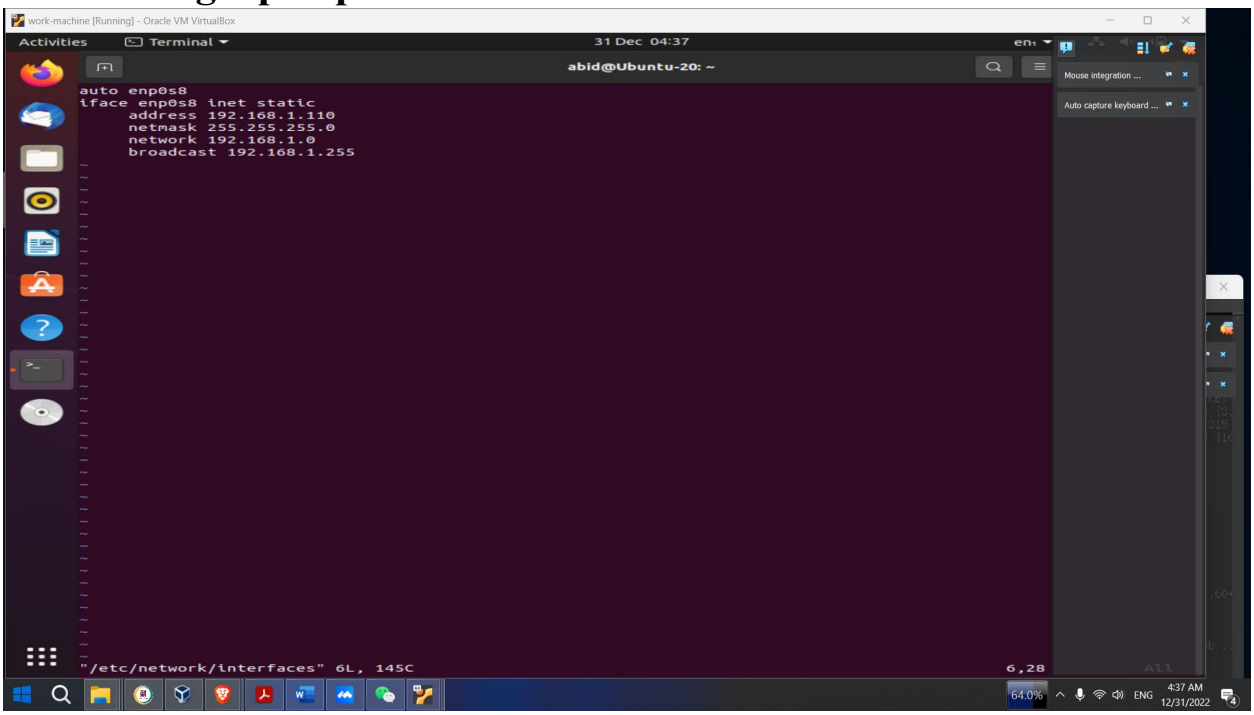
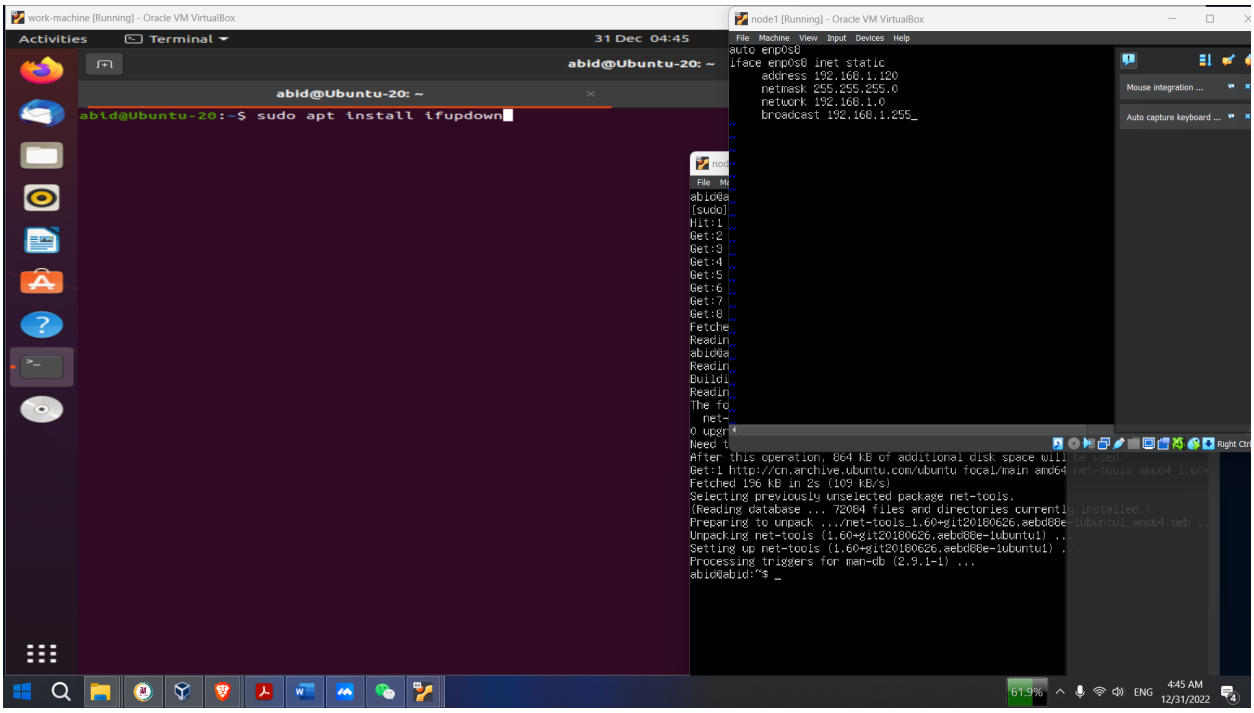


Figure: Setting Up enp0s8 Network

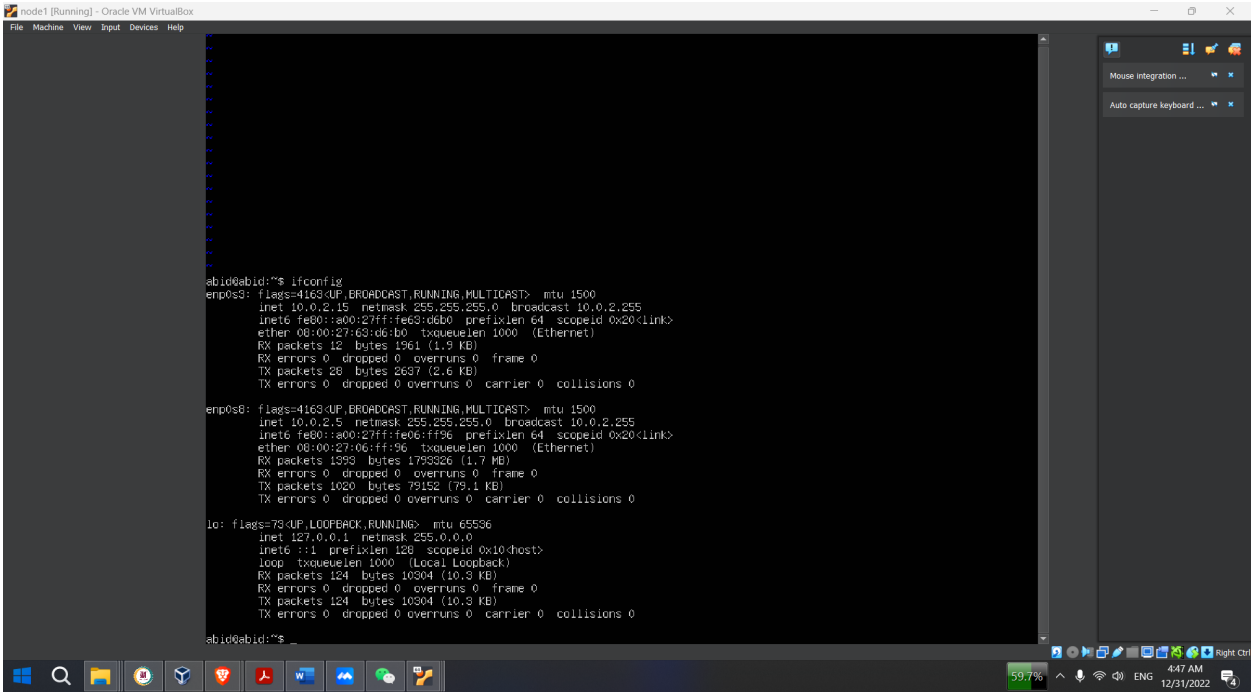
5.13 sudo apt install ifupdown

workmachine



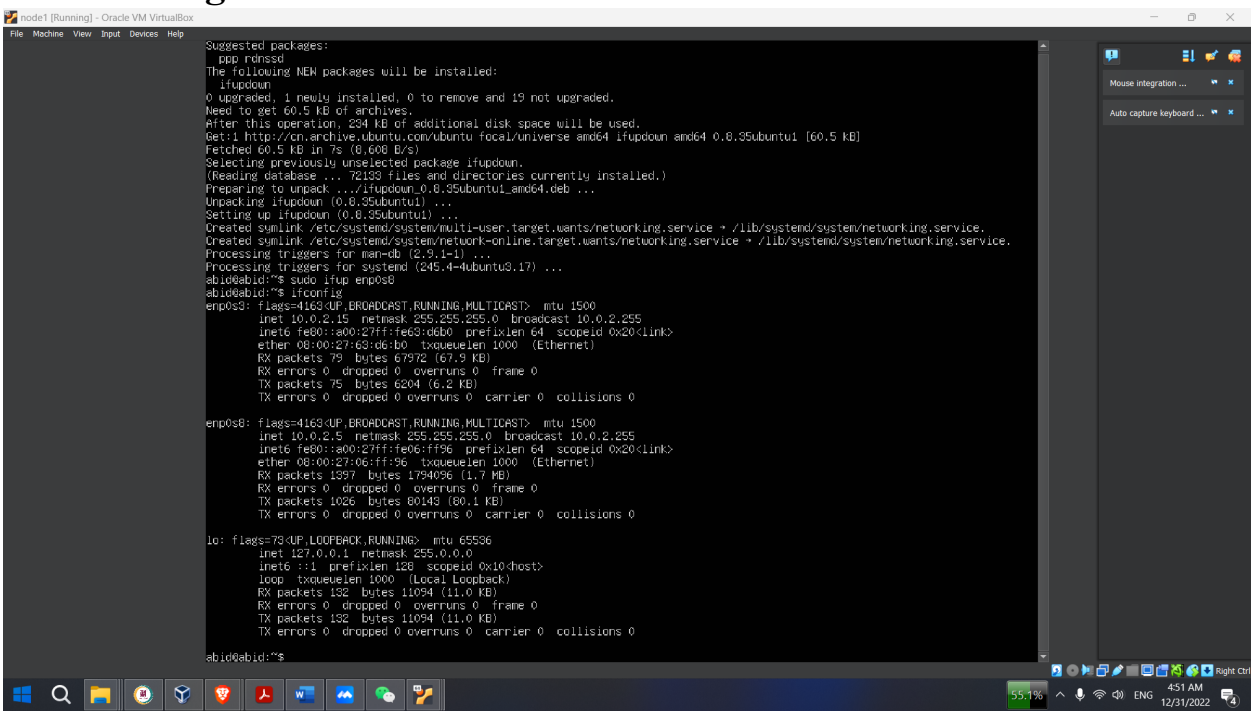
sudo apt install ifupdown

5.14 ifconfig node1

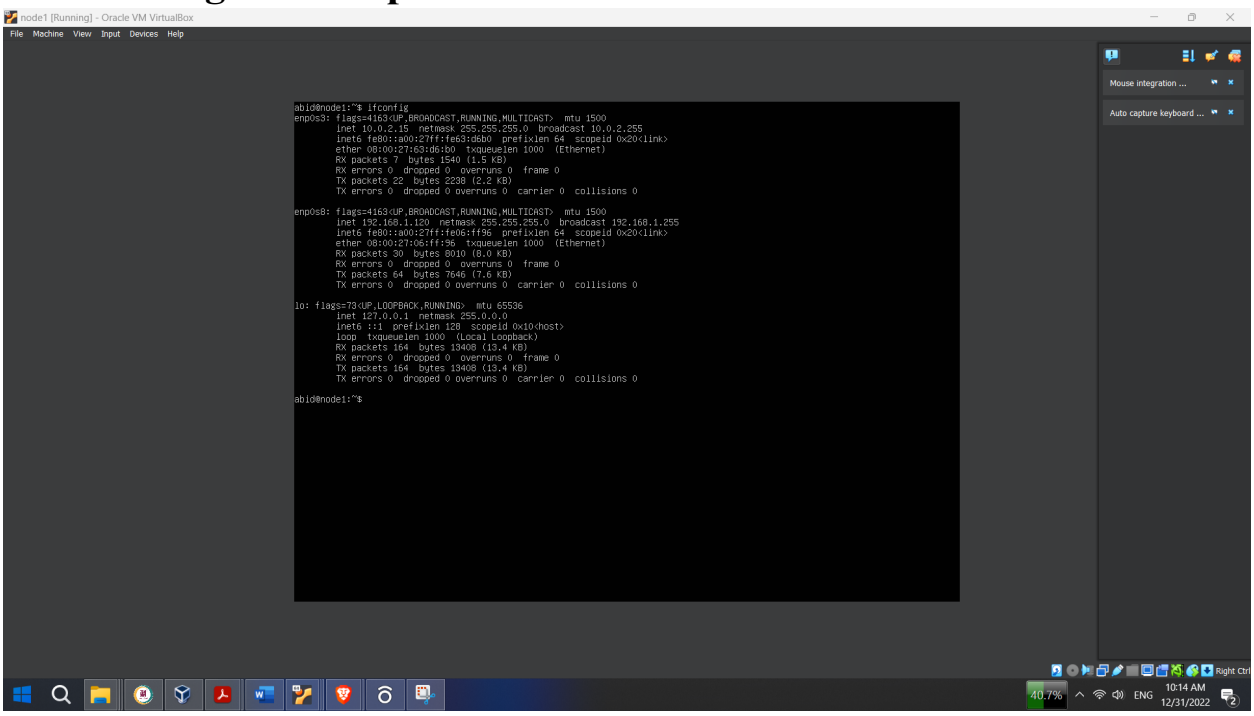


ifconfig

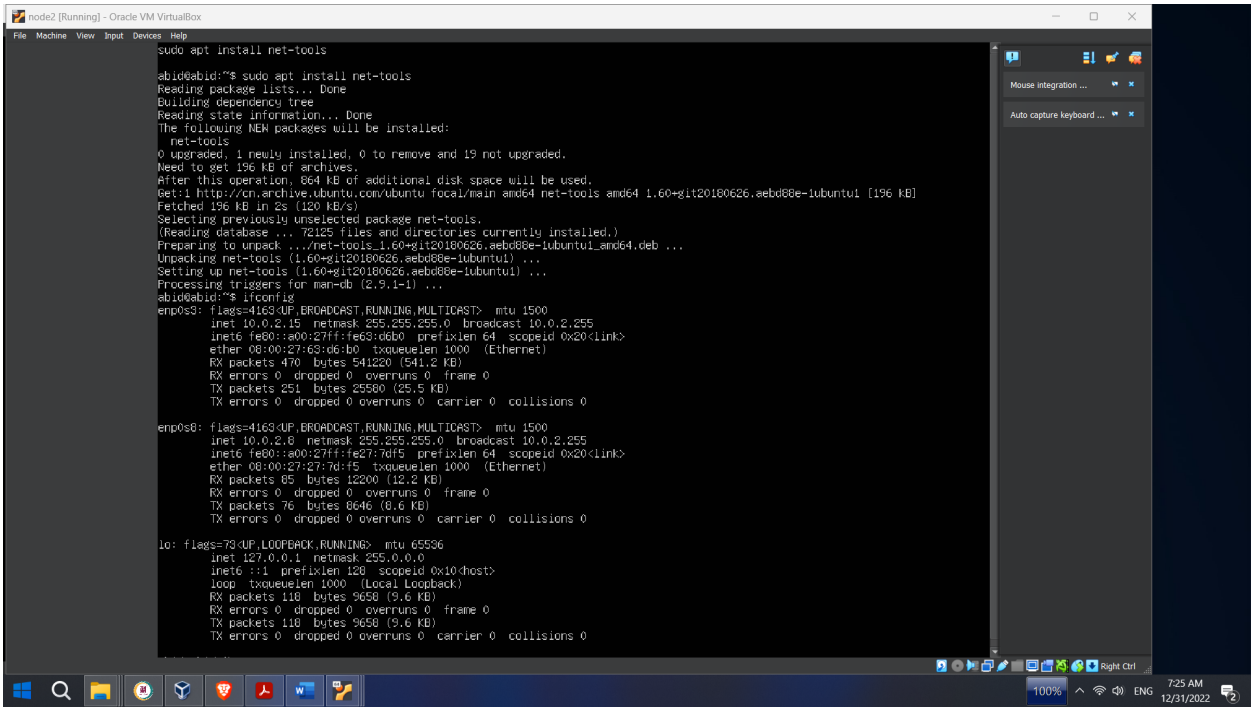
5.15 ifconfig node1 Default

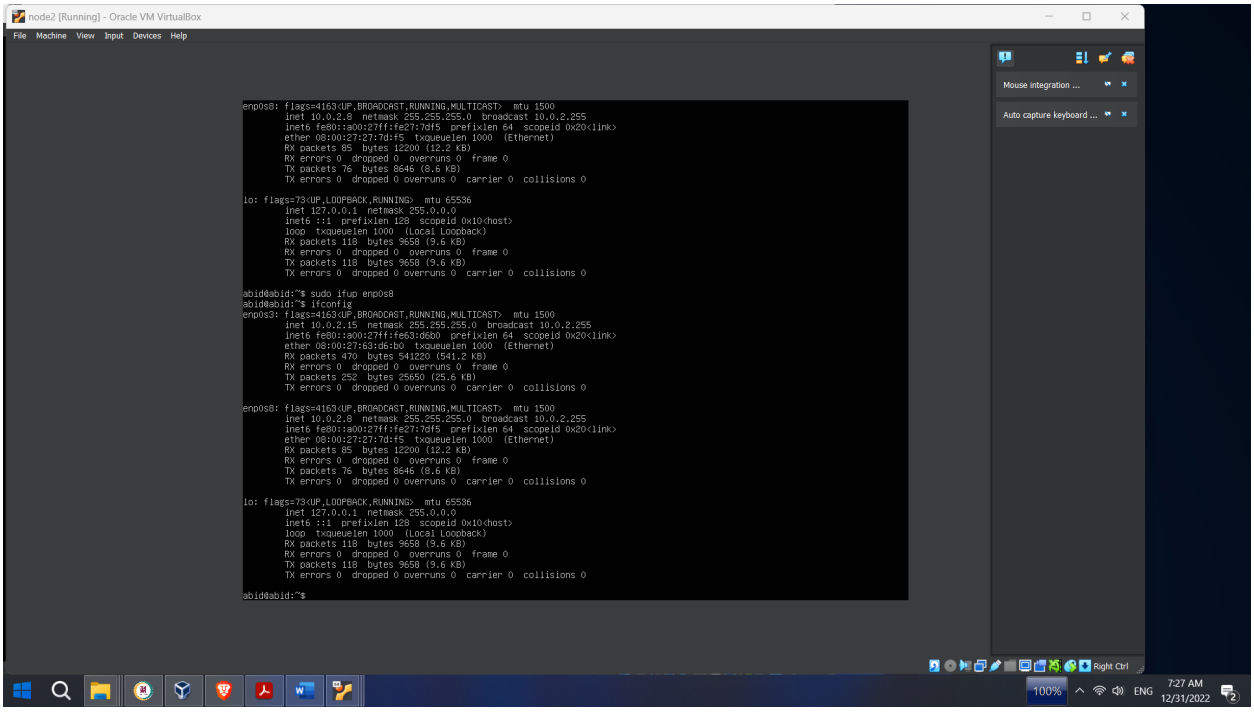


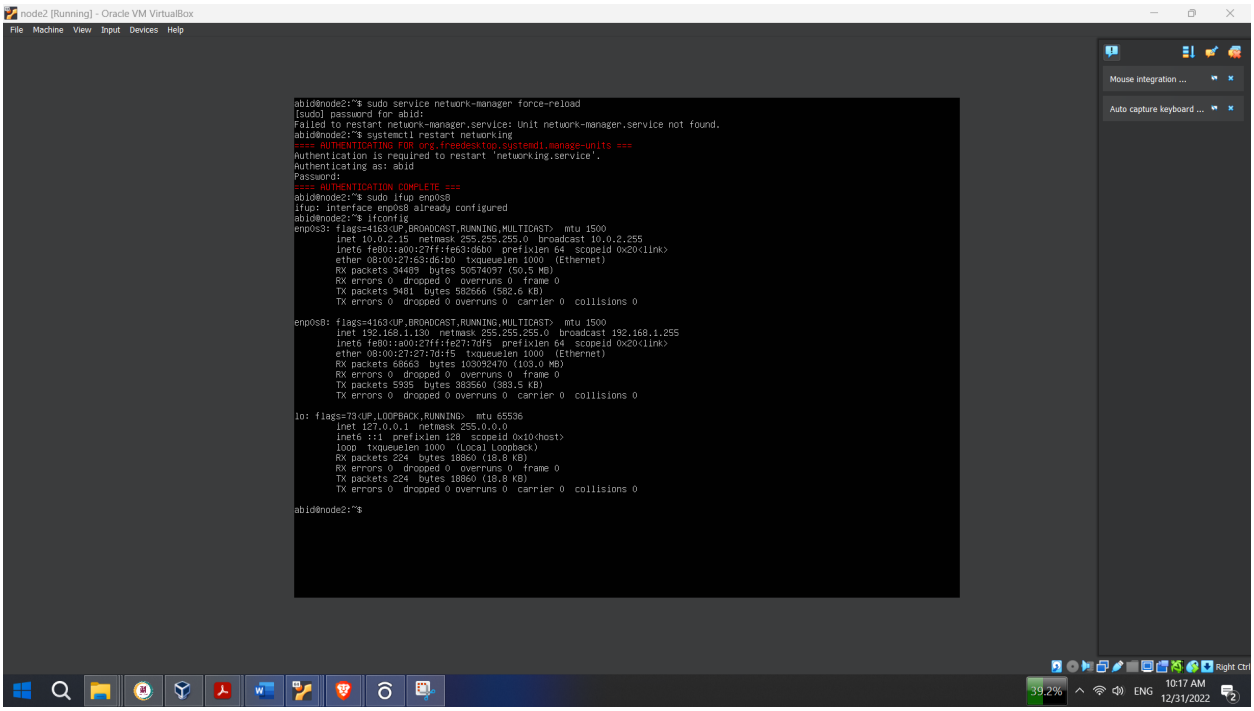
5.16 ifconfig node1 Updated



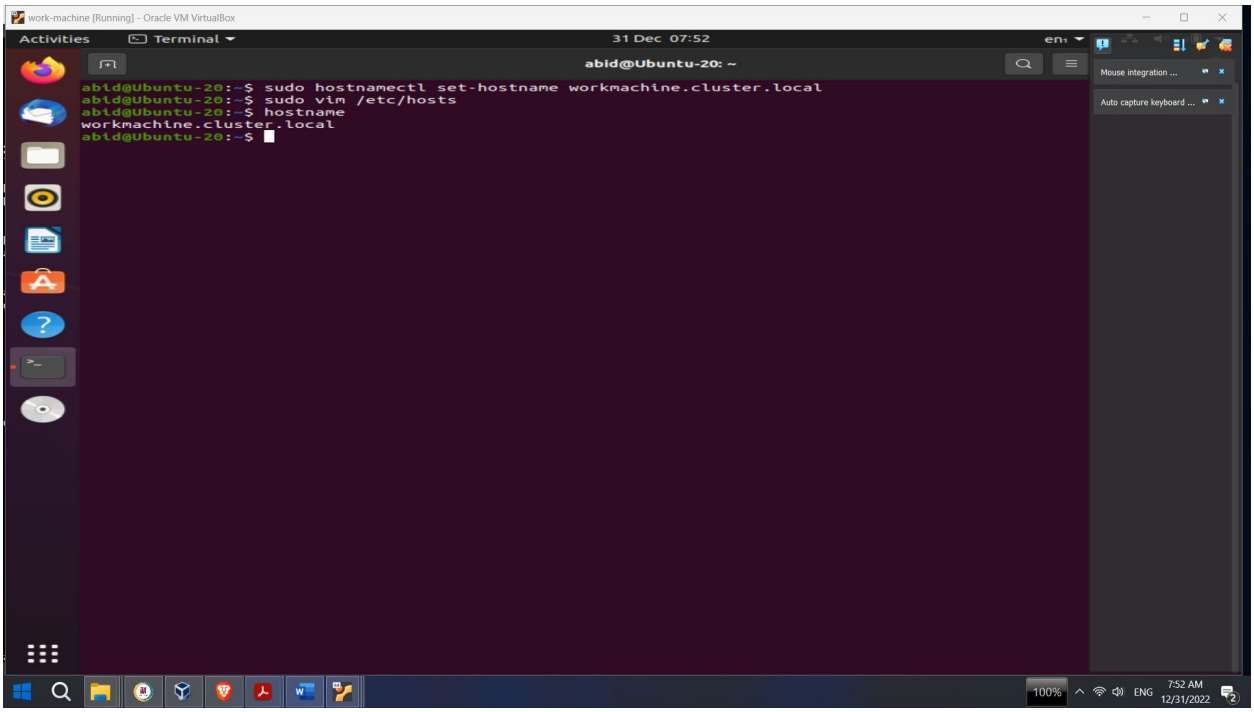
5.17 Node2


node2 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
sudo apt install net-tools
abid@abid:~$ sudo apt install net-tools
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following NEW packages will be installed:
net-tools
0 upgraded, 1 newly installed, 0 to remove and 19 not upgraded.
Need to get 196 kB of archives.
After this operation, 864 kB of additional disk space will be used.
Get:1 http://cn.archive.ubuntu.com/ubuntu focal/main amd64 net-tools amd64 1.60+git20180626.aebd88e-1ubuntu1 [196 kB]
Fetched 196 kB in 2s (120 kB/s)
Selecting previously unselected package net-tools.
(Reading database ... 72125 files and directories currently installed.)
Preparing to unpack .../net-tools_1.60+git20180626.aebd88e-1ubuntu1_amd64.deb ...
Unpacking net-tools (1.60+git20180626.aebd88e-1ubuntu1) ...
Setting up net-tools (1.60+git20180626.aebd88e-1ubuntu1) ...
Processing triggers for man-db (2.9.1-1) ...
abid@abid:~$ ifconfig
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 10.0.2.15 netmask 255.255.255.0 broadcast 10.0.2.255
inet6 fe80::a00:27ff:fe63:d6b0 prefixlen 64 scopeid 0x20<link>
ether 08:00:27:63:d6:b0 txqueuelen 1000 (Ethernet)
RX packets 470 bytes 541220 (541.2 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 251 bytes 25580 (25.5 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
enp0s8: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 10.0.2.8 netmask 255.255.255.0 broadcast 10.0.2.255
inet6 fe80::a00:27ff:fe27:7df5 prefixlen 64 scopeid 0x20<link>
ether 08:00:27:27:7d:f5 txqueuelen 1000 (Ethernet)
RX packets 85 bytes 12200 (12.2 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 76 bytes 8646 (8.6 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
inet 127.0.0.1 netmask 255.0.0.0
inet6 ::1 prefixlen 128 scopeid 0x10<host>
loop txqueuelen 1000 (Local Loopback)
RX packets 118 bytes 9658 (9.6 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 118 bytes 9658 (9.6 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
Mouse integration ...
Auto capture keyboard ...
Right Ctrl
100%
ENG
7:25 AM
12/31/2022


node2 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
enp0s8: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 10.0.2.8 netmask 255.255.255.0 broadcast 10.0.2.255
inet6 fe80::a00:27ff:fe27:7df5 prefixlen 64 scopeid 0x20<link>
ether 08:00:27:27:7d:f5 txqueuelen 1000 (Ethernet)
RX packets 85 bytes 12200 (12.2 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 76 bytes 8646 (8.6 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
inet 127.0.0.1 netmask 255.0.0.0
inet6 ::1 prefixlen 128 scopeid 0x10<host>
loop txqueuelen 1000 (Local Loopback)
RX packets 118 bytes 9658 (9.6 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 118 bytes 9658 (9.6 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
abid@abid:~$ sudo ifup enp0s8
abid@abid:~$ ifconfig
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 10.0.2.15 netmask 255.255.255.0 broadcast 10.0.2.255
inet6 fe80::a00:27ff:fe63:d6b0 prefixlen 64 scopeid 0x20<link>
ether 08:00:27:63:d6:b0 txqueuelen 1000 (Ethernet)
RX packets 470 bytes 541220 (541.2 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 252 bytes 25650 (25.6 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
enp0s8: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 10.0.2.8 netmask 255.255.255.0 broadcast 10.0.2.255
inet6 fe80::a00:27ff:fe27:7df5 prefixlen 64 scopeid 0x20<link>
ether 08:00:27:27:7d:f5 txqueuelen 1000 (Ethernet)
RX packets 85 bytes 12200 (12.2 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 76 bytes 8646 (8.6 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
inet 127.0.0.1 netmask 255.0.0.0
inet6 ::1 prefixlen 128 scopeid 0x10<host>
loop txqueuelen 1000 (Local Loopback)
RX packets 118 bytes 9658 (9.6 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 118 bytes 9658 (9.6 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
abid@abid:~$
Mouse integration ...
Auto capture keyboard ...
Right Ctrl
100%
ENG
7:27 AM
12/31/2022

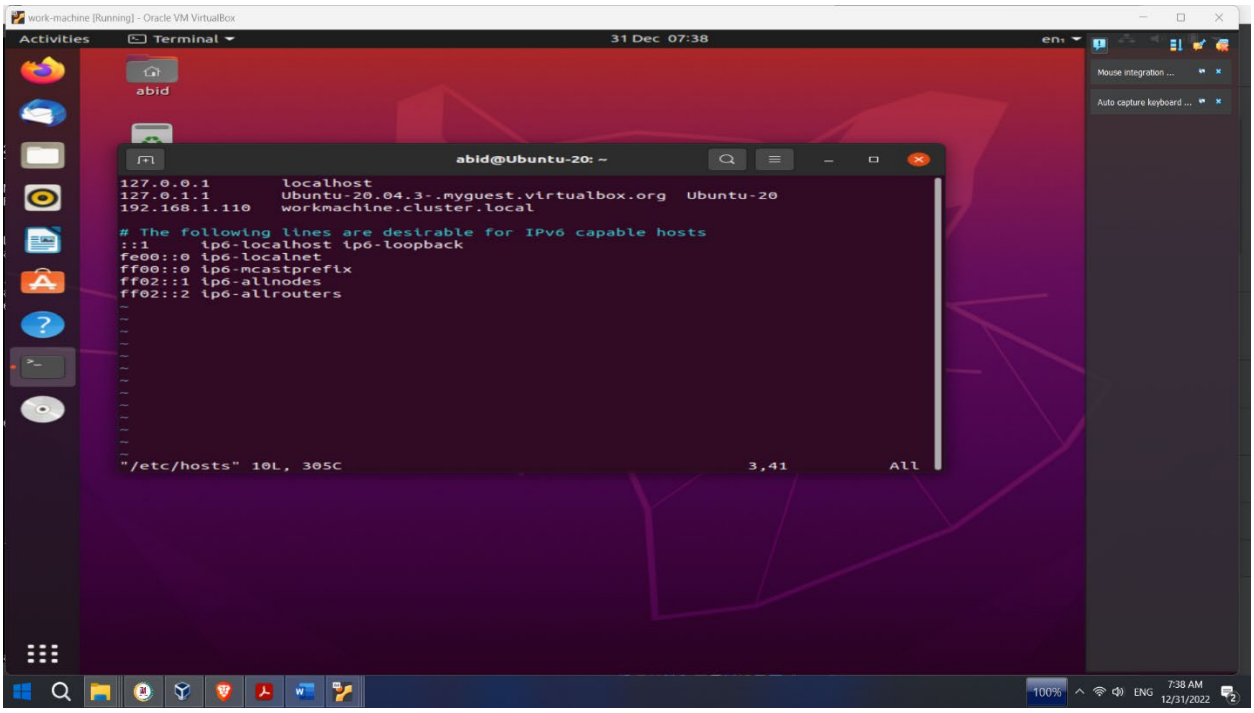


5.18 Work-machine sudo vim /etc/hosts



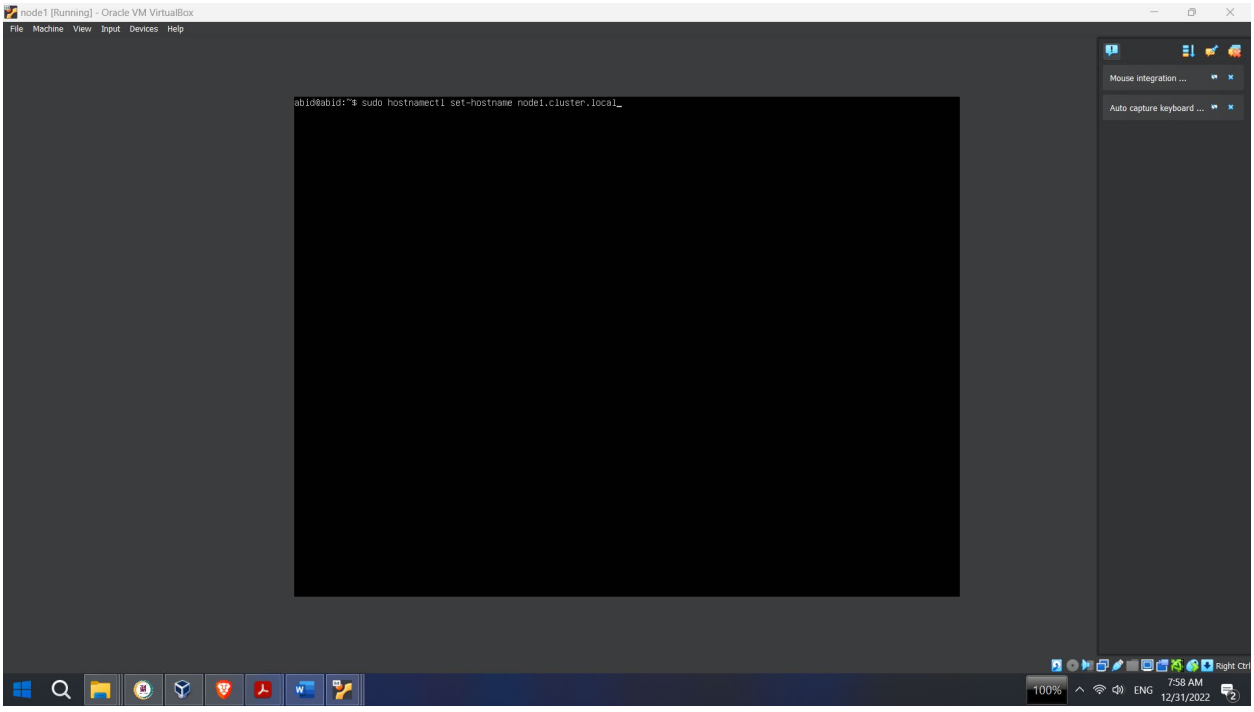
sudo vim /etc/hosts

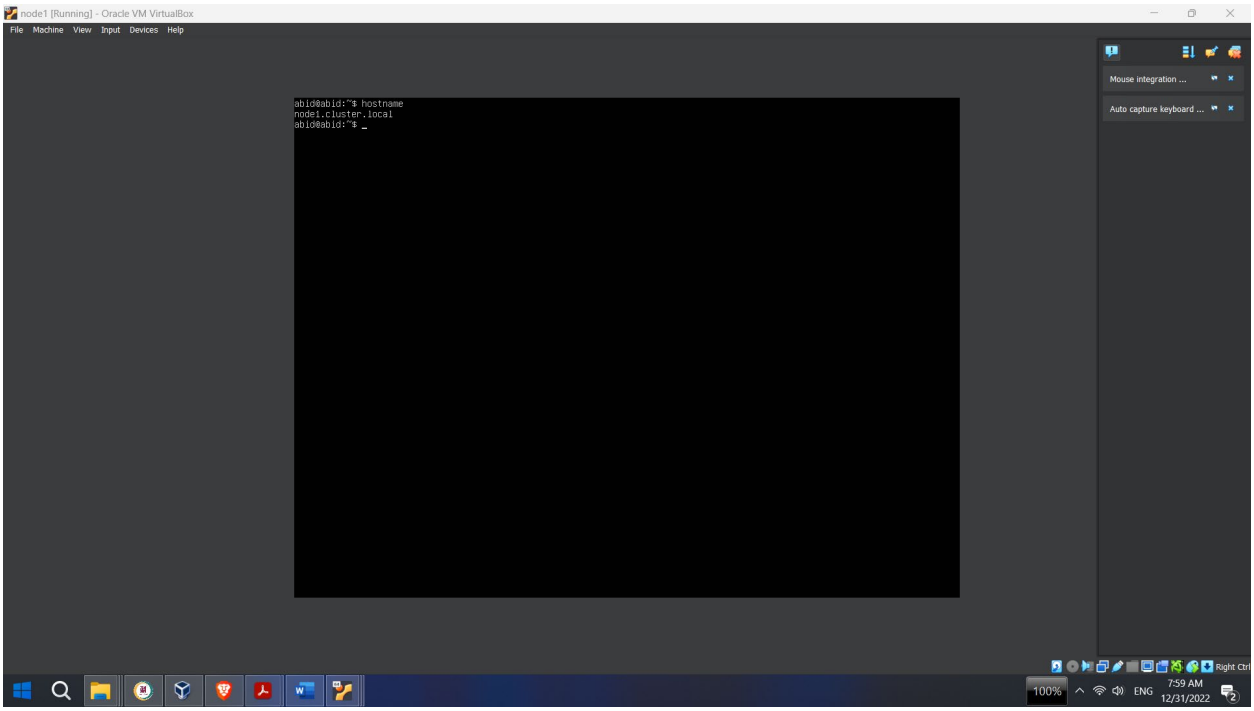
5.19 sudo hostnamectl set-hostname workmachine.cluster.local

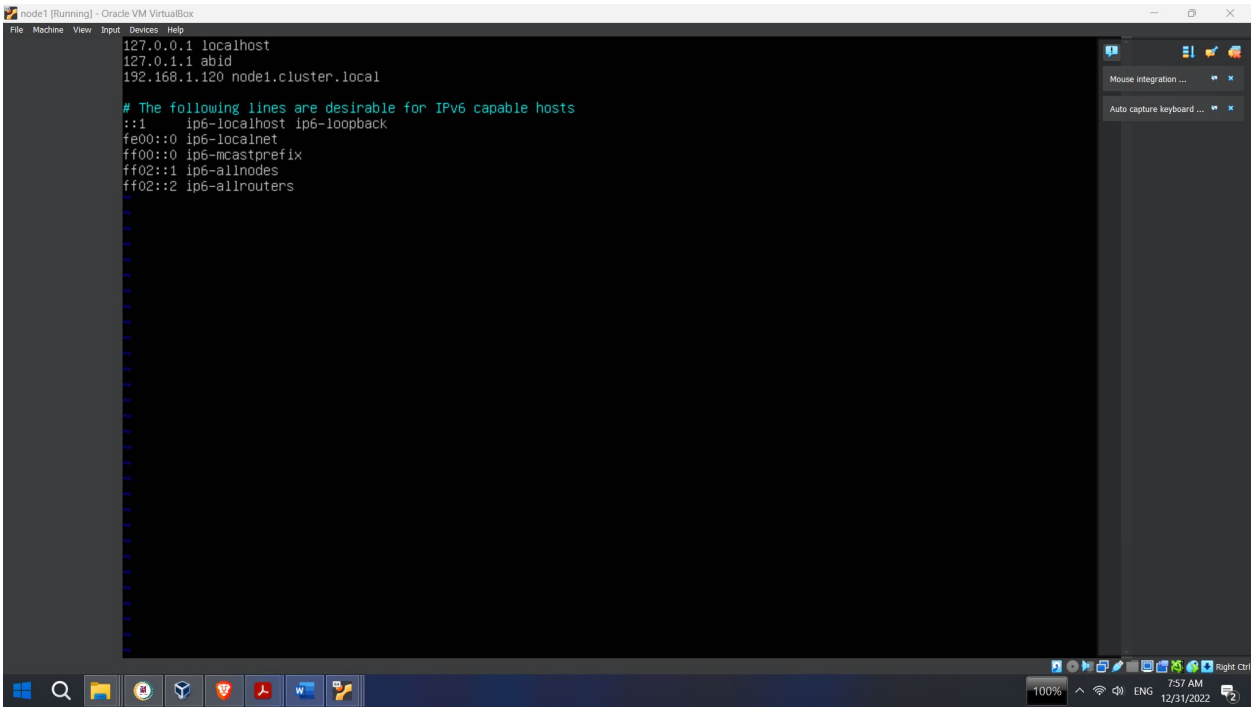


sudo hostnamectl set-hostname workmachine.cluster.local

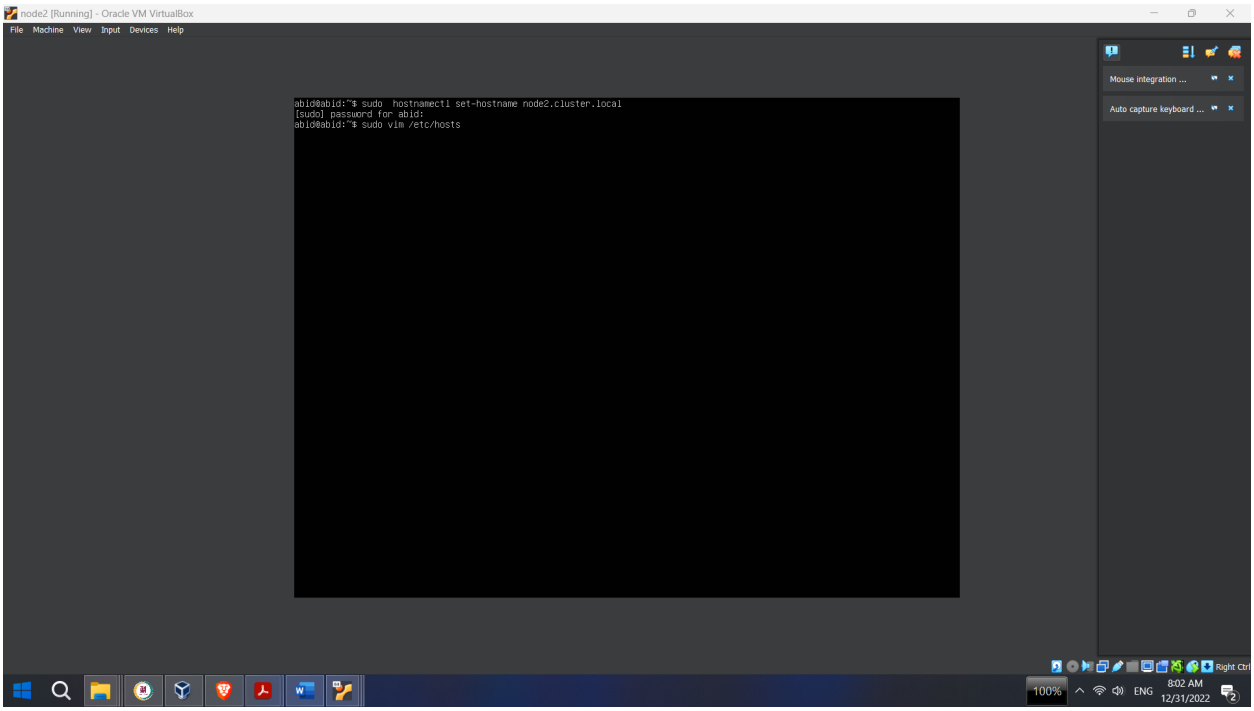
5.20 Node 1

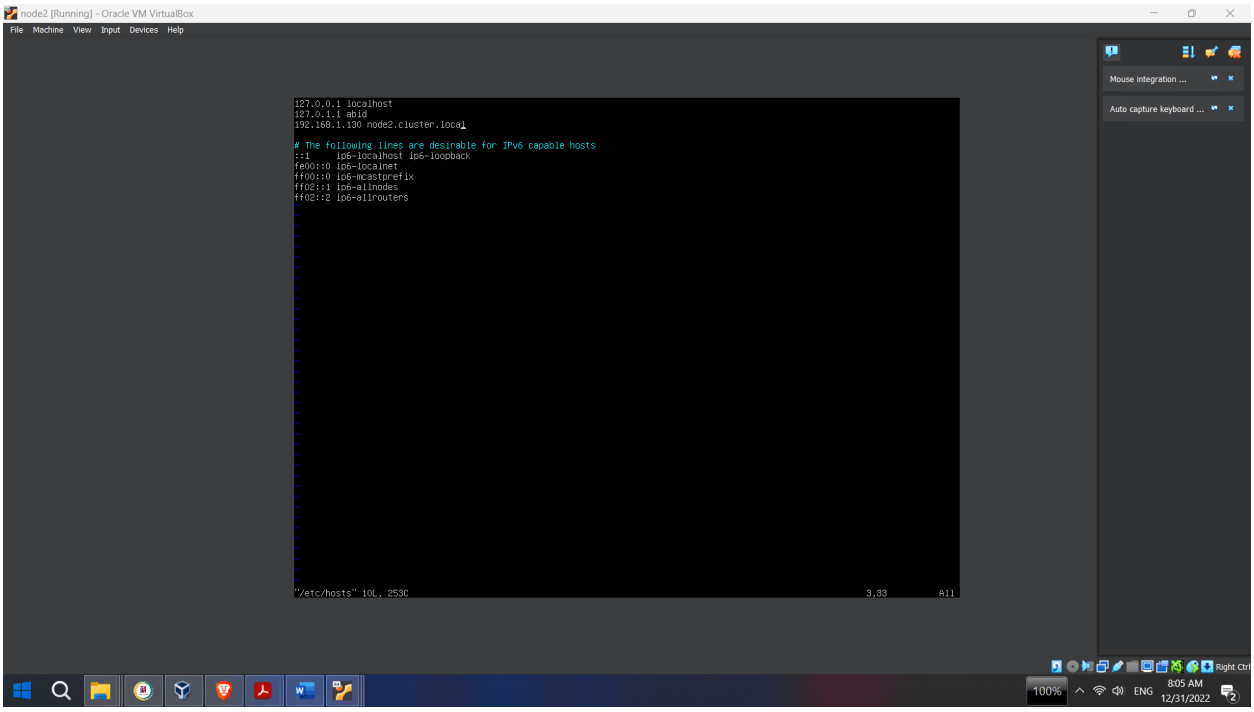


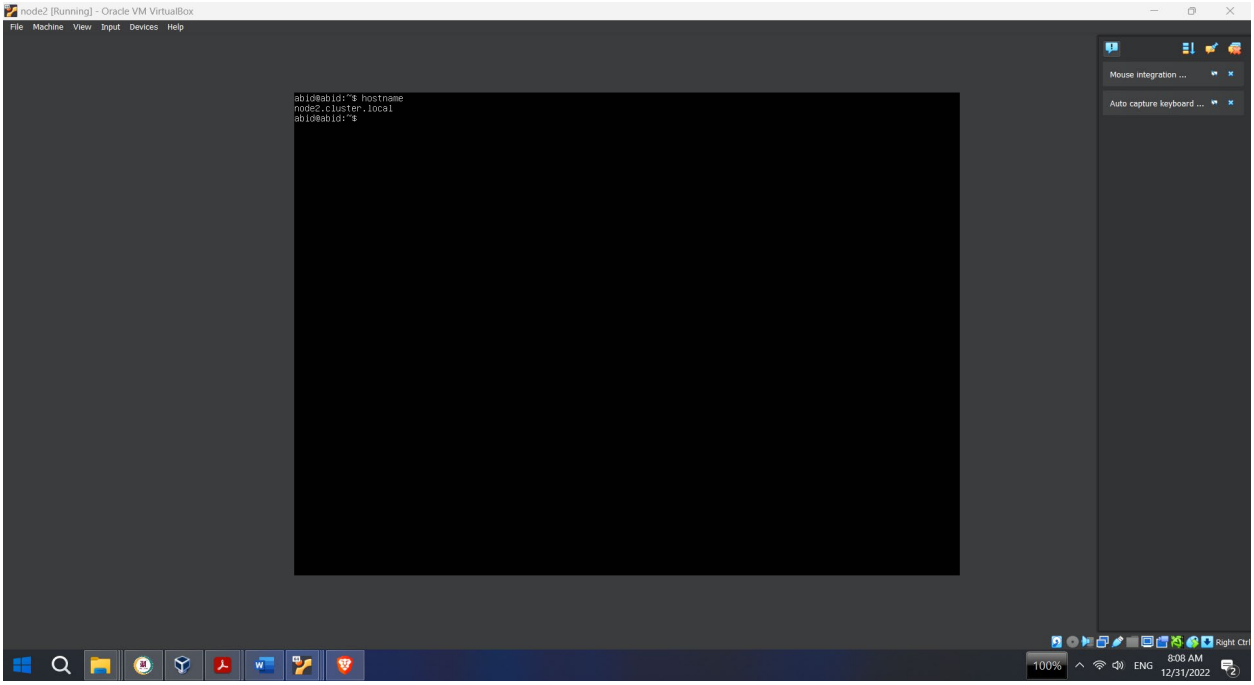

node1 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
abid@abid:~$ hostname
node1.cluster.local
abid@abid:~$ _
Mouse integration ...
Auto capture keyboard ...
Right Ctrl
100%
ENG
7:59 AM
12/31/2022


node1 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
127.0.0.1 localhost
127.0.1.1 abid
192.168.1.120 node1.cluster.local
The following lines are desirable for IPv6 capable hosts
::1 ip6-localhost ip6-loopback
fe00::0 ip6-localnet
ff00::0 ip6-mcastprefix
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters
Mouse integration ...
Auto capture keyboard ...
Right Ctrl
100%
ENG
7:57 AM
12/31/2022

5.21 Node 2


node2 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
abid@abid:~$ sudo hostnamectl set-hostname node2.cluster.local
[sudo] password for abid:
abid@abid:~$ sudo vim /etc/hosts
Mouse integration ...
Auto capture keyboard ...
Right Ctrl
100%
ENG
8:02 AM
12/31/2022


node2 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
127.0.0.1 localhost
127.0.1.1 abid
192.168.1.130 node2.cluster.local
The following lines are desirable for IPv6 capable hosts
::1 ip6-localhost ip6-loopback
fe00::0 ip6-localnet
ff00::0 ip6-mcastprefix
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters
"/etc/hosts" 10L, 253C 3,33 All
Mouse integration ...
Auto capture keyboard ...
Right Ctrl
100%
ENG
8:05 AM
12/31/2022



5.22 Work-machine's Entry Point

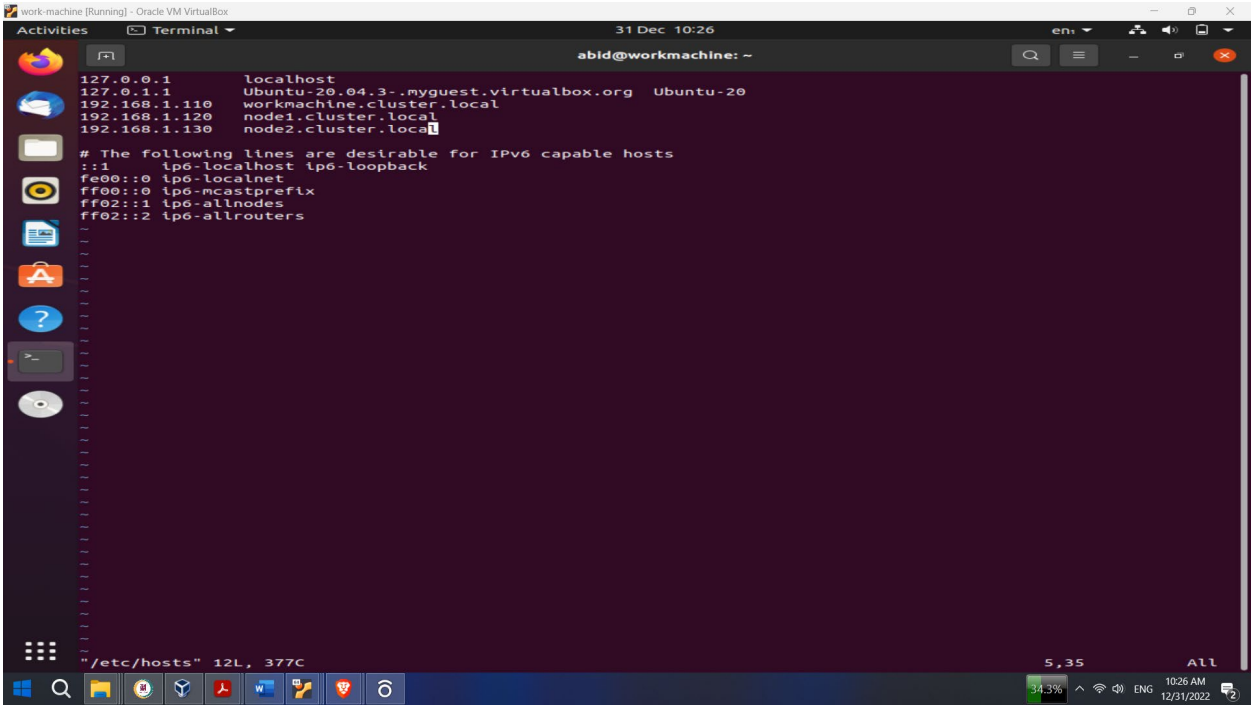
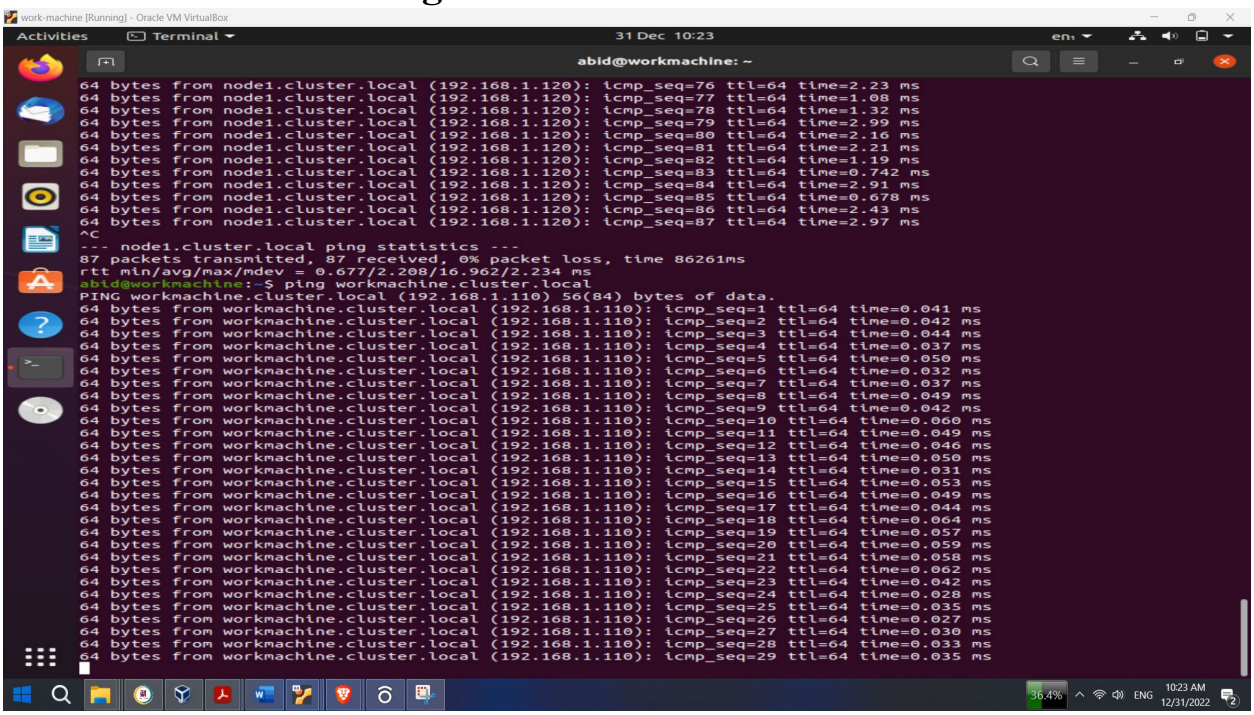
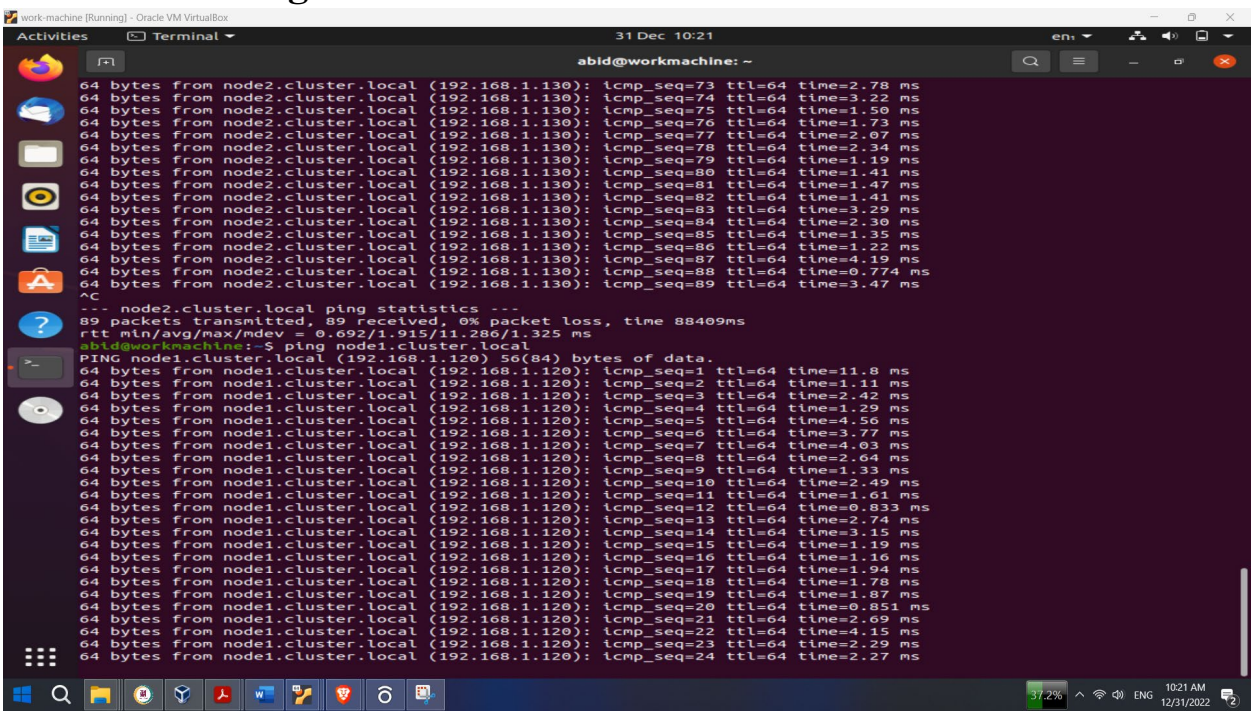


Figure: Work-machine's the entry point

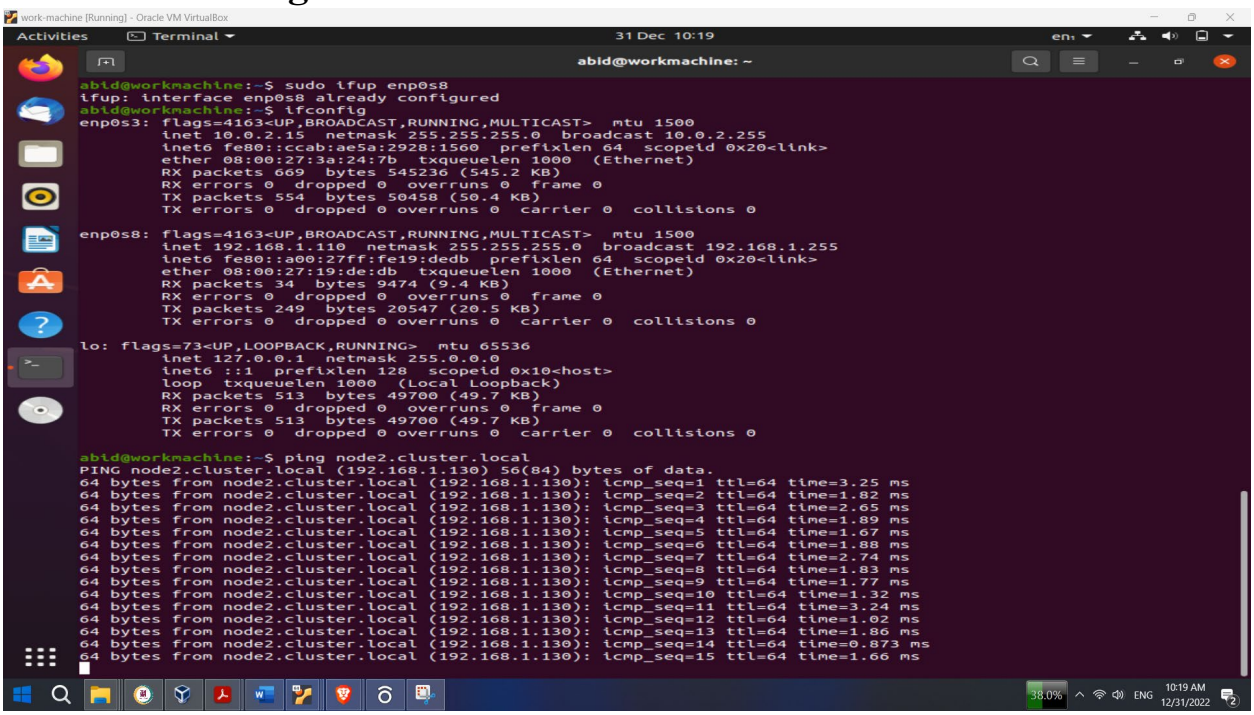
5.23 Workmachine Ping Result



5.24 Node 1 Ping Result

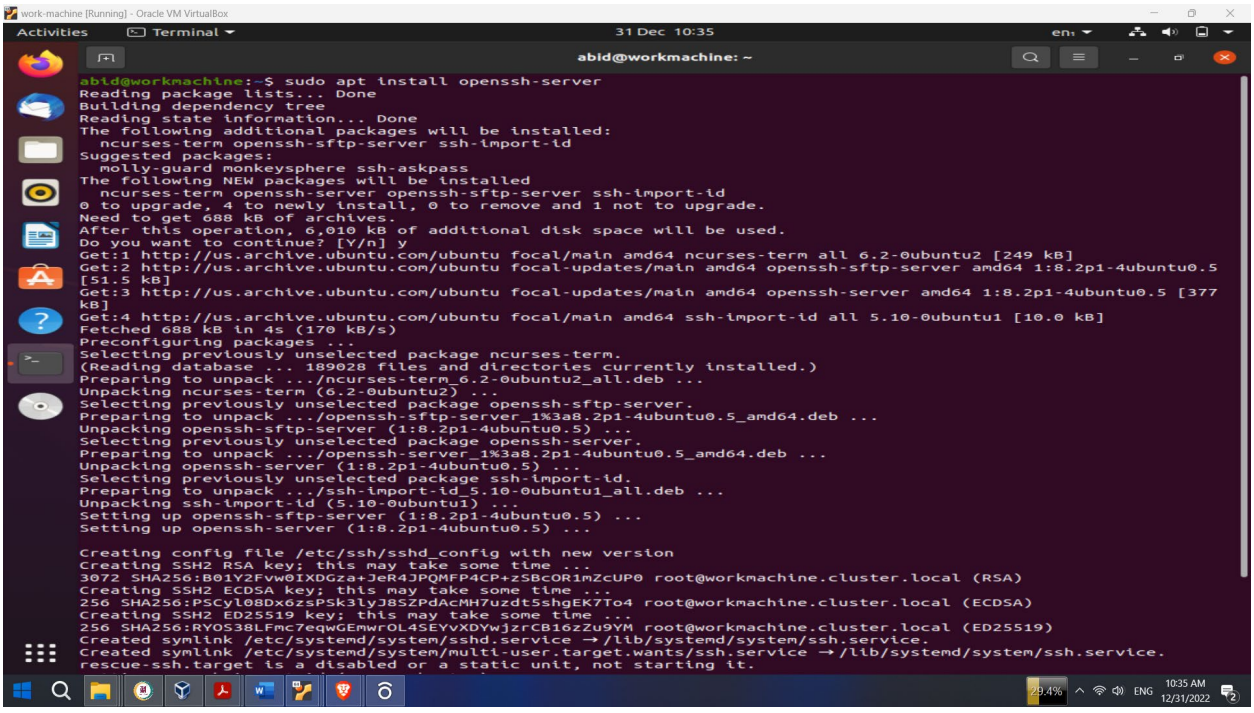


5.25 Node 2 Ping Result



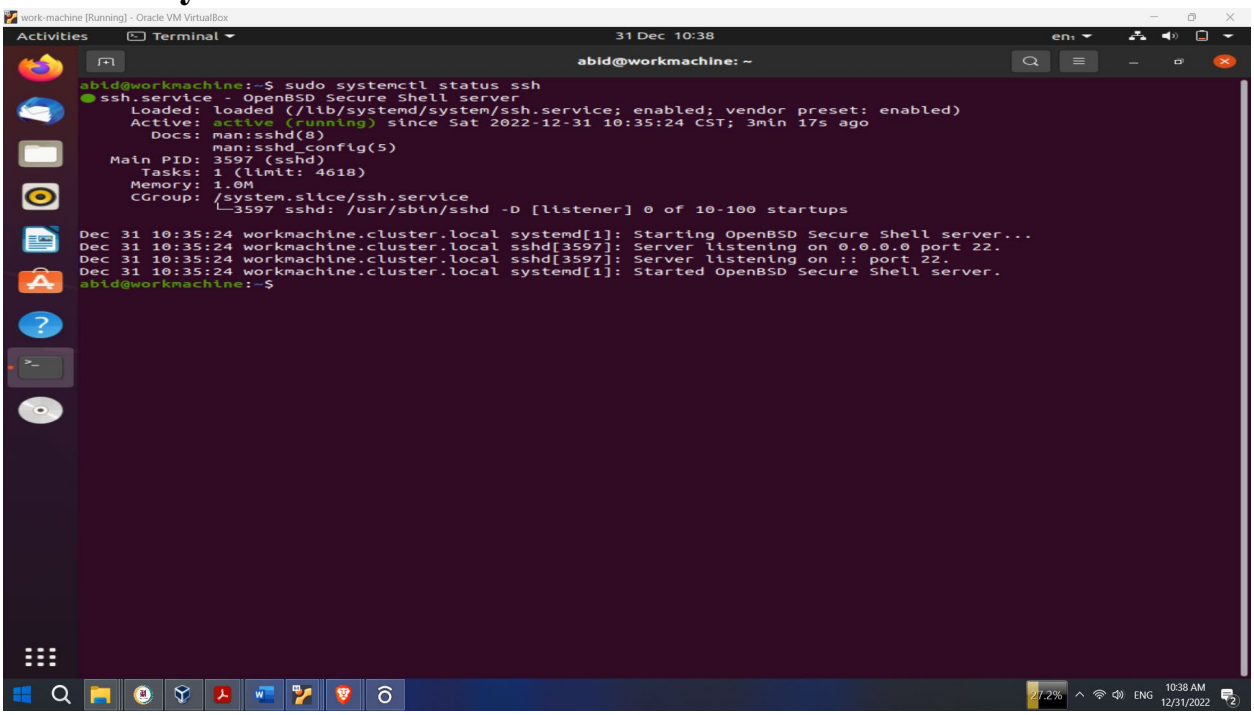
6. SSH

6.1 Enable SSH server



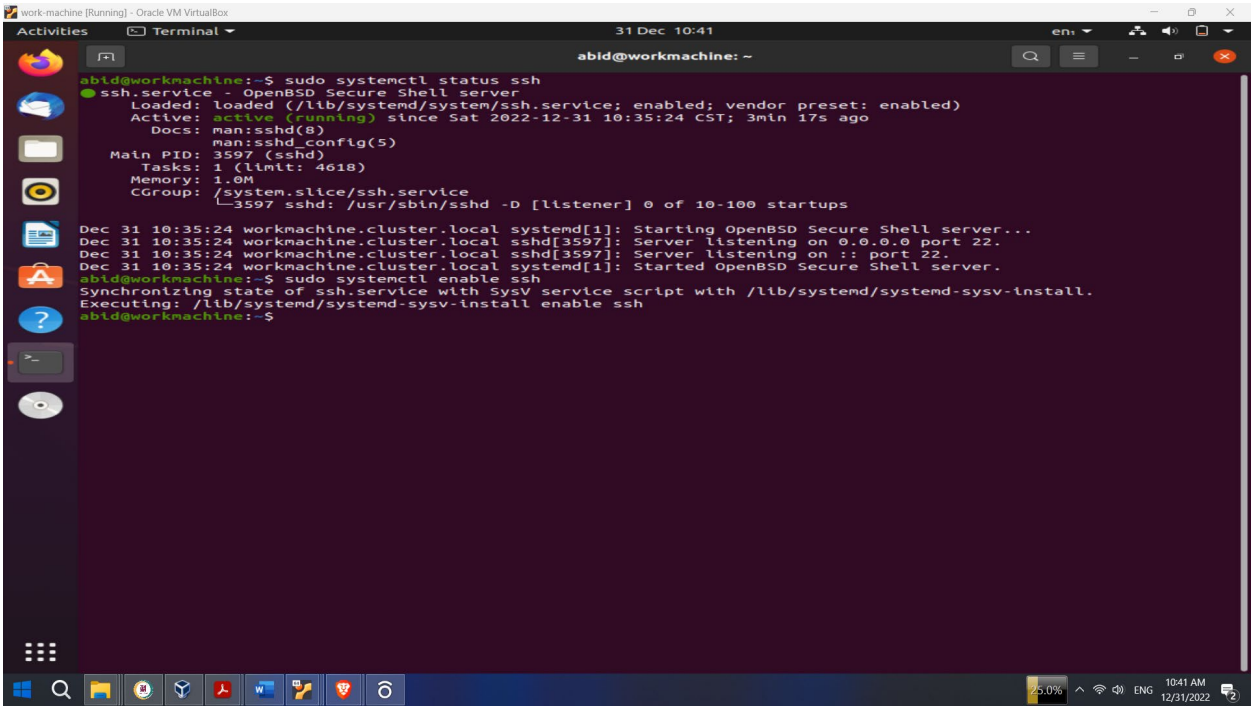
sudo apt install openssh-server

6.2 sudo systemctl status ssh



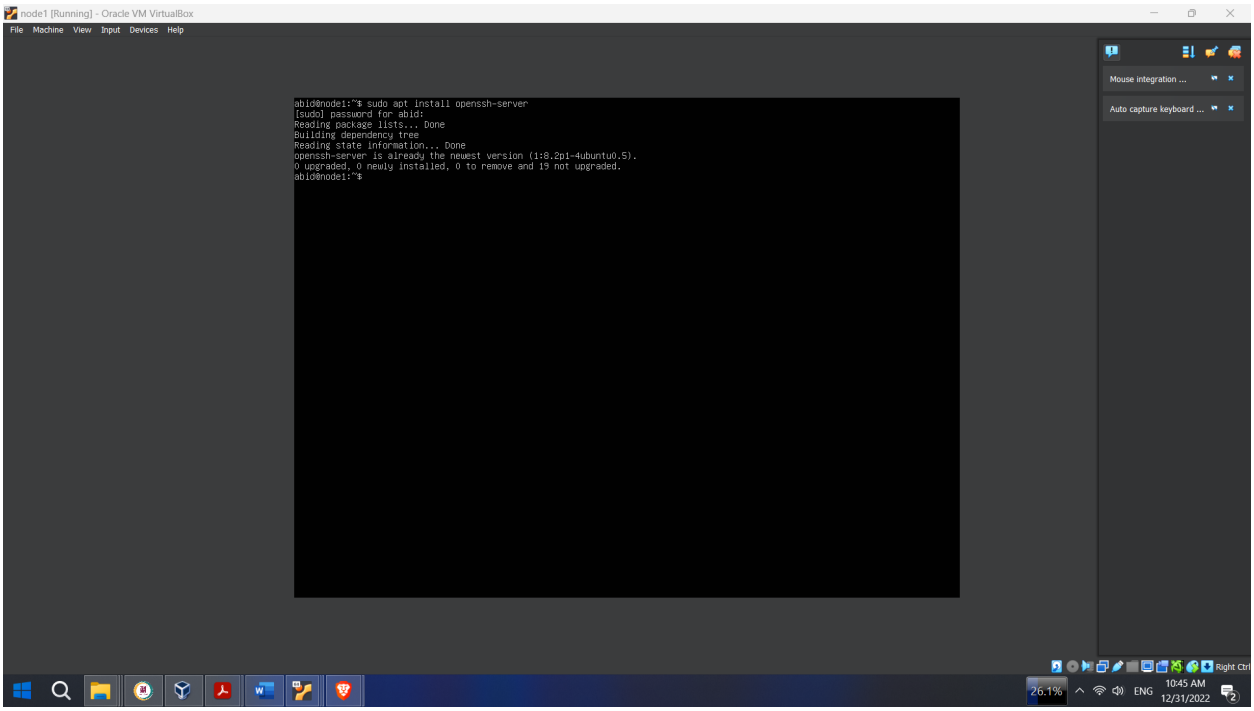
sudo systemctl status ssh

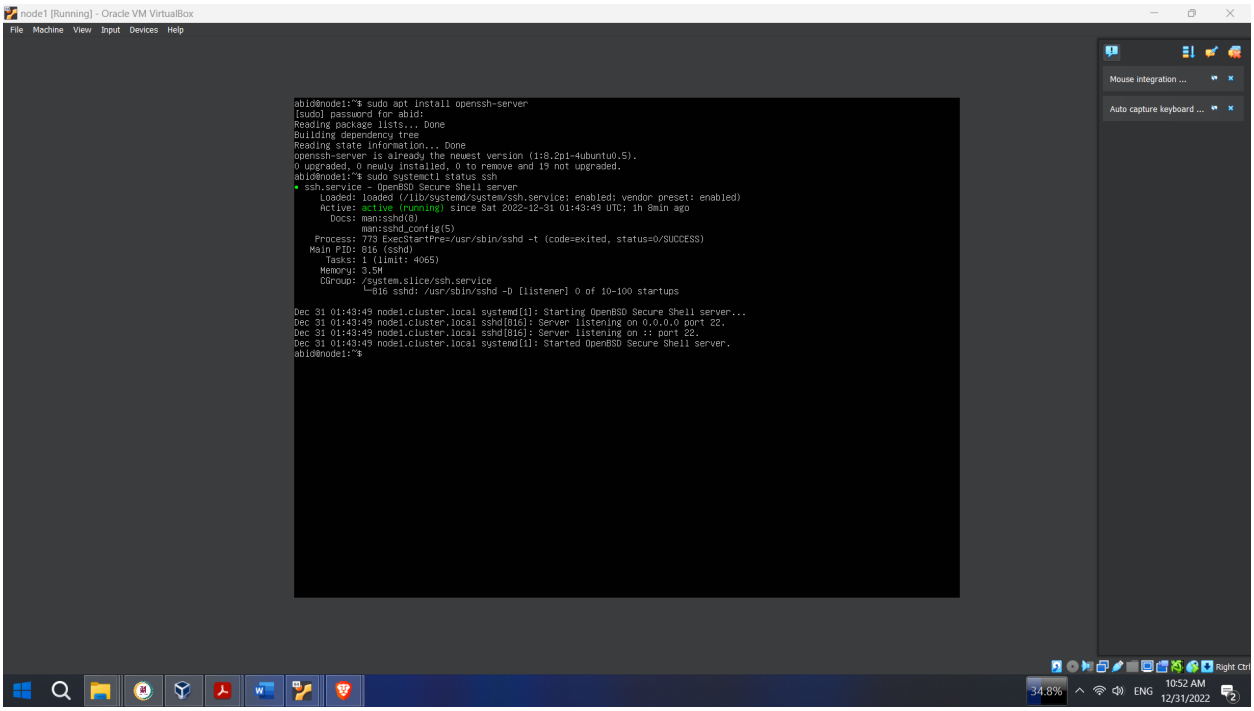
6.3 sudo systemctl enable ssh

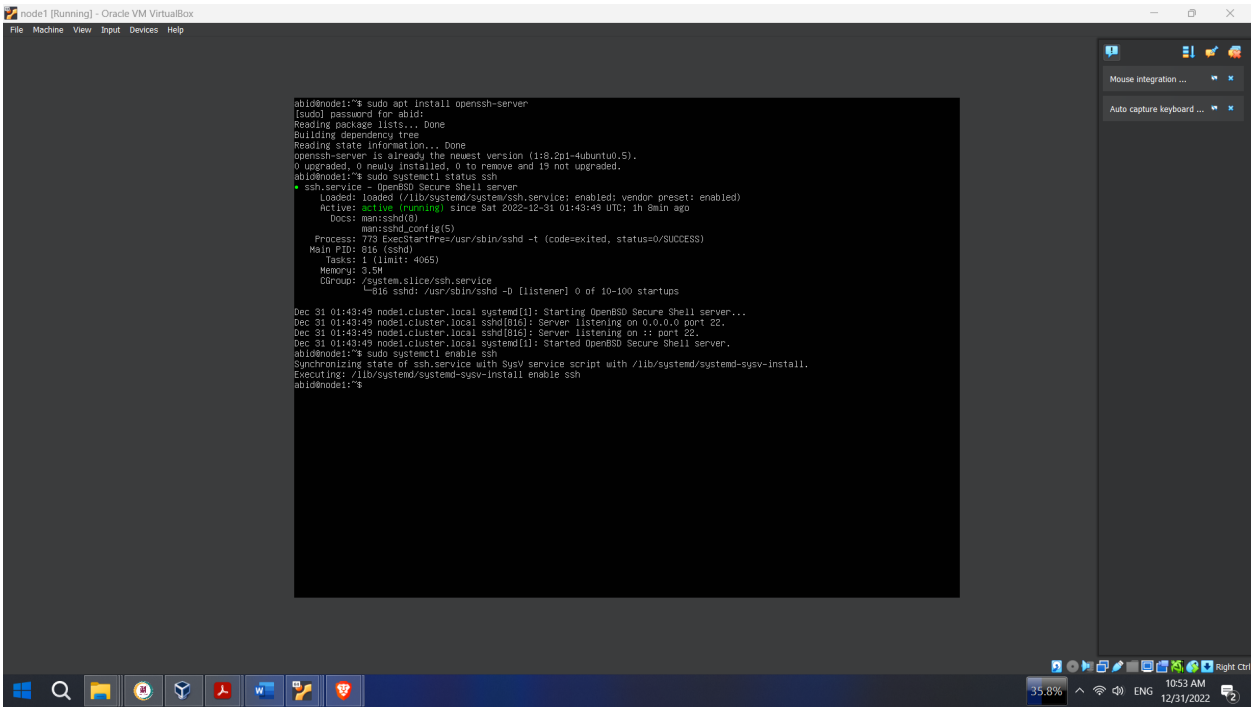


sudo systemctl enable ssh

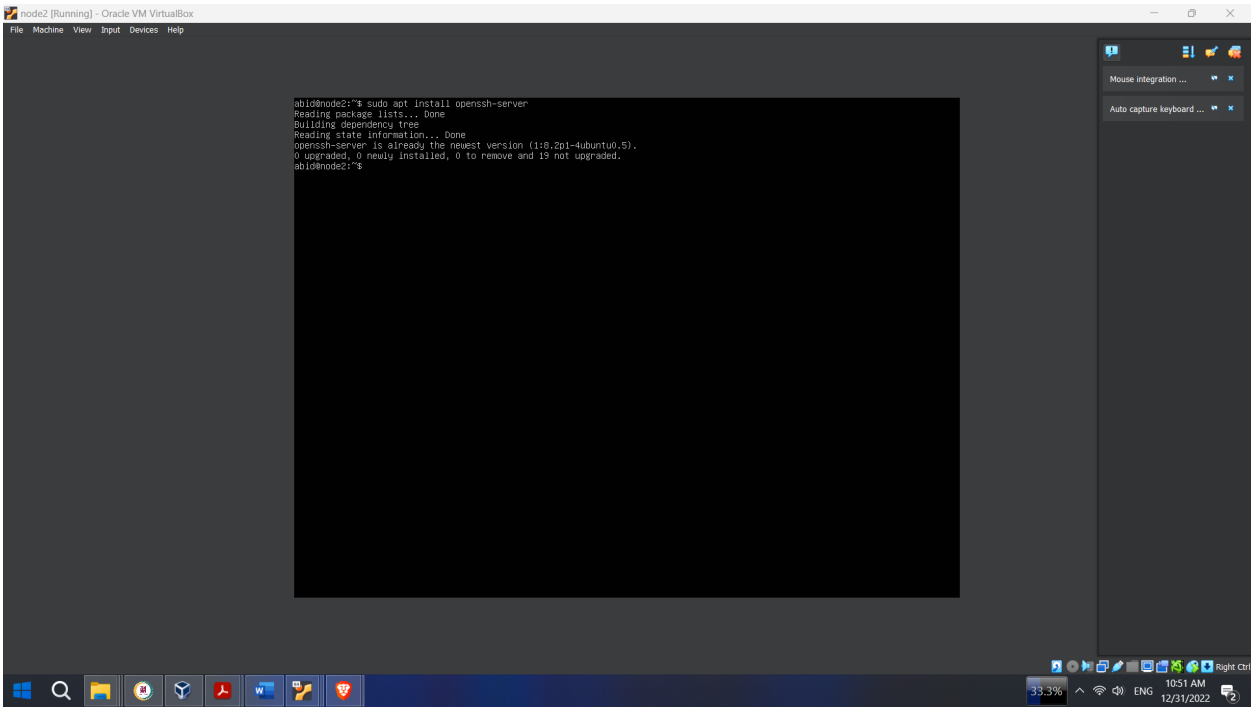
6.4 Node 1

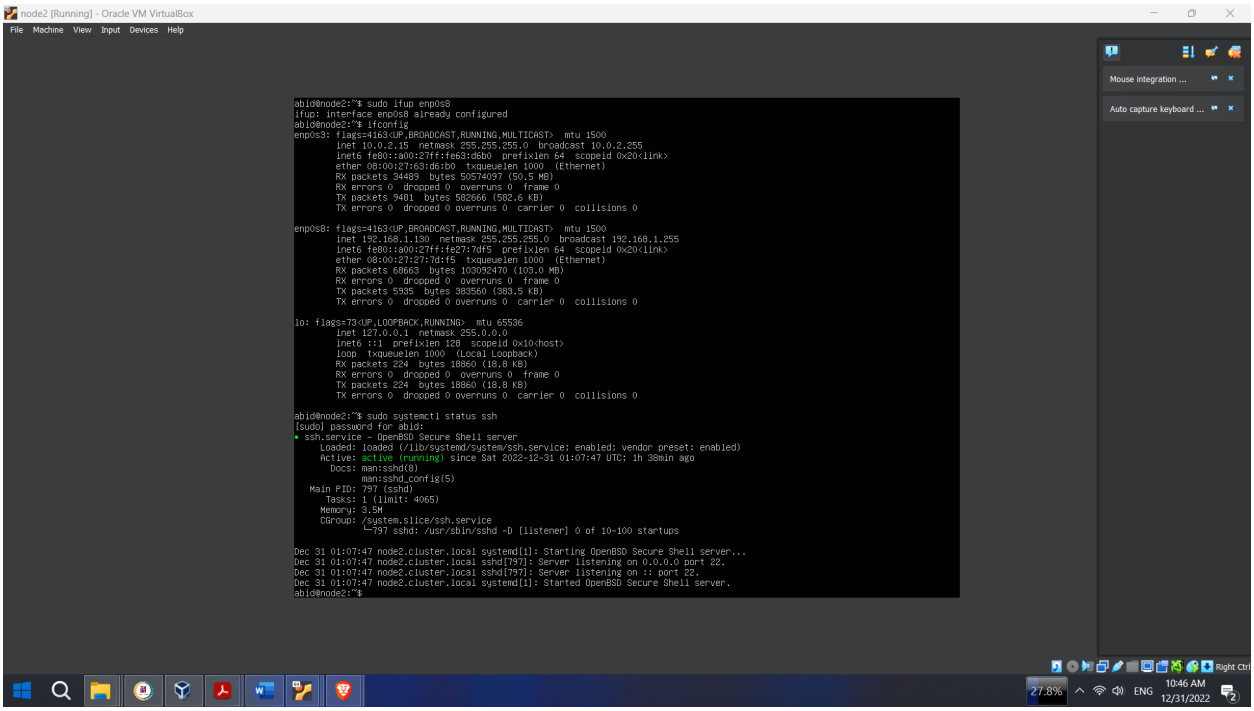

node1 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
abid@node1:~$ sudo apt install openssh-server
[sudo] password for abid:
Reading package lists... Done
Building dependency tree
Reading state information... Done
openssh-server is already the newest version (1:8.2p1-4ubuntu0.5).
0 upgraded, 0 newly installed, 0 to remove and 19 not upgraded.
abid@node1:~$
Mouse integration ...
Auto capture keyboard ...
Right Ctrl
26.1%
ENG
10:45 AM
12/31/2022

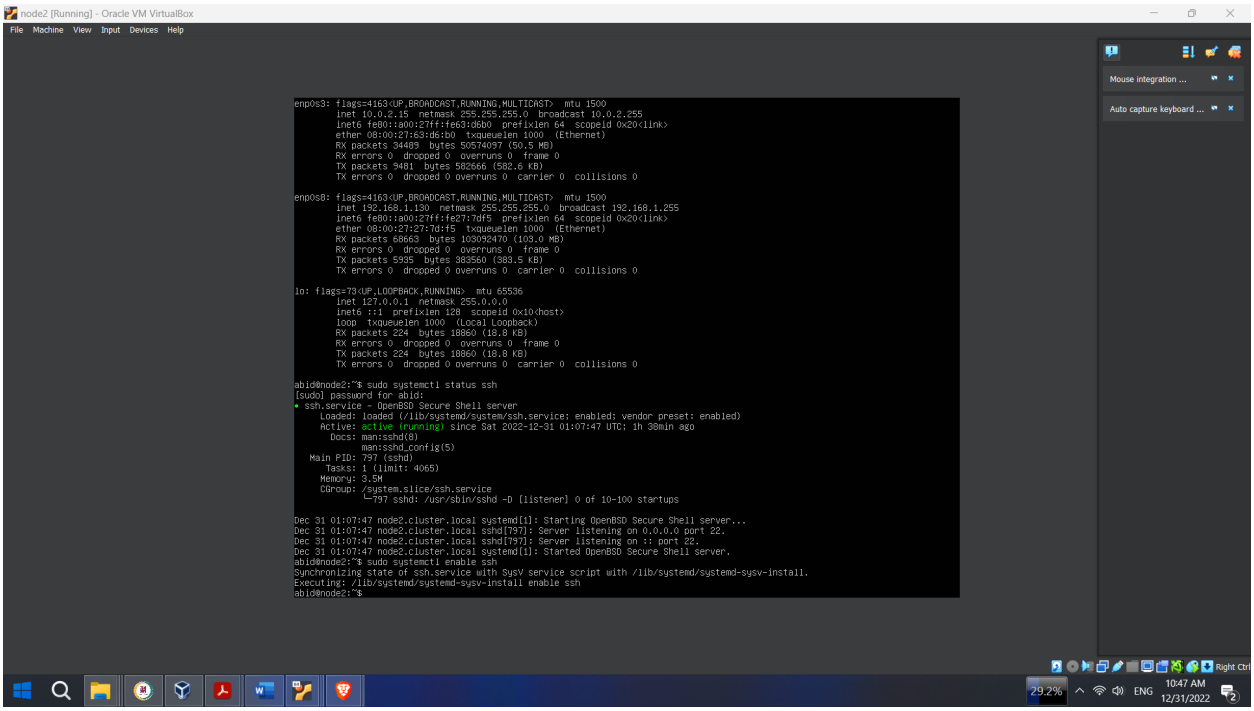

node1 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
abid@node1:~$ sudo apt install openssh-server
[sudo] password for abid:
Reading package lists... Done
Building dependency tree
Reading state information... Done
openssh-server is already the newest version (1:8.2p1-4ubuntu0.5).
0 upgraded, 0 newly installed, 0 to remove and 19 not upgraded.
abid@node1:~$ sudo systemctl status ssh
● ssh.service - OpenBSD Secure Shell server
Loaded: loaded (/lib/systemd/system/ssh.service; enabled; vendor preset: enabled)
Active: active (running) since Sat 2022-12-31 01:43:49 UTC; 1h 8min ago
Docs: man:sshd(8)
man:sshd_config(5)
Process: 773 ExecStartPre=/usr/sbin/sshd -t (code=exited, status=0/SUCCESS)
Main PID: 816 (sshd)
Tasks: 1 (limit: 4065)
Memory: 3.5M
CGroup: /system.slice/ssh.service
└─816 sshd: /usr/sbin/sshd -D [listener] 0 of 10-100 startups
Dec 31 01:43:49 node1.cluster.local systemd[1]: Starting OpenBSD Secure Shell server...
Dec 31 01:43:49 node1.cluster.local sshd[816]: Server listening on 0.0.0.0 port 22.
Dec 31 01:43:49 node1.cluster.local sshd[816]: Server listening on :: port 22.
Dec 31 01:43:49 node1.cluster.local systemd[1]: Started OpenBSD Secure Shell server.
abid@node1:~$
Mouse integration ...
Auto capture keyboard ...
Right Ctrl
34.8%
ENG
10:52 AM
12/31/2022


node1 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
abid@node1:~$ sudo apt install openssh-server
[sudo] password for abid:
Reading package lists... Done
Building dependency tree
Reading state information... Done
openssh-server is already the newest version (1:8.2p1-4ubuntu0.5).
0 upgraded, 0 newly installed, 0 to remove and 19 not upgraded.
abid@node1:~$ sudo systemctl status ssh
● ssh.service - OpenBSD Secure Shell server
Loaded: loaded (/lib/systemd/system/ssh.service; enabled; vendor preset: enabled)
Active: active (running) since Sat 2022-12-31 01:43:49 UTC; 1h 8min ago
Docs: man:sshd(8)
man:sshd_config(5)
Process: 773 ExecStartPre=/usr/sbin/sshd -t (code=exited, status=0/SUCCESS)
Main PID: 816 (sshd)
Tasks: 1 (limit: 4065)
Memory: 3.5M
CGroup: /system.slice/ssh.service
└─816 sshd: /usr/sbin/sshd -D [listener] 0 of 10-100 startups
Dec 31 01:43:49 node1.cluster.local systemd[1]: Starting OpenBSD Secure Shell server...
Dec 31 01:43:49 node1.cluster.local sshd[816]: Server listening on 0.0.0.0 port 22.
Dec 31 01:43:49 node1.cluster.local sshd[816]: Server listening on :: port 22.
Dec 31 01:43:49 node1.cluster.local systemd[1]: Started OpenBSD Secure Shell server.
abid@node1:~$ sudo systemctl enable ssh
Synchronizing state of ssh.service with SysV service script with /lib/systemd/systemd-sysv-install.
Executing: /lib/systemd/systemd-sysv-install enable ssh
abid@node1:~$
Mouse integration ...
Auto capture keyboard ...
Right Ctrl
35.8%
ENG
10:53 AM
12/31/2022

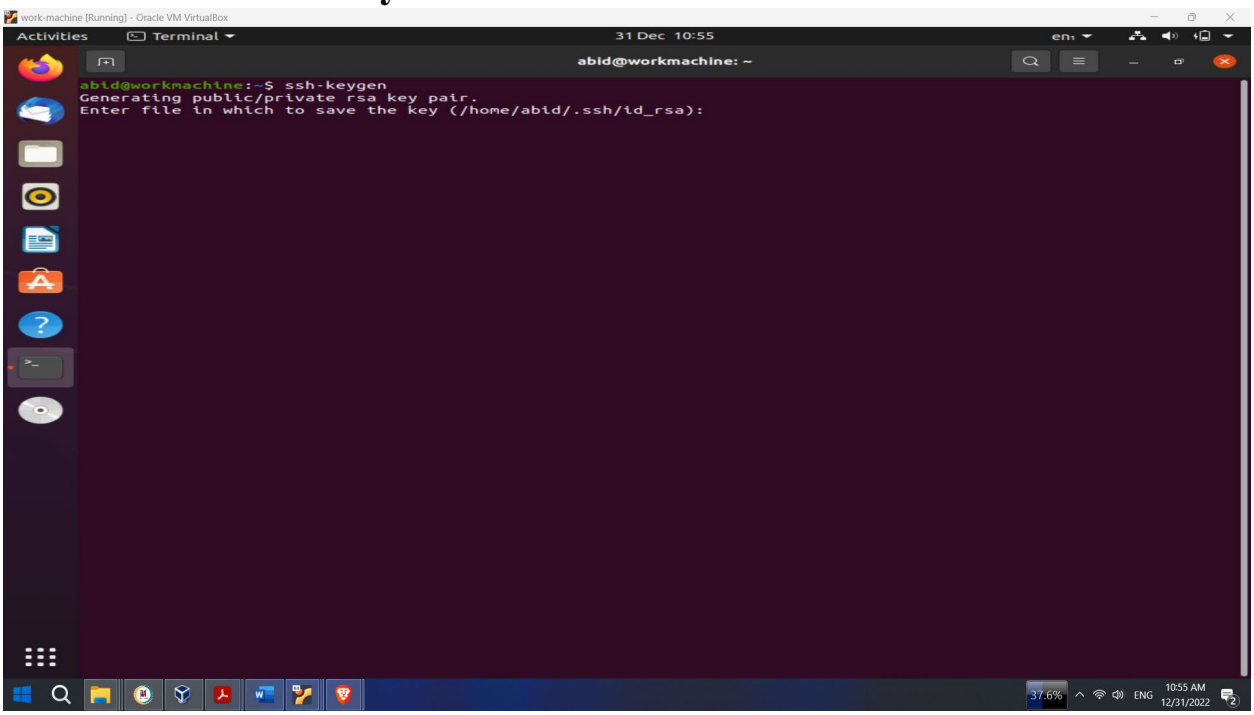
6.5 Node 2

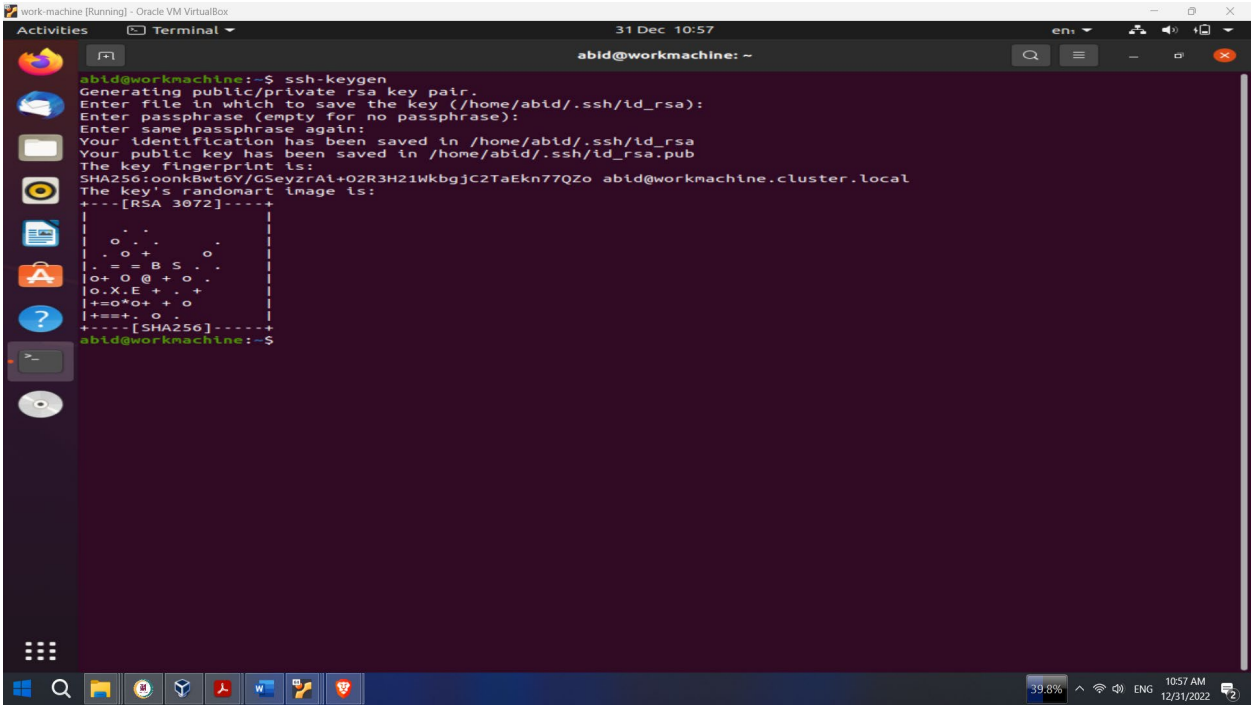

node2 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
abid@node2:~$ sudo apt install openssh-server
Reading package lists... Done
Building dependency tree
Reading state information... Done
openssh-server is already the newest version (1:8.2p1-4ubuntu0.5).
0 upgraded, 0 newly installed, 0 to remove and 19 not upgraded.
abid@node2:~$
Mouse integration ...
Auto capture keyboard ...
Right Ctrl
33.3%
ENG
10:51 AM
12/31/2022


node2 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
abid@node2:~$ sudo ifup enp0s8
ifup: interface enp0s8 already configured
abid@node2:~$ ifconfig
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 10.0.2.15 netmask 255.255.255.0 broadcast 10.0.2.255
inet6 fe80::a00:27ff:fe63:d6b0 prefixlen 64 scopeid 0x20<link>
ether 08:00:27:63:d6:b0 txqueuelen 1000 (Ethernet)
RX packets 34489 bytes 50574097 (50.5 MB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 9481 bytes 582666 (582.6 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
enp0s8: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 192.168.1.130 netmask 255.255.255.0 broadcast 192.168.1.255
inet6 fe80::a00:27ff:fe27:7df5 prefixlen 64 scopeid 0x20<link>
ether 08:00:27:27:7d:f5 txqueuelen 1000 (Ethernet)
RX packets 68663 bytes 103092470 (103.0 MB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 5935 bytes 383560 (383.5 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
inet 127.0.0.1 netmask 255.0.0.0
inet6 ::1 prefixlen 128 scopeid 0x10<host>
loop txqueuelen 1000 (Local Loopback)
RX packets 224 bytes 18860 (18.8 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 224 bytes 18860 (18.8 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
abid@node2:~$ sudo systemctl status ssh
[sudo] password for abid:
● ssh.service - OpenBSD Secure Shell server
Loaded: loaded (/lib/systemd/system/ssh.service; enabled; vendor preset: enabled)
Active: active (running) since Sat 2022-12-31 01:07:47 UTC; 1h 38min ago
Docs: man:sshd(8)
man:sshd_config(5)
Main PID: 797 (sshd)
Tasks: 1 (limit: 4065)
Memory: 3.5M
CGroup: /system.slice/ssh.service
└─797 sshd: /usr/sbin/sshd -D [listener] 0 of 10-100 startups
Dec 31 01:07:47 node2.cluster.local systemd[1]: Starting OpenBSD Secure Shell server...
Dec 31 01:07:47 node2.cluster.local sshd[797]: Server listening on 0.0.0.0 port 22.
Dec 31 01:07:47 node2.cluster.local sshd[797]: Server listening on :: port 22.
Dec 31 01:07:47 node2.cluster.local systemd[1]: Started OpenBSD Secure Shell server.
abid@node2:~$
Mouse integration ...
Auto capture keyboard ...
Right Ctrl
27.8%
ENG
10:46 AM
12/31/2022

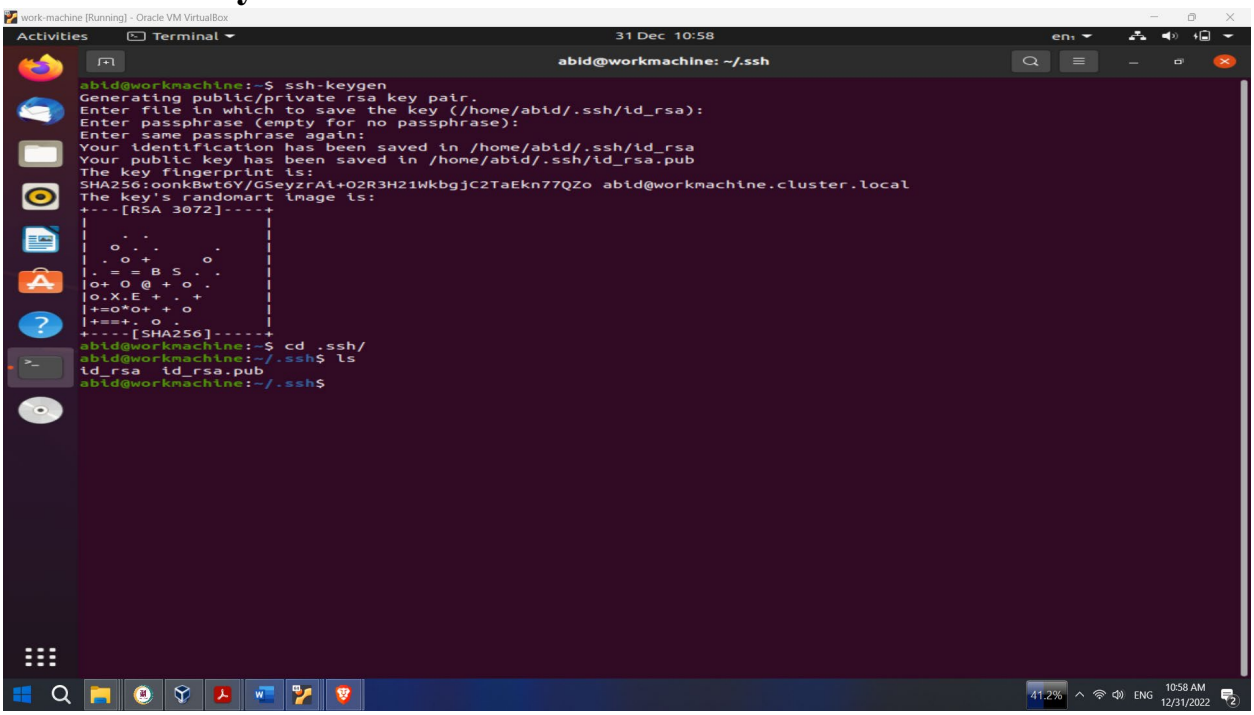

node2 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 10.0.2.15 netmask 255.255.255.0 broadcast 10.0.2.255
inet6 fe80::a00:27ff:fe63:d6b0 prefixlen 64 scopeid 0x20<link>
ether 08:00:27:63:d6:b0 txqueuelen 1000 (Ethernet)
RX packets 34489 bytes 50574097 (50.5 MB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 9481 bytes 582666 (582.6 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
enp0s8: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 192.168.1.130 netmask 255.255.255.0 broadcast 192.168.1.255
inet6 fe80::a00:27ff:fe27:7df5 prefixlen 64 scopeid 0x20<link>
ether 08:00:27:27:7d:f5 txqueuelen 1000 (Ethernet)
RX packets 68663 bytes 103092470 (103.0 MB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 5935 bytes 383560 (383.5 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
inet 127.0.0.1 netmask 255.0.0.0
inet6 ::1 prefixlen 128 scopeid 0x10<host>
loop txqueuelen 1000 (Local Loopback)
RX packets 224 bytes 18860 (18.8 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 224 bytes 18860 (18.8 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
abid@node2:~$ sudo systemctl status ssh
[sudo] password for abid:
● ssh.service - OpenBSD Secure Shell server
Loaded: loaded (/lib/systemd/system/ssh.service; enabled; vendor preset: enabled)
Active: active (running) since Sat 2022-12-31 01:07:47 UTC; 1h 38min ago
Docs: man:sshd(8)
man:sshd_config(5)
Main PID: 797 (sshd)
Tasks: 1 (limit: 4065)
Memory: 3.5M
CGroup: /system.slice/ssh.service
└─797 sshd: /usr/sbin/sshd -D [listener] 0 of 10-100 startups
Dec 31 01:07:47 node2.cluster.local systemd[1]: Starting OpenBSD Secure Shell server...
Dec 31 01:07:47 node2.cluster.local sshd[797]: Server listening on 0.0.0.0 port 22.
Dec 31 01:07:47 node2.cluster.local sshd[797]: Server listening on :: port 22.
Dec 31 01:07:47 node2.cluster.local systemd[1]: Started OpenBSD Secure Shell server.
abid@node2:~$ sudo systemctl enable ssh
Synchronizing state of ssh.service with SysV service script with /lib/systemd/systemd-sysv-install.
Executing: /lib/systemd/systemd-sysv-install enable ssh
abid@node2:~$
Mouse integration ...
Auto capture keyboard ...
Right Ctrl
29.2%
ENG
10:47 AM
12/31/2022

6.6 Generate SSH key For WorkMachine

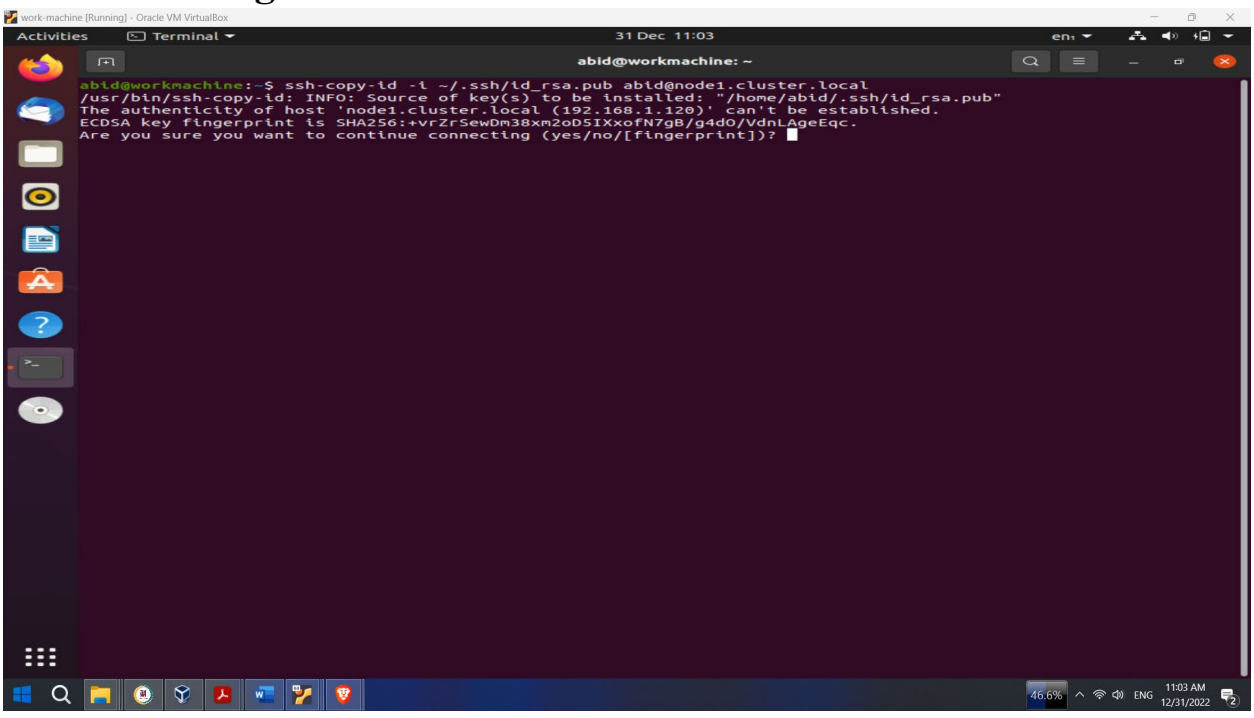




6.7 Public key

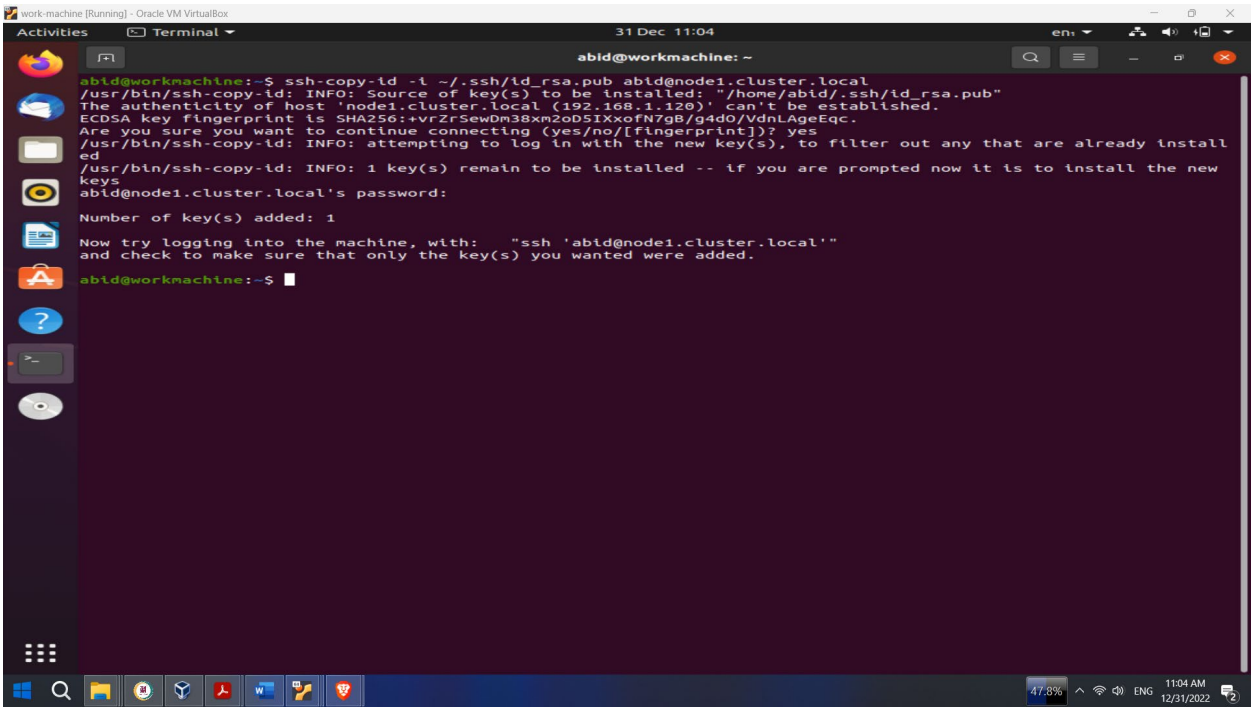


6.8 Connecting in node1



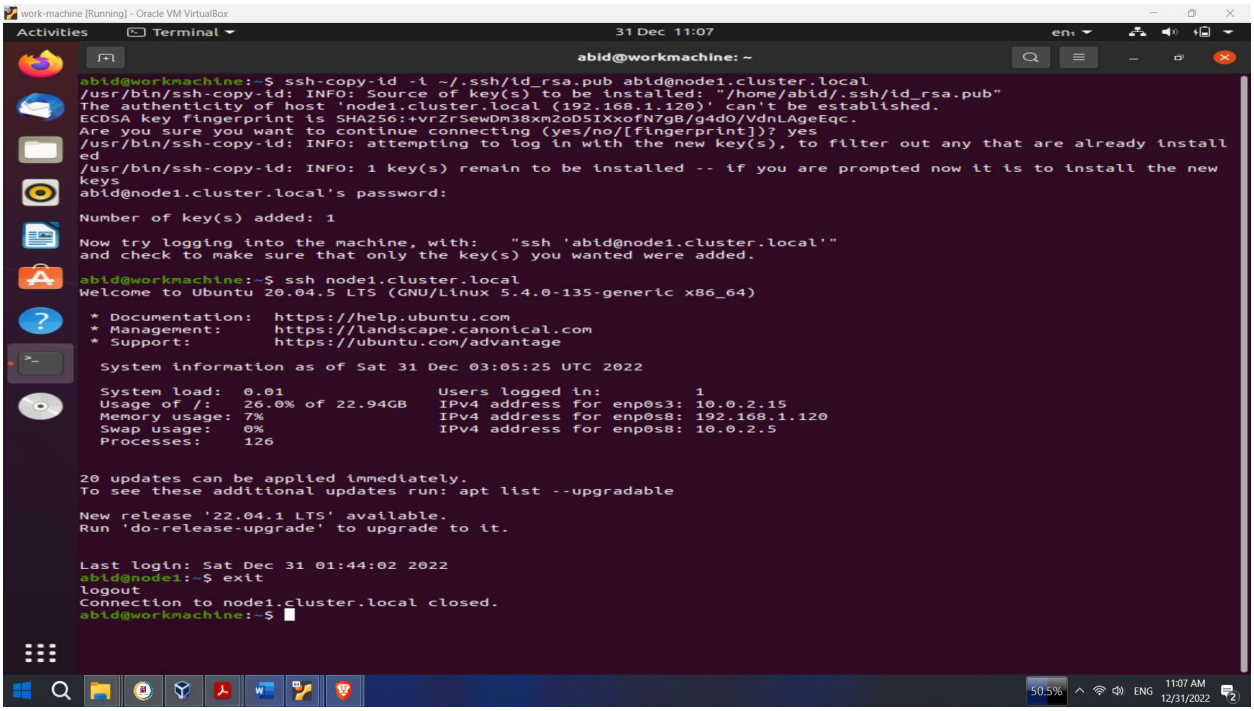
ssh-copy-id -i ~/.ssh/id_rsa.pub abid@node1.cluster.local

6.9 Result of node1

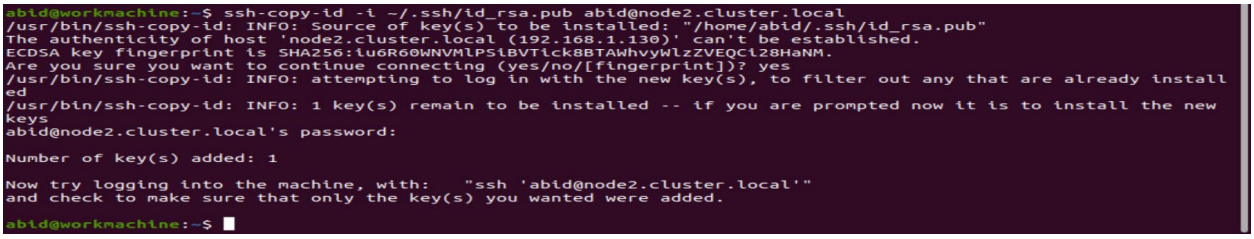



```
abid@workmachine:~$ ssh node1.cluster.local
Welcome to Ubuntu 20.04.5 LTS (GNU/Linux 5.4.0-135-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:     https://landscape.canonical.com
 * Support:        https://ubuntu.com/advantage

  System information as of Sat 31 Dec 03:05:25 UTC 2022

  System load:  0.01                Users logged in:          1
  Usage of /:   26.0% of 22.94GB    IPv4 address for enp0s3: 10.0.2.15
  Memory usage: 7%                  IPv4 address for enp0s8: 192.168.1.120
  Swap usage:   0%                  IPv4 address for enp0s8: 10.0.2.5
  Processes:    126


20 updates can be applied immediately.
To see these additional updates run: apt list --upgradable

New release '22.04.1 LTS' available.
Run 'do-release-upgrade' to upgrade to it.


Last login: Sat Dec 31 01:44:02 2022
abid@node1:~$
```

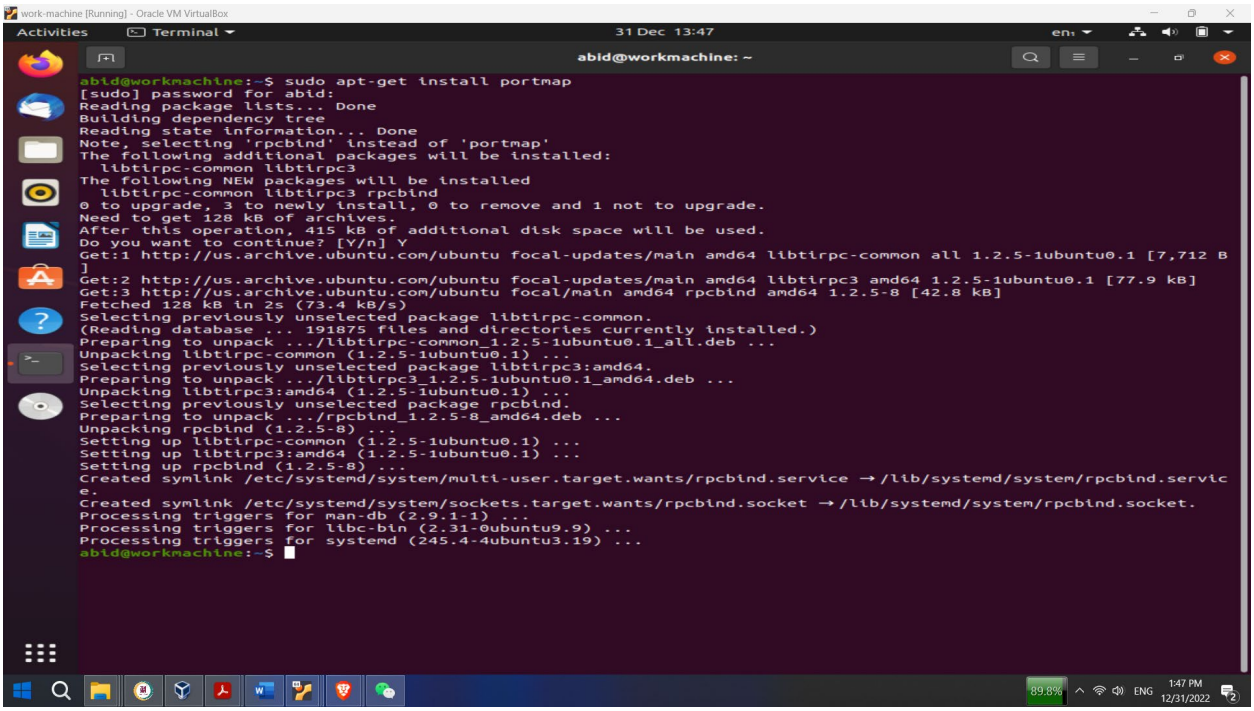
Logout



6.10 Result of node2

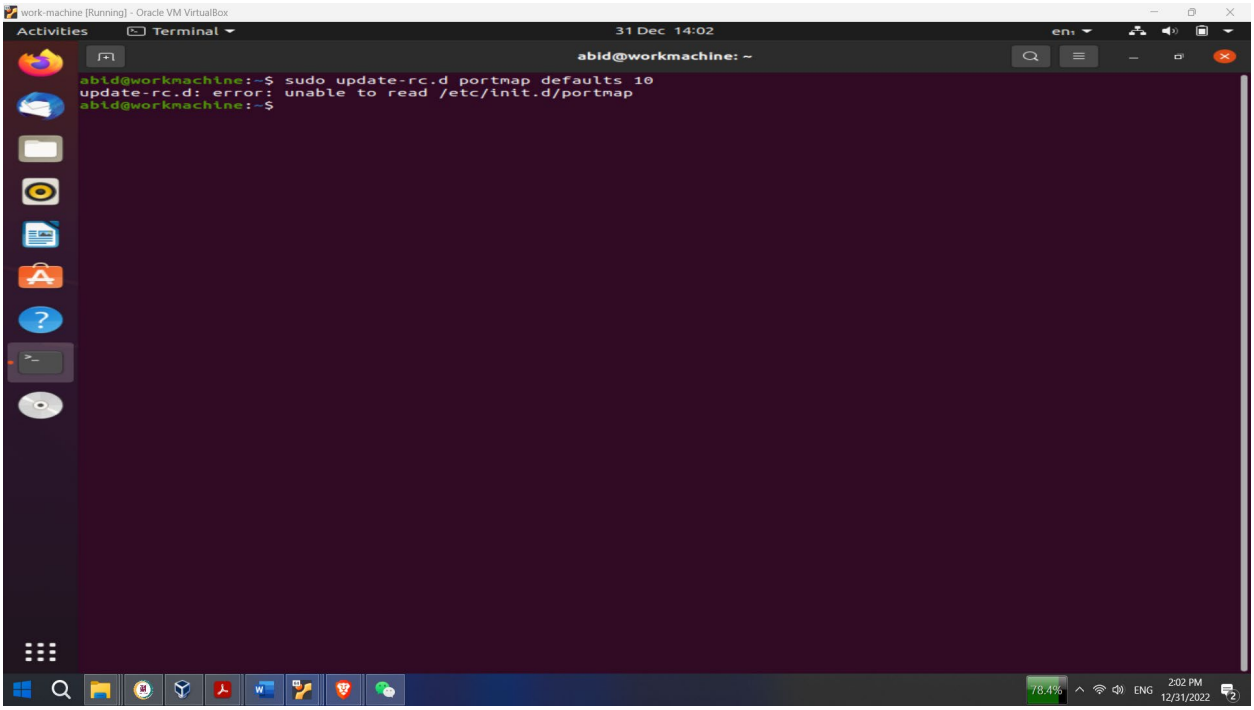


7. NIS

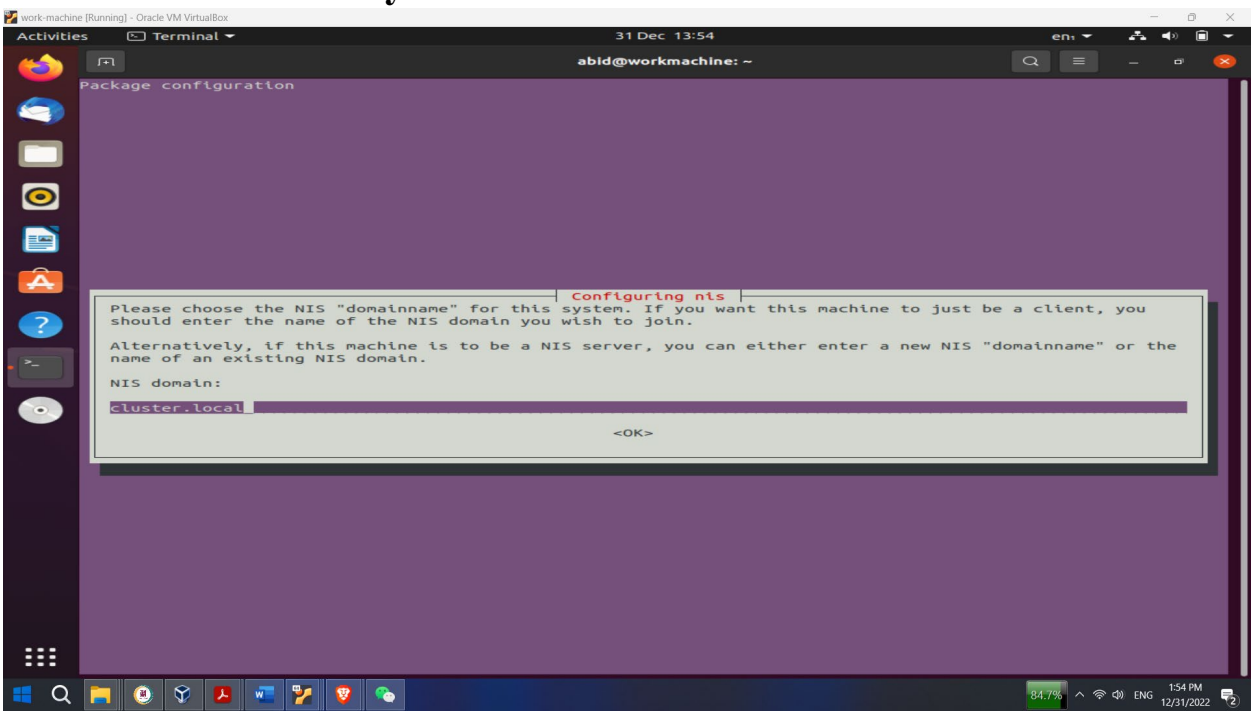


sudo apt-get install portmap

7.1 Problem Faced in NIS



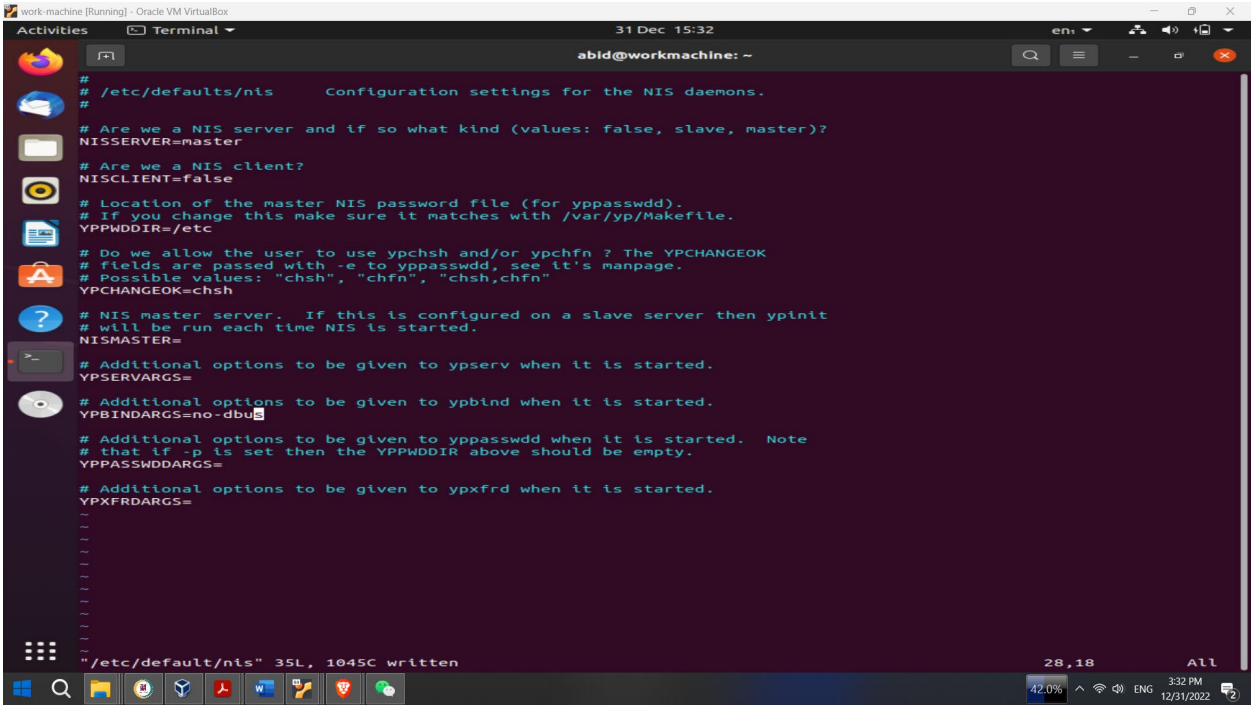
7.2 Installation NIS system



sudo apt -y install nis

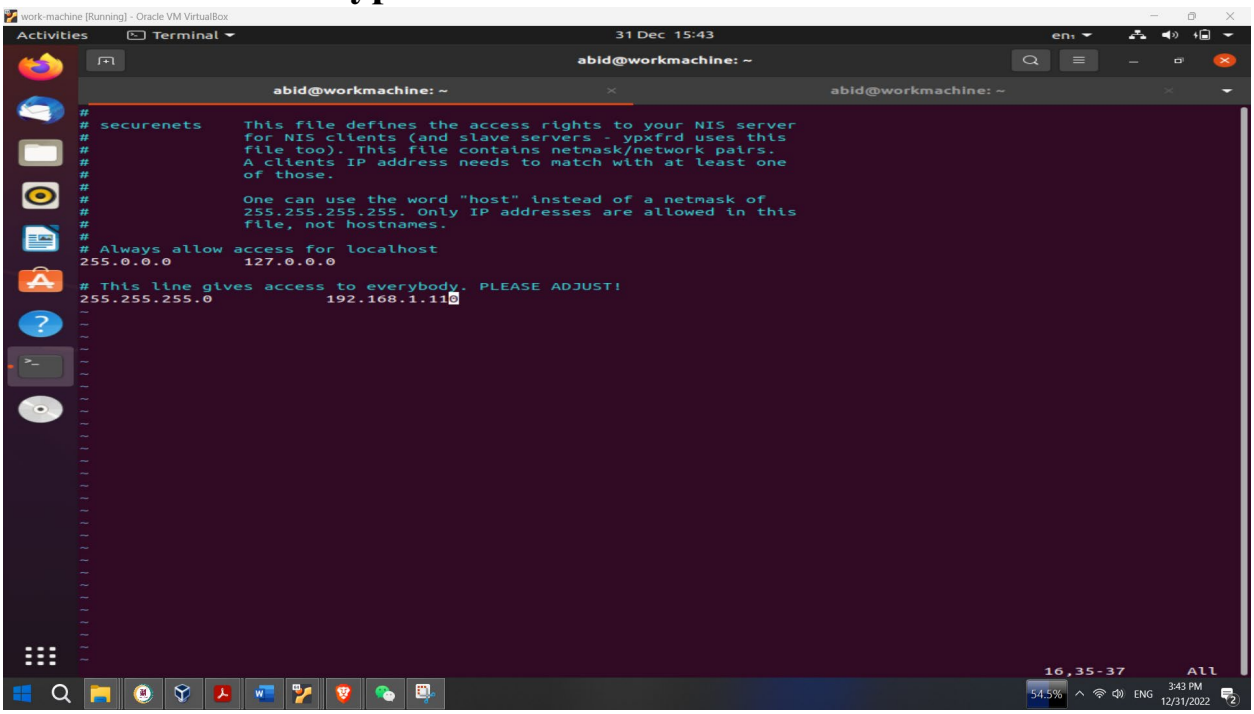
7.3 On the server side

7.3.1 sudo vim /etc/default/nis

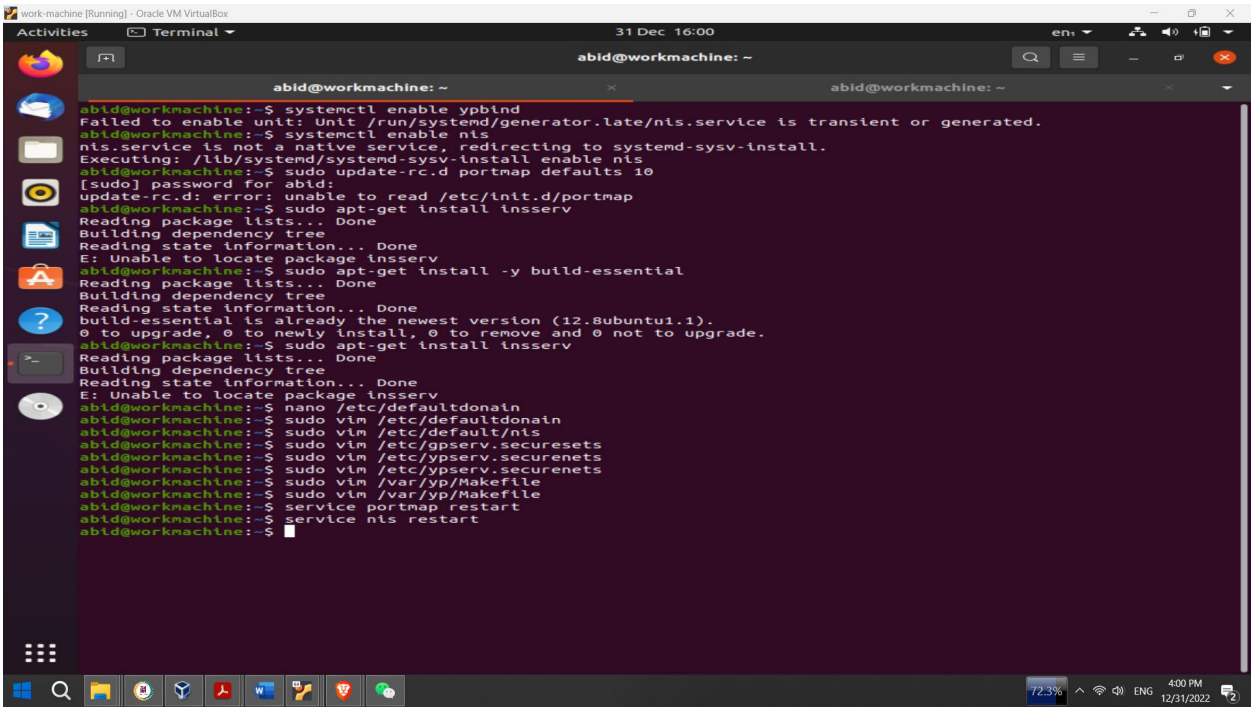


sudo vim /etc/default/nis

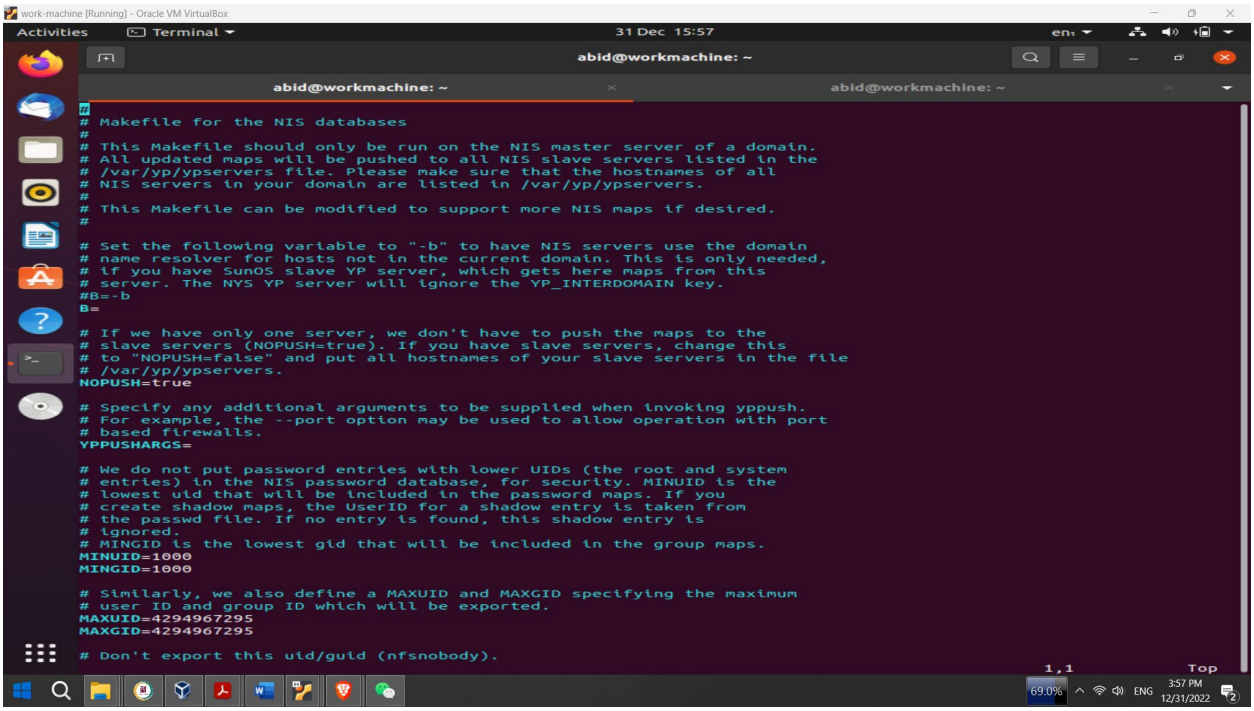
7.3.2 sudo vim /etc/ypserv.securenets



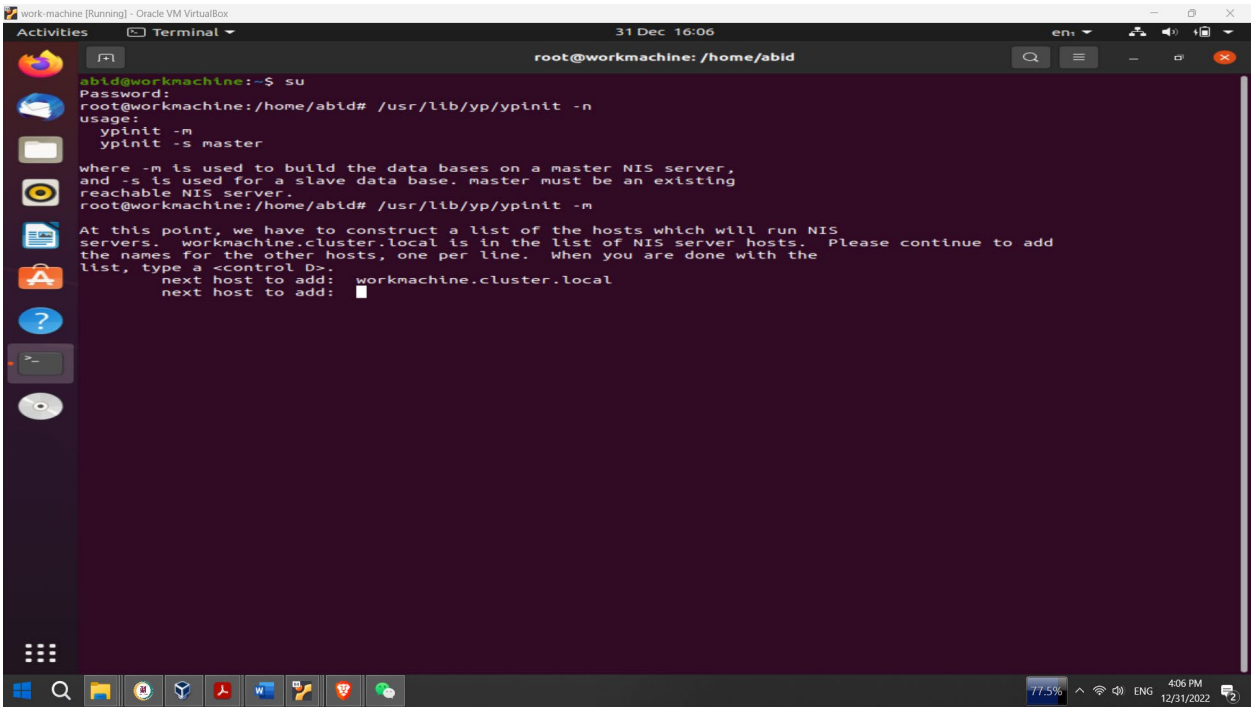
sudo vim /etc/ypserv.securenets



7.3.3 Makefile for the NIS databases



7.4 On the Server Side

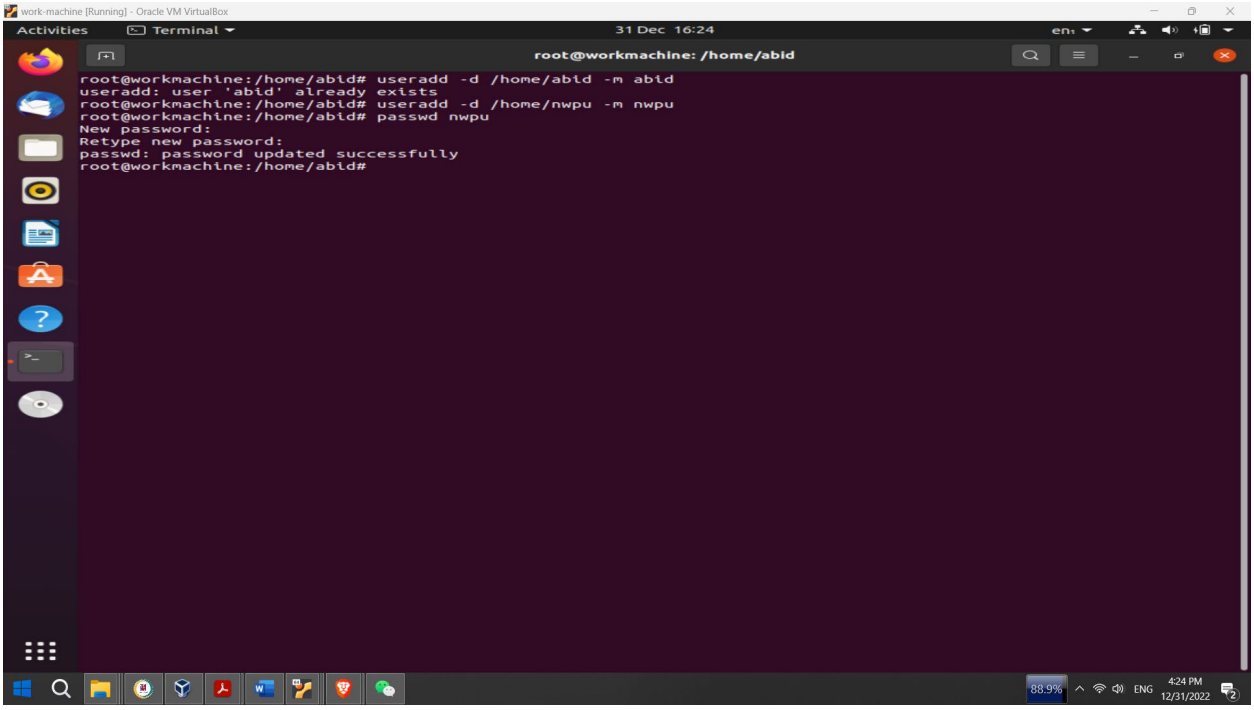


7.4.1 /usr/lib/yp/ypinit -m

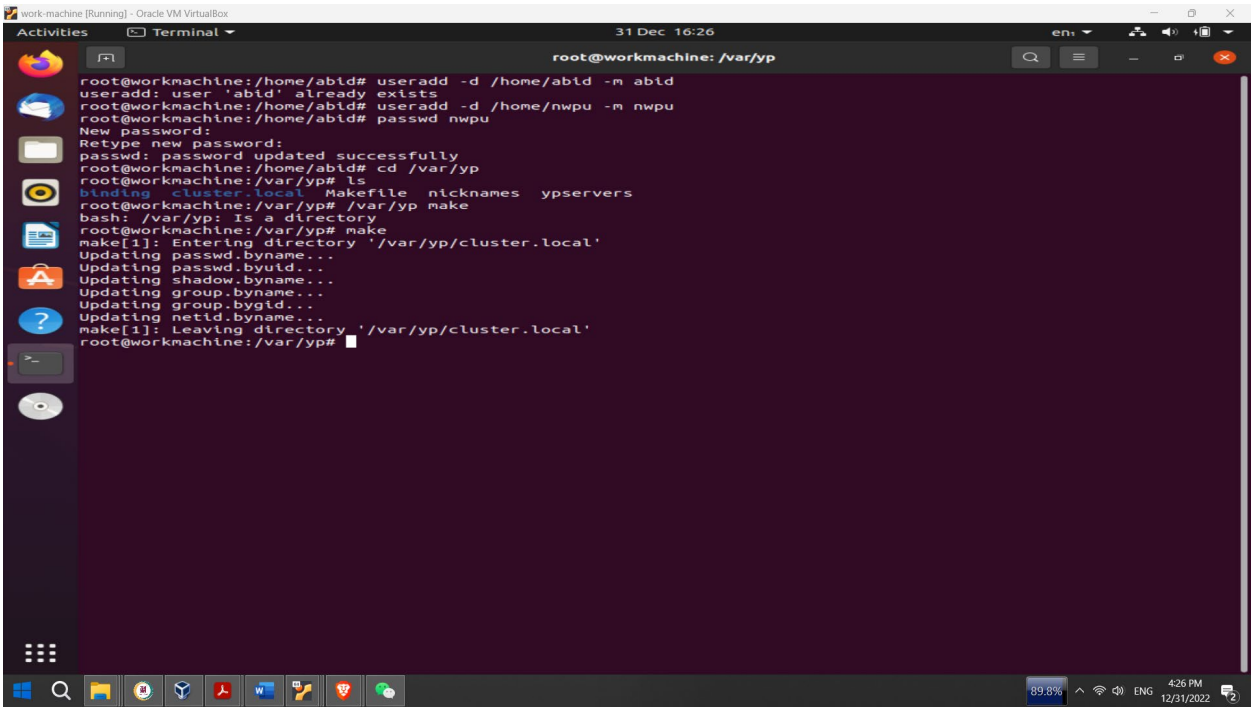
```
At this point, we have to construct a list of the hosts which will run NIS
servers.  workmachine.cluster.local is in the list of NIS server hosts.  Please continue to add
the names for the other hosts, one per line.  When you are done with the
list, type a <control D>.
        next host to add:  workmachine.cluster.local
        next host to add:
The current list of NIS servers looks like this:

workmachine.cluster.local

Is this correct?  [y/n: y]  y
We need a few minutes to build the databases...
Building /var/yp/cluster.local/ypservers...
Running /var/yp/Makefile...
make[1]: Entering directory '/var/yp/cluster.local'
Updating passwd.byname...
Updating passwd.byuid...
Updating shadow.byname...
Updating group.byname...
Updating group.bygid...
Updating hosts.byname...
Updating hosts.byaddr...
Updating rpc.byname...
Updating rpc.bynumber...
Updating services.byname...
Updating services.byservicename...
Updating netid.byname...
Updating protocols.bynumber...
Updating protocols.byname...
Updating netgroup...
Updating netgroup.byhost...
Updating netgroup.byuser...
make[1]: Leaving directory '/var/yp/cluster.local'

workmachine.cluster.local has been set up as a NIS master server.

Now you can run ypinit -s workmachine.cluster.local on all slave server.
root@workmachine:/home/abid#
```

/usr/lib/yp/ypinit -m

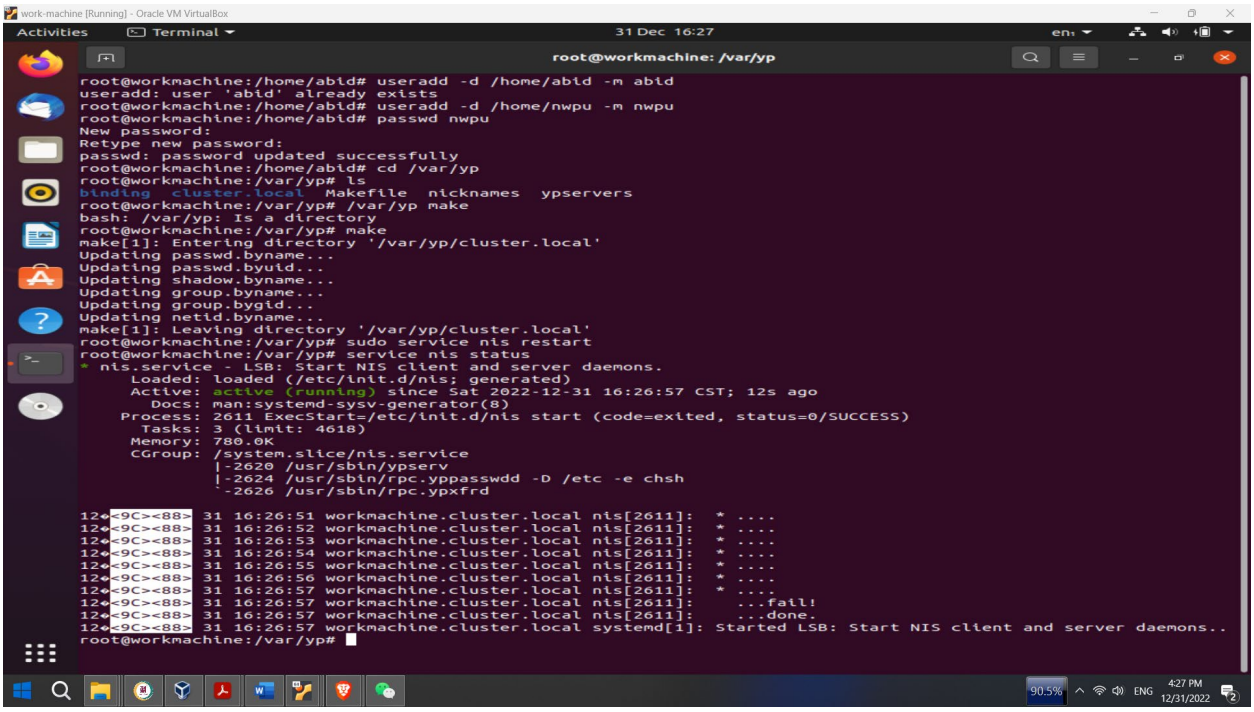
7.4.2 Adding user



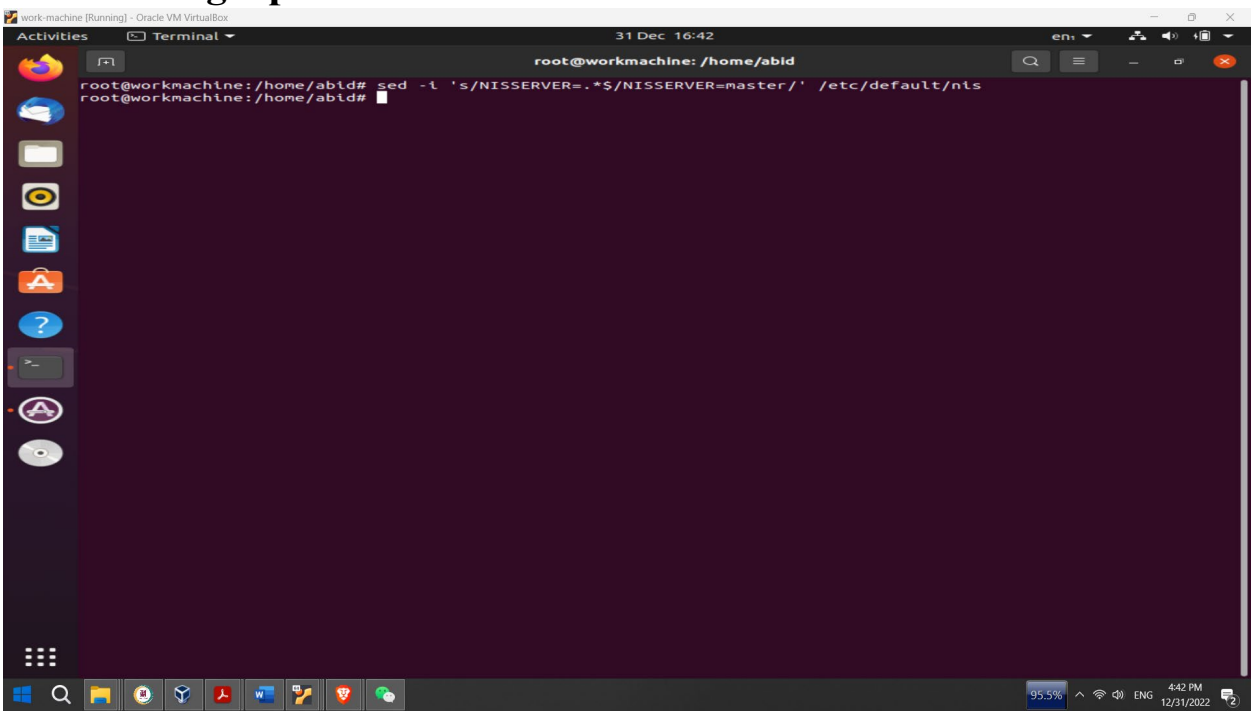
7.4.3 Make



7.4.4 NIS Activate

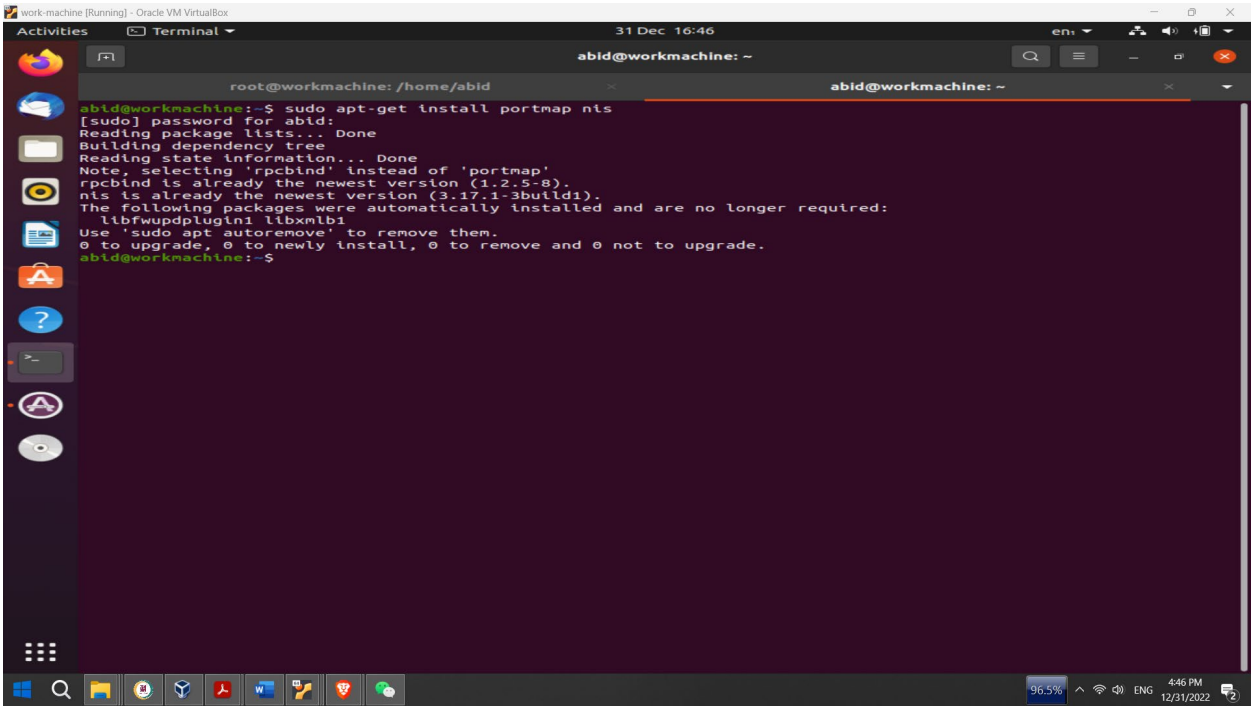


7.4.5 Setting Up The NIS Server



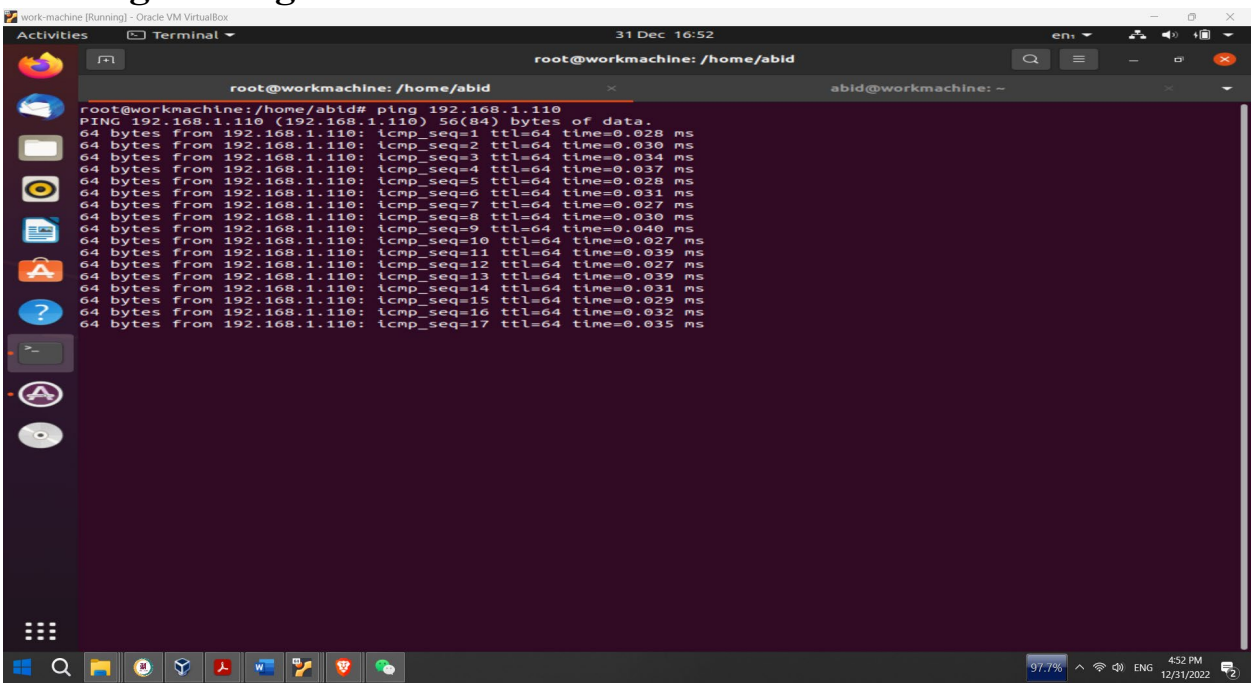
sed -i 's/NISSERVER=.*$/NISSERVER=master/' /etc/default/nis

7.5 sudo apt-get install portmap nis

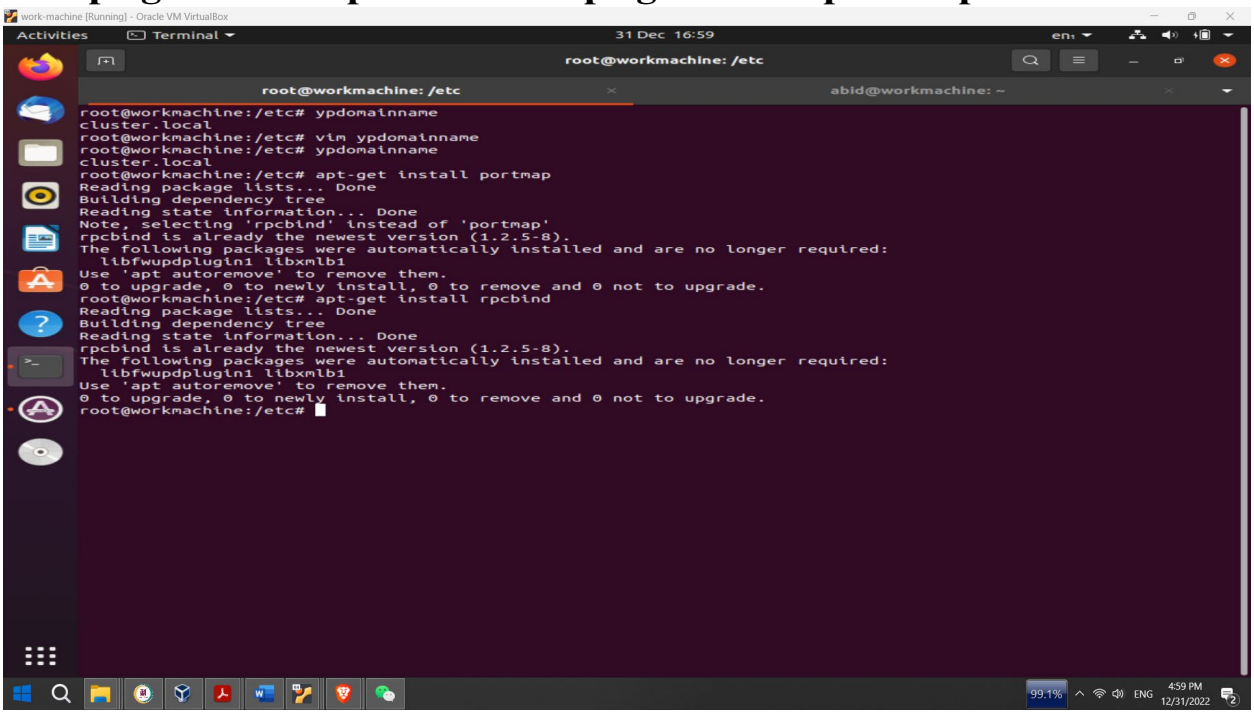


sudo apt-get install portmap nis

7.6 Ping Testing Workmachine



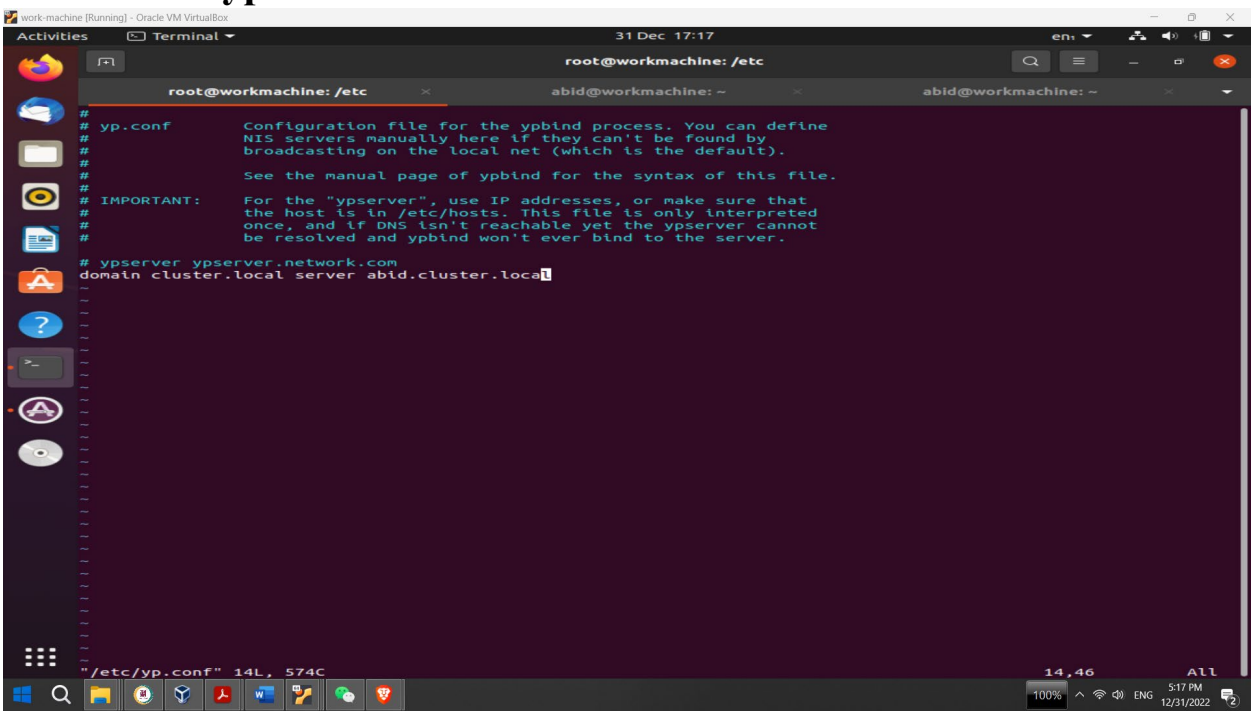
7.7 apt-get install rpcbind and apt-get install portmap



apt-get install rpcbind

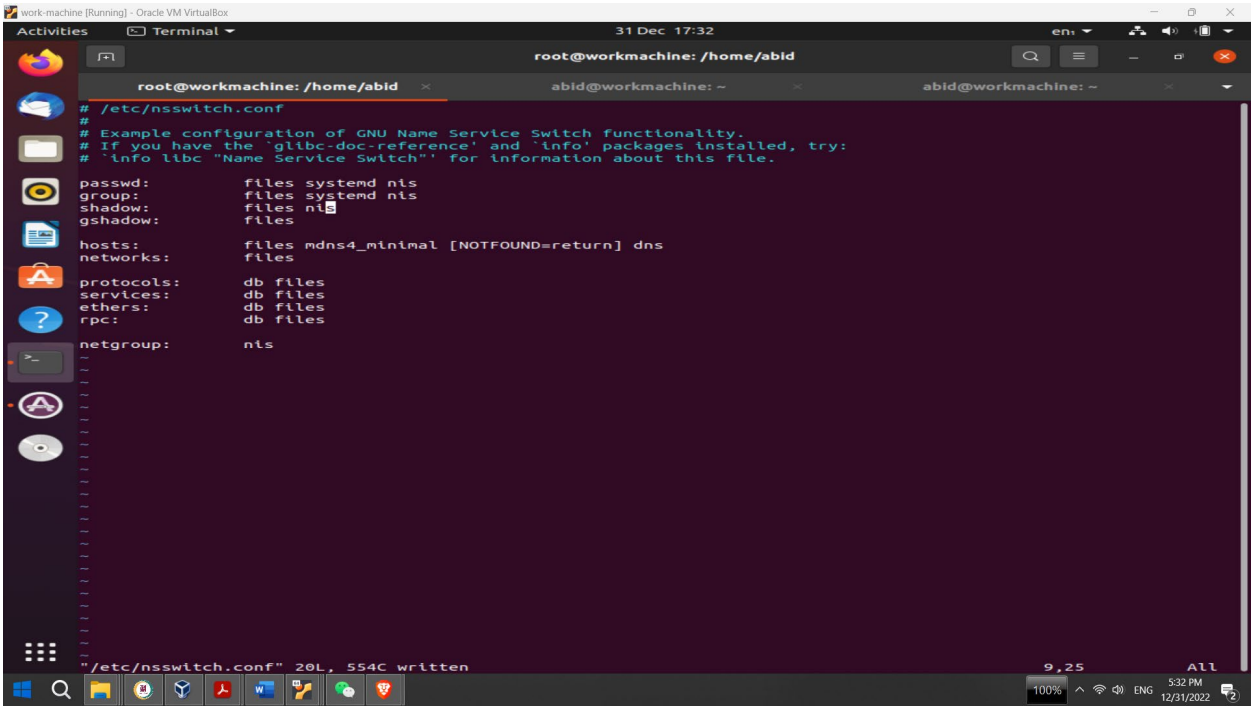
apt-get install portmap

7.8 vim /etc/yp.conf



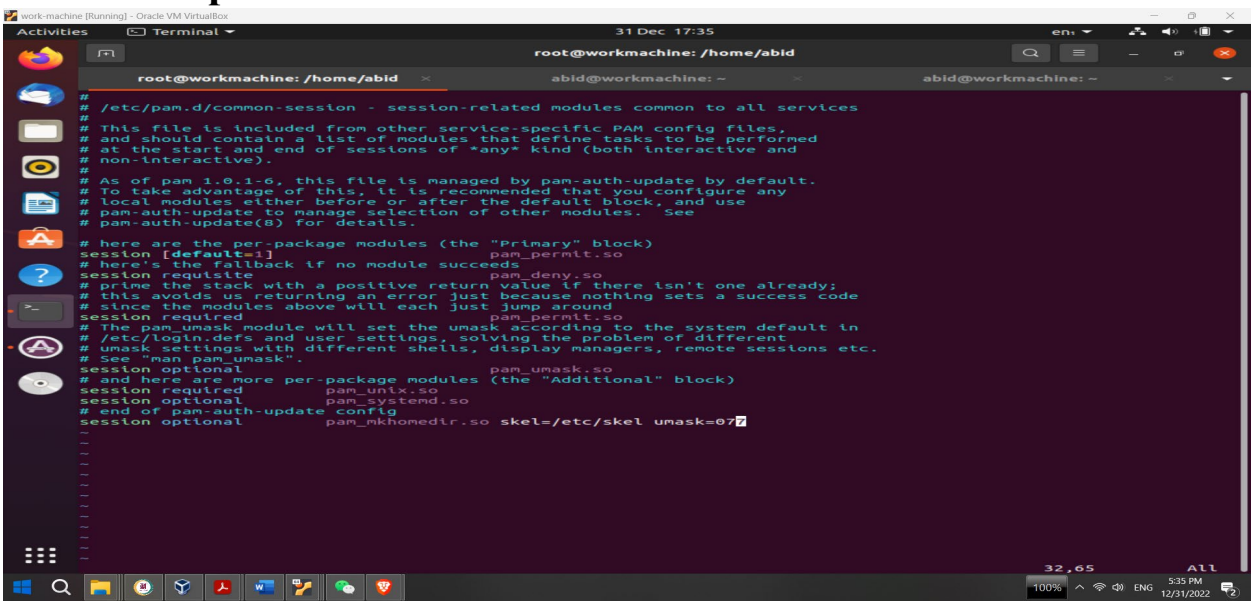
vim /etc/yp.conf

7.9 vim /etc/nsswitch.conf



vim /etc/nsswitch.conf

7.10 vi /etc/pam.d/common-session



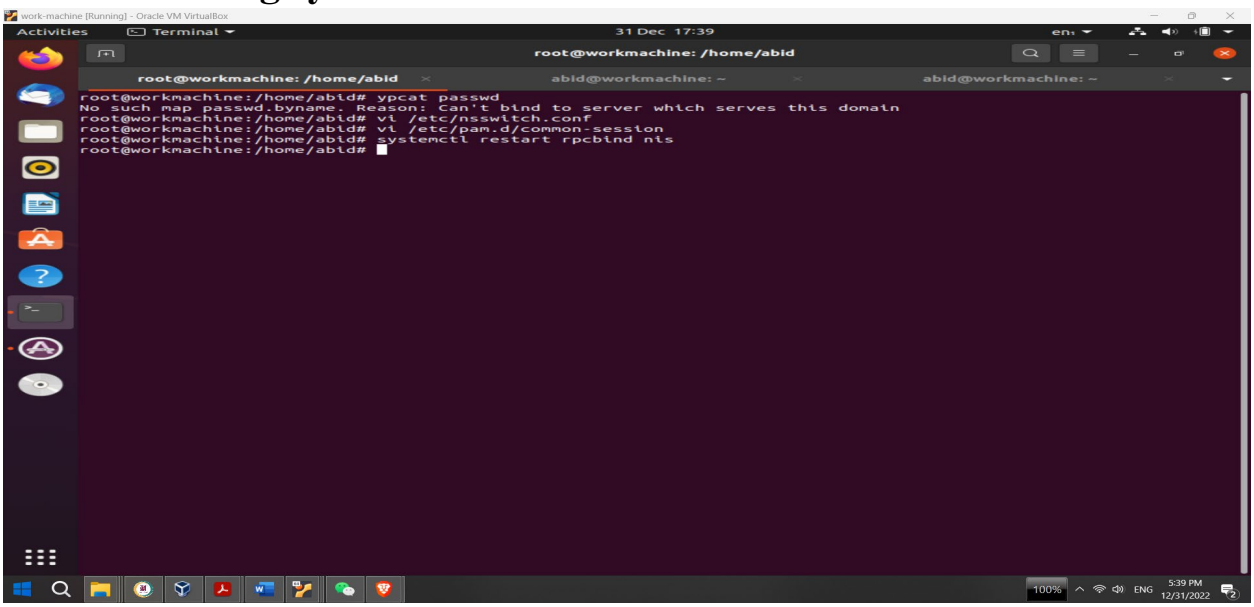
Note

vi /etc/pam.d/common-session

adding to the end

session optional pam_mkhomedir.so skel=/etc/skel umask=077

7.11 Restarting systemctl

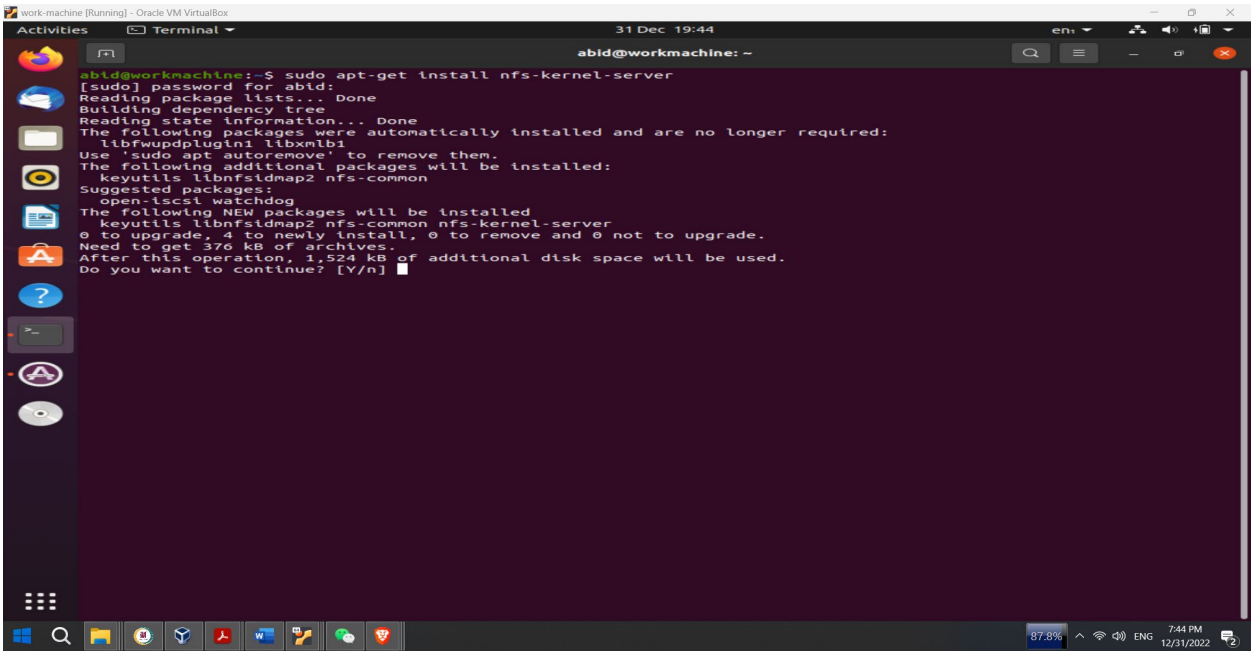


Restarting systemctl

systemctl restart rpcbind nis

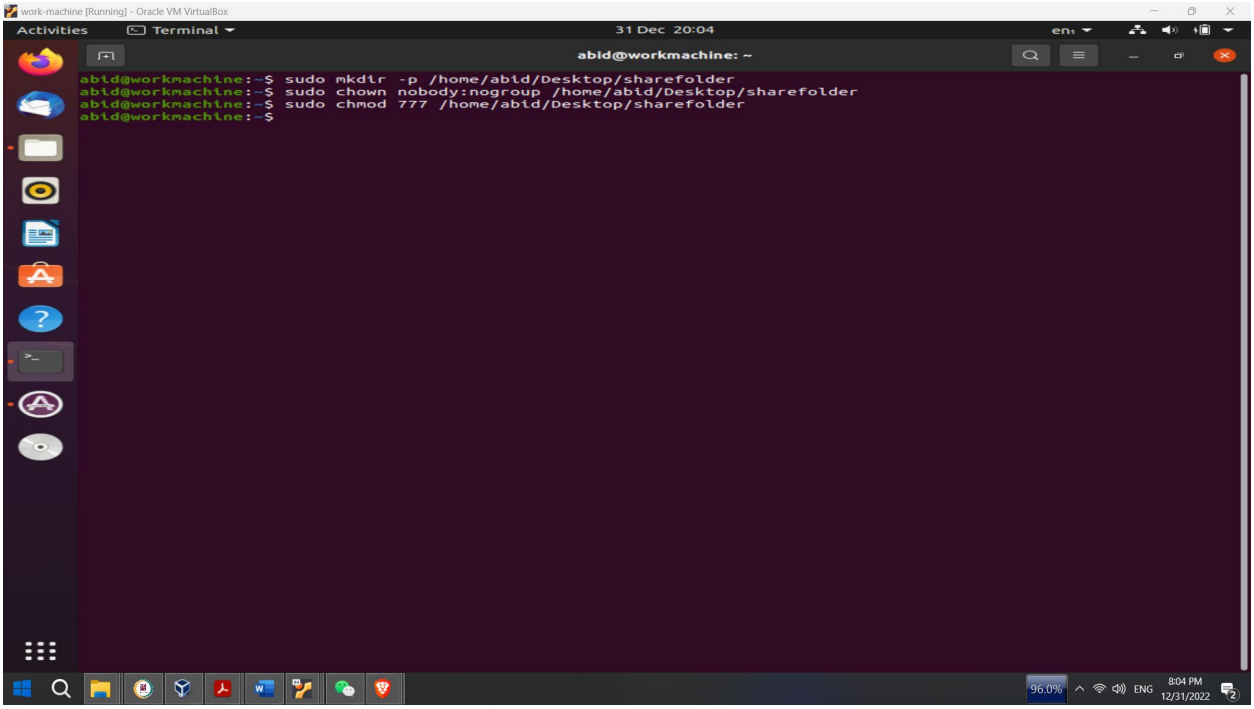
8. NFS

8.1 Install nfs server on master machine



sudo apt-get install nfs-kernel-server

8.2 Creating a directory



sudo mkdir -p /home/abid/Desktop/sharefolder

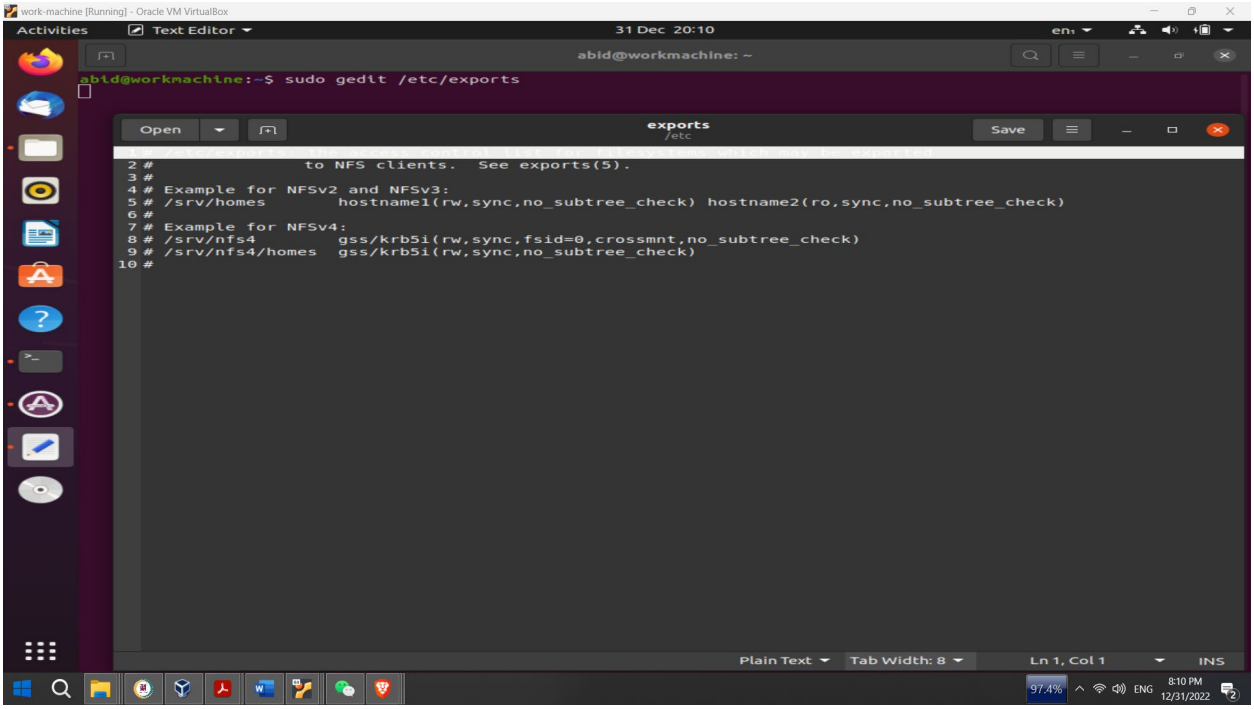
sudo chown nobody:nogroup /home/abid/Desktop/sharefolderS

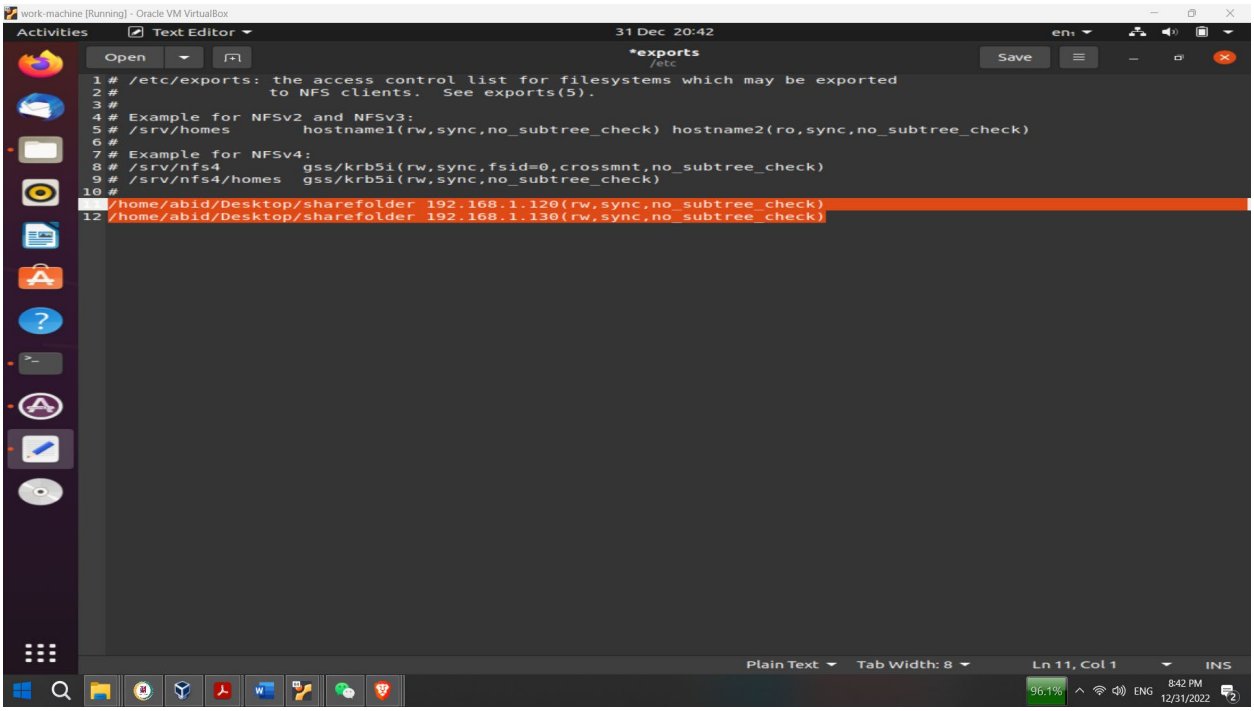
sudo chmod 777 /home/abid/Desktop/sharefolder

8.3 Install gedit

```
abid@workmachine:~$ sudo apt-get install gedit
Reading package lists... Done
Building dependency tree
Reading state information... Done
gedit is already the newest version (3.36.2-0ubuntu1).
gedit set to manually installed.
The following packages were automatically installed and are no longer required:
  libfwupdplugin1 libxmlb1
Use 'sudo apt autoremove' to remove them.
0 to upgrade, 0 to newly install, 0 to remove and 0 not to upgrade.
abid@workmachine:~$
```

sudo apt-get install gedit





Adding those two lines

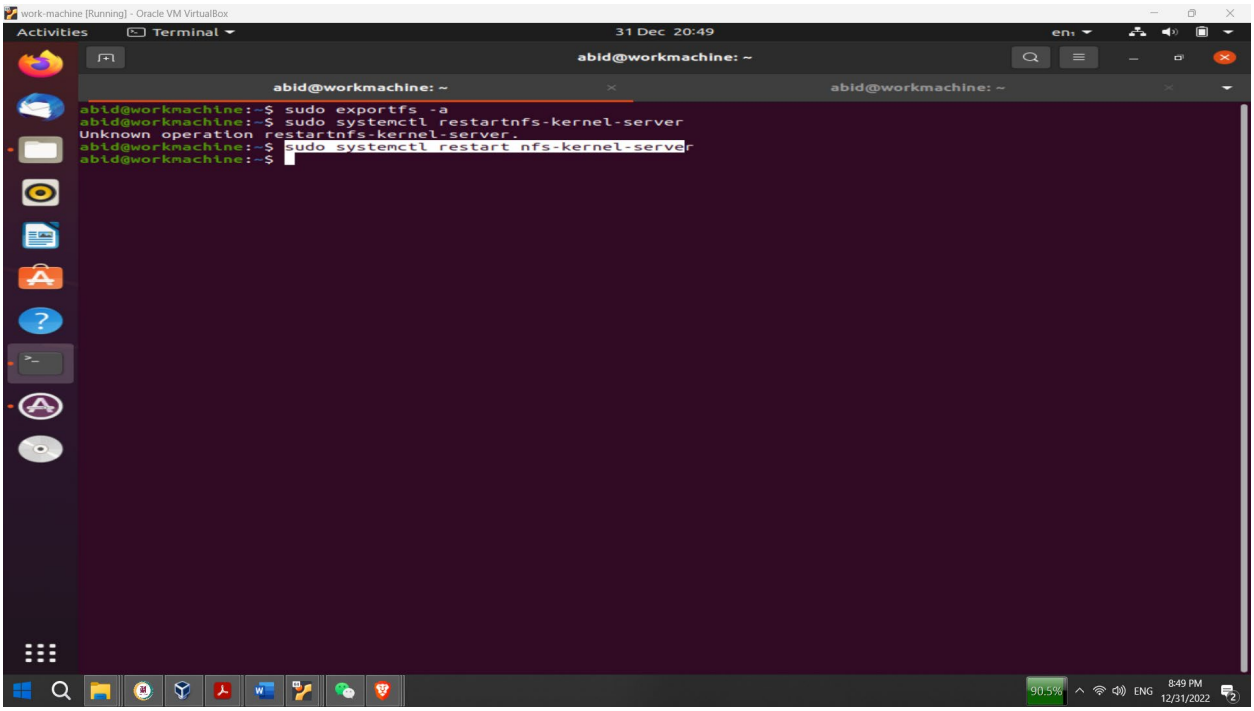
/home/abid/Desktop/sharefolder 192.168.1.120(rw,sync,no_subtree_check)

/home/abid/Desktop/sharefolder 192.168.1.130(rw,sync,no_subtree_check)

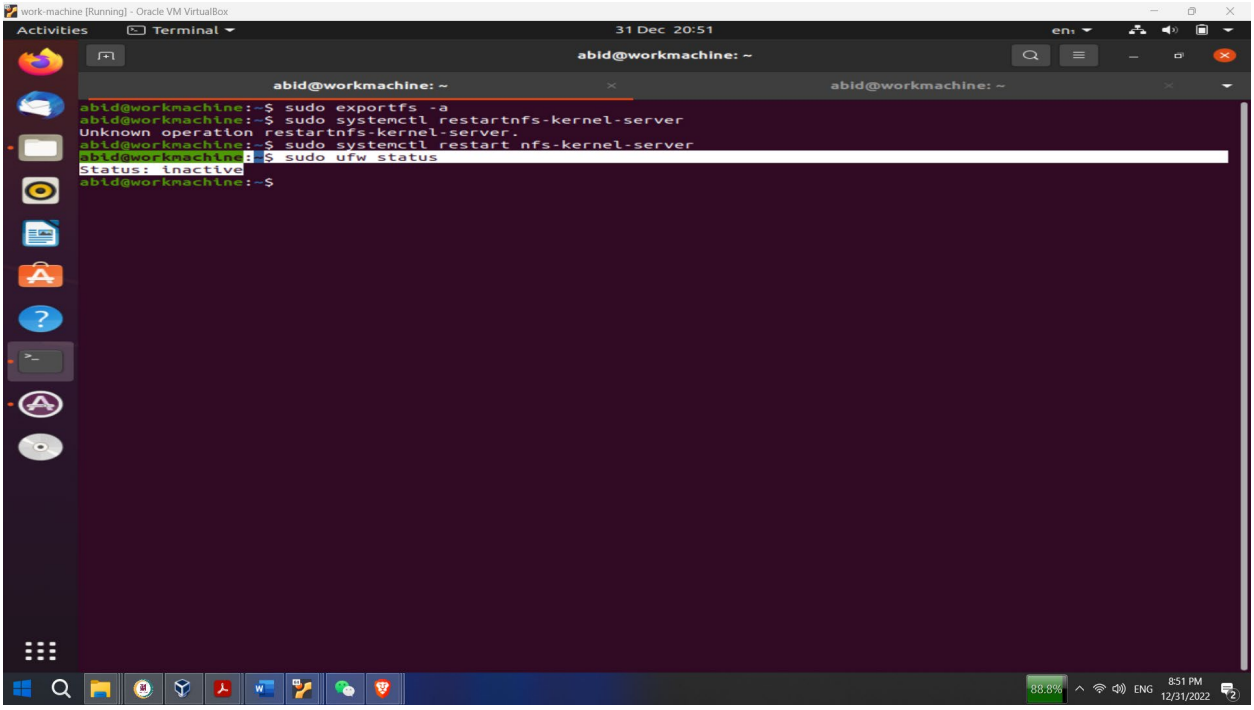
Export shared directory and restart server

sudo exportfs -a

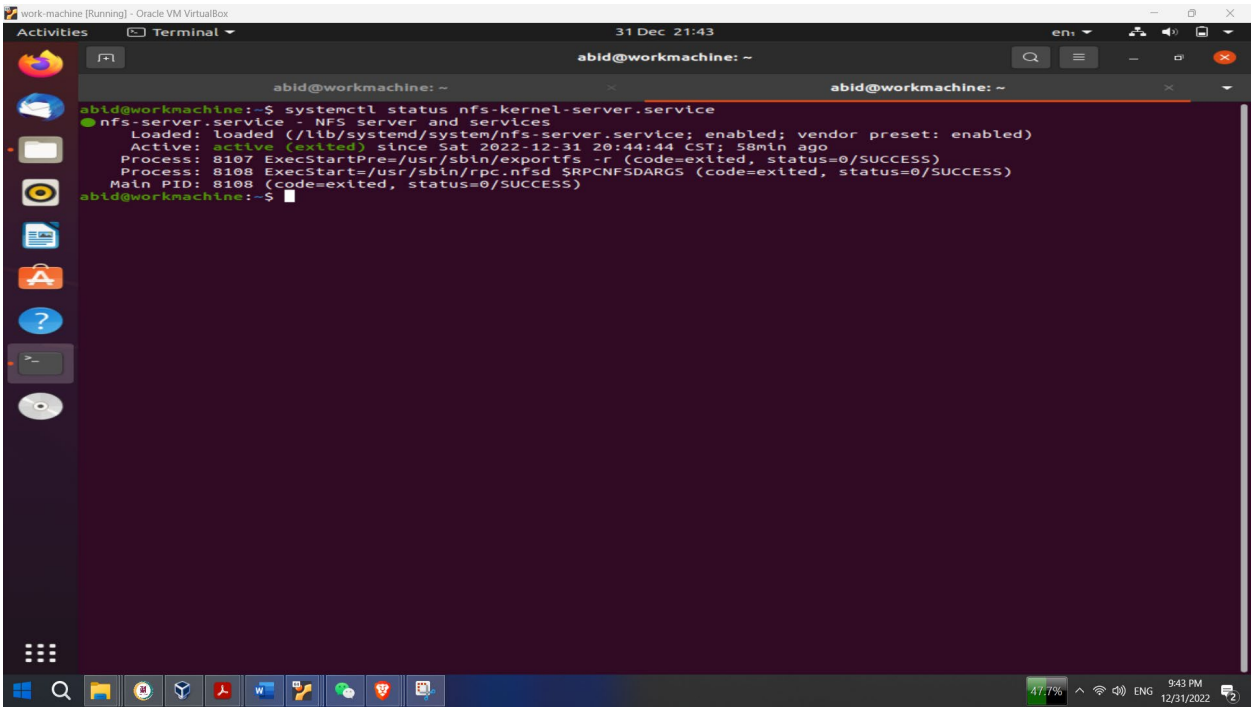
sudo systemctl restart nfs-kernel-server



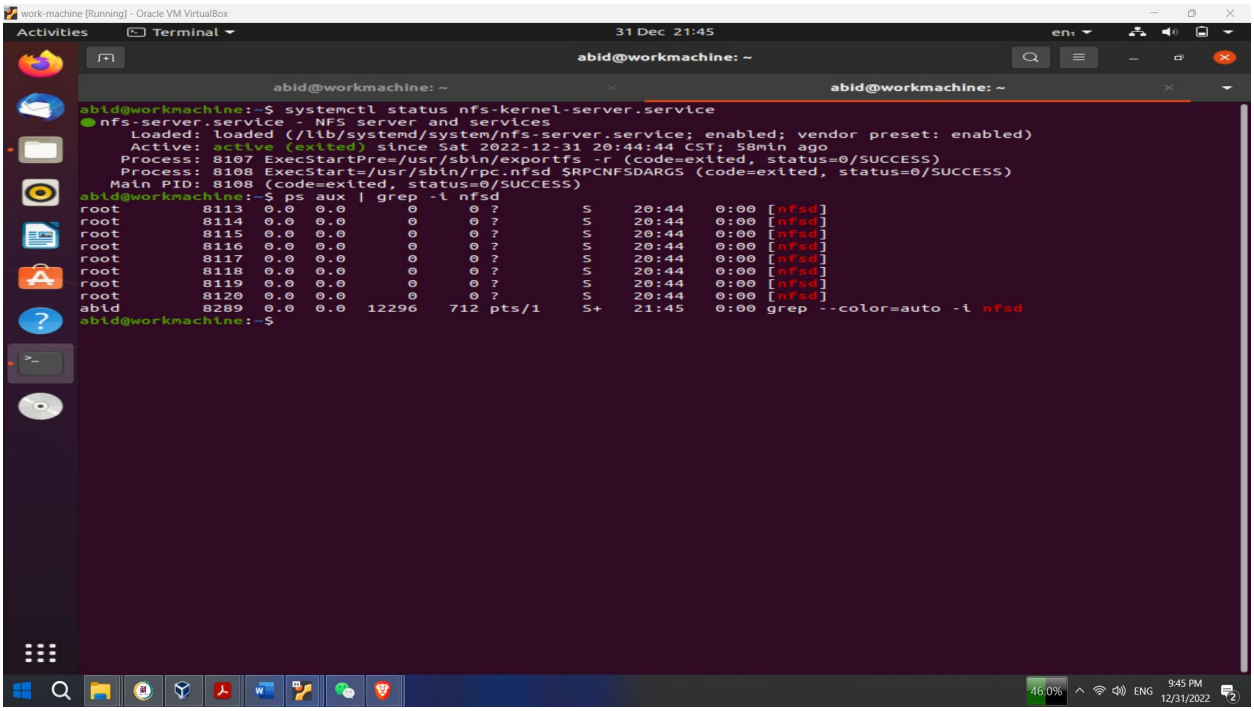
8.4 Checking Firewall Status



8.5 status nfs-kernel-server.service



systemctl status nfs-kernel-server.service

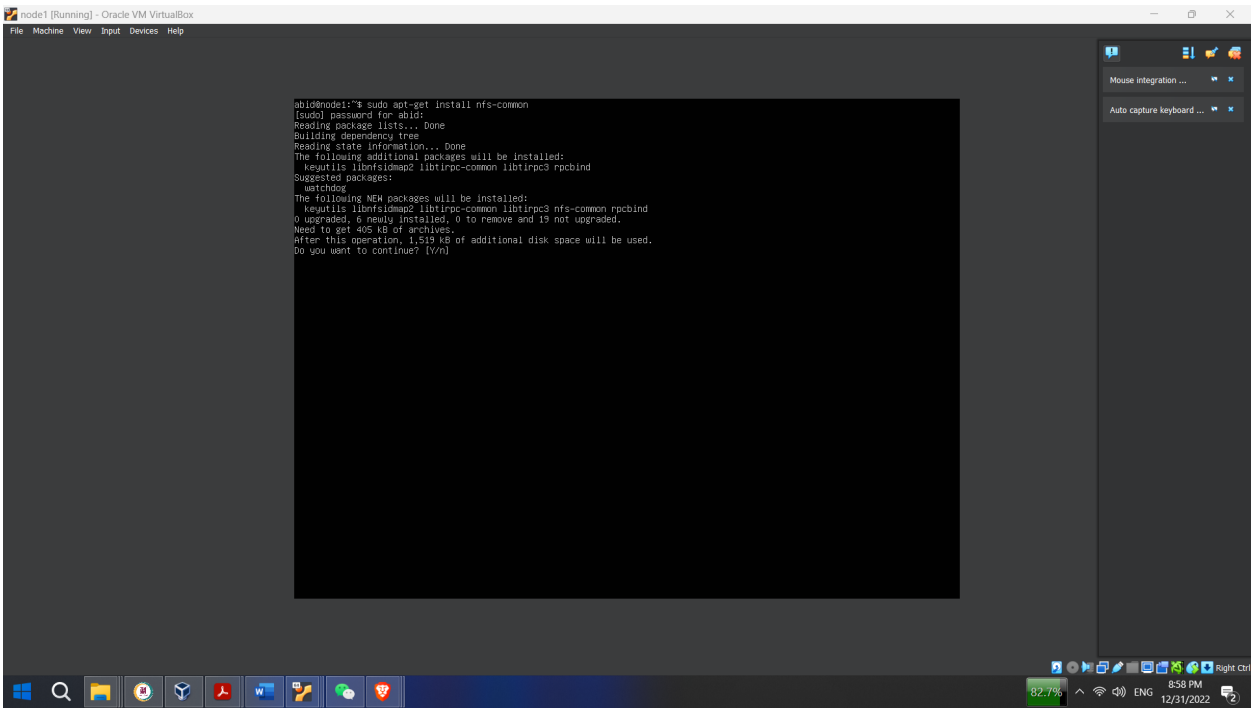


ps aux | grep -i nfsd

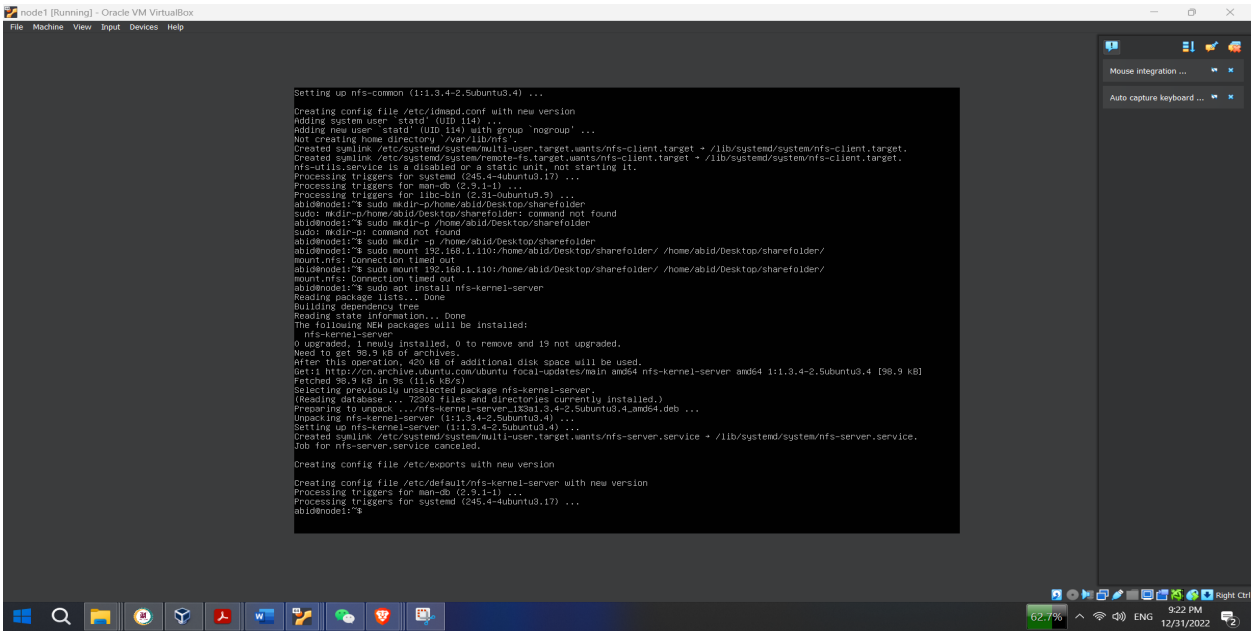
8.6 Install nfs client as slave node 1 and node2

Installing nfs client,run:

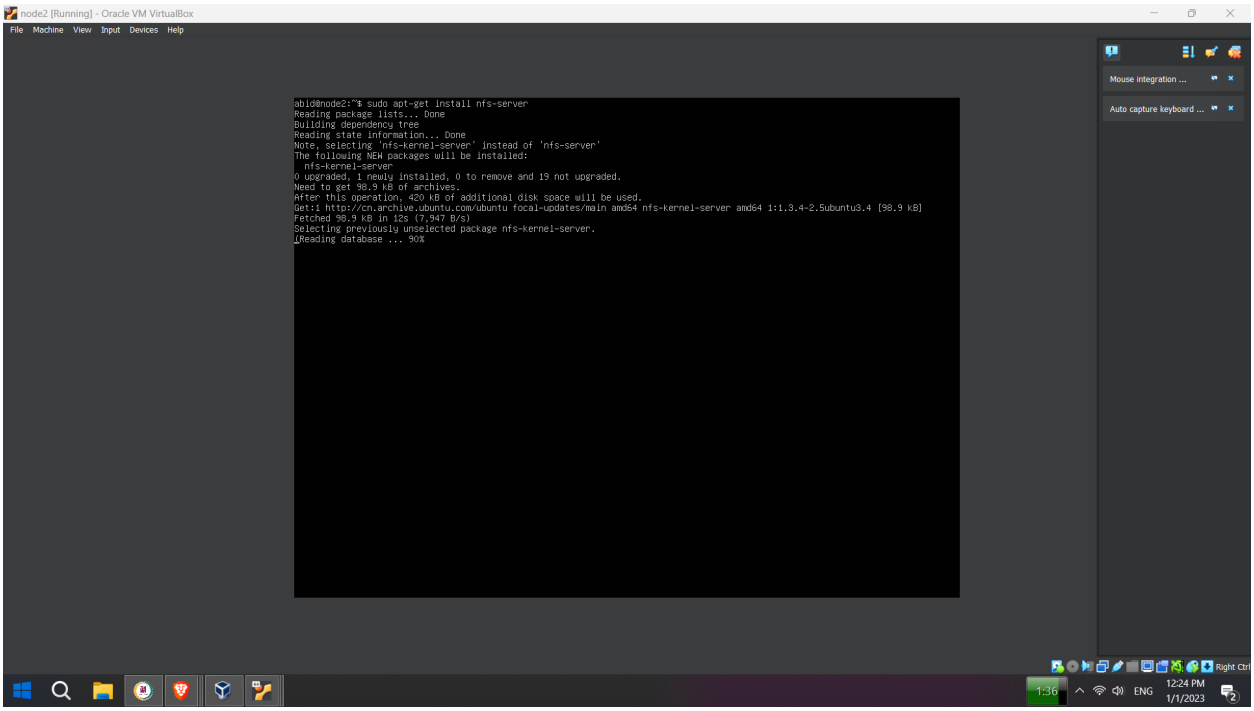
Node1



sudo apt-get install nfs-common



sudo apt install nfs-kernel-server

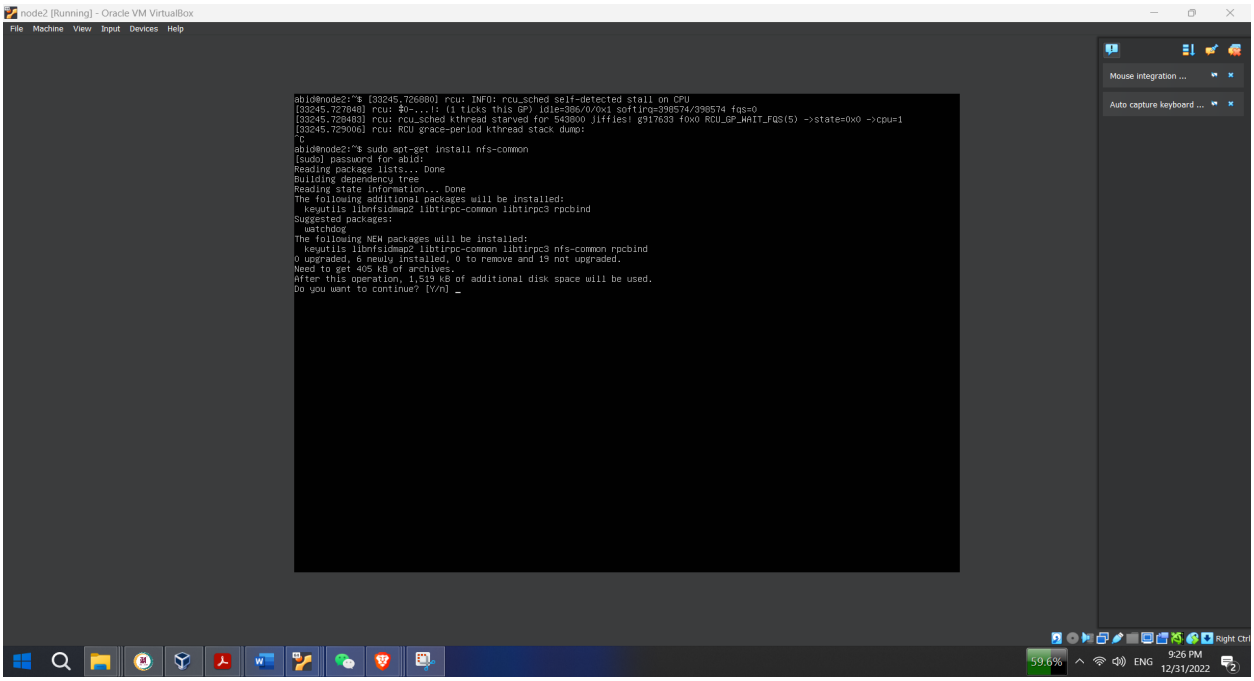


Sudo apt-get install nfs server

Installing nfs client,run:

Node2

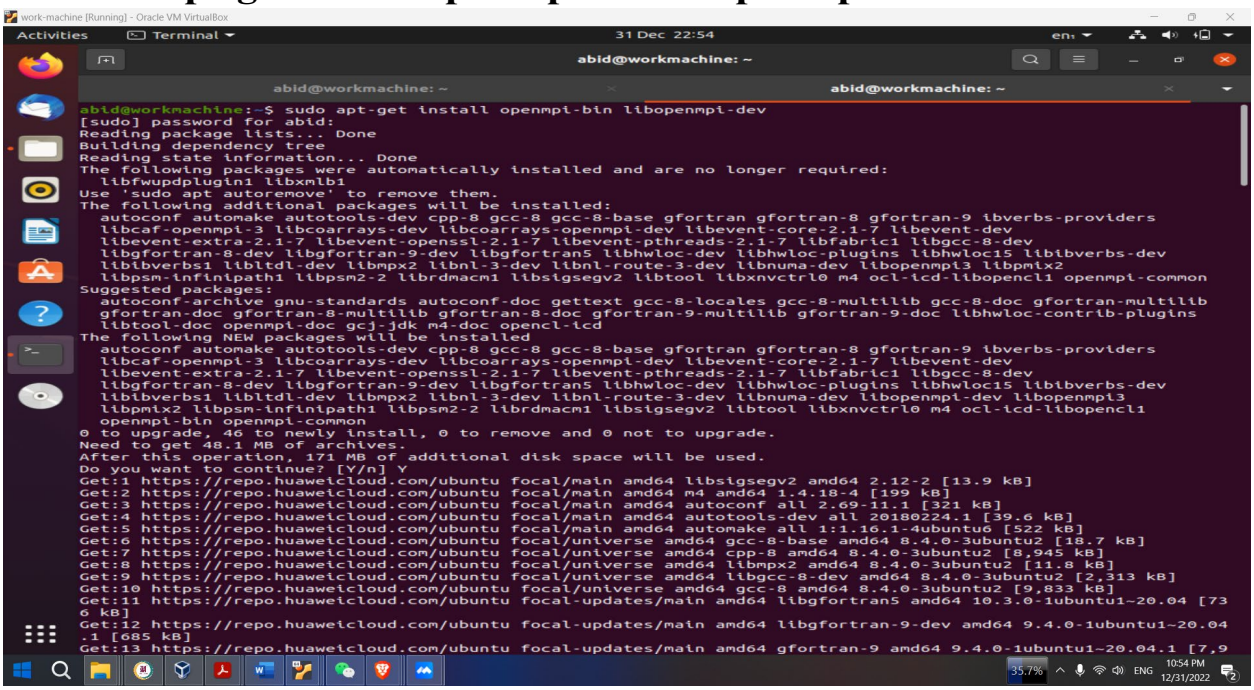
Installing nfs client,run:



sudo apt-get install nfs-common

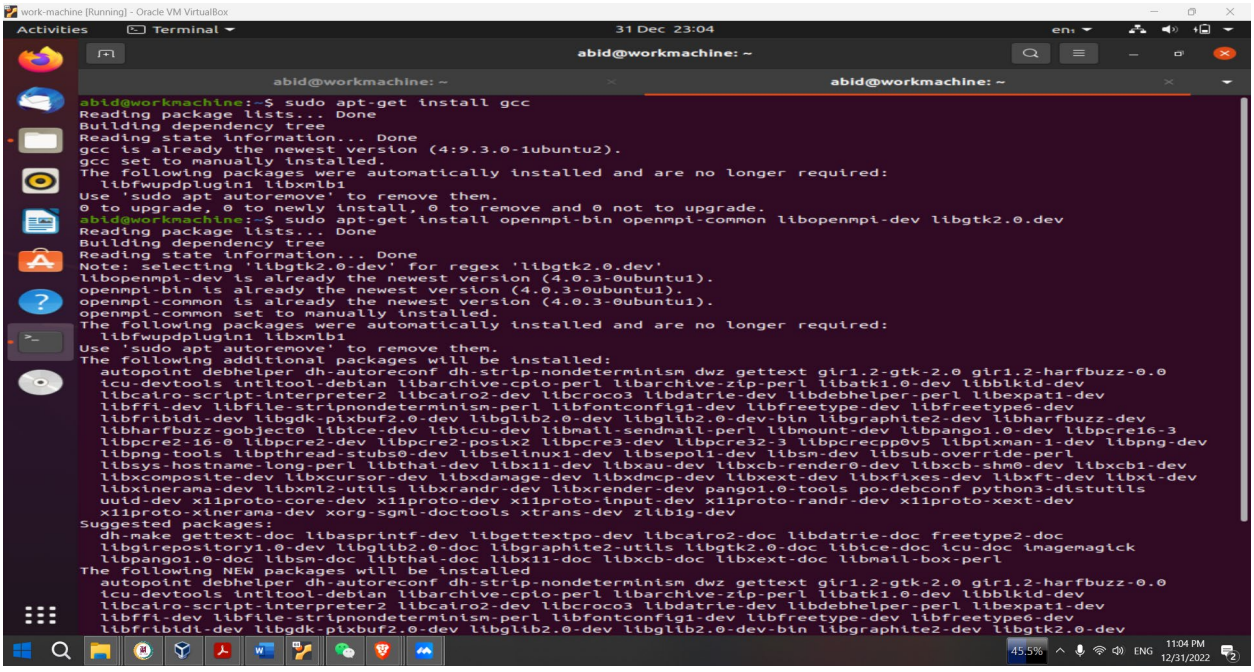
9.MPI

9.1 sudo apt-get install openmpi-bin libopenmpi-dev



sudo apt-get install openmpi-bin libopenmpi-dev

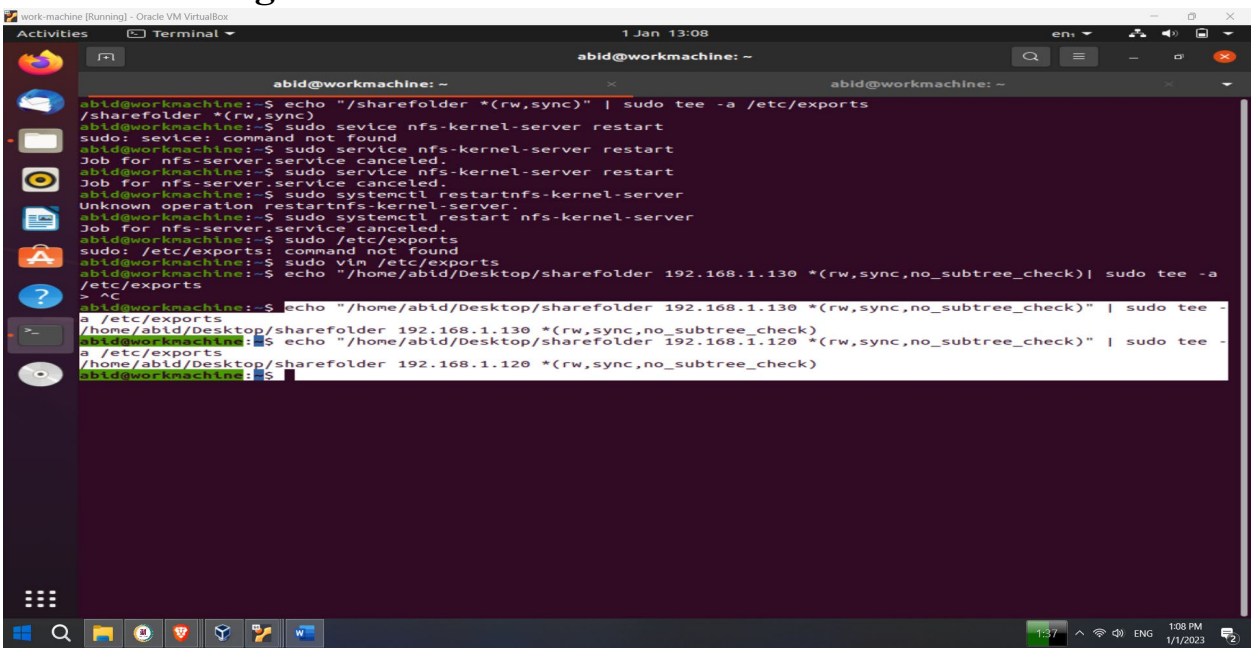
9.2 sudo apt-get install gcc



sudo apt-get install gcc

sudo apt-get install openmpi-bin openmpi-common libopenmpi-dev libgtk2.0.dev

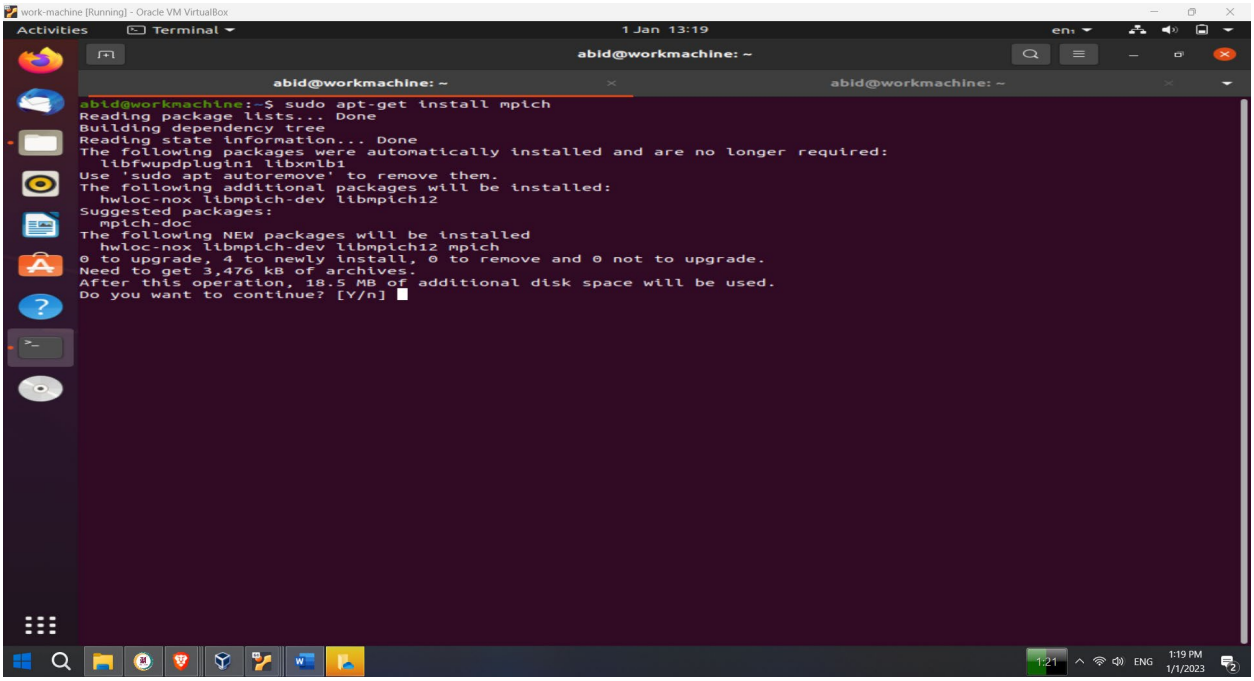
9.3 Connecting with Sharedfolder



echo "/home/abid/Desktop/sharefolder 192.168.1.130 *(rw,sync,no_subtree_check)" | sudo tee -a /etc/exports

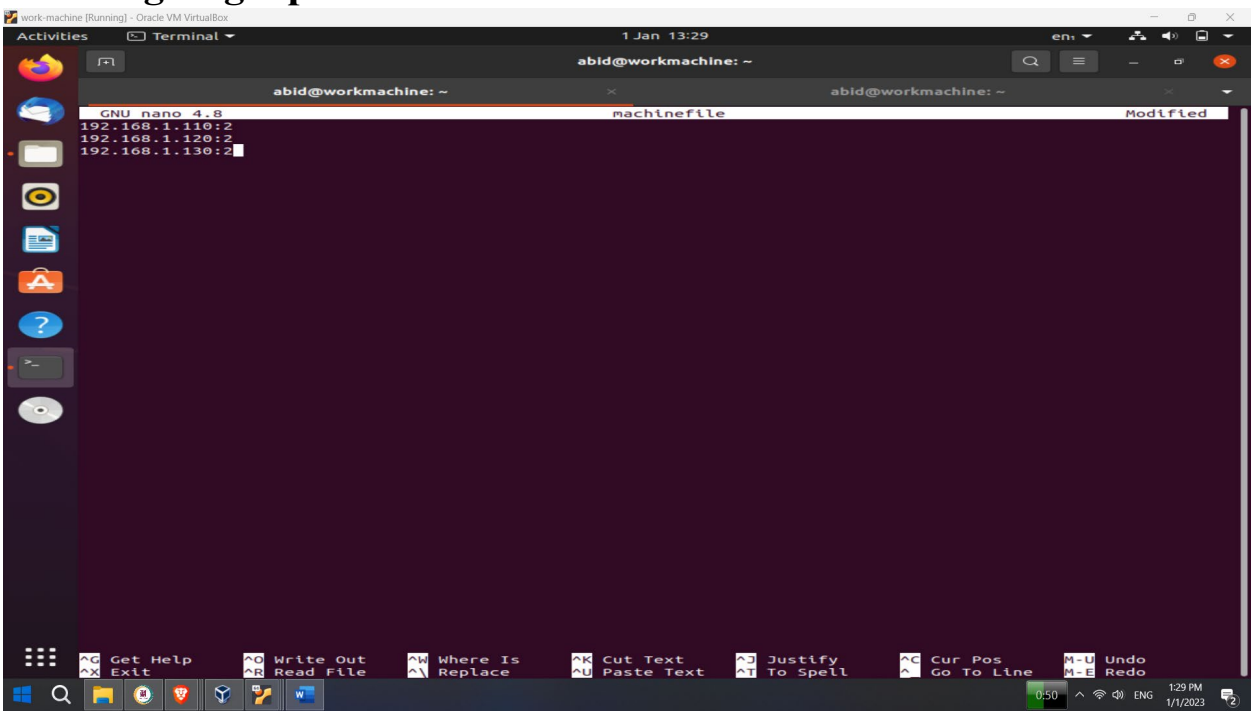
echo "/home/abid/Desktop/sharefolder 192.168.1.120 *(rw,sync,no_subtree_check)" | sudo tee -a /etc/exports

9.4 sudo apt-get install mpich

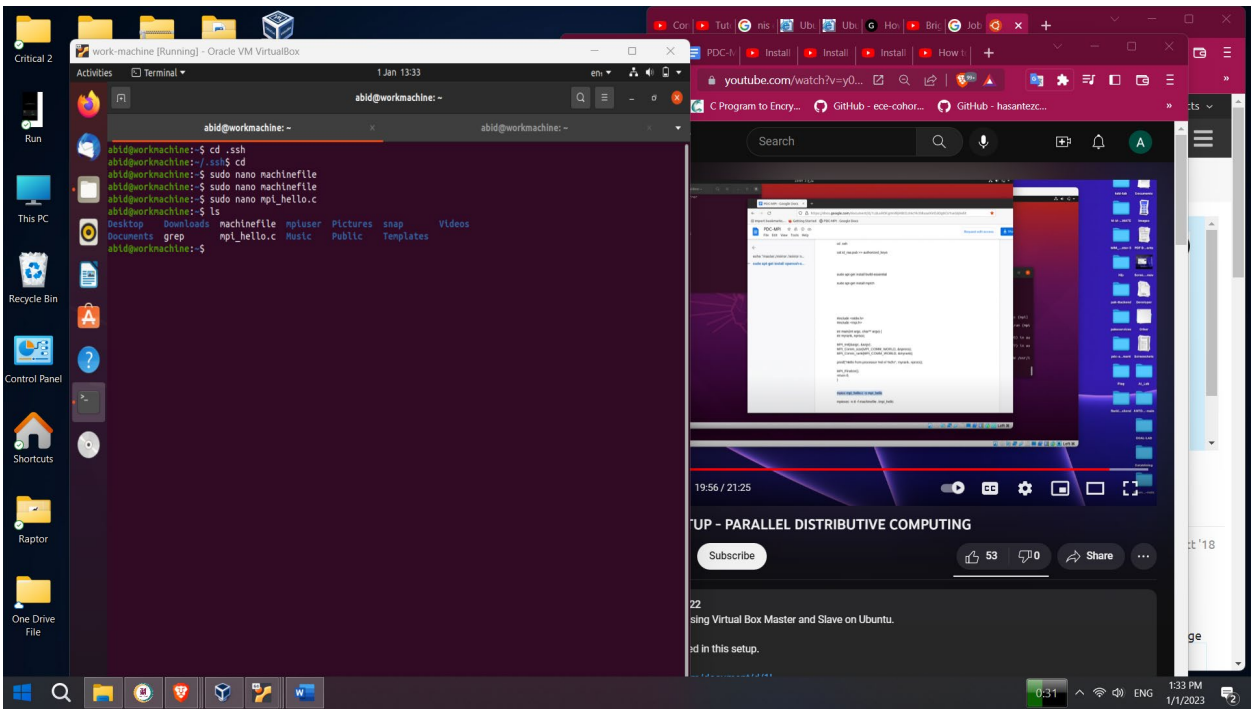


sudo apt-get install mpich

9.5 Assigning 2 processor for each node



2 processor given

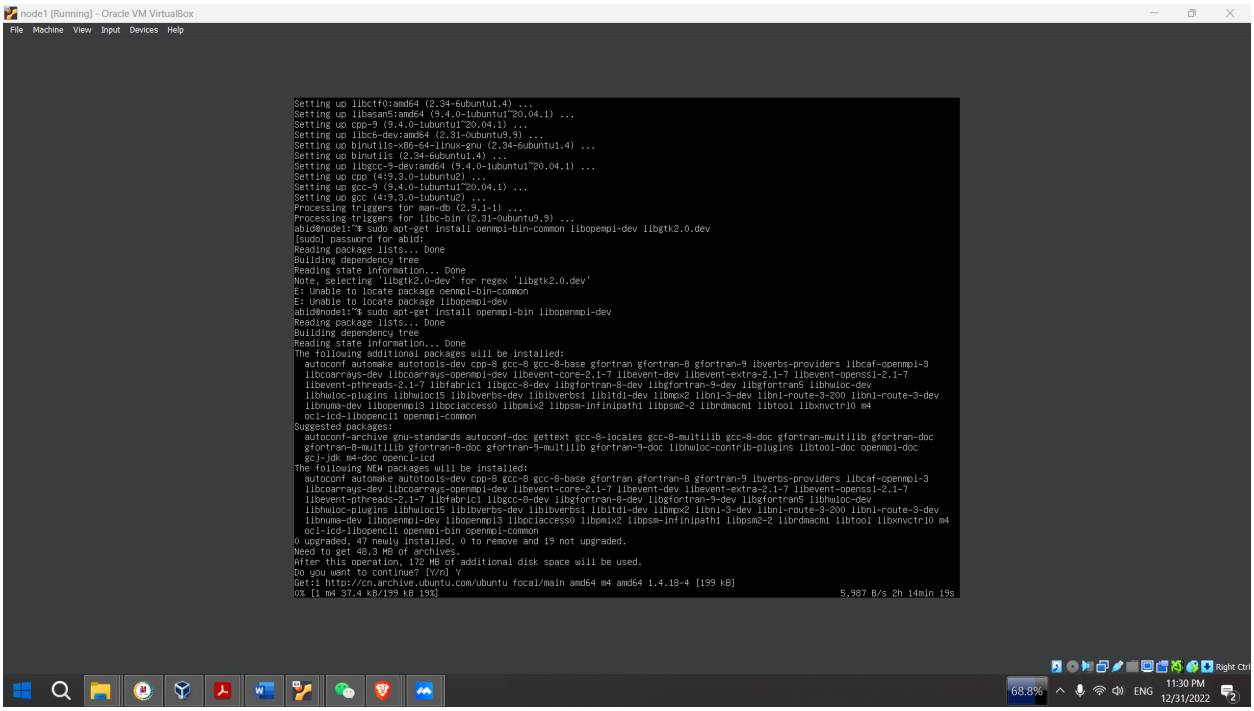


9.6 Node 1

```
abid@node1:~$ sudo apt-get install gcc
[sudo] password for abid:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following additional packages will be installed:
  binutils binutils-common binutils-x86-64-linux-gnu cpp cpp-9 gcc-9 gcc-9-base libasan5 libatomic1 libbinutils libc-dev-bin
  libc6-dev libcc1-0 libcrypt-dev libctf-nobfd0 libctf0 libgcc-9-dev libgomp1 libisl22 libitm1 liblsan0 libmpc3 libquadmath0
  libtsan0 libubsan1 linux-libc-dev manpages-dev
Suggested packages:
  binutils-doc cpp-doc gcc-9-locales gcc-multilib make autoconf automake libtool flex bison gdb gcc-doc gcc-9-multilib
  gcc-9-doc glibc-doc
The following NEW packages will be installed:
  binutils binutils-common binutils-x86-64-linux-gnu cpp cpp-9 gcc gcc-9 gcc-9-base libasan5 libatomic1 libbinutils
  libc-dev-bin libc6-dev libcc1-0 libcrypt-dev libctf-nobfd0 libctf0 libgcc-9-dev libgomp1 libisl22 libitm1 liblsan0 libmpc3
  libquadmath0 libtsan0 libubsan1 linux-libc-dev manpages-dev
0 upgraded, 28 newly installed, 0 to remove and 19 not upgraded.
Need to get 34.0 MB of archives.
After this operation, 150 MB of additional disk space will be used.
Do you want to continue? [Y/n] Y
Get:1 http://cn.archive.ubuntu.com/ubuntu focal-updates/main amd64 binutils-common amd64 2.34-6ubuntu1.4 [207 kB]
Get:2 http://cn.archive.ubuntu.com/ubuntu focal-updates/main amd64 libbinutils amd64 2.34-6ubuntu1.4 [474 kB]
Get:3 http://cn.archive.ubuntu.com/ubuntu focal-updates/main amd64 libctf-nobfd0 amd64 2.34-6ubuntu1.4 [47.2 kB]
Get:4 http://cn.archive.ubuntu.com/ubuntu focal-updates/main amd64 libctf0 amd64 2.34-6ubuntu1.4 [46.6 kB]
Get:5 http://cn.archive.ubuntu.com/ubuntu focal-updates/main amd64 binutils-x86-64-linux-gnu amd64 2.34-6ubuntu1.4 [1,613 kB]
Get:6 http://cn.archive.ubuntu.com/ubuntu focal-updates/main amd64 binutils amd64 2.34-6ubuntu1.4 [3,380 B]
Get:7 http://cn.archive.ubuntu.com/ubuntu focal-updates/main amd64 gcc-9-base amd64 9.4.0-1ubuntu1~20.04.1 [19.4 kB]
Get:8 http://cn.archive.ubuntu.com/ubuntu focal/main amd64 libisl22 amd64 0.22.1-1 [592 kB]
Get:9 http://cn.archive.ubuntu.com/ubuntu focal/main amd64 libmpc3 amd64 1.1.0-1 [40.8 kB]
Get:10 http://cn.archive.ubuntu.com/ubuntu focal-updates/main amd64 cpp-9 amd64 9.4.0-1ubuntu1~20.04.1 [7,500 kB]
24% [10 cpp-9 4,236 kB/7,500 kB 56%]                                                                    22.2 kB/s 20min 1s
```

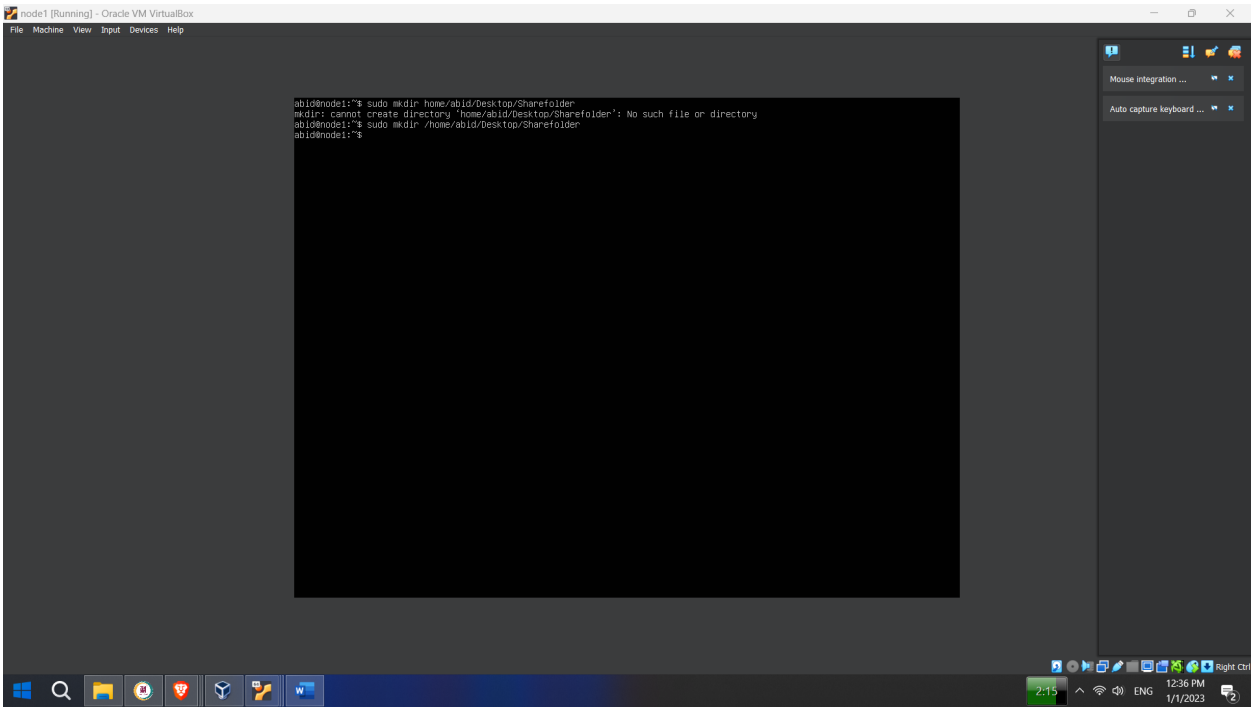
sudo apt-get install gcc

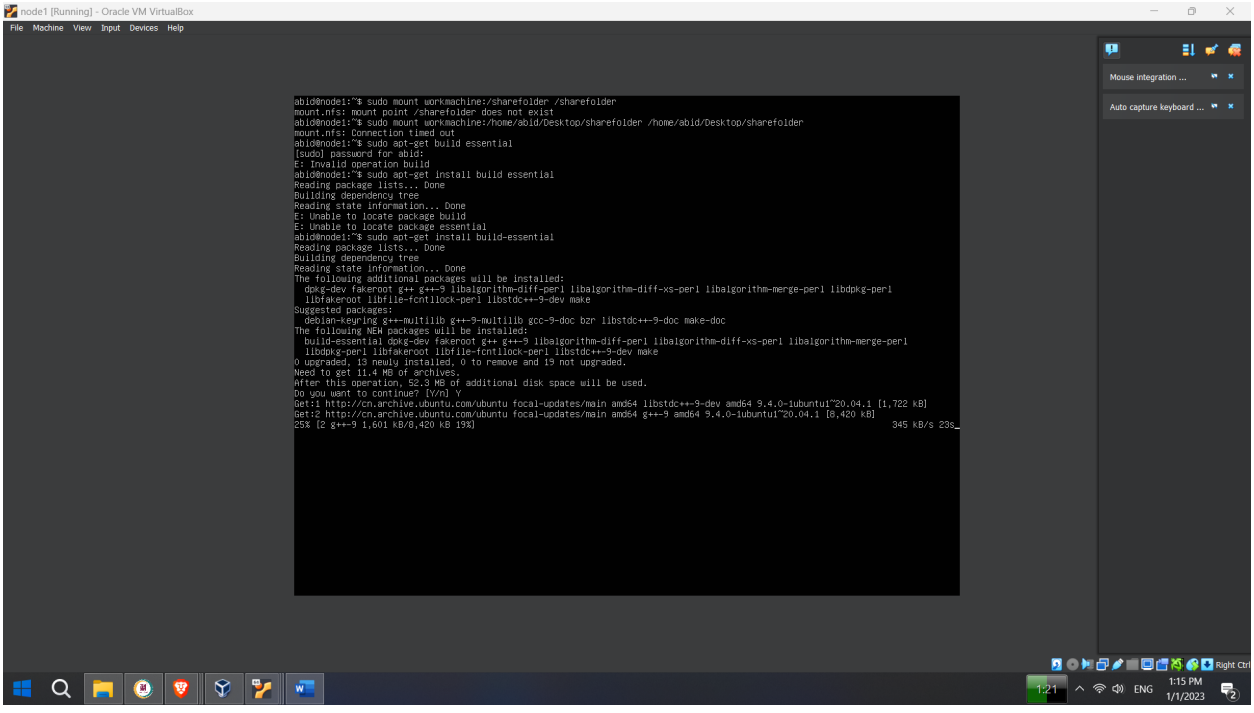
sudo apt-get install openmpi-bin openmpi-common libopenmpi-dev libgtk2.0.dev



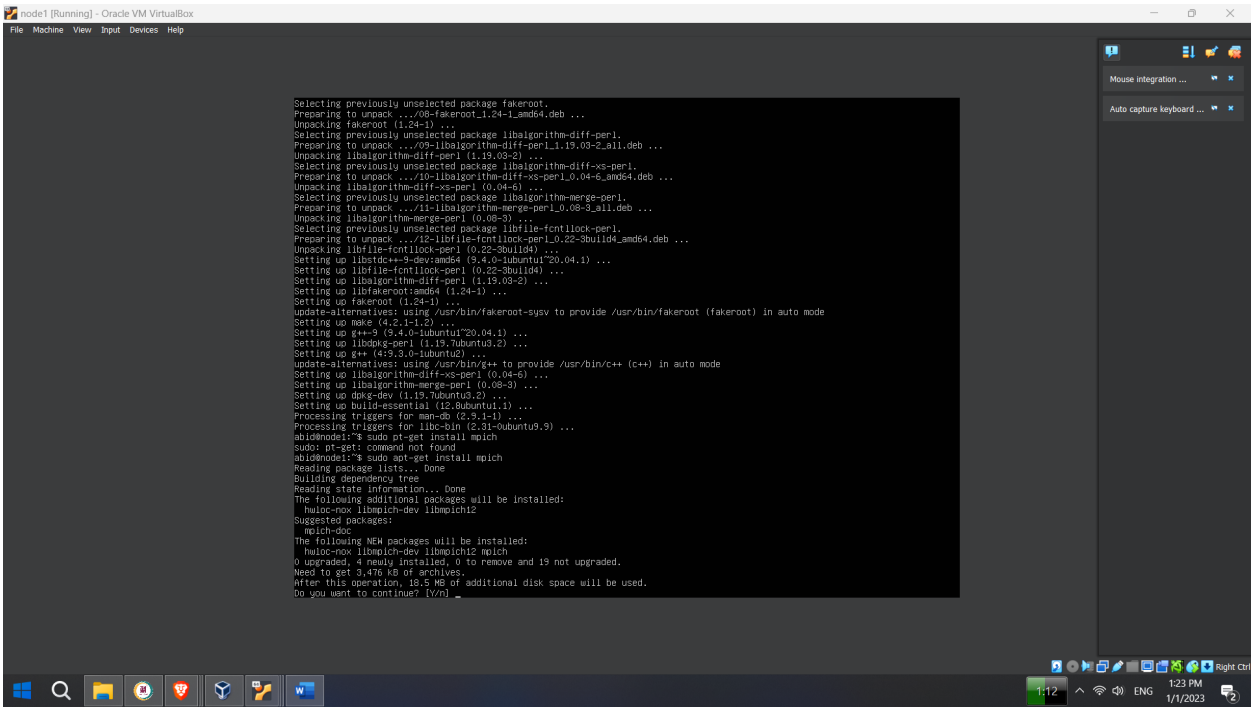
sudo apt-get install openmpi-bin libopenmpi-dev

Make Folder



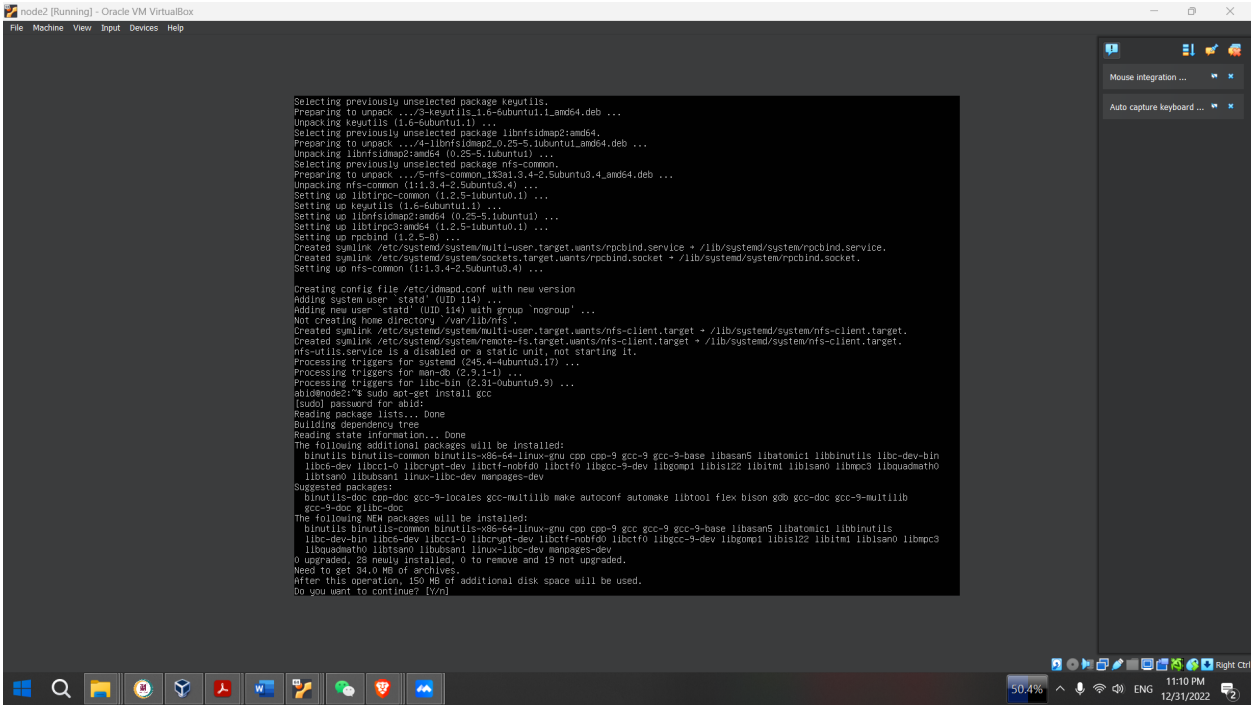


sudo apt-get install build-essential



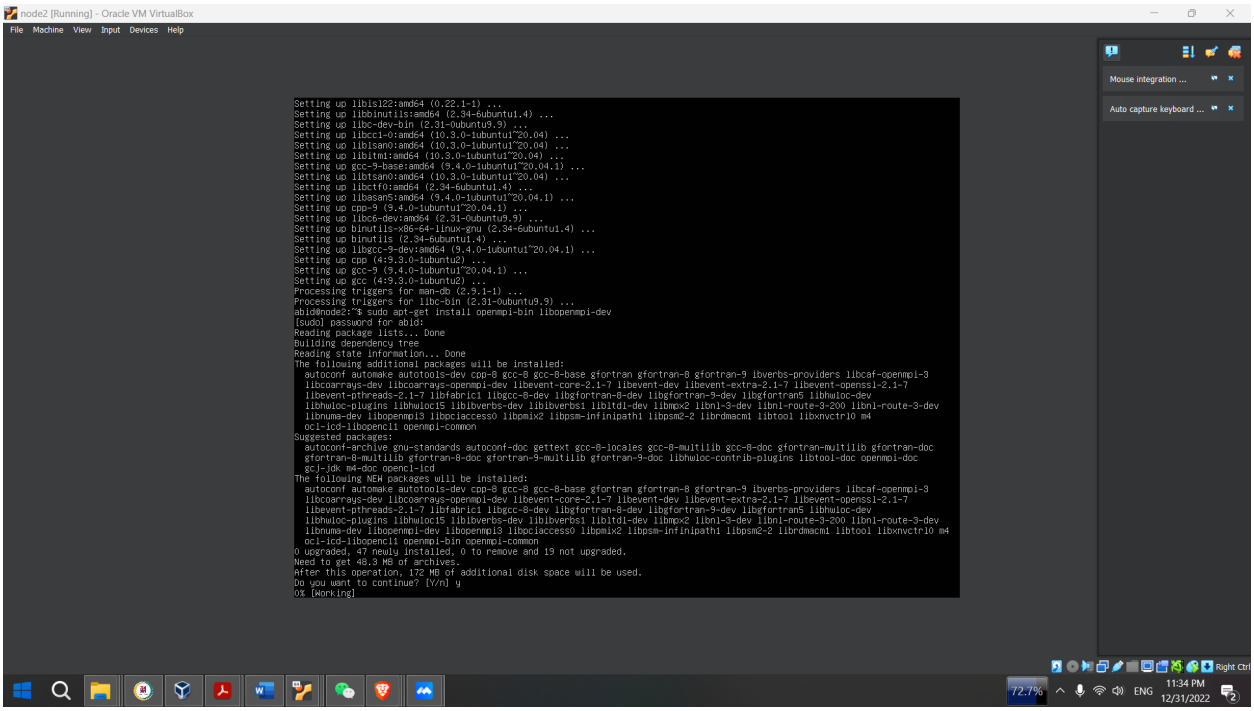
sudo apt-get install mpich

9.7 Node 2

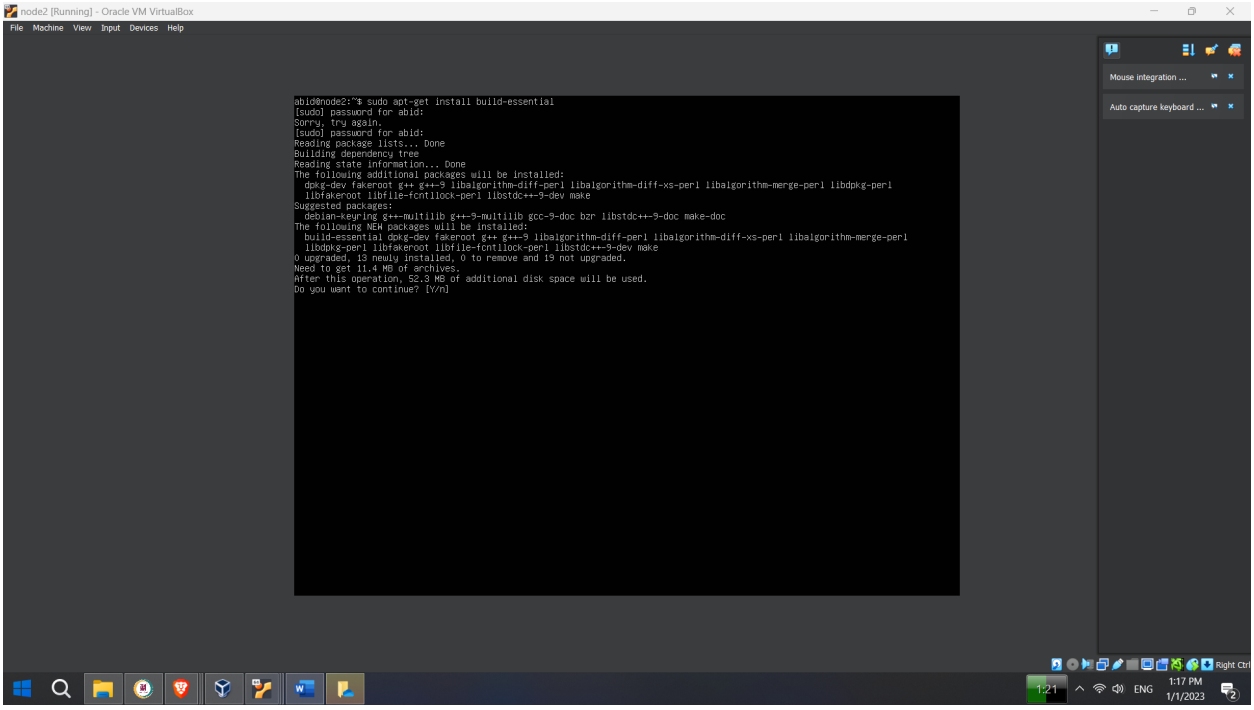


sudo apt-get install gcc

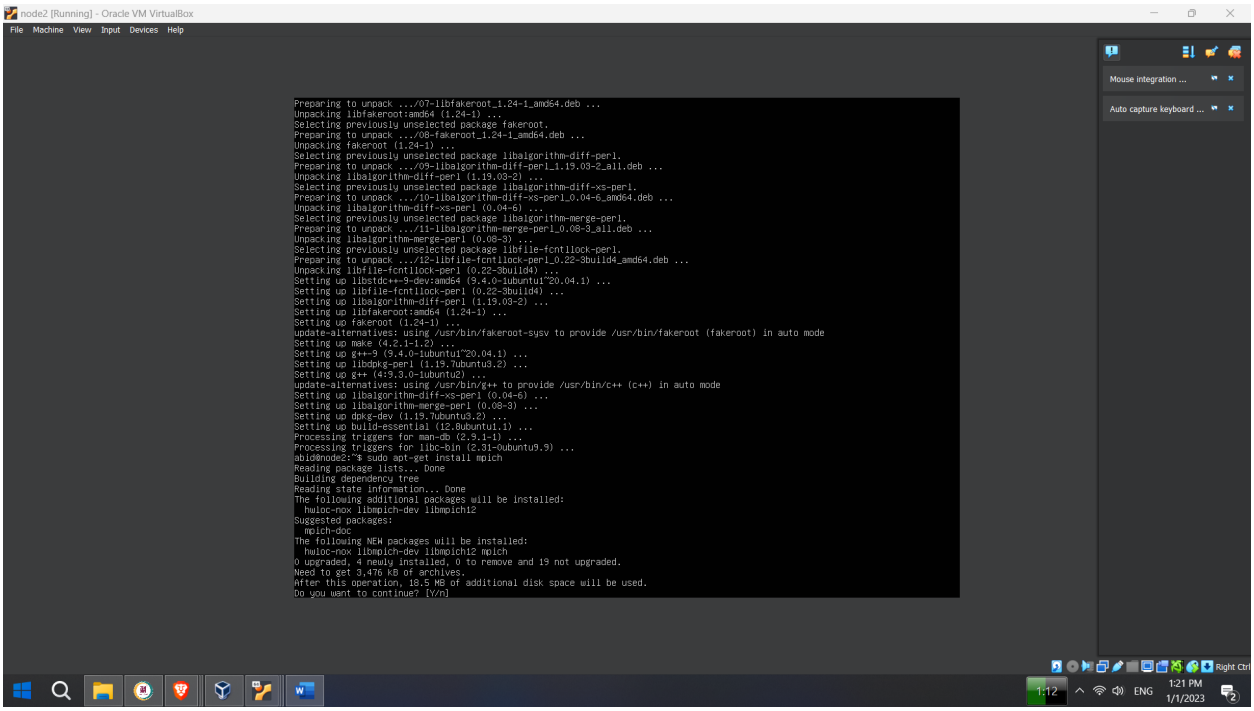
sudo apt-get install openmpi-bin openmpi-common libopenmpi-dev libgtk2.0.dev



sudo apt-get install openmpi-bin libopenmpi-dev

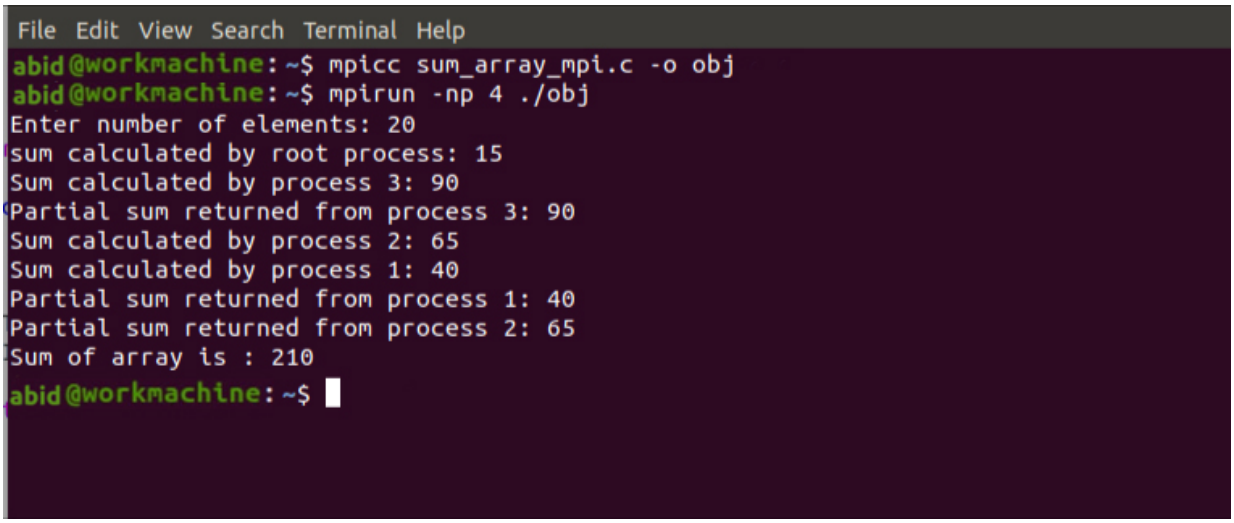


sudo apt-get install build-essential



sudo apt-get install mpich

9.8 Result



```
abid@workmachine:~$ sudo apt-get install  openmpi-bin libopenmpi-dev
[sudo] password for amir:
Reading package lists... Done
Building dependency tree
Reading state information... Done
libopenmpi-dev is already the newest version (4.0.3-0ubuntu1).
openmpi-bin is already the newest version (4.0.3-0ubuntu1).
The following packages were automatically installed and are no longer required:
  chromium-codecs-ffmpeg-extra gstreamer1.0-vaapi
  libgstreamer-plugins-bad1.0-0 libva-wayland2
Use 'sudo apt autoremove' to remove them.
0 upgraded, 0 newly installed, 0 to remove and 8 not upgraded.
abid@workmachine:~$ cd /home/amir/Desktop
abid@workmachine:~/Desktop$ cd /home/amir/Desktop
abid@workmachine:~/Desktop$ cd openmpi-4.1.1/
abid@workmachine:~/Desktop/openmpi-4.1.1$ ./configure --prefix="/home/amir/.openmpi"
checking for perl... perl

==========================================================================
== Configuring Open MPI
==========================================================================

*** Startup tests
checking build system type... x86_64-pc-linux-gnu
checking host system type... x86_64-pc-linux-gnu
checking target system type... x86_64-pc-linux-gnu
checking for gcc... gcc
checking whether the C compiler works... yes
checking for C compiler default output file name... a.out
checking for suffix of executables...
checking whether we are cross compiling... no
checking for suffix of object files... o
checking whether we are using the GNU C compiler... yes
checking whether gcc accepts -g... yes
checking for gcc option to accept ISO C89... none needed
checking whether gcc understands -c and -o together... yes
checking how to run the C preprocessor... gcc -E
checking for grep that handles long lines and -e... /usr/bin/grep
checking for egrep... /usr/bin/grep -E
checking for ANSI C header files... yes
checking for sys/types.h... yes
checking for sys/stat.h... yes
checking for stdlib.h... yes
```

```
abid@workmachine: ~/sharedfolder
abid@workmachine:~/sharedfolder$ mpicc MPIserver.c -o MPIserver
abid@workmachine:~/sharedfolder$ mpirun -np 1 ./MPIserver
Server available at port: 2168455169.0:2560756268
Enter the string :
AVINASH

Reversed string is : HSANIVA
```

```
abid@workmachine: ~/sharedfolder
abid@workmachine:~/sharedfolder$ mpicc MPIclient.c -o MPIclient
abid@workmachine:~/sharedfolder$ mpirun -np 1 ./MPIclient 2166161409.0:1627668610
```

10. Conclusion

I have created virtual cluster in my computer and continued through the processes simultaneously. Being completely new to parallel computing, while creating virtual cluster we might run into complexities in the later stages that might require to start all over again. To eliminate the risk, I have done the complete processes in the computer and successfully completed all the tasks. Hence, I solved the project alone.

11.Acknowledgement

During the process I have faced many obstacles and problems that took countless hours of searching and trials but at the end I was happy to learn the vital skills of parallel computing and thankful to our teacher who have taught us really well and provided us with the best possible resources.

11. Reference

(a) https://ubuntu.com/download/server

(b) https://releases.ubuntu.com/20.04/ubuntu-20.04.5-desktop-amd64.iso.torrent

(c) https://www.server-world.info/en/note?os=Ubuntu_20.04&p=nis&f=2

(d) https://www.thegeekdiary.com/how-to-configure-nis-network-information-system-master-and-slave-servers-in-centos-rhel/

(e) https://www.server-world.info/en/note?os=Ubuntu_20.04&p=nis&f=2

(f) https://www.youtube.com/watch?v=8DodjQ7QmsI&ab_channel=SelfTuts

(e) https://youtu.be/-t4k6IwmtFI