

## **Pemrosesan Paralel**

### **MPI**



**Disusun Oleh :**

**Kelompok 3**

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**Dosen Pengampu :**

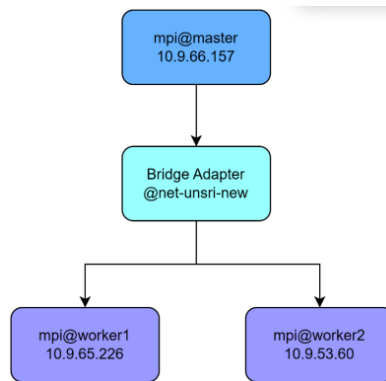
**Jurusan Sistem Komputer**

**Fakultas Ilmu Komputer**

**Universitas Sriwijaya**

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## TOPOLOGI MPI



### MPI-Bubblesort menggunakan Python

#### Menyiapkan Ubuntu Server dan Linux Mint

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

```
master@master-virtual-machine: ~  
To run a command as administrator (user "root"), use "sudo <command>".  
See "man sudo_root" for details.  
  
master@master-virtual-machine:~$ sudo apt update && sudo apt upgrade  
[sudo] password for master:  
Hit:1 http://id.archive.ubuntu.com/ubuntu jammy InRelease  
Hit:2 http://id.archive.ubuntu.com/ubuntu jammy-updates InRelease  
Hit:3 http://id.archive.ubuntu.com/ubuntu jammy-backports InRelease  
Hit:4 http://security.ubuntu.com/ubuntu jammy-security InRelease  
Reading package lists... Done  
Building dependency tree... Done  
Reading state information... Done  
358 packages can be upgraded. Run 'apt list --upgradable' to see them.  
Reading package lists... Done  
Building dependency tree... Done  
Reading state information... Done  
Calculating upgrade... Done  
yThe following NEW packages will be installed:  
  firefox libwp6-1.0-1 libwp6backend-fdo-1.0-1  
The following packages have been kept back:  
  apt apt-utils gjs libapt-pkg6.0 libgjs0g ubuntu-drivers-common  
The following packages will be upgraded:  
  accountsservice alsa-ucm-conf amd64-microcode apparmor apport apport-gtk avahi-autoipd  
  avahi-daemon avahi-utils base-files bind9-dnssutils bind9-host bind9-libseccomp ca-certificates  
  cpp-11 cups cups-browsed cups-bsd cups-client cups-common cups-core-drivers cups-daemon  
  cups-filters cups-filters-core-drivers cups-ipp-utils cups-ppdc cups-server-common  
  distro-info distro-info-data dnsmasq-base dpkg evince evince-common evolution-data-server  
  evolution-data-server-common file firmware-sof-signed fonts-opensymbol fwupd fwupd-signed  
  gcc-11-base gcc-12-base gdm3 ghostscript ghostscript-x glr1.2-accountsservice-1.0  
  glr1.2-adw-1 glr1.2-gdm-1.0 glr1.2-gnome-desktop-3.0 glr1.2-gst-plugins-base-1.0  
  glr1.2-gtk-4.0 glr1.2-javascriptcoregtk-4.0 glr1.2-mutter-10 glr1.2-pango-1.0  
  glr1.2-rsvg-2.0 glr1.2-webkit2-4.0 gnome-control-center gnome-control-center-data  
  gnome-control-center-faces gnome-desktop3-data gnome-remote-desktop gnome-session-canberra  
  gnome-settings-daemon gnome-settings-daemon-common gnome-shell gnome-shell-common  
  gnome-shell-extension-ubuntu-dock gstreamer1.0-alsa gstreamer1.0-gl gstreamer1.0-gtk3  
  gstreamer1.0-plugins-base gstreamer1.0-plugins-base-apps gstreamer1.0-plugins-good  
  gstreamer1.0-pulseaudio gstreamer1.0-x in-config initramfs-tools initramfs-tools-bin  
  initramfs-tools-core intel-microcode lpp-usb iptables irqbalance isc-dhcp-client  
  isc-dhcp-common libaccountsservice0 libadwaita-1-0 libapparmor1 libatomic1 libavahi-client3  
  libavahi-common-data libavahi-common3 libavahi-core7 libavahi-glib1 libavahi-ui-gtk3-0
```

```
worker1@worker1-virtual-machine: ~
To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.

worker1@worker1-virtual-machine: ~$ sudo apt update && sudo apt upgrade
[sudo] password for worker1:
Hit:1 http://id.archive.ubuntu.com/ubuntu jammy InRelease
Hit:2 http://id.archive.ubuntu.com/ubuntu jammy-updates InRelease
Hit:3 http://id.archive.ubuntu.com/ubuntu jammy-backports InRelease
Hit:4 http://security.ubuntu.com/ubuntu jammy-security InRelease
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
358 packages can be upgraded. Run 'apt list --upgradable' to see them.
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
Calculating upgrade... Done
The following NEW packages will be installed:
  firefox libwpe-1.0-1 libwpebackend-fdo-1.0-1
The following packages have been kept back:
  apt apt-utils gjs libapt-pkg6.0 libgjs0g ubuntu-drivers-common
The following packages will be upgraded:
  accountsservice alsa-ucm-conf amd64-microcode apparmor apport apport-gtk avahi-autolp
  avahi-daemon avahi-utils base-files bind9-dnsutils bind9-host bind9-lbns ca-certificates
  cpp-11 cups cups-browsed cups-bsd cups-client cups-common cups-core-drivers cups-daemon
  cups-filters cups-filters-core-drivers cups-lpp-utils cups-ppdc cups-server-common
  distro-info distro-info-data dnsmasq-base dpkg evince evince-common evolution-data-server
  evolution-data-server-common file firmware-sof-signed fonts-opensymbol fwupd fwupd-signed
  gcc-11-base gcc-12-base gdm3 ghostscript ghostscript-x gir1.2-accountsservice-1.0
  gir1.2-adv-1 gir1.2-gdm-1.0 gir1.2-gnomedesktop-3.0 gir1.2-gst-plugins-base-1.0
  gir1.2-gtk-4.0 gir1.2-javascriptcoregtk-4.0 gir1.2-mutter-10 gir1.2-pango-1.0
  gir1.2-rsvg-2.0 gir1.2-webkit2-4.0 gnome-control-center gnome-control-center-data
  gnome-control-center-faces gnome-desktop3-data gnome-remote-desktop gnome-session-canberra
  gnome-settings-daemon gnome-settings-daemon-common gnome-shell gnome-shell-common
  gnome-shell-extension-ubuntu-dock gstreamer1.0-alsa gstreamer1.0-gl gstreamer1.0-gtk3
  gstreamer1.0-plugins-base gstreamer1.0-plugins-base-apps gstreamer1.0-plugins-good
  gstreamer1.0-pulseaudio gstreamer1.0-x lm-config lntrams-tools lntrams-tools-bin
  lntrams-tools-core intel-microcode lpp-usb lptables irqbalance lsc-dhcc-client
  lsc-dhcc-common libaccountsservice0 libadwaita-1-0 libapparmor1 libatomic1 libavahi-client3
  libavahi-common-data libavahi-common3 libavahi-core7 libavahi-glib1 libavahi-ui-gtk3-0
```

### 3. Melakukan penginstalan berikut: net-tools untuk memeriksa IP, vim untuk editor teks.

```
master@master-virtual-machine:~$ sudo apt install net-tools vim
[sudo] password for master:
Reading package lists... Done
Building dependency tree... Done
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 6 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]

worker1@worker1-virtual-machine:~$ sudo apt install net-tools vim
[sudo] password for worker1:
Reading package lists... Done
Building dependency tree... Done
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 6 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]
```

### 4. Melakukan pengecekan IP dengan perintah berikut:

```

master@master-virtual-machine:~$ ifconfig
ens33: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.1.24 netmask 255.255.255.0 broadcast 192.168.1.255
    inet6 fe80::ae78:10d2:f069:9498 prefixlen 64 scopeid 0x20<link>
    ether 00:0c:29:8b:d6:06 txqueuelen 1000 (Ethernet)
    RX packets 28588 bytes 42029400 (42.0 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 20746 bytes 1604428 (1.6 MB)
    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 443 bytes 39129 (39.1 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 443 bytes 39129 (39.1 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

worker1@worker1-virtual-machine:~$ ifconfig
ens33: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.1.25 netmask 255.255.255.0 broadcast 192.168.1.255
    inet6 fe80::80b0:bfe9:6f07:f13 prefixlen 64 scopeid 0x20<link>
    ether 00:0c:29:d2:b5:e2 txqueuelen 1000 (Ethernet)
    RX packets 27877 bytes 41019562 (41.0 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 20116 bytes 1567869 (1.5 MB)
    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 442 bytes 39285 (39.2 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 442 bytes 39285 (39.2 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

worker1@worker1-virtual-machine:~$ 

worker2@worker2-virtual-machine:~$ ifconfig
ens33: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.1.22 netmask 255.255.255.0 broadcast 192.168.1.255
    inet6 fe80::e5de:ad76:1431:3d3 prefixlen 64 scopeid 0x20<link>
    ether 00:0c:29:6f:d4:7d txqueuelen 1000 (Ethernet)
    RX packets 7521 bytes 10697630 (10.6 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 5533 bytes 487832 (487.8 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 381 bytes 32311 (32.3 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 381 bytes 32311 (32.3 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

worker3@worker3-virtual-machine:~$ ifconfig
ens33: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.1.23 netmask 255.255.255.0 broadcast 192.168.1.255
    inet6 fe80::e363:cf50:bc75:7a0d prefixlen 64 scopeid 0x20<link>
    ether 00:0c:29:9a:6a:3a txqueuelen 1000 (Ethernet)
    RX packets 7511 bytes 10700529 (10.7 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 5599 bytes 490699 (490.6 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 388 bytes 33085 (33.0 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 388 bytes 33085 (33.0 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

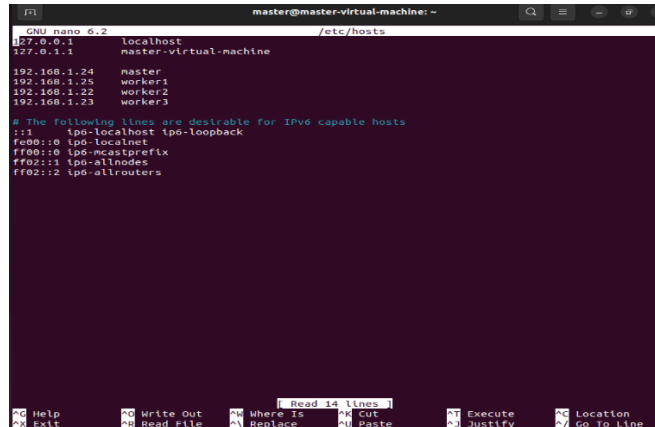
```

Nama	Master	Worker 1	Worker 2	Worker 3
IP	192.168.1.24	192.168.1.25	192.168.1.22	192.168.1.23

## Membuat Klaster MPI

## 1. Konfigurasi file host /etc/hosts

- Pada Master

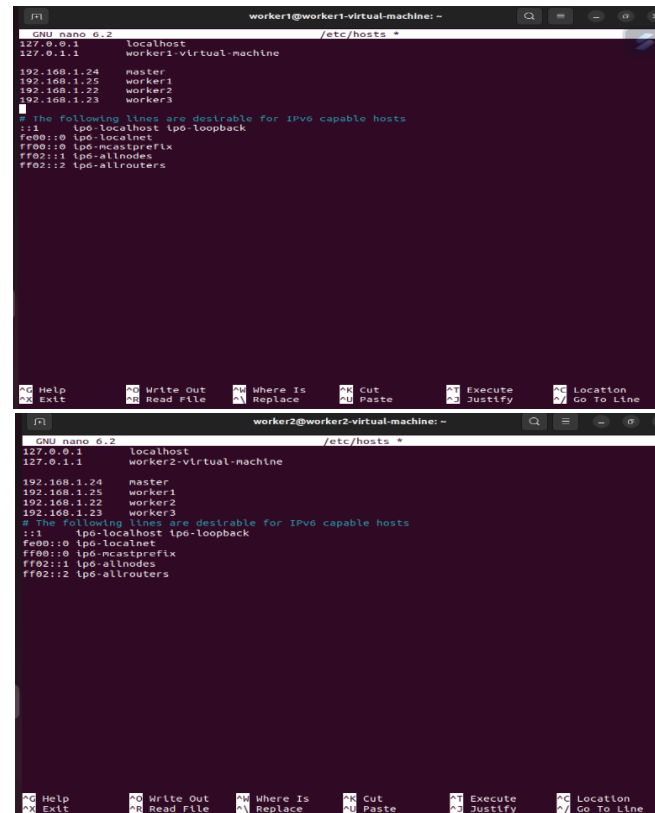


```
GNU nano 6.2 /etc/hosts
127.0.0.1 localhost
127.0.1.1 master-virtual-machine

192.168.1.24 master
192.168.1.25 worker1
192.168.1.22 worker2
192.168.1.23 worker3

# The following lines are desirable for IPv6 capable hosts
::1 ip6-localhost ip6-loopback
fe80::0 ip6-localnet
ff00::0 ip6-mcastprefix
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters
```

- Pada Worker



```
GNU nano 6.2 /etc/hosts *
127.0.0.1 localhost
127.0.1.1 worker1-virtual-machine

192.168.1.24 master
192.168.1.25 worker1
192.168.1.22 worker2
192.168.1.23 worker3

# The following lines are desirable for IPv6 capable hosts
::1 ip6-localhost ip6-loopback
fe80::0 ip6-localnet
ff00::0 ip6-mcastprefix
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters
```

```
GNU nano 6.2 /etc/hosts *
127.0.0.1 localhost
127.0.1.1 worker2-virtual-machine

192.168.1.24 master
192.168.1.25 worker1
192.168.1.22 worker2
192.168.1.23 worker3

# The following lines are desirable for IPv6 capable hosts
::1 ip6-localhost ip6-loopback
fe80::0 ip6-localnet
ff00::0 ip6-mcastprefix
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters
```

```
worker3@worker3-virtual-machine: ~  
GNU nano 6.2 /etc/hosts *  
127.0.0.1 localhost  
127.0.1.1 worker3-virtual-machine  
  
192.168.1.24 master  
192.168.1.25 worker1  
192.168.1.22 worker2  
192.168.1.23 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
```

## 2. Membuat Pengguna Baru

Lakukan pembuatan user terlebih dahulu karna harus menggunakan user yang memiliki nama yang sama. Dapat menggunakan command berikut untuk membuat user baru “sudo adduser mpi” (disini saya menggunakan user dengan nama mpi), setelah itu berikan akses root ke user baru tadi menggunakan command “sudo usermod -aG sudo mpi”.

```
$ sudo adduser  
$ sudo usermod -aG sudo  
$ su -mpi
```

- Pada Master

```
mpi@master: ~  
master@master:~$ sudo adduser mpi  
[sudo] password for master:  
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 is shorter than 8 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  
master@master:~$ sudo usermod -aG sudo mpi  
master@master:~$ su - mpi  
Password:  
To run a command as administrator (user "root"), use "sudo <command>".  
See "man sudo_root" for details.
```

- Pada Worker

```
mpi@worker1: ~  
worker1@worker1:~$ sudo adduser mpi  
[sudo] password for worker1:  
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 is shorter than 8 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  
worker1@worker1:~$ sudo usermod -aG sudo mpi  
Command 'udo' not found, but can be installed with:  
sudo apt install udo  
worker1@worker1:~$ sudo usermod -aG sudo mpi  
worker1@worker1:~$ su - mpi  
Password:  
To run a command as administrator (user "root"), use "sudo <command>".  
See "man sudo_root" for details.  
mpi@worker1:~$
```

```
mpi@worker2: ~  
worker2@worker2:~$ sudo adduser mpi  
[sudo] password for worker2:  
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 is shorter than 8 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  
worker2@worker2:~$ sudo usermod -aG sudo mpi  
worker2@worker2:~$ su - mpi  
Password:  
To run a command as administrator (user "root"), use "sudo <command>".  
See "man sudo_root" for details.  
mpi@worker3: ~  
worker3@worker3:~$ sudo adduser mpi  
[sudo] password for worker3:  
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 is shorter than 8 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  
worker3@worker3:~$ sudo usermod -aG sudo mpi  
worker3@worker3:~$ su - mpi  
Password:  
To run a command as administrator (user "root"), use "sudo <command>".  
See "man sudo_root" for details.
```

### 3. Konfigurasi SSH

Setelah membuat dan masuk ke user, lakukan konfigurasi SSH.

- Masuk ke user baru terlebih dahulu pada master dan workernya menggunakan command “su – mpi”.
- Install SSH dahulu menggunakan command “sudo apt install openssh-server” di master dan worker.

**\$ sudo apt install openssh-server**

```
mpi@master:~$ 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 6 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
```

```
mpi@worker1:~$ 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 6 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
```

```
mpi@worker2:~$ 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 6 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
```

```
mpi@worker3:~$ 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 6 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
```

c) Melakukan pengecekan SSH

Untuk pengecekan SSH bisa dilakukan dengan cara menghubungkan dari master ke worker dan sebaliknya.

**\$ ssh @**

- SSH dari Master ke Worker



```
mpi@worker1: ~  
master@master:~$ su - mpi  
Password:  
mpi@master:~$ ssh mpi@worker1  
The authenticity of host 'worker1 (192.168.1.25)' can't be established.  
ED25519 key fingerprint is SHA256:dBSsqVyjIoDC0ry093GhdLGfBVdSjwhMLWftNFGcqUM.  
This key is not known by any other names  
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes  
Warning: Permanently added 'worker1' (ED25519) 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@worker1:~$  
mpi@master:~$ ssh mpi@worker2  
The authenticity of host 'worker2 (192.168.1.22)' can't be established.  
ED25519 key fingerprint is SHA256:GO/w0I3TnU7k77dxwFYqRmxRFB6AF0ZgWolamltnBcw.  
This key is not known by any other names  
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes  
Warning: Permanently added 'worker2' (ED25519) to the list of known hosts.  
mpi@worker2'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.
```

Bisa langsung masuk tanpa memasukkan password worker yang dituju.

- SSH dari Worker ke Master

```
mpi@master: ~  
worker2@worker2:~$ su - mpi  
Password:  
mpi@worker2:~$ ssh mpi@master  
The authenticity of host 'master (192.168.1.24)' can't be established.  
ED25519 key fingerprint is SHA256:WJwo6w6ZP0Ko755F4exKS8Cu0CW6GJy0quk4IT00t24.  
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 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  
  
Failed to connect to https://changelogs.ubuntu.com/meta-release-lts. Check your Internet connect  
ion or proxy settings  
  
Last login: Wed Nov 15 23:25:26 2023 from 192.168.1.23  
mpi@master:~$
```



```

mpi@master:~$ cd .ssh
mpi@master:~/.ssh$ cat id_rsa.pub | ssh mpi@worker1 "mkdir .ssh; cat >> .ssh/authorized_keys"
mpi@worker1's password:
mkdir: cannot create directory '.ssh': File exists
mpi@master:~/.ssh$ cat id_rsa.pub | ssh mpi@worker2 "mkdir .ssh; cat >> .ssh/authorized_keys"
mpi@worker2's password:
mkdir: cannot create directory '.ssh': File exists
mpi@master:~/.ssh$ cat id_rsa.pub | ssh mpi@worker3 "mkdir .ssh; cat >> .ssh/authorized_keys"
The authenticity of host 'worker3 (192.168.1.23)' can't be established.
ED25519 key fingerprint is SHA256:Zx3Jyr8un9uqME4lgQAj1zy7pvUAQY2fx0VhHsjxmM.
This key is not known by any other names
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added 'worker3' (ED25519) to the list of known hosts.
mpi@worker3's password:
mkdir: cannot create directory '.ssh': File exists
mpi@master:~/.ssh$

```

### 3) Konfigurasi NFS

Selanjutnya membuat shared folder menggunakan NFS agar master dan worker dapat mengolah data dari folder yang sama secara langsung.

- a) Pertama, buat folder baru di master dan worker dengan nama yang sama.

**\$ mkdir cloud**

```

mpi@master:~$ mkdir cloud
mpi@master:~$

```

```

mpi@worker1:~$ mkdir cloud
mpi@worker1:~$

```

```

mpi@worker3:~$ mkdir cloud
mpi@worker3:~$

```

```

mpi@worker2:~$ mkdir cloud
mpi@worker2:~$

```

- b) Pada master, lakukan instalasi NFS server menggunakan command “sudo apt install nfs-kernel-server”

**\$ sudo apt install nfs-kernel-server**

```

mpi@master:~$ sudo apt install nfs-kernel-server
[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 nfs-common rpcbind
Suggested packages:
  open-iscsi watchdog
The following NEW packages will be installed:
  keyutils libevent-core-2.1-7 libnfsidmap1 nfs-common nfs-kernel-server rpcbind
0 upgraded, 6 newly installed, 0 to remove and 6 not upgraded.
Need to get 615 kB of archives.
After this operation, 2.235 kB of additional disk space will be used.
Do you want to continue? [Y/n] y

```

- c) Konfigurasi file /etc/exports

**\*(rw, sync, no\_root\_squash, no\_subtree\_check)**

```
mpi@master: ~  
GNU nano 6.2 /etc/exports *  
# /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_subtree_check)  
#  
# 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/mpl/cloud *(rw,sync,no_root_squash,no_subtree_check)
```

**\$ sudo exportfs -a**

**\$ sudo systemctl restart nfs-kernel-server**

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

d) Install NFS Client pada Worker

**\$ sudo apt install nfs-common**

```
mpi@worker1:~$ 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 6 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]
```

```
mpi@worker2:~$ 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 6 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]
```

```
mpi@worker3:~$ 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 6 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]
```

e) Mounting

**\$ sudo mount :**

```
mpi@worker1:~$ sudo mount master:/home/mpi/cloud /home/mpi/cloud
mpi@worker1:~$
mpi@worker2:~$ sudo mount master:/home/mpi/cloud /home/mpi/cloud
mpi@worker2:~$
mpi@worker3:~$ sudo mount master:/home/mpi/cloud /home/mpi/cloud
mpi@worker3:~$
```

#### 4) Instalasi MPI

Ada 3 hal yang harus di download pada bagian ini, yaitu :

- MPI
- Python3
- Library mpi4py

a) Install MPI

**\$ sudo apt install openmpi-bin libopenmpi-dev**

```
mpi@master:~$ 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 libverbs-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-infinipath1 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 gltbc-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:
```

```

mpi@worker1:~$ 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-infinipath1 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:

```

```

mpi@worker2:~$ 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-infinipath1 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-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
0 upgraded, 69 newly installed, 0 to remove and 6 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

```

```

mpi@worker3:~$ 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-infinipath1 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-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
0 upgraded, 69 newly installed, 0 to remove and 6 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

```

## Menjalankan Program Bubblesort.py

### 1. Membuat Program

```
$ touch bubblesort.py
```

```
$ sudo nano bubblesort.py
```

```
GNU nano 6.2 bubblesort.py *
from mpi4py import MPI
import random
import time

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

# Membuat 10 array acak
array_list = [random.sample(range(1, 1000), 10) for _ in range(10)]

# Menampilkan data mentah dan data yang sudah diurutkan
for i, arr in enumerate(array_list):
    print(f"Data mentah array {i + 1}: {arr}")

    # Mengukur waktu eksekusi Bubble Sort dan mengurutkan array
    start_time = time.time()
    bubble_sort(arr)
    end_time = time.time()
    elapsed_time = end_time - start_time

    print(f"Data yang sudah diurutkan array {i + 1}: {arr}")
    print(f"Waktu eksekusi: {elapsed_time:.6f} detik\n")

# Menampilkan array yang belum terurutkan
unsorted_arrays = [unsorted_arrays[i] for i, arr in enumerate(array_list) if arr != sorted(arr)]
print(f"Jumlah array yang belum terurutkan: {len(unsorted_arrays)}")
```

## 2. Eksekusi Numerik menggunakan Python

\$ python3 bubblesort.py

```
mpi@master:~/cloud$ sudo nano numerik.py
mpi@master:~/cloud$ python3 numerik.py
Total hasil perhitungan: 55
Waktu di kerjakan: 0.00033211708008847056
mpi@master:~/cloud$ sudo nano bubblesort.py
mpi@master:~/cloud$ python3 bubblesort.py
Data mentah array 1: [358, 614, 124, 859, 112, 578, 924, 962, 623, 566]
Data yang sudah diurutkan array 1: [112, 124, 358, 566, 578, 614, 623, 859, 924, 962]
Waktu eksekusi: 0.000025 detik

Data mentah array 2: [941, 429, 90, 942, 789, 716, 331, 95, 192, 438]
Data yang sudah diurutkan array 2: [90, 95, 192, 331, 429, 438, 716, 789, 941, 942]
Waktu eksekusi: 0.000027 detik

Data mentah array 3: [793, 875, 133, 790, 96, 712, 606, 366, 339, 165]
Data yang sudah diurutkan array 3: [96, 105, 133, 339, 366, 606, 712, 790, 793, 875]
Waktu eksekusi: 0.000029 detik

Data mentah array 4: [515, 569, 266, 888, 61, 677, 164, 344, 534, 125]
Data yang sudah diurutkan array 4: [61, 125, 164, 266, 344, 515, 534, 569, 677, 888]
Waktu eksekusi: 0.000027 detik

Data mentah array 5: [318, 515, 507, 472, 870, 311, 593, 661, 232, 332]
Data yang sudah diurutkan array 5: [232, 310, 311, 332, 472, 507, 515, 593, 661, 870]
Waktu eksekusi: 0.000026 detik

Data mentah array 6: [379, 701, 332, 129, 937, 27, 494, 211, 763, 365]
Data yang sudah diurutkan array 6: [27, 129, 211, 332, 365, 379, 494, 701, 763, 937]
Waktu eksekusi: 0.000023 detik

Data mentah array 7: [621, 580, 50, 144, 889, 42, 726, 498, 848, 944]
Data yang sudah diurutkan array 7: [42, 50, 144, 498, 580, 621, 726, 848, 889, 944]
Waktu eksekusi: 0.000021 detik

Data mentah array 8: [653, 23, 156, 875, 271, 230, 941, 793, 109, 985]
Data yang sudah diurutkan array 8: [23, 109, 156, 230, 271, 653, 793, 875, 941, 985]
Waktu eksekusi: 0.000024 detik

Data mentah array 9: [955, 964, 496, 156, 57, 525, 59, 577, 581, 352]
Data yang sudah diurutkan array 9: [57, 59, 156, 352, 496, 501, 525, 577, 955, 964]
Waktu eksekusi: 0.000020 detik
```

Dari 2 kodingan diatas, tahap pertama yang dilakukan adalah memanggil library mpi4py karna program yang dijalankan akan menggunakan mpi.

## 3. Eksekusi Bubblesort menggunakan MPI

\$ mpirun -np 3 -host master,worker,worker2,worker3 python3 bubblesort.py



```
mpi@master:~/cloud
jumlah array yang belum terurutkan: 10
mpi@master:~/cloud$ python3 bubbleSort.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
Data mentah array 1: [818, 408, 295, 812, 464, 306, 764, 393, 839, 445]
Data yang sudah diurutkan array 1: [295, 306, 393, 408, 445, 464, 764, 812, 818, 839]
Waktu eksekusi: 0.000028 detik

Data mentah array 2: [320, 817, 673, 41, 103, 603, 116, 485, 674, 121]
Data yang sudah diurutkan array 2: [41, 103, 116, 121, 320, 485, 603, 673, 674, 817]
Waktu eksekusi: 0.000027 detik

Data mentah array 3: [819, 484, 472, 196, 823, 589, 795, 922, 282, 974]
Data yang sudah diurutkan array 3: [196, 282, 472, 484, 589, 795, 819, 823, 922, 974]
Waktu eksekusi: 0.000027 detik

Data mentah array 4: [217, 73, 564, 910, 737, 5, 233, 81, 792, 782]
Data yang sudah diurutkan array 4: [5, 73, 81, 217, 233, 564, 782, 737, 792, 910]
Waktu eksekusi: 0.000025 detik

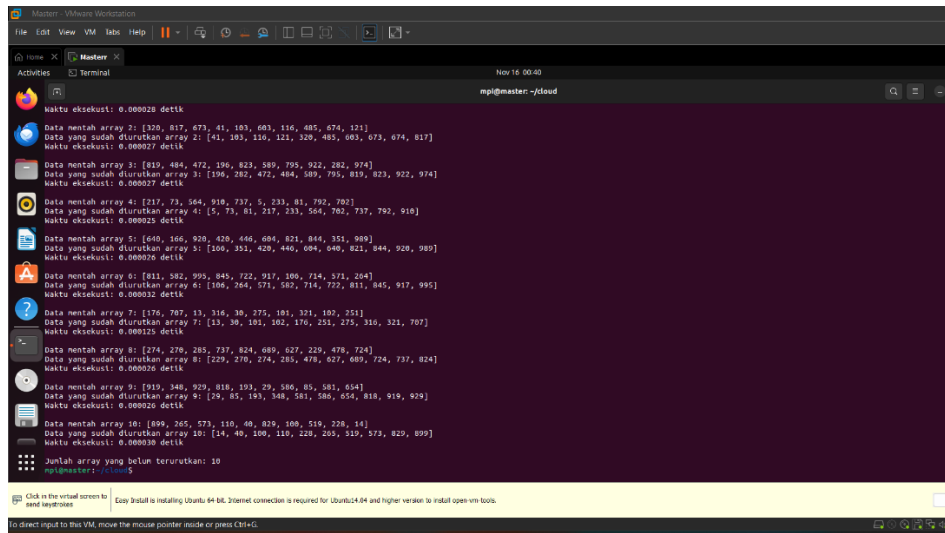
Data mentah array 5: [640, 166, 920, 420, 446, 604, 821, 844, 351, 989]
Data yang sudah diurutkan array 5: [166, 351, 420, 446, 604, 640, 821, 844, 920, 989]
Waktu eksekusi: 0.000026 detik

Data mentah array 6: [811, 582, 995, 845, 722, 917, 106, 714, 571, 264]
Data yang sudah diurutkan array 6: [106, 264, 571, 582, 714, 722, 811, 845, 917, 995]
Waktu eksekusi: 0.000032 detik

Data mentah array 7: [176, 707, 13, 316, 30, 275, 101, 321, 182, 251]
Data yang sudah diurutkan array 7: [13, 30, 101, 102, 176, 251, 275, 316, 321, 707]
Waktu eksekusi: 0.000125 detik

Data mentah array 8: [274, 270, 285, 737, 824, 689, 627, 229, 478, 724]
Data yang sudah diurutkan array 8: [229, 270, 274, 285, 478, 627, 689, 724, 737, 824]
Waktu eksekusi: 0.000026 detik

Data mentah array 9: [919, 348, 929, 818, 193, 29, 506, 85, 581, 654]
Data yang sudah diurutkan array 9: [29, 85, 193, 348, 581, 586, 654, 818, 919, 929]
Waktu eksekusi: 0.000026 detik
```



```
mpi@master: ~/cloud
-----
mpi@master:~/cloud$ mpirun -np 2 -host master,worker2 python3 bubblesort.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
Data mentah array 1: [527, 429, 12, 442, 558, 3, 96, 228, 886, 517]
Data yang sudah diurutkan array 1: [3, 12, 96, 228, 429, 442, 517, 527, 558, 886]
Waktu eksekusi: 0.000017 detik

Data mentah array 2: [920, 747, 674, 675, 333, 117, 575, 653, 886, 346]
Data yang sudah diurutkan array 2: [117, 333, 346, 575, 653, 674, 675, 747, 886, 920]
Waktu eksekusi: 0.000016 detik

Data mentah array 3: [770, 432, 867, 139, 330, 59, 708, 910, 462, 797]
Data yang sudah diurutkan array 3: [59, 139, 330, 432, 462, 708, 770, 797, 867, 910]
Waktu eksekusi: 0.000018 detik

Data mentah array 4: [246, 693, 628, 436, 57, 413, 162, 67, 719, 341]
Data yang sudah diurutkan array 4: [57, 67, 162, 246, 341, 413, 436, 628, 693, 719]
Waktu eksekusi: 0.000006 detik

Data mentah array 5: [881, 36, 134, 235, 487, 604, 155, 473, 565, 968]
Data yang sudah diurutkan array 5: [36, 134, 155, 235, 473, 487, 565, 604, 881, 968]
Waktu eksekusi: 0.000004 detik

Data mentah array 6: [138, 611, 886, 441, 482, 284, 345, 402, 840, 373]
Data yang sudah diurutkan array 6: [138, 284, 345, 373, 402, 441, 482, 611, 840, 886]
Waktu eksekusi: 0.000005 detik

Data mentah array 7: [524, 995, 798, 372, 126, 747, 780, 414, 463, 582]
Data yang sudah diurutkan array 7: [126, 372, 414, 463, 524, 582, 747, 780, 798, 995]
Waktu eksekusi: 0.000005 detik

Data mentah array 8: [939, 642, 563, 806, 800, 525, 91, 714, 669, 379]
Data yang sudah diurutkan array 8: [91, 379, 525, 563, 642, 669, 714, 800, 806, 939]
Waktu eksekusi: 0.000006 detik

Data mentah array 9: [236, 862, 728, 224, 32, 362, 811, 391, 495, 331]
Data yang sudah diurutkan array 9: [32, 224, 236, 331, 362, 391, 495, 728, 811, 862]
Waktu eksekusi: 0.000005 detik
```

Dari hasil program bubblesort dan numerik diatas, diketahui bahwa program yang dijalankan secara MPI dapat menghasilkan processing yang lebih cepat daripada yang tidak menggunakan MPI. Oleh karena itu, untuk program yang lebih rumit dan berat, akan sangat disarankan menggunakan multi-processing karena dapat sedikit menghemat waktu kerja.