

PEMROSESAN PARALEL
“CREATING AN MPI CLUSTER”



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PROGRAM STUDI SISTEM KOMPUTER

FAKULTAS ILMU KOMPUTER

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MEMBUAT CLUSTER MPI

- Sebelum membuat Mpi

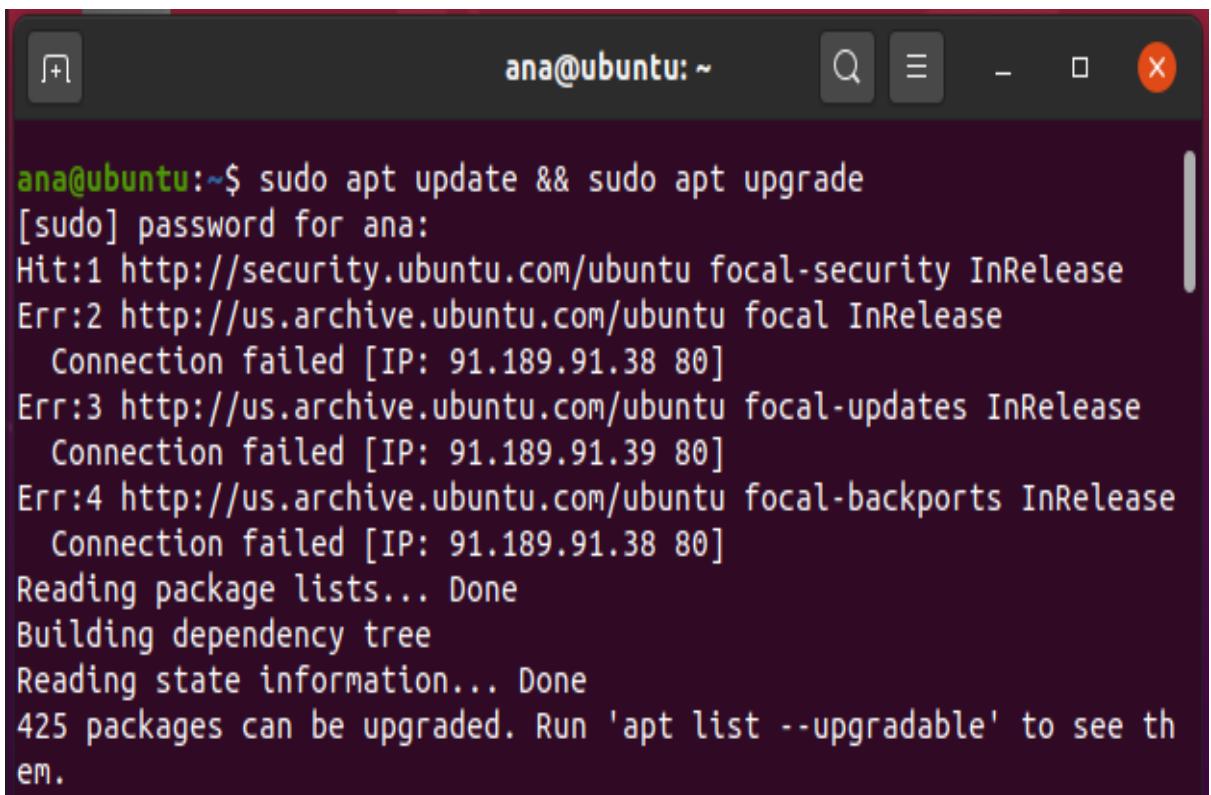
1. Pastikan sudah dalam satu jaringan yang sama setiap (Master, Worker1, Worker2, dan Worker3)
 2. Melakukan Upgrade OS

Master

```
ayulestari@ubuntu:~$ sudo apt update && sudo apt upgrade
[sudo] password for ayulestari:
Hit:1 http://security.ubuntu.com/ubuntu focal-security InRelease
Err:2 http://us.archive.ubuntu.com/ubuntu focal InRelease
      Connection failed [IP: 91.189.91.38 80]
Err:3 http://us.archive.ubuntu.com/ubuntu focal-updates InRelease
      Connection failed [IP: 91.189.91.39 80]
Err:4 http://us.archive.ubuntu.com/ubuntu focal-backports InRelease
      Connection failed [IP: 91.189.91.38 80]
Reading package lists... Done
Building dependency tree
Reading state information... Done
426 packages can be upgraded. Run 'apt list --upgradable' to see them.
W: Failed to fetch http://us.archive.ubuntu.com/ubuntu/dists/focal/InRelease  Connection failed [IP: 91.189.91.38 80]
W: Failed to fetch http://us.archive.ubuntu.com/ubuntu/dists/focal-updates/InRelease  Connection failed [IP: 91.189.91.39 80]
W: Failed to fetch http://us.archive.ubuntu.com/ubuntu/dists/focal-backports/InRelease  Connection failed [IP: 91.189.91.38 80]
W: Some index files failed to download. They have been ignored, or old ones used instead.
Reading package lists... Done
Building dependency tree
Reading state information... Done
Calculating upgrade... Done
The following package was automatically installed and is no longer required:
```

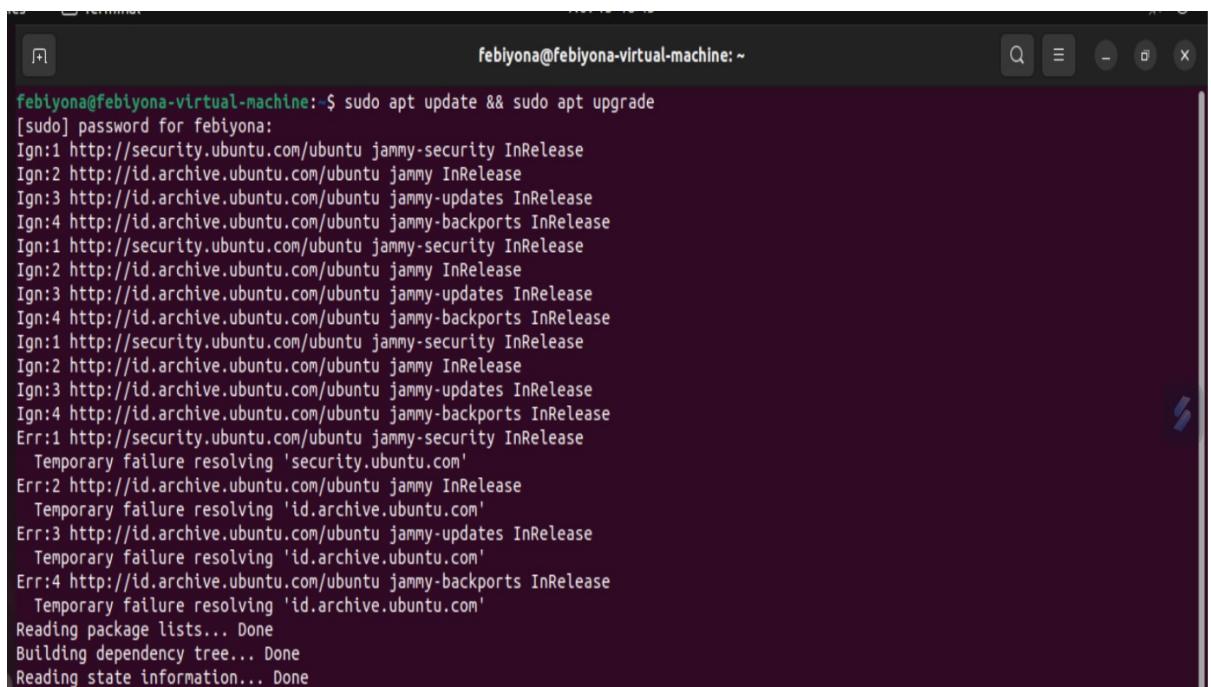
Worker 1

Worker 2



```
ana@ubuntu:~$ sudo apt update && sudo apt upgrade
[sudo] password for ana:
Hit:1 http://security.ubuntu.com/ubuntu focal-security InRelease
Err:2 http://us.archive.ubuntu.com/ubuntu focal InRelease
      Connection failed [IP: 91.189.91.38 80]
Err:3 http://us.archive.ubuntu.com/ubuntu focal-updates InRelease
      Connection failed [IP: 91.189.91.39 80]
Err:4 http://us.archive.ubuntu.com/ubuntu focal-backports InRelease
      Connection failed [IP: 91.189.91.38 80]
Reading package lists... Done
Building dependency tree
Reading state information... Done
425 packages can be upgraded. Run 'apt list --upgradable' to see them.
```

Worker 3



```
febiyona@febiyona-virtual-machine:~$ sudo apt update && sudo apt upgrade
[sudo] password for febiyona:
Ign:1 http://security.ubuntu.com/ubuntu jammy-security InRelease
Ign:2 http://id.archive.ubuntu.com/ubuntu jammy InRelease
Ign:3 http://id.archive.ubuntu.com/ubuntu jammy-updates InRelease
Ign:4 http://id.archive.ubuntu.com/ubuntu jammy-backports InRelease
Ign:1 http://security.ubuntu.com/ubuntu jammy-security InRelease
Ign:2 http://id.archive.ubuntu.com/ubuntu jammy InRelease
Ign:3 http://id.archive.ubuntu.com/ubuntu jammy-updates InRelease
Ign:4 http://id.archive.ubuntu.com/ubuntu jammy-backports InRelease
Err:1 http://security.ubuntu.com/ubuntu jammy-security InRelease
      Temporary failure resolving 'security.ubuntu.com'
Err:2 http://id.archive.ubuntu.com/ubuntu jammy InRelease
      Temporary failure resolving 'id.archive.ubuntu.com'
Err:3 http://id.archive.ubuntu.com/ubuntu jammy-updates InRelease
      Temporary failure resolving 'id.archive.ubuntu.com'
Err:4 http://id.archive.ubuntu.com/ubuntu jammy-backports InRelease
      Temporary failure resolving 'id.archive.ubuntu.com'
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
```

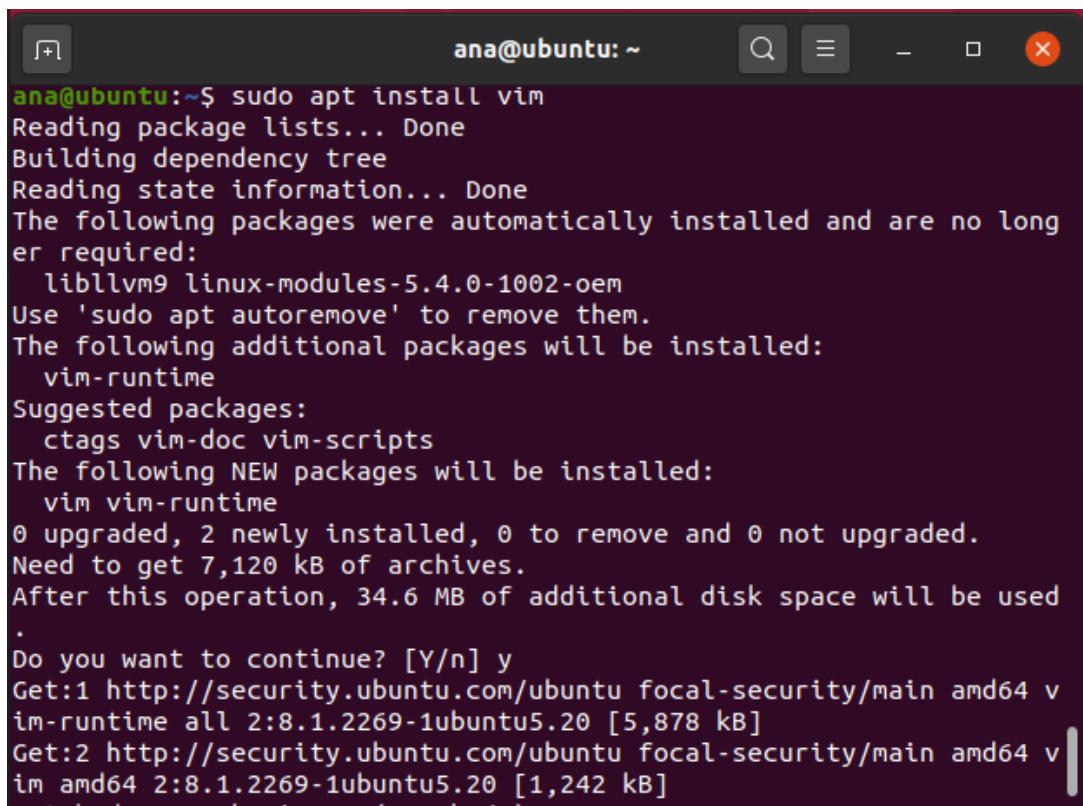
3. Melakukan Penginstalan net-tools untuk melihat IP, vim untuk teks editor Master

```
ayulestari@ubuntu:~$ sudo apt install vim
Reading package lists... Done
Building dependency tree...
Reading state information... Done
The following packages were automatically installed and are no longer required:
  libllvm9 linux-modules-5.4.0-1002-oem
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  vim-runtime
Suggested packages:
  ctags vim-doc vim-scripts
The following NEW packages will be installed:
  vim vim-runtime
0 upgraded, 2 newly installed, 0 to remove and 0 not upgraded.
Need to get 7,120 kB of archives.
After this operation, 34.6 MB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://security.ubuntu.com/ubuntu focal-security/main amd64 vim-runtime all 2:8.1.2269-1ubuntu5.20 [5,878 kB]
Get:2 http://security.ubuntu.com/ubuntu focal-security/main amd64 vim amd64 2:8.1.2269-1ubuntu5.20 [1,242 kB]
Fetched 7,120 kB in 5s (1,524 kB/s)
Selecting previously unselected package vim-runtime.
(Reading database ... 163240 files and directories currently installed.)
Preparing to unpack .../vim-runtime_2%3a8.1.2269-1ubuntu5.20_all.deb ...
Adding 'diversion of /usr/share/vim/vim81/doc/help.txt to /usr/share/vim/vim81/doc/help.txt.vim-tiny by vim-runtime'
Adding 'diversion of /usr/share/vim/vim81/doc/tags to /usr/share/vim/vim81/doc/tags.vim-tiny by vim-runtime'
```

Worker 1

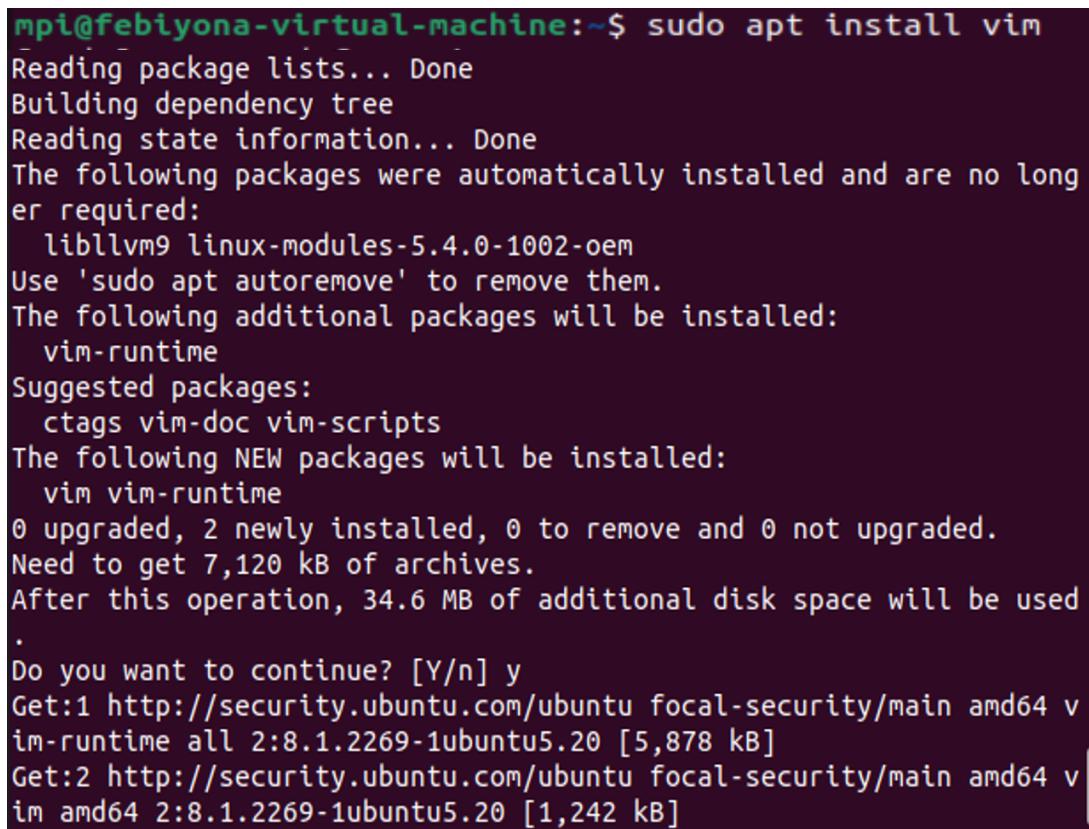
```
mardaharyani@mardaharyani-virtual-machine:~$ sudo apt install net-tools vim
Reading package lists... Done
Building dependency tree...
Reading state information... Done
The following additional packages will be installed:
  vim-runtime
Suggested packages:
  ctags vim-doc vim-scripts
The following NEW packages will be installed:
  net-tools vim vim-runtime
0 upgraded, 3 newly installed, 0 to remove and 2 not upgraded.
Need to get 8.773 kB of archives.
After this operation, 38.4 MB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 net-tools amd64 1.60+git20181103.0eebece-1ubuntu5 [204 kB]
Get:2 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 vim-runtime all 2:8.2.3995-1ubuntu2.13 [6.834 kB]
Get:3 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 vim amd64 2:8.2.3995-1ubuntu2.13 [1.734 kB]
Fetched 8.773 kB in 10s (920 kB/s)
Selecting previously unselected package net-tools.
(Reading database ... 198978 files and directories currently installed.)
Preparing to unpack .../net-tools_1.60+git20181103.0eebece-1ubuntu5_amd64.deb ...
Unpacking net-tools (1.60+git20181103.0eebece-1ubuntu5) ...
Selecting previously unselected package vim-runtime.
Preparing to unpack .../vim-runtime_2%3a8.2.3995-1ubuntu2.13_all.deb ...
Adding 'diversion of /usr/share/vim/vim82/doc/help.txt to /usr/share/vim/vim82/doc/help.txt.vim-tiny by vim-runtime'
Adding 'diversion of /usr/share/vim/vim82/doc/tags to /usr/share/vim/vim82/doc/tags.vim-tiny by vim-runtime'
Unpacking vim-runtime (2:8.2.3995-1ubuntu2.13) ...
Selecting previously unselected package vim.
Preparing to unpack .../vim_2%3a8.2.3995-1ubuntu2.13_amd64.deb ...
Unpacking vim (2:8.2.3995-1ubuntu2.13) ...
Setting up net-tools (1.60+git20181103.0eebece-1ubuntu5) ...
Setting up vim-runtime (2:8.2.3995-1ubuntu2.13) ...
Setting up vim (2:8.2.3995-1ubuntu2.13) ...
update-alternatives: using /usr/bin/vim.basic to provide /usr/bin/vim (vim) in auto mode
update-alternatives: using /usr/bin/vim.basic to provide /usr/bin/vimdiff (vimdiff) in auto mode
update-alternatives: using /usr/bin/vim.basic to provide /usr/bin/rvim (rvim) in auto mode
update-alternatives: using /usr/bin/vim.basic to provide /usr/bin/rview (rview) in auto mode
update-alternatives: using /usr/bin/vim.basic to provide /usr/bin/vi (vi) in auto mode
update-alternatives: using /usr/bin/vim.basic to provide /usr/bin/view (view) in auto mode
update-alternatives: using /usr/bin/vim.basic to provide /usr/bin/ex (ex) in auto mode
Processing triggers for man-db (2.10.2-1) ...
```

Worker 2



```
ana@ubuntu:~$ sudo apt install vim
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  libllvm9 linux-modules-5.4.0-1002-oem
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  vim-runtime
Suggested packages:
  ctags vim-doc vim-scripts
The following NEW packages will be installed:
  vim vim-runtime
0 upgraded, 2 newly installed, 0 to remove and 0 not upgraded.
Need to get 7,120 kB of archives.
After this operation, 34.6 MB of additional disk space will be used
.
Do you want to continue? [Y/n] y
Get:1 http://security.ubuntu.com/ubuntu focal-security/main amd64 vim-runtime all 2:8.1.2269-1ubuntu5.20 [5,878 kB]
Get:2 http://security.ubuntu.com/ubuntu focal-security/main amd64 vim amd64 2:8.1.2269-1ubuntu5.20 [1,242 kB]
```

Worker 3



```
mpi@febiyona-virtual-machine:~$ sudo apt install vim
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  libllvm9 linux-modules-5.4.0-1002-oem
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  vim-runtime
Suggested packages:
  ctags vim-doc vim-scripts
The following NEW packages will be installed:
  vim vim-runtime
0 upgraded, 2 newly installed, 0 to remove and 0 not upgraded.
Need to get 7,120 kB of archives.
After this operation, 34.6 MB of additional disk space will be used
.
Do you want to continue? [Y/n] y
Get:1 http://security.ubuntu.com/ubuntu focal-security/main amd64 vim-runtime all 2:8.1.2269-1ubuntu5.20 [5,878 kB]
Get:2 http://security.ubuntu.com/ubuntu focal-security/main amd64 vim amd64 2:8.1.2269-1ubuntu5.20 [1,242 kB]
```

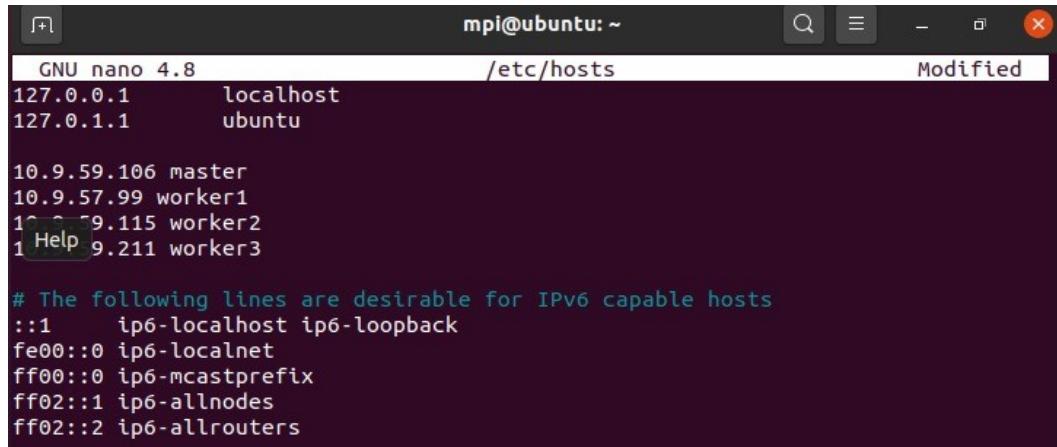
4. Melakukan pengecekan IP dengan perintah berikut:

Nama	Master	Worker1	Worker2	Worker3
IP	10.9.59.106	10.9.57.99	10.9.59.115	10.9.59.211

- Steps to Create an MPI Cluster

1. Konfigurasi hosts file /etc/hosts

- Pada Master



```

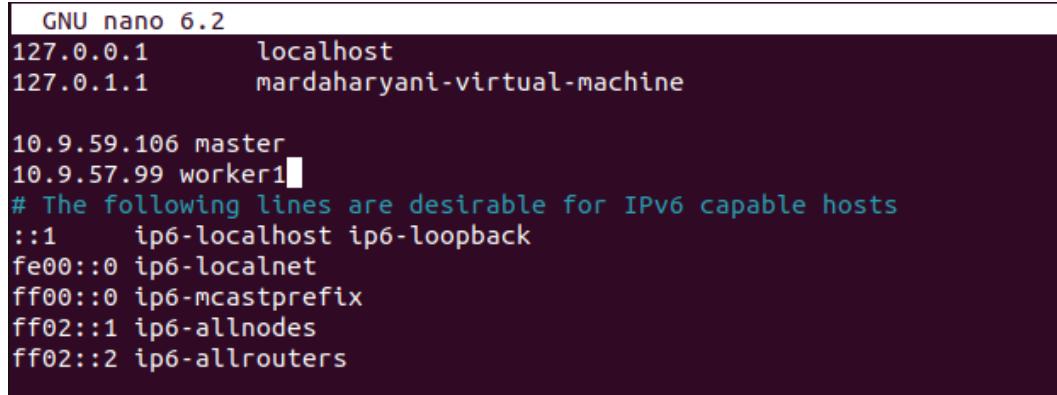
GNU nano 4.8                               /etc/hosts                         Modified
127.0.0.1      localhost
127.0.1.1      ubuntu

10.9.59.106    master
10.9.57.99    worker1
10.9.59.115    worker2
10.9.59.211    worker3

# 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

```

- Pada Worker1



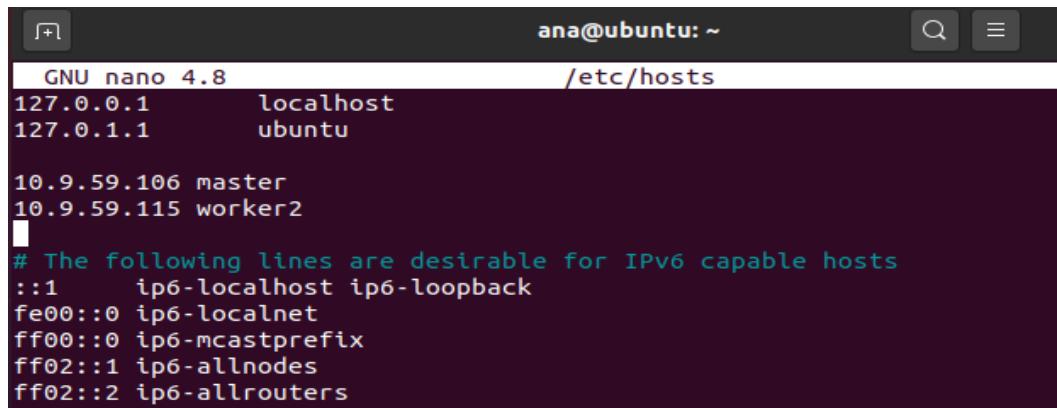
```

GNU nano 6.2
127.0.0.1      localhost
127.0.1.1      mardaharyani-virtual-machine

10.9.59.106    master
10.9.57.99    worker1
# 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

```

- Pada Worker2



```

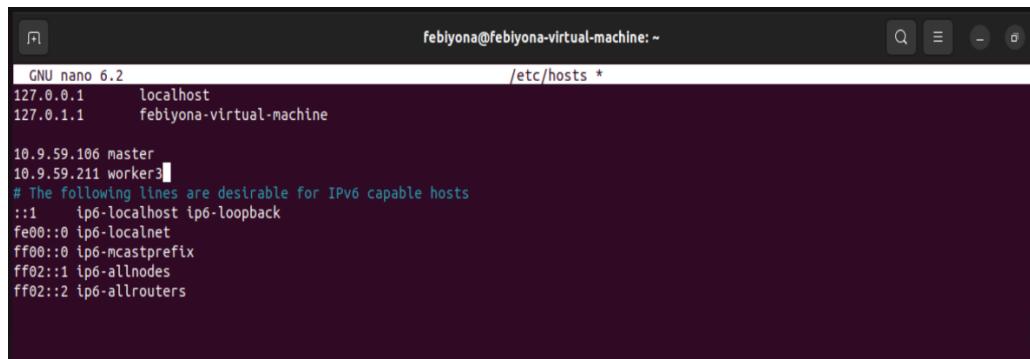
GNU nano 4.8                               /etc/hosts                         ana@ubuntu: ~
127.0.0.1      localhost
127.0.1.1      ubuntu

10.9.59.106    master
10.9.59.115    worker2

# 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

```

- Pada Worker3



```
GNU nano 6.2          /etc/hosts *
127.0.0.1      localhost
127.0.1.1      febiyona-virtual-machine

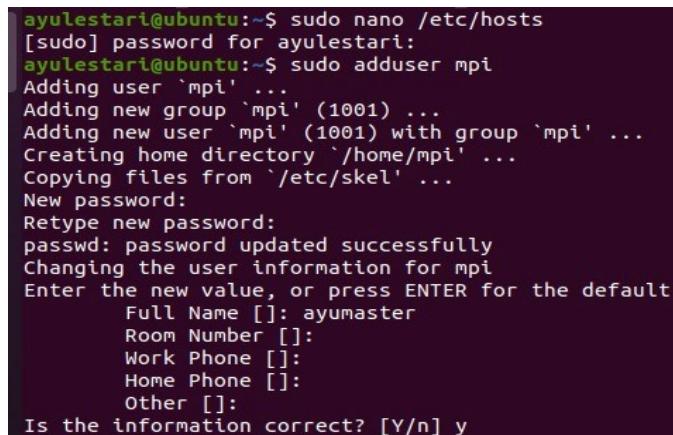
10.9.59.106 master
10.9.59.211 worker3
# The following lines are desirable for IPv6 capable hosts
::1    ip6-localhost ip6-loopback
fe00::0 ip6-localnet
ff00::0 ip6-mcastprefix
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters
```

- Step2: Create a new user

Buat user baru di Server dan Client. Nama User harus sama semua di seluruh Komputer.

Server

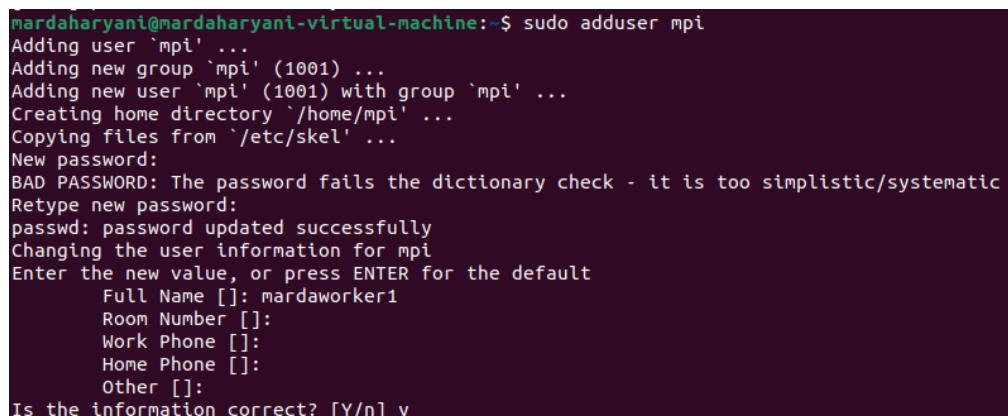
- Master



```
ayulestari@ubuntu:~$ sudo nano /etc/hosts
[sudo] password for ayulestari:
ayulestari@ubuntu:~$ sudo adduser mpi
Adding user `mpi' ...
Adding new group `mpi' (1001) ...
Adding new user `mpi' (1001) with group `mpi' ...
Creating home directory `/home/mpi' ...
Copying files from `/etc/skel' ...
New password:
Retype new password:
passwd: password updated successfully
Changing the user information for mpi
Enter the new value, or press ENTER for the default
      Full Name []: ayumaster
      Room Number []:
      Work Phone []:
      Home Phone []:
      Other []:
Is the information correct? [Y/n] y
```

Client

- Worker1



```
mardaharyani@mardaharyani-virtual-machine:~$ sudo adduser mpi
Adding user `mpi' ...
Adding new group `mpi' (1001) ...
Adding new user `mpi' (1001) with group `mpi' ...
Creating home directory `/home/mpi' ...
Copying files from `/etc/skel' ...
New password:
BAD PASSWORD: The password fails the dictionary check - it is too simplistic/systematic
Retype new password:
passwd: password updated successfully
Changing the user information for mpi
Enter the new value, or press ENTER for the default
      Full Name []: mardaworker1
      Room Number []:
      Work Phone []:
      Home Phone []:
      Other []:
Is the information correct? [Y/n] y
```

```
mardaharyani@mardaharyani-virtual-machine:~$ sudo usermod -aG sudo mpi
mardaharyani@mardaharyani-virtual-machine:~$ su - mpi
Password:
To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.

mpi@mardaharyani-virtual-machine:~$
```

- Worker2

```
ana@ubuntu:~$ sudo adduser mpi
Adding user `mpi' ...
Adding new group `mpi' (1001) ...
Adding new user `mpi' (1001) with group `mpi' ...
Creating home directory `/home/mpi' ...
Copying files from `/etc/skel' ...
New password:
Retype new password:
passwd: password updated successfully
Changing the user information for mpi
Enter the new value, or press ENTER for the default
  Full Name []:
  Room Number []:
  Work Phone []:
  Home Phone []:
  Other []:
Is the information correct? [Y/n] y
ana@ubuntu:~$
```

```
ana@ubuntu:~$ sudo usermod -aG sudo mpi
ana@ubuntu:~$ su - mpi
Password:
To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.

mpi@ubuntu:~$
```

- Worker3

```
febiyona@febiyona-virtual-machine:~$ sudo adduser mpi
Adding user `mpi' ...
Adding new group `mpi' (1001) ...
Adding new user `mpi' (1001) with group `mpi' ...
Creating home directory `/home/mpi' ...
Copying files from `/etc/skel' ...
New password:
BAD PASSWORD: The password fails the dictionary check - it does not contain enough DIFFERENT characters
Retype new password:
passwd: password updated successfully
Changing the user information for mpi
Enter the new value, or press ENTER for the default
  Full Name []:
  Room Number []:
  Work Phone []:
  Home Phone []:
  Other []:
Is the information correct? [Y/n] Y
```

```
febiyona@febiyona-virtual-machine:~$ sudo usermod -aG sudo mpi
febiyona@febiyona-virtual-machine:~$ su - mpi
Password:
To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.
```

- **Konfigurasi SSH**

Setelah membuat dan masuk ke user, lakukan konfigurasi SSH.

1. Install SSH

- Pada Master

```
mpi@ubuntu:~$ sudo apt install openssh-server
[sudo] password for mpi:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  libllvm9 linux-modules-5.4.0-1002-oem
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  ncurses-term openssh-sftp-server
Suggested packages:
  molly-guard monkeysphere ssh-askpass
Recommended packages:
  ssh-import-id
The following NEW packages will be installed:
  ncurses-term openssh-server openssh-sftp-server
0 upgraded, 3 newly installed, 0 to remove and 0 not upgraded.
Need to get 678 kB of archives.
After this operation, 5,963 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://security.ubuntu.com/ubuntu focal-security/main amd64 ncurses-term
all 6.2-0ubuntu2.1 [249 kB]
Get:2 http://security.ubuntu.com/ubuntu focal-security/main amd64 openssh-sftp-
server amd64 1:8.2p1-4ubuntu0.9 [51.7 kB]
Get:3 http://security.ubuntu.com/ubuntu focal-security/main amd64 openssh-serv
r amd64 1:8.2p1-4ubuntu0.9 [377 kB]
Fetched 678 kB in 5s (124 kB/s)
Preconfiguring packages ...
```

- Pada Worker1

```
mpi@mardaharyani-virtual-machine:~$ sudo apt install openssh-server
[sudo] password for mpi:
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  ncurses-term openssh-sftp-server ssh-import-id
Suggested packages:
  molly-guard monkeysphere ssh-askpass
The following NEW packages will be installed:
  ncurses-term openssh-server openssh-sftp-server ssh-import-id
0 upgraded, 4 newly installed, 0 to remove and 2 not upgraded.
Need to get 751 kB of archives.
After this operation, 6,046 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 openssh-sftp-server amd64 1:8.9p1-3ubuntu0.4 [38,7 kB]
Get:2 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 openssh-server amd64 1:8.9p1-3ubuntu0.4 [434 kB]
Get:3 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 ncurses-term all 6.3-2ubuntu0.1 [267 kB]
Get:4 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 ssh-import-id all 5.11-0ubuntu1 [10,1 kB]
Fetched 751 kB in 6s (132 kB/s)
Preconfiguring packages ...
Selecting previously unselected package openssh-sftp-server.
(Reading database ... 200968 files and directories currently installed.)
Preparing to unpack .../openssh-sftp-server_1%3a8.9p1-3ubuntu0.4_amd64.deb ...
Unpacking openssh-sftp-server (1:8.9p1-3ubuntu0.4) ...
Selecting previously unselected package openssh-server.
Preparing to unpack .../openssh-server_1%3a8.9p1-3ubuntu0.4_amd64.deb ...
Unpacking openssh-server (1:8.9p1-3ubuntu0.4) ...
Selecting previously unselected package ncurses-term.
Preparing to unpack .../ncurses-term_6.3-2ubuntu0.1_all.deb ...
Unpacking ncurses-term (6.3-2ubuntu0.1) ...
Selecting previously unselected package ssh-import-id.
Preparing to unpack .../ssh-import-id_5.11-0ubuntu1_all.deb ...
Unpacking ssh-import-id (5.11-0ubuntu1) ...
Setting up openssh-sftp-server (1:8.9p1-3ubuntu0.4) ...
Setting up openssh-server (1:8.9p1-3ubuntu0.4) ...

Creating config file /etc/ssh/sshd_config with new version
Creating SSH2 RSA key: this may take some time ...
3072 SHA256:XFEqcm4JwJqmRj1uax1ds9RjdZ7qqpf/nsoGnd5MG6c root@mardaharyani-virtual-machine (RSA)
```

- Pada Worker2

```
mpi@ubuntu:~$ sudo apt install openssh-server
[sudo] password for mpi:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  libllvm9 linux-modules-5.4.0-1002-oem
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  ncurses-term openssh-sftp-server
Suggested packages:
  molly-guard monkeysphere ssh-askpass
Recommended packages:
  ssh-import-id
The following NEW packages will be installed:
  ncurses-term openssh-server openssh-sftp-server
0 upgraded, 3 newly installed, 0 to remove and 0 not upgraded.
Need to get 678 kB of archives.
After this operation, 5,963 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://security.ubuntu.com/ubuntu focal-security/main amd64 ncurses-term
all 6.2-0ubuntu2.1 [249 kB]
Get:2 http://security.ubuntu.com/ubuntu focal-security/main amd64 openssh-sftp-
server amd64 1:8.2p1-4ubuntu0.9 [51.7 kB]
Get:3 http://security.ubuntu.com/ubuntu focal-security/main amd64 openssh-serv
r amd64 1:8.2p1-4ubuntu0.9 [377 kB]
Fetched 678 kB in 10s (71.3 kB/s)
```

- Pada Worker3

```
febiyona@febiyona-virtual-machine:~/Desktop$ sudo apt install openssh-server
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  ncurses-term openssh-client openssh-sftp-server ssh-import-id
Suggested packages:
  keychain libpam-ssh monkeysphere ssh-askpass molly-guard
The following NEW packages will be installed:
  ncurses-term openssh-server openssh-sftp-server ssh-import-id
The following packages will be upgraded:
  openssh-client
1 upgraded, 4 newly installed, 0 to remove and 115 not upgraded.
Need to get 1.655 kB of archives.
After this operation, 6.046 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 openssh-client amd64 1:8.9p1-3ubuntu0.4 [905 kB]
Get:2 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 openssh-sftp-server amd64 1:8.9p1-3ubuntu0.4 [38,7 kB]
Get:3 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 openssh-server amd64 1:8.9p1-3ubuntu0.4 [434 kB]
Get:4 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 ncurses-term all 6.3-2ubuntu0.1 [267 kB]
Get:5 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 ssh-import-id all 5.11-0ubuntu1 [10,1 kB]
Fetched 1.655 kB in 1s (2.552 kB/s)
Preconfiguring packages...
(Reading database ... 161840 files and directories currently installed.)
Preparing to unpack .../openssh-client_1%3a8.9p1-3ubuntu0.4_amd64.deb ...
Unpacking openssh-client (1:8.9p1-3ubuntu0.4) over (1:8.9p1-3ubuntu0.3) ...
Selecting previously unselected package openssh-sftp-server.
Preparing to unpack .../openssh-sftp-server_1%3a8.9p1-3ubuntu0.4_amd64.deb ...
Unpacking openssh-sftp-server (1:8.9p1-3ubuntu0.4) ...
Selecting previously unselected package openssh-server.
Preparing to unpack .../openssh-server_1%3a8.9p1-3ubuntu0.4_amd64.deb ...
Unpacking openssh-server (1:8.9p1-3ubuntu0.4) ...
Selecting previously unselected package ncurses-term.
Preparing to unpack .../ncurses-term_6.3-2ubuntu0.1_all.deb ...
Unpacking ncurses-term (6.3-2ubuntu0.1) ...
Selecting previously unselected package ssh-import-id.
Preparing to unpack .../ssh-import-id_5.11-0ubuntu1_all.deb ...
Unpacking ssh-import-id (5.11-0ubuntu1) ...
Setting up openssh-client (1:8.9p1-3ubuntu0.4) ...
Setting up ssh-import-id (5.11-0ubuntu1) ...
```

2. Melakukan pengecekan SSH

- SSH dari Master ke Worker

```
mpi@ubuntu:~$ ssh mpi@worker1
The authenticity of host 'worker1 (10.9.57.99)' can't be established.
ECDSA key fingerprint is SHA256:BeXMjPVy3Yy7EULOWkktD+rax8hpGZi0qnwq5kP8ME8.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added 'worker1,10.9.57.99' (ECDSA) to the list of known hosts.
mpi@worker1's password:
Welcome to Ubuntu 22.04.3 LTS (GNU/Linux 6.2.0-36-generic x86_64)

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

Expanded Security Maintenance for Applications is not enabled.

0 updates can be applied immediately.

Enable ESM Apps to receive additional future security updates.
See https://ubuntu.com/esm or run: sudo pro status

The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.

mpi@mardaharyani-virtual-machine:~$
```

- SSH dari Worker1 ke Master

```
mpi@mardaharyani-virtual-machine:~$ ssh mpi@master
The authenticity of host 'master (10.9.59.106)' can't be established.
ED25519 key fingerprint is SHA256:sjnmGkuvILG3sFGy3n2NjgXwMdPLFcFXA0yEiBjcxzg.
This key is not known by any other names
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added 'master' (ED25519) to the list of known hosts.
mpi@master's password:
Welcome to Ubuntu Focal Fossa (development branch) (GNU/Linux 5.4.0-166-generic x86_64)

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

0 updates can be installed immediately.
0 of these updates are security updates.

The programs included with the Ubuntu system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*copyright.

Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.
```

- SSH dari Worker2 ke Master

```
mpi@ubuntu:~$ ssh mpi@master
The authenticity of host 'master (10.9.59.106)' can't be established.
ECDSA key fingerprint is SHA256:QcBVGSfUITmZTu7Sl+kr4Nuv51eyOWuL1GDMUsELuJE.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added 'master,10.9.59.106' (ECDSA) to the list of known hosts.
mpi@master's password:
Welcome to Ubuntu Focal Fossa (development branch) (GNU/Linux 5.4.0-166-generic
x86_64)

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

0 updates can be installed immediately.
0 of these updates are security updates.

Last login: Wed Nov 15 00:55:50 2023 from 10.9.59.211
mpi@ubuntu:~$
```

- SSH dari Worker3 ke Master

```
febiyona@febiyona-virtual-machine:~/Desktop$ ssh mpi@master
The authenticity of host 'master (10.9.59.106)' can't be established.
ED25519 key fingerprint is SHA256:sjnmGkuvILG3sFGy3n2NjgXwMdPLFcFxAOyEiBjcxzg.
This key is not known by any other names
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added 'master' (ED25519) to the list of known hosts.
mpi@master's password:
Welcome to Ubuntu Focal Fossa (development branch) (GNU/Linux 5.4.0-166-generic x86_64)

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

0 updates can be installed immediately.
0 of these updates are security updates.

Last login: Wed Nov 15 00:45:00 2023 from 10.9.57.99
```

3. Generate Keygen

- Lakukan di Server

```
mpi@ubuntu:~$ ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (/home/mpi/.ssh/id_rsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/mpi/.ssh/id_rsa
Your public key has been saved in /home/mpi/.ssh/id_rsa.pub
The key fingerprint is:
SHA256:QylkAoQdGFabnOyxJ66IyGJl0UI1l4DWQGJB8iN/XTY mpi@ubuntu
The key's randomart image is:
+---[RSA 3072]---+
|+%B***+..          |
|*.=++=o.. .         |
|. =B. . E          |
| o.+oo = .          |
| .++... S           |
| .+o   .             |
| o.                 |
|*..                |
|*o                 |
+---[SHA256]---+
```

4. Copy key publik ke Client

- Copy Key

```
mpi@ubuntu:~$ cd .ssh  
mpi@ubuntu:~/ssh$ cat id_rsa.pub | ssh mpi@worker1 "mkdir .ssh; cat >> .ssh/au  
thorized_keys"  
mpi@worker1's password:  
Permission denied, please try again.  
mpi@worker1's password:  
mkdir: cannot create directory '.ssh': File exists  
mpi@ubuntu:~/ssh$
```

- Konfigurasi NFS

1. Buat Shared folder

- Pada Master

```
mpi@ubuntu:~$ mkdir cloud  
mpi@ubuntu:~$
```

- Pada Worker1

```
mpi@mardaharyani-virtual-machine:~$ mkdir cloud  
mpi@mardaharyani-virtual-machine:~$
```

- Pada Worker2

```
mpi@ubuntu:~$ mkdir cloud  
mpi@ubuntu:~$
```

- Pada Worker3

```
mpi@febiyona-virtual-machine:~$ mkdir cloud  
mpi@febiyona-virtual-machine:~$
```

2. Install NFS Server

- Sudo apt install nfs-kernel-server

```
mpi@ubuntu:~$ sudo apt install nfs-kernel-server  
Reading package lists... Done  
Building dependency tree  
Reading state information... Done  
The following packages were automatically installed and are no longer required:  
  liblbbm9 linux-modules-5.4.0-1002-oem  
Use 'sudo apt autoremove' to remove them.  
The following additional packages will be installed:  
  keyutils libevent-2.1-7 libnfsidmap2 libtirpc-common libtirpc3 nfs-common  
  rpcbind  
Suggested packages:  
  open-iscsi watchdog  
The following NEW packages will be installed:  
  keyutils libevent-2.1-7 libnfsidmap2 libtirpc-common libtirpc3 nfs-common  
  nfs-kernel-server rpcbind  
0 upgraded, 8 newly installed, 0 to remove and 360 not upgraded.  
Need to get 642 kB of archives.  
After this operation, 2,344 kB of additional disk space will be used.  
Do you want to continue? [Y/n] y  
Get:1 http://us.archive.ubuntu.com/ubuntu focal-updates/main amd64 libtirpc-com  
mon all 1.2.5-1ubuntu0.1 [7,712 B]  
Get:2 http://us.archive.ubuntu.com/ubuntu focal-updates/main amd64 libtirpc3 am  
d64 1.2.5-1ubuntu0.1 [77.9 kB]  
Get:3 http://us.archive.ubuntu.com/ubuntu focal/main amd64 rpcbind amd64 1.2.5-  
8 [42.8 kB]  
Get:4 http://us.archive.ubuntu.com/ubuntu focal-updates/main amd64 keyutils amd  
64 1.6-6ubuntu1.1 [44.8 kB]  
Get:5 http://us.archive.ubuntu.com/ubuntu focal/main amd64 libevent-2.1-7 amd64  
2.1.11-stable-1 [138 kB]
```

3. Konfigurasi file /etc(exports

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

```
GNU nano 4.8                               /etc/exports                         Modified
# /etc/exports: the access control list for filesystems which may be exported
#                   to NFS clients. See exports(5).
#
# Example for NFSv2 and NFSv3:
# /srv/homes      hostname1(rw,sync,no_subtree_check) hostname2(ro,sync,no_su>
#
# 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/mpi/cloud *(rw,sync,no_root_squash,no_subtree_check)■

mpi@ubuntu:~$ sudo nano /etc/exports
mpi@ubuntu:~$ sudo exportfs -a
mpi@ubuntu:~$ sudo systemctl restart nfs-kernel-server
mpi@ubuntu:~$ ■
```

4. Install NFS Client

- Worker1

```
mpl@mardaharyani-virtual-machine: $ sudo apt install nfs-common
[sudo] password for mpl:
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  keyutils libevent-core-2.1-7 libnfsidmap1 rpcbind
Suggested packages:
  open-iscsi watchdog
The following NEW packages will be installed:
  keyutils libevent-core-2.1-7 libnfsidmap1 nfs-common rpcbind
0 upgraded, 5 newly installed, 0 to remove and 2 not upgraded.
Need to get 475 kB of archives.
After this operation, 1,709 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 libevent-core-2.1-7 amd64 2.1.12-stable-1build3 [93,9 kB]
Get:2 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 libnfsidmap1 amd64 1:2.6.1-1ubuntu1.2 [42,9 kB]
Get:3 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 rpcbind amd64 1:2.6.2build1 [46,0 kB]
Get:4 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 keyutils amd64 1.6.1-2ubuntu3 [50,4 kB]
Get:5 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 nfs-common amd64 1:2.6.1-1ubuntu1.2 [241 kB]
Fetched 475 kB in 0s (1,047 kB/s)
Selecting previously unselected package libevent-core-2.1-7:amd64.
(Reading database ... 293844 files and directories currently installed.)
Preparing to unpack .../libevent-core-2.1-7-2.1.12-stable-1build3_amd64.deb ...
Unpacking libevent-core-2.1-7:amd64 (2.1.12-stable-1build3) ...
Selecting previously unselected package libnfsidmap1:amd64.
Preparing to unpack .../libnfsidmap1_1%3a2.6.1-1ubuntu1.2_amd64.deb ...
Unpacking libnfsidmap1:amd64 (1:2.6.1-1ubuntu1.2) ...
Selecting previously unselected package rpcbind.
Preparing to unpack .../rpcbind_1.2.6-2build1_amd64.deb ...
Unpacking rpcbind (1:2.6.2build1) ...
Selecting previously unselected package keyutils.
Preparing to unpack .../keyutils_1.6.1-2ubuntu3_amd64.deb ...
Unpacking keyutils (1:6.1-1ubuntu3) ...
Selecting previously unselected package nfs-common.
Preparing to unpack .../nfs-common_1%3a2.6.1-1ubuntu1.2_amd64.deb ...
Unpacking nfs-common (1:2.6.1-1ubuntu1.2) ...
Setting up libnfsidmap1:amd64 (1:2.6.1-1ubuntu1.2) ...
```

- Worker2

```
mpi@ubuntu:~$ sudo apt install nfs-common
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  liblvm9 linux-modules-5.4.0-1002-oem
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  keyutils libevent-2.1-7 libnfsidmap2 libtirpc-common libtirpc3 rpcbind
Suggested packages:
  open-iscsi watchdog
The following NEW packages will be installed:
  keyutils libevent-2.1-7 libnfsidmap2 libtirpc-common libtirpc3 nfs-common
  rpcbind
0 upgraded, 7 newly installed, 0 to remove and 360 not upgraded.
Need to get 543 kB of archives.
After this operation, 1,924 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://us.archive.ubuntu.com/ubuntu focal-updates/main amd64 libtirpc-common all 1:2.5-1ubuntu0.1 [7,712 B]
Get:2 http://us.archive.ubuntu.com/ubuntu focal-updates/main amd64 libtirpc3 amd64 1:2.5-1ubuntu0.1 [77.9 kB]
Get:3 http://us.archive.ubuntu.com/ubuntu focal/main amd64 rpcbind amd64 1:2.5-8 [42.8 kB]
Get:4 http://us.archive.ubuntu.com/ubuntu focal-updates/main amd64 keyutils amd64 1:6-6ubuntu1.1 [44.8 kB]
Get:5 http://us.archive.ubuntu.com/ubuntu focal/main amd64 libevent-2.1-7 amd64 2.1.11-stable-1 [138 kB]
```

- Worker3

```
mpi@febiyona-virtual-machine:~$ sudo apt install nfs-common
[sudo] password for mpi:
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  keyutils libevent-core-2.1-7 libnfsidmap1 rpcbind
Suggested packages:
  open-iscsi watchdog
The following NEW packages will be installed:
  keyutils libevent-core-2.1-7 libnfsidmap1 nfs-common rpcbind
0 upgraded, 5 newly installed, 0 to remove and 115 not upgraded.
Need to get 475 kB of archives.
After this operation, 1,709 kB of additional disk space will be used.
Do you want to continue? [Y/n] Y
Get:1 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 libevent-core-2.1-7 amd64 2.1.12-stable-1build3 [93,9 kB]
Get:2 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 libnfsidmap1 amd64 1:2.6.1-1ubuntu1.2 [42,9 kB]
Get:3 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 rpcbind amd64 1.2.6-2build1 [46,6 kB]
Get:4 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 keyutils amd64 1.6.1-2ubuntu3 [50,4 kB]
Get:5 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 nfs-common amd64 1:2.6.1-1ubuntu1.2 [241 kB]
Fetched 475 kB in 0s (1,337 kB/s)
Selecting previously unselected package libevent-core-2.1-7:amd64.
(Reading database ... 164716 files and directories currently installed.)
Preparing to unpack .../libevent-core-2.1-7_2.1.12-stable-1build3_amd64.deb ...
Unpacking libevent-core-2.1-7:amd64 (2.1.12-stable-1build3) ...
Selecting previously unselected package libnfsidmap1:amd64.
Preparing to unpack .../libnfsidmap1_1%3a2.6.1-1ubuntu1.2_amd64.deb ...
Unpacking libnfsidmap1:amd64 (1:2.6.1-1ubuntu1.2) ...
Selecting previously unselected package rpcbind.
Preparing to unpack .../rpcbind_1.2.6-2build1_amd64.deb ...
Unpacking rpcbind (1.2.6-2build1) ...
Selecting previously unselected package keyutils.
Preparing to unpack .../keyutils_1.6.1-2ubuntu3_amd64.deb ...
Unpacking keyutils (1.6.1-2ubuntu3) ...
Selecting previously unselected package nfs-common.
Preparing to unpack .../nfs-common_1%3a2.6.1-1ubuntu1.2_amd64.deb ...
Unpacking nfs-common (1:2.6.1-1ubuntu1.2) ...
Setting up libnfsidmap1:amd64 (1:2.6.1-1ubuntu1.2) ...
Setting up rpcbind (1.2.6-2build1) ...
Created symlink /etc/systemd/system/multi-user.target.wants/rpcbind.service → /lib/systemd/system/rpcbind.service.
```

5. Mounting

- Sudo mount <server host>:<lokasi shared folder di server>lokasi shared folder di client>

```
mpi@mardaharyani-virtual-machine:~$ sudo mount master:/home/mpi/cloud /home/mpi/cloud
mpi@mardaharyani-virtual-machine:~$
```

- MPI

1. Install MPI

- Pada Master

```
mpi@ubuntu:~$ sudo apt install openmpi-bin libopenmpi-dev
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  liblvm9 linux-modules-5.4.0-1002-oem
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  autoconf automake autotools-dev binutils binutils-common
  binutils-x86-64-linux-gnu cpp-8 gcc gcc-8 gcc-8-base gcc-9 gfortran
  gfortran-8 gfortran-9 ibverbs-providers libasan5 libbinutils libc-dev-bin
  libc6 libc6-dbg libc6-dev libcaf-openmpi-3 libcoarrays-dev
  libcoarrays-openmpi-dev libcrypt-dev libctf-nobfd0 libctf0
  libevent-core-2.1-7 libevent-dev libevent-extra-2.1-7
  libevent-openssl-2.1-7 libevent-pthreads-2.1-7 libfabric1 libgcc-8-dev
  libgcc-9-dev libgfortran-8-dev libgfortran-9-dev libgfortran5 libhwloc-dev
  libhwloc-plugins libhwloc15 libibverbs-dev libibverbs1 libitm1 liblsan0
  libltdl-dev libltdl7 libmpx2 libnl-3-200 libnl-3-dev libnl-genl-3-200
  libnl-route-3-200 libnl-route-3-dev libnuma-dev libopenmpi3 libpmix2
  libpsm-infinipath1 libpsm2-2 libquadmath0 librdrmac1 libsigsegv2 libtool
  libtsan0 libubsan1 libnvctrl0 linux-libc-dev m4 manpages-dev
  ocl-icd-libopencl1 openmpi-common
Suggested packages:
  autoconf-archive gnu-standards autoconf-doc gettext binutils-doc
  gcc-8-locales gcc-multilib make flex bison gcc-doc gcc-8-multilib gcc-8-doc
  libasan5-dev libasan5-doc libbinutils-dev libbinutils-doc libltdl-dev libltdl-doc
```

- Pada Worker1

```
mpi@mardaharyani-virtual-machine:~$ sudo apt install openmpi-bin libopenmpi-dev
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  autoconf automake autotools-dev binutils binutils-common binutils-x86-64-linux-gnu gcc
  gcc-11 gfortran gfortran-11 ibverbs-providers javascript-common libasan6 libbinutils
  libc-dev-bin libc-devtools libc6-dev libcaf-openmpi-3 libcc1-0 libcoarrays-dev
  libcoarrays-openmpi-dev libcrypt-dev libctf-nobfd0 libctf0 libevent-dev libevent-extra-2.1-7
  libevent-openssl-2.1-7 libevent-pthreads-2.1-7 libfabric1 libgcc-11-dev libgfortran-11-dev
  libgfortran5 libhwloc-dev libhwloc-plugins libhwloc15 libibverbs-dev libibverbs1 libitm1
  libjs-jquery libjs-jquery-ui liblsan0 libltdl-dev libnl-3-dev libnl-route-3-dev libnsl-dev
  libnuma-dev libopenmpi3 libpmix-dev libpmix2 libpsm-infinopath1 libpsm2-2 libquadmath0
  librdmacm1 libsigsegv2 libtirpc-dev libtool libtsan0 libubsan1 libucx0 libxnvctrl0
  linux-libc-dev m4 manpages-dev ocl-icd-libopencl1 openmpi-common rpcsvc-proto zlib1g-dev
Suggested packages:
  autoconf-archive gnu-standards autoconf-doc gettext binutils-doc gcc-multilib make flex
  bison gcc-doc gcc-11-multilib gcc-11-doc gcc-11-locales gfortran-multilib gfortran-doc
  gfortran-11-multilib gfortran-11-doc apache2 | lighttpd | httpd glibc-doc
  libhwloc-contrib-plugins libjs-jquery-ui-docs libtool-doc openmpi-doc gcj-jdk m4-doc
  opencl-icd
The following NEW packages will be installed:
  autoconf automake autotools-dev binutils binutils-common binutils-x86-64-linux-gnu gcc
  gcc-11 gfortran gfortran-11 ibverbs-providers javascript-common libasan6 libbinutils
  libc-dev-bin libc-devtools libc6-dev libcaf-openmpi-3 libcc1-0 libcoarrays-dev
  libcoarrays-openmpi-dev libcrypt-dev libctf-nobfd0 libctf0 libevent-dev libevent-extra-2.1-7
  libevent-openssl-2.1-7 libevent-pthreads-2.1-7 libfabric1 libgcc-11-dev libgfortran-11-dev
  libgfortran5 libhwloc-dev libhwloc-plugins libhwloc15 libibverbs-dev libibverbs1 libitm1
  libjs-jquery libjs-jquery-ui liblsan0 libltdl-dev libnl-3-dev libnl-route-3-dev libnsl-dev
  libnuma-dev libopenmpi-dev libopenmpi3 libpmix-dev libpmix2 libpsm-infinopath1 libpsm2-2
  libquadmath0 librdmacm1 libsigsegv2 libtirpc-dev libtool libtsan0 libubsan1 libucx0
  libxnvctrl0 linux-libc-dev m4 manpages-dev ocl-icd-libopencl1 openmpi-bin openmpi-common
  rpcsvc-proto zlib1g-dev
0 upgraded, 69 newly installed, 0 to remove and 2 not upgraded.
Need to get 64,1 MB of archives.
After this operation, 230 MB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 libsigsegv2 amd64 2.13-1ubuntu3 [14,6 kB]
Get:2 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 m4 amd64 1.4.18-5ubuntu2 [199 kB]
```

- Pada Worker2

```
mpi@ubuntu:~$ sudo apt install openmpi-bin libopenmpi-dev
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  liblvm9 linux-modules-5.4.0-1002-oem
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  autoconf automake autotools-dev binutils binutils-common
  binutils-x86-64-linux-gnu cpp-8 gcc gcc-8 gcc-8-base gcc-9 gfortran
  gfortran-8 gfortran-9 ibverbs-providers libasan5 libbinutils libc-dev-bin
  libc6 libc6-dbg libc6-dev libcaf-openmpi-3 libcoarrays-dev
  libcoarrays-openmpi-dev libcrypt-dev libctf-nobfd0 libctf0
  libevent-core-2.1-7 libevent-dev libevent-extra-2.1-7
  libevent-openssl-2.1-7 libevent-pthreads-2.1-7 libfabric1 libgcc-8-dev
  libgcc-9-dev libgfortran-8-dev libgfortran-9-dev libgfortran5 libhwloc-dev
  libhwloc-plugins libhwloc15 libibverbs-dev libibverbs1 libitm1 liblsan0
  libltdl-dev libltdl7 libmpx2 libnl-3-200 libnl-3-dev libnl-genl-3-200
  libnl-route-3-200 libnl-route-3-dev libnuma-dev libopenmpi3 libpmix2
  libpsm-infinopath1 libpsm2-2 libquadmath0 librdmacm1 libsigsegv2 libtool
  libtsan0 libubsan1 libxnvctrl0 linux-libc-dev m4 manpages-dev
  ocl-icd-libopencl1 openmpi-common
Suggested packages:
  autoconf-archive gnu-standards autoconf-doc gettext binutils-doc
  gcc-8-locales gcc-multilib make flex bison gcc-doc gcc-8-multilib gcc-8-doc
  gcc-9-multilib gcc-9-doc gcc-9-locales gfortran-multilib gfortran-doc
  gfortran-8-multilib gfortran-8-doc gfortran-9-multilib gfortran-9-doc
  glibc-doc libhwloc-contrib-plugins libtool-doc openmpi-doc gcj-jdk m4-doc
  opencl-icd
```

- Pada Worker3

```
mpi@febyona-virtual-machine: ~$ sudo apt install openmpi-bin libopenmpi-dev
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  autoconf automake autotools-dev binutils binutils-common binutils-x86-64-linux-gnu gcc gcc-11 gfortran gfortran-11
  ibverbs-providers javascript-common libasano libbinutils libc-dev-bin libc-dev-tools libc6 libc6-dbg libc6-dev libcaf-openmpi-3
  libcc1-0 libcoarrays-dev libcoarrays-openmpi-dev libcrypt-dev libctf-nobfd0 libctf0 libevent-dev libevent-extra-2.1-7
  libevent-openssl-2.1-7 libevent-pthreads-2.1-7 libfabric1 libgcc-11-dev libgfortran-11-dev libgfortran5 libhwloc-dev
  libhwloc-plugins libhwloc5 libibverbs-dev libibverbs1 libitm libjs-jquery libjs-jquery-ui libasan0 libltdl-dev libnl-3-dev
  libnl-route-3-dev libnsl-dev libnuma-dev libopenmpi3 libpmix-dev libpmix2 libpsm-infinipath1 libpsm2-2 libquadmath0 librdmacm
  libsigsegv2 libtirpc-dev libtool libtsan0 libubsan1 libucx0 libxnvctrl0 linux-libc-dev m4 manpages-dev ocl-icd-libopencl1
  openmpi-common rpcsvc-proto zlib1g-dev
Suggested packages:
  autoconf-archive gnu-standards autoconf-doc gettext binutils-doc gcc-multilib make flex bison gcc-doc gcc-11-multilib gcc-11-doc
  gcc-11-locales gfortran-multilib gfortran-doc gfortran-11-multilib gfortran-11-doc apache2 | lighttpd | httpd glibc-doc
  libhwloc-contrib-plugins libjs-jquery-ui-docs libtool-doc openmpi-doc gcj-jdk m4-doc opencl-icd
Recommended packages:
  libnss-nis libnss-nisplus
The following NEW packages will be installed:
  autoconf automake autotools-dev binutils binutils-common binutils-x86-64-linux-gnu gcc gcc-11 gfortran gfortran-11
  ibverbs-providers javascript-common libasano libbinutils libc-dev-bin libc-dev-tools libc6 libc6-dbg libc6-dev libcaf-openmpi-3 libcc1-0
  libcoarrays-dev libcoarrays-openmpi-dev libcrypt-dev libctf-nobfd0 libctf0 libevent-dev libevent-extra-2.1-7
  libevent-openssl-2.1-7 libevent-pthreads-2.1-7 libfabric1 libgcc-11-dev libgfortran-11-dev libgfortran5 libhwloc-dev
  libhwloc-plugins libhwloc5 libibverbs-dev libibverbs1 libitm libjs-jquery libjs-jquery-ui libasan0 libltdl-dev libnl-3-dev
  libnl-route-3-dev libnsl-dev libnuma-dev libopenmpi-dev libopenmpi3 libpmix-dev libpmix2 libpsm-infinipath1 libpsm2-2
  libquadmath0 librdmacm1 libsigsegv2 libtirpc-dev libtool libtsan0 libubsan1 libucx0 libxnvctrl0 linux-libc-dev m4 manpages-dev
  ocl-icd-libopencl1 openmpi-bin openmpi-common rpcsvc-proto zlib1g-dev
The following packages will be upgraded:
  libc6 libc6-dbg
2 upgraded, 69 newly installed, 0 to remove and 113 not upgraded.
Need to get 81,2 MB of archives.
After this operation, 230 MB of additional disk space will be used.
Do you want to continue? [Y/n] Y
Get:1 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 libc6-dbg amd64 2.35-0ubuntu3.4 [13,9 MB]
Get:2 http://id.archive.ubuntu.com/ubuntu jammy-updates/main amd64 libc6 amd64 2.35-0ubuntu3.4 [3,234 kB]
Get:3 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 libsigsegv2 amd64 2.13-1ubuntu3 [14,6 kB]
Get:4 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 m4 amd64 1.4.18-2ubuntu2 [199 kB]
Get:5 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 autoconf all 2.71-2 [338 kB]
Get:6 http://id.archive.ubuntu.com/ubuntu jammy/main amd64 autotools-dev all 20220109.1 [44,9 kB]
```

2. Testing

- Touch test.py

```
mpi@ubuntu: ~$ touch bubblesort.py
mpi@ubuntu: ~$ sudo nano bubblesort.py
mpi@ubuntu: ~$ sudo apt install python3-pip
[sudo] password for mpi:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  liblomm9 linux-modules-5.4.0-1002-oem
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  build-essential dpkg-dev fakeroot g++ g++-9 libalgorithm-diff-perl
  libalgorithm-diff-xs-perl libalgorithm-merge-perl libexpat1-dev libfakeroot
  libpython3-dev libpython3-stdlib libpython3.8-dev libstdc++-9-dev make
  python-pip-whl python3 python3-dev python3-distutils python3-lib2to3
  python3-minimal python3-setuptools python3-wheel python3.8-dev zlib1g-dev
Suggested packages:
  debian-keyring g++-multilib g++-9-multilib gcc-9-doc libstdc++-9-doc
  make-doc python3-doc python3-tk python3-venv python-setuptools-doc
The following NEW packages will be installed:
  build-essential dpkg-dev fakeroot g++ g++-9 libalgorithm-diff-perl
  libalgorithm-diff-xs-perl libalgorithm-merge-perl libexpat1-dev libfakeroot
  libpython3-dev libpython3.8-dev libstdc++-9-dev make python-pip-whl
  python3-dev python3-distutils python3-lib2to3 python3-pip
  python3-setuptools python3-wheel python3.8-dev zlib1g-dev
The following packages will be upgraded:
  libpython3-stdlib python3 python3-minimal
3 upgraded, 23 newly installed, 0 to remove and 351 not upgraded.
Need to get 18,5 MB of archives.
```

- **Running MPI Program**

1. Code program

```
GNU nano 6.2                                         bubbleshort.py *
def bubble_sort(arr):
    n = len(arr)

    for i in range(n):
        swapped = False

        for j in range(0, n-i-1):
            if arr[j] > arr[j+1]:
                arr[j], arr[j+1] = arr[j+1], arr[j]
                swapped = True

        if not swapped:
            break

# Contoh penggunaan:
arr = [64, 34, 25, 12, 22, 11, 90]
bubble_sort(arr)

print("Hasil setelah Bubble Sort:")
for i in range(len(arr)):
    print(arr[i], end=" ")
```

2. Eksekusi bubblesort di python3

- Menggunakan worker

```
Hasil setelah Bubble Sort:
11 12 22 25 34 64 90 Hasil setelah Bubble Sort:
11 12 22 25 34 64 90 mpi@mardaharyani-virtual-machine:~/cloud$ █
```