

LAPORAN EKSEKUSI NUMERIK SOLUTIONS DENGAN OPEN MPI PADA UBUNTU DESKTOP

Disusun untuk memenuhi tugas Mata Kuliah Pemrosesan Paralel



Disusun Oleh :

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Dosen Pengampu :

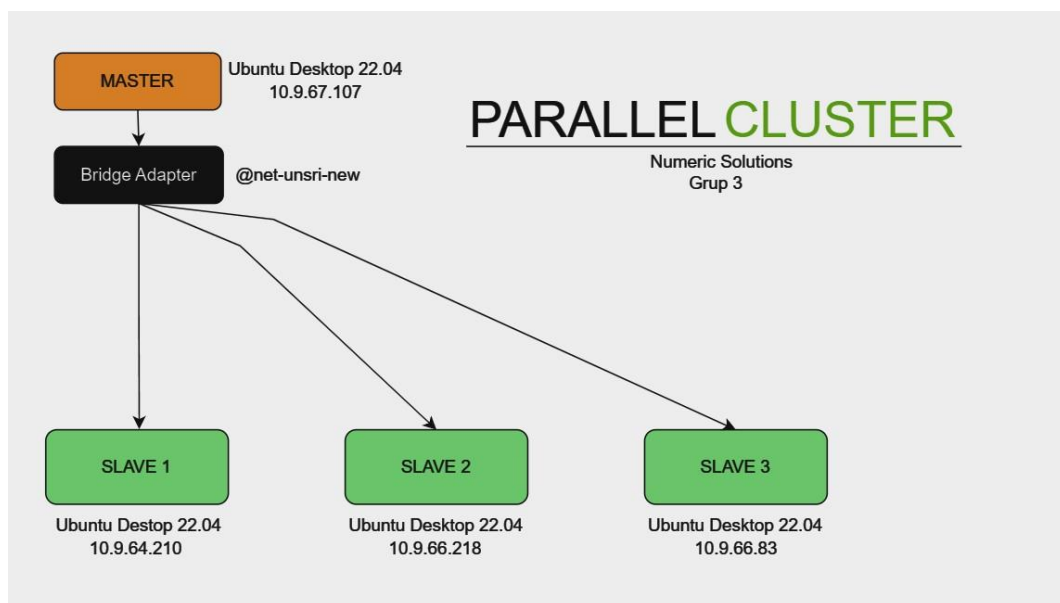
Adi Hermansyah, S.Kom., M.T.

**PROGRAM STUDI SISTEM KOMPUTER
FAKULTAS ILMU KOMPUTER
UNIVERSITAS SRIWIJAYA
2023**

DEVICE DAN TOOLS YANG PERLU DISIAPKAN

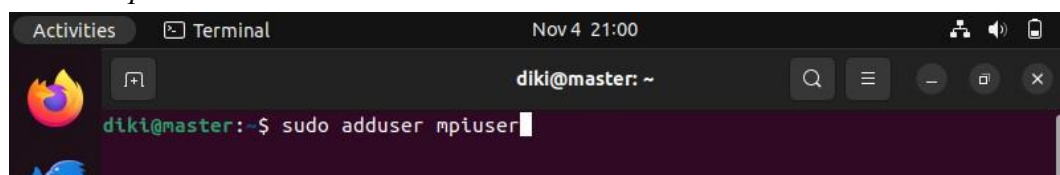
1. Ubuntu Desktop
 - Ubuntu Desktop Master
 - Ubuntu Desktop Slave 1
 - Ubuntu Desktop Slave 2
 - Ubuntu Desktop Slave 3
2. MPI (Master dan Slave)
3. SSH (Master dan Slave)
4. NFS (Master dan Slave)
5. Kodingan Numerik Python

TOPOLOGI BRIDGED



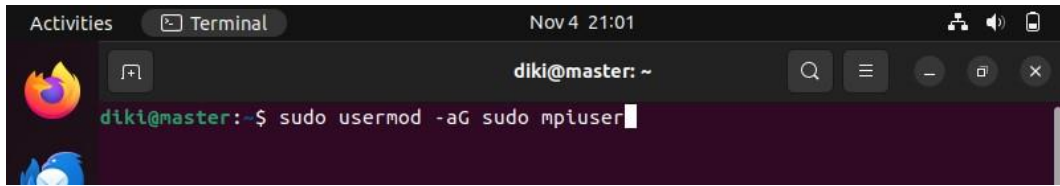
PEMBUATAN MASTER DAN SLAVE

1. Sebelum menginstal pastikan master dan setiap slave menggunakan Network Bridge Adapter, dan menggunakan internet yang sama
2. Tentukanlah device mana yang sebagai master, slave1, slave2, slave3
3. Pertama, buatlah user baru dengan perintah dibawah ini **diki@master:~\$ sudo adduser mpiuser**



Untuk dislave perintahnya sama, ganti bagian master menjadi slave1, slave2, dst.

4. Kemudian berikan akses kepada root dengan perintah dibawah ini *diki@master:~\$ sudo usermod -aG sudo mpiuser*

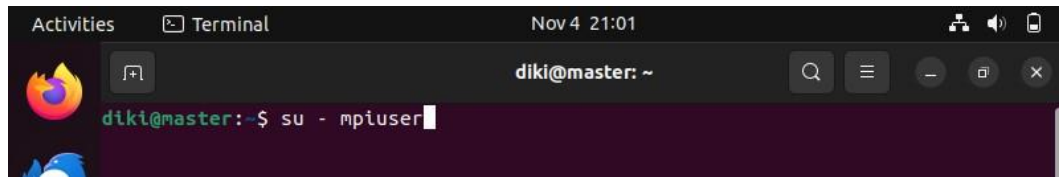


```
diki@master:~$ sudo usermod -aG sudo mpiuser
```

Lakukanlah perintah diatas disemua slave dengan merubah user master menjadi slave1, slave2, dst

5. Masuklah ke server dengan user dibawah ini dengan perintah berikut

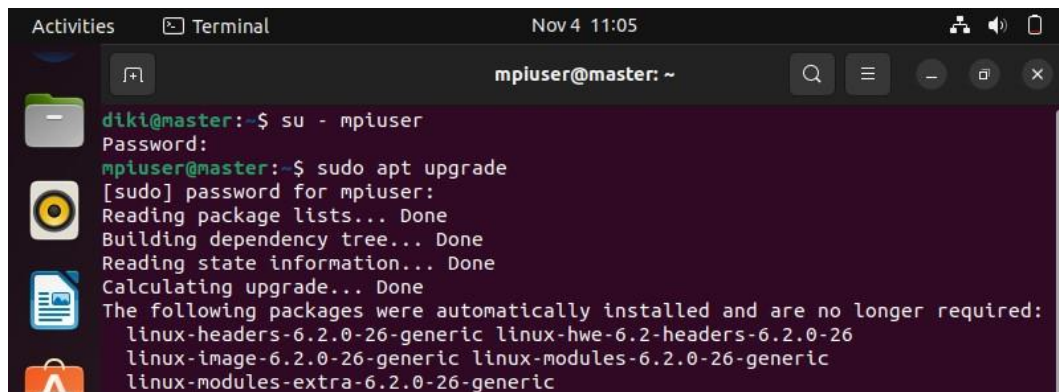
diki@master:~\$ su - mpiuser



```
diki@master:~$ su - mpiuser
```

Menjadi *mpiuser@master:~\$*

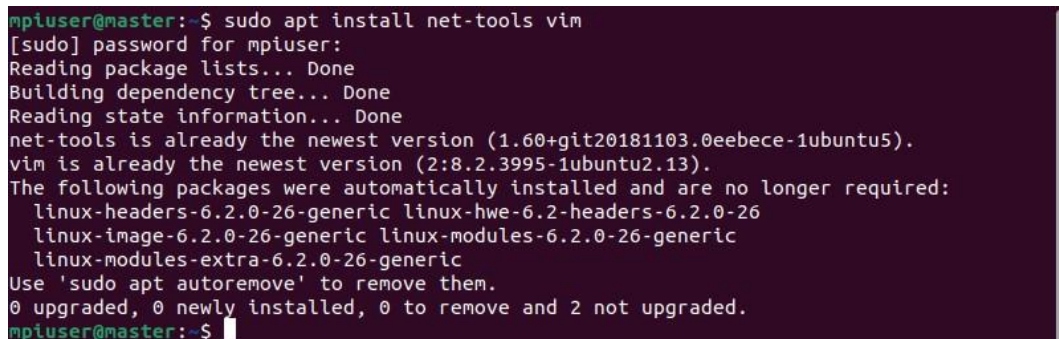
6. Langkah selanjutnya update ubuntu desktop dengan perintah berikut, lalu install tools untuk mengecek Ip, vim editor teks *mpiuser@master:~\$ sudo apt update && sudo apt upgrade*



```
diki@master:~$ su - mpiuser
Password:
mpiuser@master:~$ sudo apt update
[sudo] password for mpiuser:
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
Calculating upgrade... Done
The following packages were automatically installed and are no longer required:
  linux-headers-6.2.0-26-generic linux-hwe-6.2-headers-6.2.0-26
  linux-image-6.2.0-26-generic linux-modules-6.2.0-26-generic
  linux-modules-extra-6.2.0-26-generic
```

Selanjutnya install tools dengan perintah dibawah ini *mpiuser@master:~\$*

sudo apt install net-tools vim

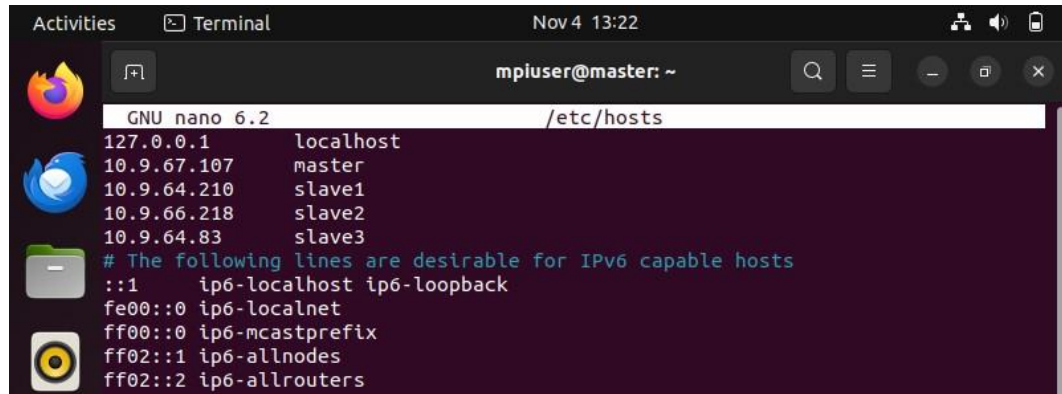


```
mpiuser@master:~$ sudo apt install net-tools vim
[sudo] password for mpiuser:
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
net-tools is already the newest version (1.60+git20181103.0eebece-1ubuntu5).
vim is already the newest version (2:8.2.3995-1ubuntu2.13).
The following packages were automatically installed and are no longer required:
  linux-headers-6.2.0-26-generic linux-hwe-6.2-headers-6.2.0-26
  linux-image-6.2.0-26-generic linux-modules-6.2.0-26-generic
  linux-modules-extra-6.2.0-26-generic
Use 'sudo apt autoremove' to remove them.
0 upgraded, 0 newly installed, 0 to remove and 2 not upgraded.
mpiuser@master:~$
```

7. Selanjutnya konfigurasi file pada master, slave1, slave2, dan slave3

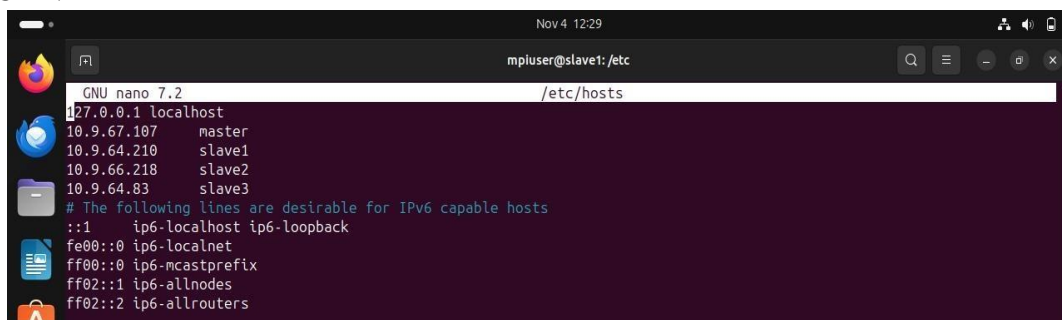
mpiuser@master:~\$ cd /etc/hosts

MASTER

A terminal window titled 'Activities Terminal' showing the contents of the /etc/hosts file on the master node. The window title bar includes the date 'Nov 4 13:22' and the user 'mpiuser@master: ~'. The terminal shows the file being edited with 'GNU nano 6.2'. The content of the file is as follows:

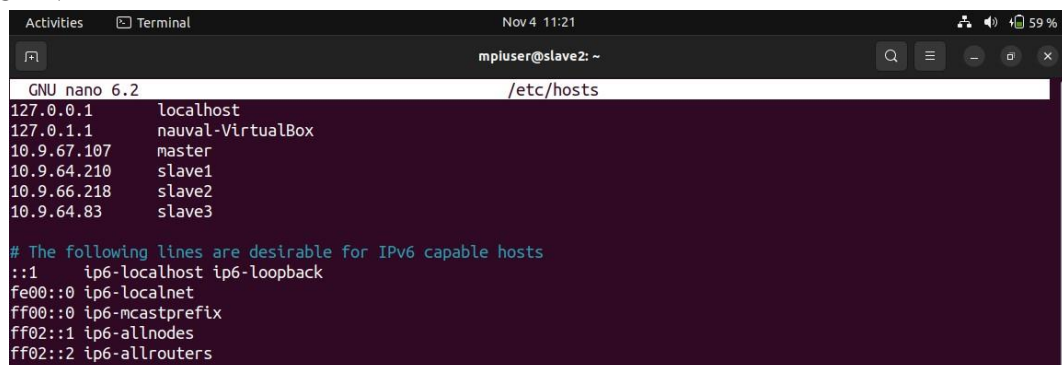
```
127.0.0.1 localhost
10.9.67.107 master
10.9.64.210 slave1
10.9.66.218 slave2
10.9.64.83 slave3
# The following lines are desirable for IPv6 capable hosts
::1 ip6-localhost ip6-loopback
fe00::0 ip6-localnet
ff00::0 ip6-mcastprefix
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters
```

SLAVE 1

A terminal window titled 'Activities Terminal' showing the contents of the /etc/hosts file on the slave1 node. The window title bar includes the date 'Nov 4 12:29' and the user 'mpiuser@slave1: /etc'. The terminal shows the file being edited with 'GNU nano 7.2'. The content of the file is as follows:

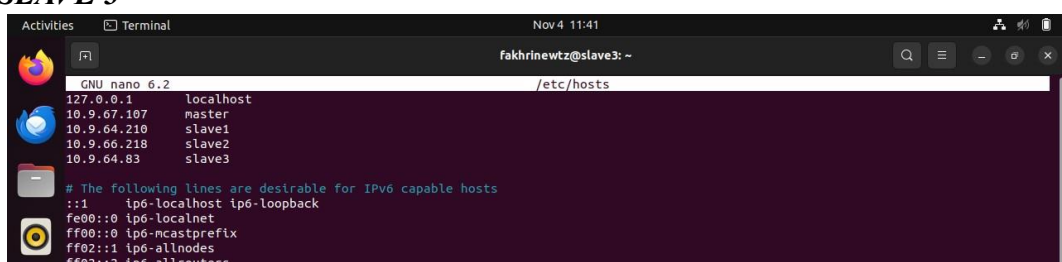
```
127.0.0.1 localhost
10.9.67.107 master
10.9.64.210 slave1
10.9.66.218 slave2
10.9.64.83 slave3
# The following lines are desirable for IPv6 capable hosts
::1 ip6-localhost ip6-loopback
fe00::0 ip6-localnet
ff00::0 ip6-mcastprefix
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters
```

SLAVE 2

A terminal window titled 'Activities Terminal' showing the contents of the /etc/hosts file on the slave2 node. The window title bar includes the date 'Nov 4 11:21' and the user 'mpiuser@slave2: ~'. The terminal shows the file being edited with 'GNU nano 6.2'. The content of the file is as follows:

```
127.0.0.1 localhost
127.0.1.1 nauval-VirtualBox
10.9.67.107 master
10.9.64.210 slave1
10.9.66.218 slave2
10.9.64.83 slave3
# 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
```

SLAVE 3

A terminal window titled 'Activities Terminal' showing the contents of the /etc/hosts file on the slave3 node. The window title bar includes the date 'Nov 4 11:41' and the user 'fakhrinewtz@slave3: ~'. The terminal shows the file being edited with 'GNU nano 6.2'. The content of the file is as follows:

```
127.0.0.1 localhost
10.9.67.107 master
10.9.64.210 slave1
10.9.66.218 slave2
10.9.64.83 slave3
# 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
```

Daftarkan IP Master dan Slave berserta hostname masing masing komputer

KONFIGURASI SSH

1. Langkah berikutnya kita akan konfigurasi SSH, pertama kita install SSH. Lakukan pada master dan semua slave ***mpiuser@master:~\$ sudo apt install openssh-server***

```
mpiuser@master:~$ sudo apt install openssh-server
[sudo] password for mpiuser:
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
openssh-server is already the newest version (1:8.9p1-3ubuntu0.4).
The following packages were automatically installed and are no longer required:
  linux-headers-6.2.0-26-generic linux-hwe-6.2-headers-6.2.0-26
  linux-image-6.2.0-26-generic linux-modules-6.2.0-26-generic
  linux-modules-extra-6.2.0-26-generic
Use 'sudo apt autoremove' to remove them.
0 upgraded, 0 newly installed, 0 to remove and 2 not upgraded.
mpiuser@master:~$
```

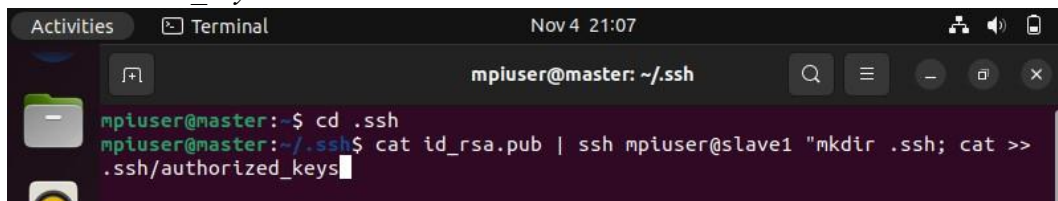
Pastikan semua slave menginstall OpenSSH server sampai selesai dan berhasil

2. Generate key lakukan pada master saja dengan perintah berikut

mpiuser@master:~\$ ssh-keygen -t rsa

```
mpiuser@master:~$ ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (/home/mpiuser/.ssh/id_rsa):
/home/mpiuser/.ssh/id_rsa already exists.
Overwrite (y/n)?
mpiuser@master:~$
```

3. Copy key public ke slave (Lakukan di Master), ketikkan perintah berikut pada direktori “.ssh” ***mpiuser@master:~\$ cd .ssh mpiuser@master:~/.ssh\$ cat id_rsa.pub | ssh mpiuser@slave1 "mkdir .ssh; cat >> .ssh/authorized_keys"***

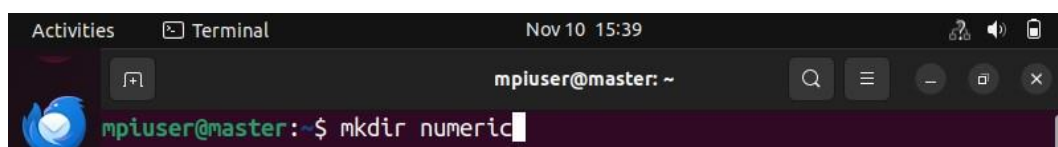


```
Activities Terminal Nov 4 21:07
mpiuser@master: ~/.ssh
mpiuser@master:~$ cd .ssh
mpiuser@master:~/.ssh$ cat id_rsa.pub | ssh mpiuser@slave1 "mkdir .ssh; cat >> .ssh/authorized_keys"
```

Lakukan perintah diatas berulang kali sebanyak slave, untuk pengecekan file `authorized_keys` di slave, yang terletak di folder `.ssh`

KONFIGURASI NFS

1. Buatlah shared folder, lakukanlah dimaster dan per slave ***mpiuser@master:~\$ mkdir numeric***



```
Activities Terminal Nov 10 15:39
mpiuser@master: ~
mpiuser@master:~$ mkdir numeric
```


2. Selanjutnya install NFS untuk master *mpiuser@master:~\$ sudo apt install nfs-kernel-server*

```
File Edit View Search Terminal Help
mpiuser@master:~$ sudo apt install nfs-kernel-server
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
nfs-kernel-server is already the newest version (1:2.6.1-1ubuntu1.2).
0 upgraded, 0 newly installed, 0 to remove and 2 not upgraded.
mpiuser@master:~$
```

3. Lakukan konfigurasi file pada master, masuk ke file export dengan perintah *mpiuser@master:~\$ sudo nano /etc/exports*

```
Activities Terminal Nov 10 15:40
mpiuser@master: ~
mpiuser@master:~$ sudo nano /etc/exports
mpiuser@master:~$
```

Konfigurasi file tambahkan commend ini pada baris berikut, ketikkan pada baris terakhir.

<lokasi shared folder> **(rw, sync, no_root_squash, no_subtree_check)*

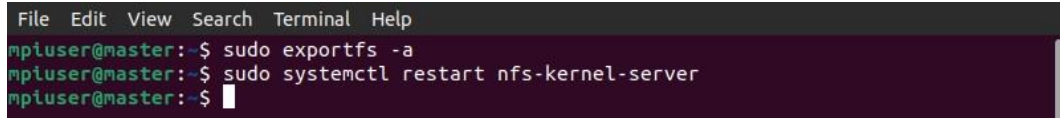
```
Activities Terminal Nov 10 15:39
GNU nano 6.2 /etc/exports *
# /etc/exports: the access control list for filesystems which may be e
# to NFS clients. See exports(5).
#
# Example for NFSv2 and NFSv3:
# /srv/homes hostname1(rw,sync,no_subtree_check) hostname2(ro,sy
#
# Example for NFSv4:
# /srv/nfs4 gss/krb5i(rw,sync,fsid=0,crossmnt,no_subtree_check)
# /srv/nfs4/homes gss/krb5i(rw,sync,no_subtree_check)
#
/home/mpiuser/numeric *(rw,sync,no_root_squash,no_subtree_check)

^G Help ^O Write Out ^W Where Is ^K Cut ^T Execute
^X Exit ^R Read File ^_ Replace ^U Paste ^J Justify
```

Lokasi Shared Folder merupakan tempat direktori membuat file diatas tadi

4. Kemudian ketikkan perintah berikut ini, untuk memulai kembali atau merestart NFS Server

```
mpiuser@master:~$ sudo exportfs -a mpiuser@master:~$  
sudo systemctl restart nfs-kernel-server
```



```
File Edit View Search Terminal Help  
mpiuser@master:~$ sudo exportfs -a  
mpiuser@master:~$ sudo systemctl restart nfs-kernel-server  
mpiuser@master:~$
```

5. Selanjutnya install NFS untuk slave **mpiuser@slave1:~\$ sudo apt install nfs-common**

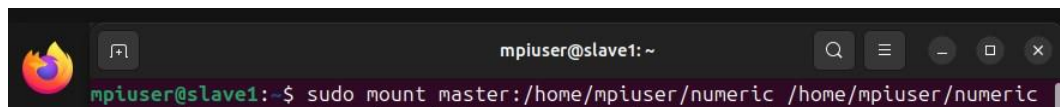
```
mpiuser@slave1:~$ sudo apt install nfs-common  
[sudo] password for mpiuser:
```

lakukan

penginstalan disemua slave

6. Setelah itu computer slave harus melakukan mounting ke computer master dengan perintah berikut **mpiuser@slave:~\$ sudo mount master:/home/mpiuser/numeric /home/mpiuser/numeric**

Slave 1

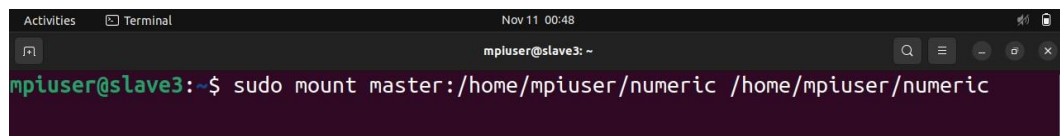


```
mpiuser@slave1:~$ sudo mount master:/home/mpiuser/numeric /home/mpiuser/numeric
```

Slave 2

```
mpiuser@slave2:~$ sudo mount master:/home/mpiuser/numeric/ /home/mpiuser/numeric/
```

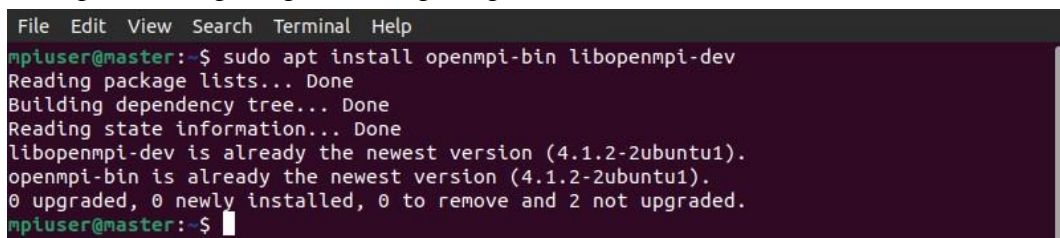
Slave 3



```
Activities Terminal Nov 11 00:48  
mpiuser@slave3:~$ sudo mount master:/home/mpiuser/numeric /home/mpiuser/numeric
```

INSTALASI MPI

1. Instalasi MPI, lakukan pada master dan semua slave **mpiuser@master:~\$ sudo apt install openmpi-bin libopenmpi-dev**



```
File Edit View Search Terminal Help  
mpiuser@master:~$ sudo apt install openmpi-bin libopenmpi-dev  
Reading package lists... Done  
Building dependency tree... Done  
Reading state information... Done  
libopenmpi-dev is already the newest version (4.1.2-2ubuntu1).  
openmpi-bin is already the newest version (4.1.2-2ubuntu1).  
0 upgraded, 0 newly installed, 0 to remove and 2 not upgraded.  
mpiuser@master:~$
```

2. Selanjutnya install library untuk MPI melalui pip *mpiuser@master:~\$ sudo apt install python3-pip*
mpiuser@master:~\$ pip install mpi4py

```
File Edit View Search Terminal Help
mpiuser@master:~$ sudo apt install python3-pip
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
python3-pip is already the newest version (22.0.2+dfsg-1ubuntu0.3).
0 upgraded, 0 newly installed, 0 to remove and 2 not upgraded.
mpiuser@master:~$ pip install mpi4py
Defaulting to user installation because normal site-packages is not writeable
Requirement already satisfied: mpi4py in ~/.local/lib/python3.10/site-packages (3.1.5)
mpiuser@master:~$
```

3. Lakukan penginstalan Numpy pada semua computer master dan slave
guna Menyediakan Fungsi Bawaan untuk Aljabar Linier dan Pembuatan
Bilangan Acak *mpiuser@(master/slave):~\$ pip3 install numpy*

```
Activities Terminal Nov 10 11:33
mpiuser@master: ~
mpiuser@master:~$ pip3 install numpy
Defaulting to user installation because normal site-packages is not writeable
Requirement already satisfied: numpy in ~/.local/lib/python3.10/site-packages (1.26.1)
mpiuser@master:~$
```

RUNNING KODINGAN PYTHON

1. Bukalah direktori numeric dengan menggunakan perintah
mpiuser@master:~/numeric\$ sudo nano num.py

```
Activities Terminal Nov 10 15:37
mpiuser@master: ~/numeric
mpiuser@master:~/numeric$ sudo nano num.py
```

kemudian tambahkan kodingan python numerik kedalamnya


```
QEMU nano 0.2                                     num.py *
from mpi4py import MPI
import numpy as np
import time

def matrix_multiply(A, B):
    return np.dot(A, B)

def scatter_data(comm, data):
    size = comm.Get_size()
    rank = comm.Get_rank()
    sendbuf = None

    if rank == 0:
        sendbuf = np.array_split(data, size)

    recvbuffers = comm.scatter(sendbuf, root=0)
    return recvbuffers

def main():
    comm = MPI.COMM_WORLD
    size = comm.Get_size()
    rank = comm.Get_rank()

    # Define matrices A and B
    A = np.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]])
    B = np.array([[9, 8, 7], [6, 5, 4], [3, 2, 1]])

    if rank == 0:
        # Scatter matrix A to all processes
        local_A = scatter_data(comm, A)
    else:
        local_A = None

    # Broadcast matrix B to all processes
    local_B = comm.bcast(B, root=0)

    # Start the timer
    start_time = time.time()

    # Scatter matrix A and perform local matrix multiplication
    local_result = scatter_data(comm, local_A)
    local_result = matrix_multiply(local_result, local_B)

    # Gather the local results to the root process
    global_result = comm.gather(local_result, root=0)

    # Stop the timer
    end_time = time.time()

    if rank == 0:
        # Concatenate the global results to get the final result
        final_result = np.concatenate(global_result)
        print("Matrix A:")
        print(A)
        print("Matrix B:")
        print(B)
        print("Result of Matrix Multiplication:")
        print(final_result)
        print("Runtime: {} seconds".format(end_time - start_time))

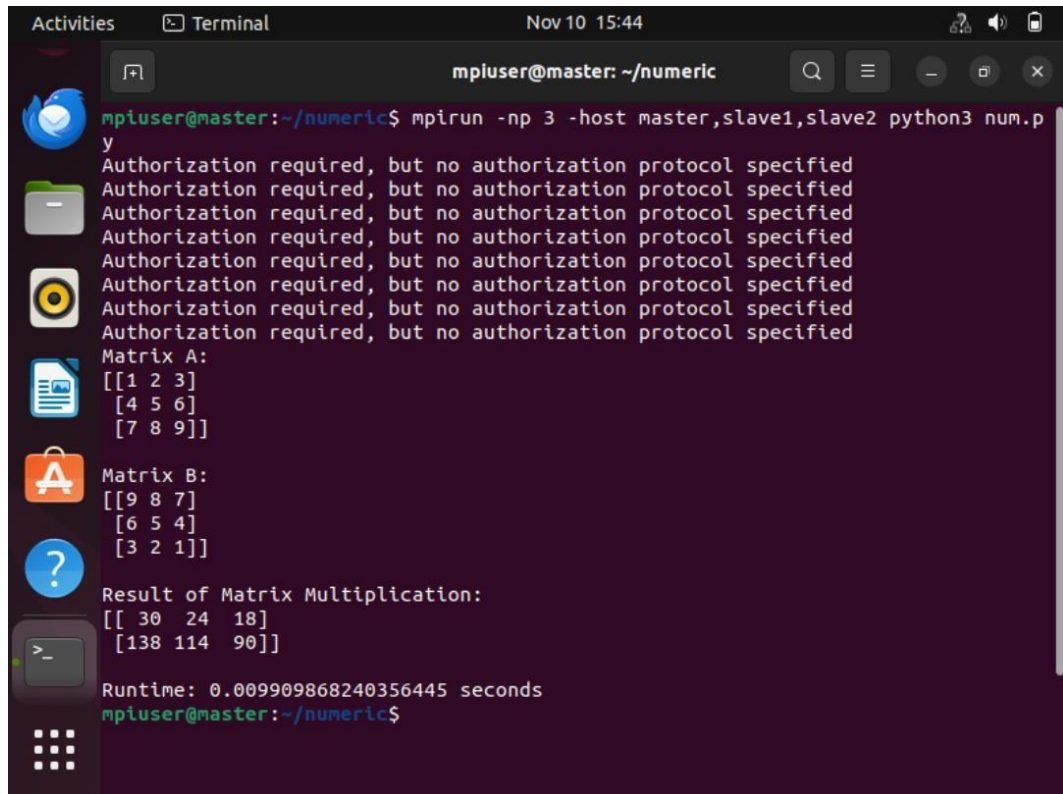
if __name__ == "__main__":
    main()
```

2. Sebelum mengetesnya di MPI kami melakukan pengetesan langsung dengan python3 menggunakan perintah ***mpiuser@master:~/numeric\$ python3 num.py***

```
Activities Terminal Nov 10 15:31
mpiuser@master: ~/numeric

mpiuser@master:~/numeric$ python3 num.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Matrix A:
[[1 2 3]
 [4 5 6]
 [7 8 9]]
Matrix B:
[[9 8 7]
 [6 5 4]
 [3 2 1]]
Result of Matrix Multiplication:
[[ 30 24 18]
 [ 84 69 54]
 [138 114 90]]
Runtime: 0.00024628639221191406 seconds
mpiuser@master:~/numeric$
```

3. Setelah pengetesan python3 berhasil barulah kami eksekusi dengan mpi
mpiuser@master:~numeric\$ mpirun -np 3 -hosts master,slave1,slave2 python3 num.py



The image shows a terminal window titled "Terminal" with the date and time "Nov 10 15:44". The prompt is "mpiuser@master: ~/numeric". The command executed is "mpirun -np 3 -host master,slave1,slave2 python3 num.py". The output shows several "Authorization required, but no authorization protocol specified" messages, followed by the definition of Matrix A and Matrix B, the result of their multiplication, and the runtime time: "Runtime: 0.009909868240356445 seconds".

```
mpiuser@master:~/numeric$ mpirun -np 3 -host master,slave1,slave2 python3 num.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Matrix A:
[[1 2 3]
 [4 5 6]
 [7 8 9]]
Matrix B:
[[9 8 7]
 [6 5 4]
 [3 2 1]]
Result of Matrix Multiplication:
[[ 30  24  18]
 [138 114  90]]
Runtime: 0.009909868240356445 seconds
mpiuser@master:~/numeric$
```

Didapatlah hasil matriks dengan runtime selama 0.00990988240356445