

LAPORAN PEMROSESAN PARALEL
(Bubble Sort Python Menggunakan MPI Secara Paralel)



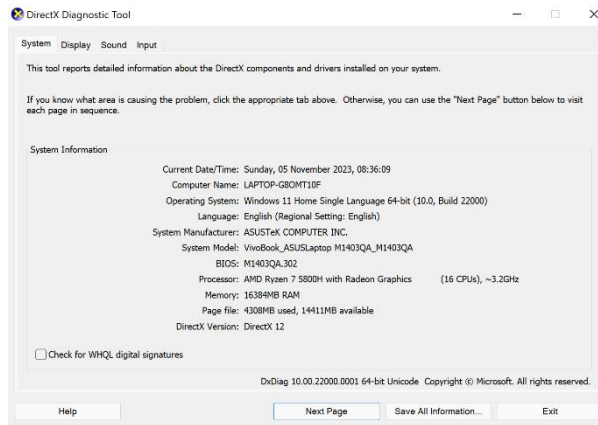
Disusun Oleh:
Kelompok 9
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FAKULTAS ILMU KOMPUTER
PROGRAM STUDI SISTEM KOMPUTER
UNIVERSITAS SRIWIJAYA
2023

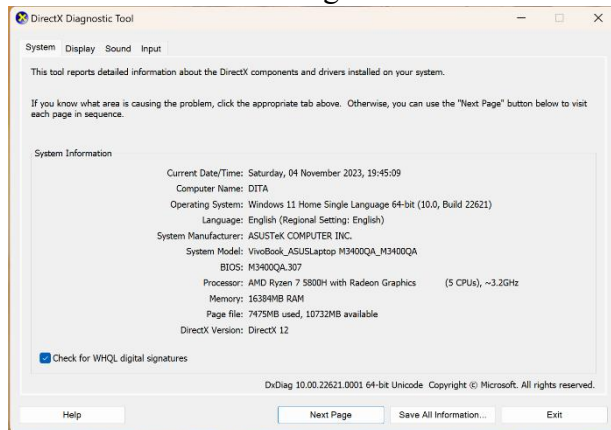
1. Master dan Worker

Menentukan master dan worker dengan melihat spesifikasi masing masing device

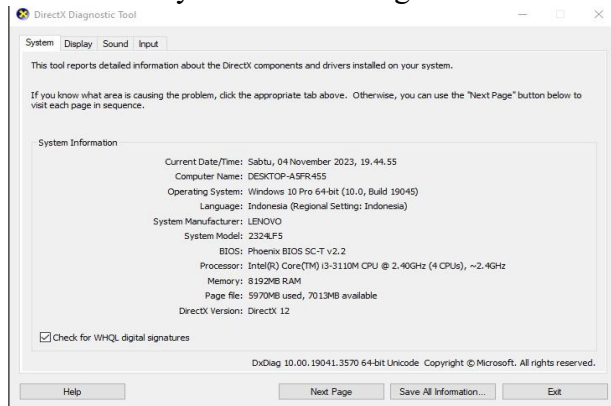
- Khairunnisa Junaidi sebagai **master**



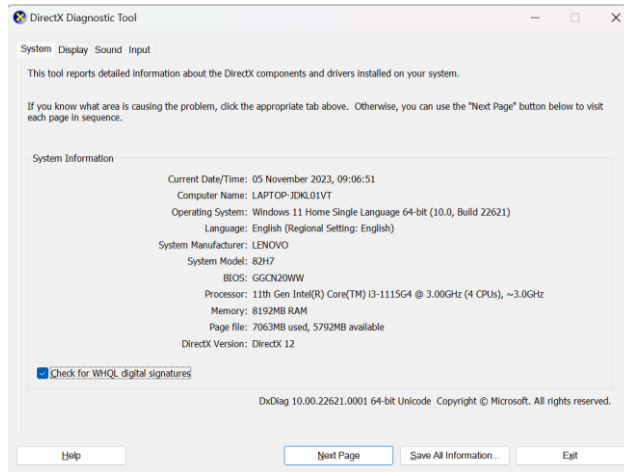
- Eka Ratna Anindita sebagai **worker1**



- Almira Callista Aurelie sebagai **worker2**



- Nabilla Suci Febriani sebagai **worker3**



2. Upgrade OS

Menggunakan command '*sudo apt update && sudo apt upgrade*' untuk memperbarui OS pada setiap device

- Master

```
khairunnisa@khairunnisa-VirtualBox:~$ sudo apt update && sudo apt upgrade
[sudo] password for khairunnisa:
Hit:1 http://id.archive.ubuntu.com/ubuntu bionic InRelease
Get:2 http://id.archive.ubuntu.com/ubuntu bionic-updates InRelease [88,7 kB]
Get:3 http://security.ubuntu.com/ubuntu bionic-security InRelease [88,7 kB]
Hit:4 http://ppa.launchpad.net/deadsnakes/ppa/ubuntu bionic InRelease
Get:5 http://id.archive.ubuntu.com/ubuntu bionic-backports InRelease [83,3 kB]
Get:6 http://security.ubuntu.com/ubuntu bionic-security/main amd64 DEP-11 Metadata [77,2 kB]
Get:7 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 DEP-11 Metadata [297 kB]
Get:8 http://security.ubuntu.com/ubuntu bionic-security/universe amd64 DEP-11 Metadata [52,5 kB]
Get:9 http://security.ubuntu.com/ubuntu bionic-security/multiverse amd64 DEP-11 Metadata [2,464 B]
Get:10 http://id.archive.ubuntu.com/ubuntu bionic-updates/universe amd64 DEP-11 Metadata [384 kB]
Get:11 http://id.archive.ubuntu.com/ubuntu bionic-updates/multiverse amd64 DEP-11 Metadata [2,468 B]
Get:12 http://id.archive.ubuntu.com/ubuntu bionic-backports/main amd64 DEP-11 Metadata [8,136 B]
Get:13 http://id.archive.ubuntu.com/ubuntu bionic-backports/universe amd64 DEP-11 Metadata [10,8 kB]
Fetched 1.024 kB in 15s (70,3 kB/s)
Reading package lists... Done
Building dependency tree
Reading state information... Done
All packages are up to date.
Reading package lists... Done
Building dependency tree
Reading state information... Done
Calculating upgrade... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
The following security updates require Ubuntu Pro with 'esm-infra' enabled:
  libwebp6 libpython3.6-minimal poppler-utils libnghttp2-14 liblscfg160
  libcup2 intel-microcode kserver-common vin-common libldap-2.4-2 openssl
  libb1 linux-generic libsystemd0 libxauth1 libx11 libxpm6b
  libpython3.6-stdlib libelf1 binutils libmagic-dbd-6 q16-3 librs160
  bind9-host linux-headers-generic-hwe-18.04 libxauth-common datautils
  libxauth-common libpython2.7 libcurl5 gir1.2-accountsservice-1.0
  libpython3.6 python3.6 libnsspr2 openssl-crypto-server libx12 liblscfg69
  udev cups-server-common amd64-microcode cups-common libncurses5 libx11-6
  python3-requests libudev1 libwp5 libapparmor1 libwebpdmuf2
python3-requests libudev1 libwp5 libapparmor1 libwebpdmuf2
```

- Worker1

```
ekaratna@ekaratna-VirtualBox:~$ sudo apt update && sudo apt upgrade
[sudo] password for ekaratna:
Hit:1 http://id.archive.ubuntu.com/ubuntu bionic InRelease
Get:2 http://id.archive.ubuntu.com/ubuntu bionic-updates InRelease [88,7 kB]
Get:3 http://security.ubuntu.com/ubuntu bionic-security InRelease [88,7 kB]
Hit:4 http://id.archive.ubuntu.com/ubuntu bionic-backports InRelease [83,3 kB]
Get:5 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 DEP-11 Metadata [297 kB]
Get:6 http://id.archive.ubuntu.com/ubuntu bionic-updates/universe amd64 DEP-11 Metadata [384 kB]
Get:7 http://id.archive.ubuntu.com/ubuntu bionic-updates/multiverse amd64 DEP-11 Metadata [2,468 B]
Get:8 http://id.archive.ubuntu.com/ubuntu bionic-backports/main amd64 DEP-11 Metadata [8,136 B]
Get:9 http://id.archive.ubuntu.com/ubuntu bionic-backports/universe amd64 DEP-11 Metadata [10,8 kB]
Get:10 http://security.ubuntu.com/ubuntu bionic-security/main amd64 DEP-11 Metadata [77,2 kB]
Get:11 http://security.ubuntu.com/ubuntu bionic-security/universe amd64 DEP-11 Metadata [52,5 kB]
Get:12 http://security.ubuntu.com/ubuntu bionic-security/multiverse amd64 DEP-11 Metadata [2,464 B]
Fetched 1.024 kB in 3s (349 kB/s)
Reading package lists... Done
Building dependency tree
Reading state information... Done
314 packages can be upgraded. Run 'apt list --upgradable' to see them.
Reading package lists... Done
Building dependency tree
Reading state information... Done
Calculating upgrade... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
Enable UA Infra: ESM to receive additional future security updates.
See https://ubuntu.com/18-04 or run: sudo ua status
Ubuntu comes with ABSOLUTELY NO WARRANTY, to the extent permitted by
applicable law.
The following NEW packages will be installed:
  linux-headers-5.4.0-150-generic linux-hwe-5.4-headers-5.4.0-150-generic
  linux-modules-5.4.0-150-generic linux-modules-extra-5.4.0-150-generic ubuntu-advantage-desktop-daemon
```

- Worker2

Menggunakan command *'ifconfig'* atau *'hostname -I'* untuk mengecek IP masing masing device

- Master

```
khairunnisa@khairunnisa-VirtualBox:~$ ifconfig
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.100.142 netmask 255.255.255.0 broadcast 192.168.100.255
    inet6 2001:448a:10ef:2ce7:850f:6161:964e:1425 prefixlen 64 scopeid 0x0<global>
    inet6 2001:448a:10ef:2ce7:698e:68c2:b302:9015 prefixlen 64 scopeid 0x0<global>
    inet6 fe80::f74b:ca96:2886:3453 prefixlen 64 scopeid 0x20<link>
    ether 08:00:27:84:33:bd txqueuelen 1000 (Ethernet)
    RX packets 2017 bytes 2715478 (2.7 MB)
    RX errors 100 dropped 0 overruns 0 frame 100
    TX packets 1677 bytes 140169 (140.1 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 188 bytes 15502 (15.5 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 188 bytes 15502 (15.5 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

- Worker1

```
ekaratna@ekaratna-VirtualBox:~$ hostname -I
192.168.100.144 2001:448a:10ef:2ce7:d88e:f316:e173:79f3 2001:448a:10ef:2ce7:8ad0:530f:b80c:4586
```

- Worker2

```
root@almirah-VirtualBox:/home/almirah# hostname -I
192.168.100.145 2001:448a:10ef:2ce7:1025:711e:2e8f:6c24 2001:448a:10ef:2ce7:222
```

- Worker3

```
nabilla@nabilla-VirtualBox:~$ hostname -I
192.168.100.146 2001:448a:10ef:2ce7:441d:73ff:ea6a:b168 2001:448a:10ef:2ce7:2c39:6beb:c7b0:af97
```

5. Konfigurasi file

Membuka file */etc/hosts* menggunakan command *'sudo nano /etc/hosts'*

```
khairunnisa@khairunnisa-VirtualBox:~$ sudo nano /etc/hosts
```

Lalu mengedit file dengan menambahkan IP dan peran.

- Master

```
GNU nano 2.9.3 /etc/hosts Modified
192.168.100.142 master1 localhost
127.0.1.1 khairunnisa-VirtualBox
# 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

192.168.100.144 worker1
192.168.100.145 worker2
192.168.100.146 worker3
```

- Worker1

```
GNU nano 2.9.3 /etc/hosts
192.168.100.144 worker1 localhost
127.0.1.1 ekaratna-VirtualBox

# 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

192.168.100.142 master
192.168.100.145 worker2
192.168.100.146 worker3
```

- Worker2


```
root@almirah-VirtualBox: /home/almirah
File Edit View Search Terminal Help
GNU nano 2.9.3 /etc/hosts Modified

198.168.100.145 worker2 localhost
127.0.1.1 almirah-VirtualBox

# 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

192.168.100.142 master
192.168.100.144 worker1
192.168.100.146 worker3
```

- Worker3

```
nabilla@nabilla-VirtualBox: ~
File Edit View Search Terminal Help
GNU nano 2.9.3 /etc/hosts Modified

192.168.100.146 worker3 localhost
127.0.1.1 nabilla-VirtualBox

# 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

192.168.100.142 master1
192.168.100.144 worker1
192.168.100.145 worker2
```

6. User bersama

Membuat user baru bersama dengan command '*sudo adduser <nama user>*'

```
root@ekaratna-VirtualBox: /home/ekaratna# adduser dina
Adding user `dina' ...
Adding new group `dina' (1001) ...
Adding new user `dina' (1001) with group `dina' ...
Creating home directory `/home/dina' ...
Copying files from `/etc/skel' ...
Enter new UNIX password:
Retype new UNIX password:
passwd: password updated successfully
Changing the user information for dina
Enter the new value, or press ENTER for the default
Full Name []: Dina
Room Number []: 123
Work Phone []: 011
Home Phone []: 1234
Other []:
Is the information correct? [Y/n] y
```

➤ User root

Memberi akses root ke user yang baru ditambahkan dengan command '*sudo usermod -aG sudo <nama user>*'

```
root@almirah-VirtualBox: /home/almirah# sudo usermod -aG sudo dina
```

➤ Login user

Masuk ke user dengan command '*su - <nama user>*'

```
nabilla@nabilla-VirtualBox: ~$ su - dina
Password:
To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.
```

7. Konfigurasi SSH

Melakukan konfigurasi SSH, SSH(Secure Shell) digunakan untuk otentikasi dan pertukaran data aman antara node dalam cluster MPI.

➤ Install SSH

Melakukan penginstallan SSH dengan command '*sudo apt install openssh-server*'

```
dina@almirah-VirtualBox:/home/almirah$ sudo apt install openssh-server
[sudo] password for dina:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  ncurses-term openssh-sftp-server ssh-import-id
Suggested packages:
  molly-guard monkeysphere rssh 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 0 not upgraded.
Need to get 637 kB of archives.
After this operation, 5.320 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 ncurses-ter
m all 6.1-1ubuntu1.18.04.1 [248 kB]
Get:2 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 openssh-sft
p-server amd64 1:7.6p1-4ubuntu0.7 [45.5 kB]
```

Dapat dilakukan pengecekan SSH untuk menghubungkan master ke klien, dengan command **'ssh <nama user>@<host>'**

```
dina@ekaratna-VirtualBox:~$ ssh dina@master
The authenticity of host 'master (192.168.100.142)' can't be established.
ECDSA key fingerprint is SHA256:Lmn8CRoRcOUPvq0NnBUvxTJ4eQxhxy6BrkQurtwAx1I.
Are you sure you want to continue connecting (yes/no)? y
Please type 'yes' or 'no': yes
Warning: Permanently added 'master,192.168.100.142' (ECDSA) to the list of known hosts.
dina@master's password:
Welcome to Ubuntu 18.04.6 LTS (GNU/Linux 5.4.0-150-generic x86_64)

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

Expanded Security Maintenance for Infrastructure is not enabled.

0 updates can be applied immediately.

130 additional security updates can be applied with ESM Infra.
Learn more about enabling ESM Infra service for Ubuntu 18.04 at
https://ubuntu.com/18-04

New release '20.04.6 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Your Hardware Enablement Stack (HWE) is supported until April 2023.
Last login: Thu Nov  2 16:02:39 2023 from 192.168.100.145
To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.

dina@khairunnisa-VirtualBox:~$
```

➤ Generate keygen

Dilakukan di master, menggunakan command **'ssh-keygen -t rsa'**

```
dina@khairunnisa-VirtualBox:~$ ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (/home/dina/.ssh/id_rsa):
Created directory '/home/dina/.ssh'.
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/dina/.ssh/id_rsa.
Your public key has been saved in /home/dina/.ssh/id_rsa.pub.
The key fingerprint is:
SHA256:3ost3qLxcWz3i13VyuVaV+a0w7nFscE+P3TtQrETWQ dina@khairunnisa-VirtualBox
The key's randomart image is:
+---[RSA 2048]---+
|      .E      |
|      o..     |
|      . o. o   |
|      o .. =  |
|      S .  o@  |
|      . o . . XB|
|      . o = o.+X|
|      ooB o =+*+|
|      .o+o+ . B*+|
+---[SHA256]-----+
```

➤ Input key publik ke klien

Dilakukan di master, membuat isi dari file *id_rsa.pub* disalin ke file *authorized_keys* menggunakan command **'cd .ssh'**

```
dina@khairunnisa-VirtualBox:~$ cd .ssh
```

- Master – worker1

```
dina@khairunnisa-VirtualBox:~/ssh$ cat id_rsa.pub | ssh dina@worker1 " cat>> .ssh/authorized_keys"
Connection to worker1 closed.
dina@ekaratna-VirtualBox:~$ ls .ssh
authorized_keys  known_hosts
```

- Master – worker2

```
dina@khairunnisa-VirtualBox:~/ssh$ cat id_rsa.pub | ssh dina@worker2 " cat>> .ssh/authorized_keys"
dina@almirah-VirtualBox:~$ ls .ssh
authorized_keys  known_hosts
```

- Master – worker3

```
dina@khairunnisa-VirtualBox:~/ssh$ cat id_rsa.pub | ssh dina@worker3 " cat>> .ssh/authorized_keys"
dina@nabilla-VirtualBox:~$ ls .ssh
authorized_keys  known_hosts
```

8. Konfigurasi NFS

Konfigurasi NFS (Network File System) merupakan proses mengatur dan mengkonfigurasi sistem berkas yang memungkinkan berbagi sistem berkas antara komputer dalam jaringan.

➤ Shared folder

Membuat folder bersama menggunakan command *'mkdir <nama folder>'*

```
dina@nabilla-VirtualBox:~$ mkdir pempar
dina@nabilla-VirtualBox:~$
```

➤ Install NFS Server

Menginstall NFS pada master dengan command *'sudo apt install nfs-kernel-server'*

```
dina@khairunnisa-VirtualBox:~$ sudo apt install nfs-kernel-server
[sudo] password for dina:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  keyutils libnfsidmap2 libtirpc1 nfs-common rpcbind
Suggested packages:
  open-iscsi watchdog
The following NEW packages will be installed:
  keyutils libnfsidmap2 libtirpc1 nfs-common nfs-kernel-server rpcbind
0 upgraded, 6 newly installed, 0 to remove and 0 not upgraded.
Need to get 492 kB of archives.
After this operation, 1.709 kB of additional disk space will be used.
Do you want to continue? [Y/n]
```

➤ Konfigurasi file

Dilakukan di master, buka file /etc/exports dengan command *'sudo nano /etc/exports'*

```
dina@khairunnisa-VirtualBox:~$ sudo nano /etc/exports
```

Dan dilakukan pengeditan pada file, dengan menambahkan *<lokasi shared folder>*
**(rw,sync,no_root_squash,no_subtree_check)*


```
Terminal
Kam 17:33
dina@khairunnisa-VirtualBox: ~
GNU nano 2.9.3 /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_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/pempar *(rw, sync, no_root_squash, no_subtree_check)
```

Lalu, untuk menyimpan ulang daftar direktori setelah mengedit file dapat menggunakan command **'sudo exportfs -a'** dan untuk memulai ulang layanan pada server dapat menggunakan command **'sudo systemctl restart nfs-kernel-server'**

```
dina@khairunnisa-VirtualBox:~$ sudo exportfs -a
dina@khairunnisa-VirtualBox:~$ sudo systemctl restart nfs-kernel-server
```

➤ Install NFS Klient

Melakukan instalasi NFS pada worker dengan command **'sudo apt install nfs-common'**

• Worker1

```
dina@ekaratna-VirtualBox:~$ sudo apt install nfs-common
Reading package lists... Done
Building dependency tree
Reading state information... Done
nfs-common is already the newest version (1:1.3.4-2.1ubuntu5.5).
nfs-common set to manually installed.
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
```

• Worker2

```
dina@almirah-VirtualBox:~$ sudo apt install nfs-common
[sudo] password for dina:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  keyutils libnfsidmap2 libtirpc1 rpcbind
Suggested packages:
  open-iscsi watchdog
The following NEW packages will be installed:
  keyutils libnfsidmap2 libtirpc1 nfs-common rpcbind
0 upgraded, 5 newly installed, 0 to remove and 0 not upgraded.
Need to get 399 kB of archives.
After this operation, 1.364 kB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 keyutils am
d64 1.5.9-9.2ubuntu2.1 [48,1 kB]
Get:2 http://id.archive.ubuntu.com/ubuntu bionic/main amd64 libnfsidmap2 amd64
0.25-5.1 [27,2 kB]
Get:3 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 libtirpc1 a
md64 0.2.5-1.2ubuntu0.1 [75,7 kB]
Get:4 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 rpcbind amd
64 0.2.3-0.6ubuntu0.18.04.4 [42,1 kB]
Get:5 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 nfs-common
```

• Worker3

```
dina@nabila-VirtualBox:~$ sudo apt install nfs-common
Reading package lists... Done
Building dependency tree
Reading state information... Done
nfs-common is already the newest version (1:1.3.4-2.1ubuntu5.5).
nfs-common set to manually installed.
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
```

➤ Mounting

Dilakukan pada worker dengan menggunakan command **'sudo mount <server host>:<lokasi shared folder di server> <lokasi shared folder di client>'**

- Worker1

```
dina@ekaratna-VirtualBox:~$ sudo mkdir /home/pempar
dina@ekaratna-VirtualBox:~$ sudo mount master:/home/pempar /home/pempar
```

- Worker2

```
dina@almirah-VirtualBox:~$ sudo mkdir /home/pempar
dina@almirah-VirtualBox:~$ sudo mount master:/home/pempar /home/pempar
```

- Worker3

```
dina@nabilla-VirtualBox:~$ sudo mkdir /home/pempar
dina@nabilla-VirtualBox:~$ sudo mount master:/home/pempar /home/pempar
```

9. MPI

MPI adalah singkatan dari "Message Passing Interface." Ini adalah standar komunikasi yang digunakan dalam pemrograman paralel, terutama dalam pemrograman terdistribusi untuk sistem berbasis kluster atau superkomputer.

➤ Install MPI

Melakukan instalasi MPI dengan command *'sudo apt install openmpi-bin libopenmpi-dev'*

```
dina@nabilla-VirtualBox:~$ 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:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'dpkg --get-selections | grep -e hold | grep -v install' to remove them.
The following additional packages will be installed:
  autotools-dev gcc gcc-7 libverbs-providers libasan4 libatomic1 libc-dev-bin libc6-dev libcilkrts5 libfabric1 libgcc-7-dev libhwloc-dev
  libhwloc-plugins libibverbs-dev libibverbs1 libitm1 liblsan0 libltdl-dev libmpx2 libnl-route-3-200 libnuma-dev libopenmpi2
  libpse-infinipath1 libquadmath0 librdmacni1 libtool libtsan0 libubsan0 linux-libc-dev nanpages-dev ocl-icd libopencl1 openmpi-bin openmpi-common
Suggested packages:
  gcc-multilib make autoconf automake flex bison gcc-doc gcc-7-multilib gcc-7-doc gcc-7-locale libgcc1-dbg libgomp1-dbg libitm1-dbg libatomic1-dbg
  libasan4-dbg liblsan0-dbg libtsan0-dbg libubsan0-dbg libcilkrts5-dbg libmpx2-dbg libquadmath0-dbg glibc-doc libhwloc-contrib-plugins libtool-doc
  openmpi-doc autotoken gfortran | fortran95-compiler gcj-jdk opencl-icd gfortran
The following NEW packages will be installed:
  autotools-dev gcc gcc-7 libverbs-providers libasan4 libatomic1 libc-dev-bin libc6-dev libcilkrts5 libfabric1 libgcc-7-dev libhwloc-dev
  libhwloc-plugins libibverbs-dev libibverbs1 libitm1 liblsan0 libltdl-dev libmpx2 libnl-route-3-200 libnuma-dev libopenmpi-dev libopenmpi2
  libpse-infinipath1 libquadmath0 librdmacni1 libtool libtsan0 libubsan0 linux-libc-dev nanpages-dev ocl-icd libopencl1 openmpi-bin openmpi-common
0 upgraded, 35 newly installed, 0 to remove and 0 not upgraded.
Need to get 23,7 MB of archives.
After this operation, 95,8 MB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://id.archive.ubuntu.com/ubuntu bionic/main amd64 autotools-dev all 20180224.1 [39,6 kB]
Get:2 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 libitm1 amd64 8.4.0-1ubuntu1-18.04 [27,9 kB]
Get:3 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 libatomic1 amd64 8.4.0-1ubuntu1-18.04 [9,192 B]
Get:4 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 libasan4 amd64 7.5.0-3ubuntu1-18.04 [338 kB]
Get:5 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 liblsan0 amd64 8.4.0-1ubuntu1-18.04 [133 kB]
Get:6 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 libtsan0 amd64 8.4.0-1ubuntu1-18.04 [288 kB]
Get:7 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 libubsan0 amd64 7.5.0-3ubuntu1-18.04 [126 kB]
Get:8 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 libcilkrts5 amd64 7.5.0-3ubuntu1-18.04 [42,5 kB]
Get:9 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 libmpx2 amd64 8.4.0-1ubuntu1-18.04 [11,6 kB]
Get:10 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 libquadmath0 amd64 8.4.0-1ubuntu1-18.04 [134 kB]
Get:11 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 libgcc-7-dev amd64 7.5.0-3ubuntu1-18.04 [2,378 kB]
16% [11 libgcc-7-dev 0 B/2.378 kB 0%]
```

➤ Testing

Dilakukan di master, membuat file python di folder sebelumnya, dengan command *'touch <nama file>.py'*

```
dina@khaairunnisa-VirtualBox:/home/pempar$ sudo chmod -R 777 /home/pempar
dina@khaairunnisa-VirtualBox:/home/pempar$ touch test.py
dina@khaairunnisa-VirtualBox:/home/pempar$
```

Lalu, dapat melakukan pengeditan dalam file dengan menggunakan command *'nano <nama file>.py'*

```
dina@khaairunnisa-VirtualBox:/home/pempar$ nano test.py
```

10. Konfigurasi python

➤ Install python

Melakukan instalasi python versi 3 dengan menggunakan command *'sudo apt install python3-pip'* dan python versi 2 dengan menggunakan command *'sudo apt install python-pip'*

```
dina@khairunnisa-VirtualBox:/home/pempar$ sudo apt install python3-pip
[sudo] password for dina:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  build-essential dh-python dpkg-dev fakeroot g++ g++-7 libalgorithm-diff-perl
  libalgorithm-diff-xs-perl libalgorithm-merge-perl libexpat1-dev libfakeroot libpython3-dev
  libpython3.6-dev libstdc++-7-dev make python-pip-whl python3-dev python3-distutils
  python3-lib2to3 python3-setuptools python3-wheel python3.6-dev
Suggested packages:
  debian-keyring g++-multilib g++-7-multilib gcc-7-doc libstdc++6-7-dbg libstdc++-7-doc make-doc
  python-setuptools-doc
The following NEW packages will be installed:
  build-essential dh-python dpkg-dev fakeroot g++ g++-7 libalgorithm-diff-perl
  libalgorithm-diff-xs-perl libalgorithm-merge-perl libexpat1-dev libfakeroot libpython3-dev
  libpython3.6-dev libstdc++-7-dev make python-pip-whl python3-dev python3-distutils
  python3-lib2to3 python3-pip python3-setuptools python3-wheel python3.6-dev
0 upgraded, 23 newly installed, 0 to remove and 0 not upgraded.
Need to get 60.0 MB of archives.
After this operation, 131 MB of additional disk space will be used.
Do you want to continue? [Y/n]
```

```
dina@khairunnisa-VirtualBox:~$ sudo apt install python-pip
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  libpython-all-dev libpython-dev libpython-stdlib libpython2.7-dev python
  python-all python-all-dev python-asn1crypto python-cffi-backend
  python-crypto python-cryptography python-dbus python-dev python-enum34
  python-gi python-idna python-ipaddress python-keyring python-keyrings.alt
  python-minimal python-pkg-resources python-secretstorage python-setuptools
  python-six python-wheel python-xdg python2.7 python2.7-dev python2.7-minimal
Suggested packages:
  python-doc python-tk python-crypto-doc python-cryptography-doc
  python-cryptography-vectors python-dbus-dbg python-dbus-doc
  python-enum34-doc python-gi-cairo libkf5wallet-bin gir1.2-gnomekeyring-1.0
  python-fs python-gdata python-keyczar python-secretstorage-doc
  python-setuptools-doc python2.7-doc binfmt-support
The following NEW packages will be installed:
  libpython-all-dev libpython-dev libpython-stdlib libpython2.7-dev python
  python-all python-all-dev python-asn1crypto python-cffi-backend
  python-crypto python-cryptography python-dbus python-dev python-enum34
  python-gi python-idna python-ipaddress python-keyring python-keyrings.alt
  python-minimal python-pip python-pkg-resources python-secretstorage
  python-setuptools python-six python-wheel python-xdg python2.7 python2.7-dev
  python2.7-minimal
0 upgraded, 30 newly installed, 0 to remove and 0 not upgraded.
Need to get 30.5 MB/32.1 MB of archives.
After this operation, 55.8 MB of additional disk space will be used.
Do you want to continue? [Y/n] y
Get:1 http://id.archive.ubuntu.com/ubuntu bionic/main amd64 python amd64 2.7.15~rc1-1 [140 kB]
```

➤ Install pustaka MPI4

Melakukan instalasi pustaka MPI4 yang menyediakan dukungan untuk komunikasi dan pemrograman paralel menggunakan MPI (Message Passing Interface) dapat dilakukan dengan command ***‘pip install mpi4py’***

```
dina@khairunnisa-VirtualBox:~$ pip install mpi4py
Collecting mpi4py
  Downloading https://files.pythonhosted.org/packages/2e/1a/1393e69df9cf7b04143a51776727dd048586781bca82543594ab439e2eb4/mpi4py-3.1.5.tar.gz (2.5MB)
    100% |#####| 2.5MB 280kB/s
Building wheels for collected packages: mpi4py
  Running setup.py bdist_wheel for mpi4py ... |
done
  Stored in directory: /home/dina/.cache/pip/wheels/6a/a2/4d/68998a0c10a3a307e55777b41b3da359a4742f087eff53acce
Successfully built mpi4py
Installing collected packages: mpi4py
Successfully installed mpi4py-3.1.5
```

➤ Input kunci

Dilakukan oleh master untuk menyalin kunci publik SSH ke mesin worker sehingga master dapat masuk ke mesin worker tanpa diminta kata sandi setiap kali menggunakan command ***‘ssh-copy-id’***

- **Master – worker1**

```
dina@master:~$ ssh-copy-id dina@worker1
/usr/bin/ssh-copy-id: INFO: Source of key(s) to be installed: "/home/dina/.ssh/id_rsa.pub"
/usr/bin/ssh-copy-id: INFO: attempting to log in with the new key(s), to filter out any that are al
ready installed

/usr/bin/ssh-copy-id: WARNING: All keys were skipped because they already exist on the remote syste
m.
(if you think this is a mistake, you may want to use -f option)
```

- **Master – worker2**

```
dina@master:~$ ssh-copy-id dina@worker2
/usr/bin/ssh-copy-id: INFO: Source of key(s) to be installed: "/home/dina/.ssh/
Files id_rsa.pub"
/usr/bin/ssh-copy-id: INFO: attempting to log in with the new key(s), to filter
out any that are already installed
/usr/bin/ssh-copy-id: INFO: 1 key(s) remain to be installed -- if you are promp
ted now it is to install the new keys
dina@worker2's password:

Number of key(s) added: 1

Now try logging into the machine, with:  "ssh 'dina@worker2'"
and check to make sure that only the key(s) you wanted were added.
```

- **Master – worker3**

```
dina@master:~$ ssh-copy-id dina@worker3
/usr/bin/ssh-copy-id: INFO: Source of key(s) to be installed: "/home/dina/.ssh/
id_rsa.pub"
/usr/bin/ssh-copy-id: INFO: attempting to log in with the new key(s), to filter
out any that are already installed
/usr/bin/ssh-copy-id: INFO: 1 key(s) remain to be installed -- if you are promp
```

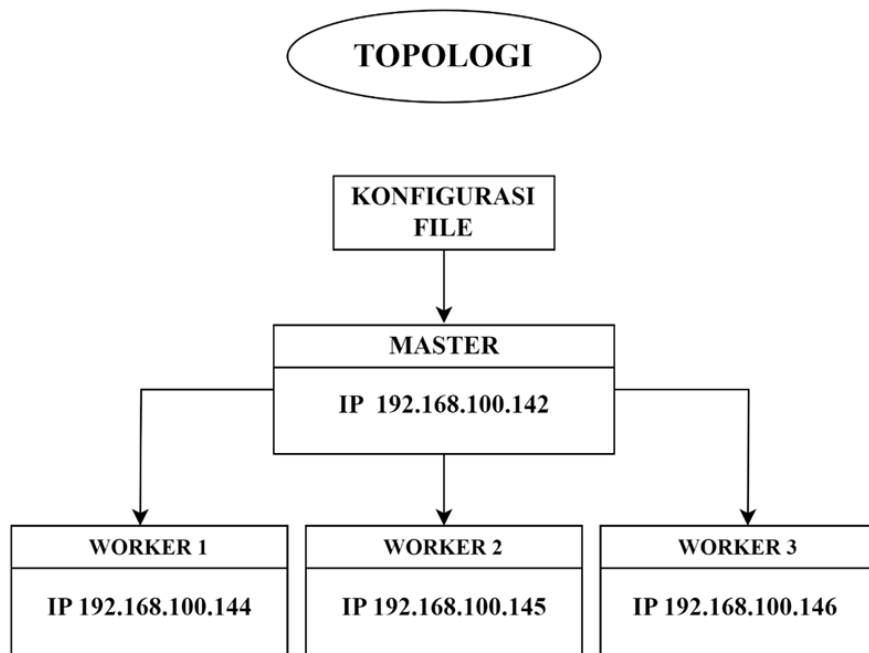
➤ **Testing**

Melakukan uji coba untuk menghasilkan perintah dasar python pada setiap device dengan hasil output “**Hello, World!**” dengan menggunakan command ‘**mpirun -np <jumlah prosesor> -host <daftar host> python3 test.py**’

```
dina@master:~$ mpirun -n 4 -host master,worker1,worker2,worker3 python3 -m mpi4
py.bench helloworld
Hello, World! I am process 0 of 4 on master.
Hello, World! I am process 1 of 4 on worker1.
Hello, World! I am process 2 of 4 on worker2.
Hello, World! I am process 3 of 4 on worker3.
```

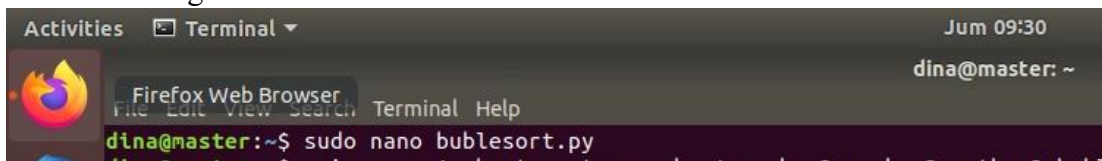
11. Bubble Sort

Bubble Sort adalah salah satu algoritma pengurutan sederhana yang digunakan dalam pemrograman. Algoritma ini bekerja dengan membandingkan dan menukar elemen-elemen dalam daftar satu per satu hingga seluruh daftar terurut.



➤ Input coding

Melakukan pengeditan pada file python dengan memasukkan codingan mengenai bubble sort dengan command **'sudo nano'**



```

GNU nano 2.9.3                                bubblesort.py
import multiprocessing
import time

def bubble_sort(arr, node_id):
    start_time = time.time()
    n = len(arr)
    for i in range(n):
        for j in range(0, n-i-1):
            if arr[j] > arr[j+1]:
                arr[j], arr[j+1] = arr[j+1], arr[j]
            print(f"Node {node_id}: Step {i + 1} - {arr}")
        end_time = time.time()
        elapsed_time = end_time - start_time
        print(f"Node {node_id}: Sorted array: {arr}")
        print(f"Node {node_id}: Time taken: {elapsed_time} seconds")

if __name__ == '__main__':
    arr = [45 , 90 , 72, 18 , 11 , 28]
    processes = []

    for i in range(4): # specify the number of processes as required
        p = multiprocessing.Process(target=bubble_sort, args=(arr, i))
        processes.append(p)
        p.start()

    for process in processes:
        process.join()
  
```

Menjalankan file yang telah diedit dengan command **'mpirun -np <jumlah prosesor> -host <daftar host> python3 <nama file>.py'**

Dari proses yang telah berjalan, maka akan menghasilkan output berupa pengurutan dari data yang telah diinput pada codingan.


```
dina@master:~$ mpirun -n 1 -host master,worker1,worker2,worker3 python3 bubblesort.py
Node 1: Step 1 - [45, 72, 18, 11, 28, 90]
Node 0: Step 1 - [45, 72, 18, 11, 28, 90]
Node 2: Step 1 - [45, 72, 18, 11, 28, 90]
Node 0: Step 2 - [45, 18, 11, 28, 72, 90]
Node 0: Step 3 - [18, 11, 28, 45, 72, 90]
Node 0: Step 4 - [11, 18, 28, 45, 72, 90]
Node 0: Step 5 - [11, 18, 28, 45, 72, 90]
Node 0: Step 6 - [11, 18, 28, 45, 72, 90]
Node 1: Step 2 - [45, 18, 11, 28, 72, 90]
Node 0: Sorted array: [11, 18, 28, 45, 72, 90]
Node 1: Step 3 - [18, 11, 28, 45, 72, 90]
Node 0: Time taken: 0.002367734909057617 seconds
Node 2: Step 2 - [45, 18, 11, 28, 72, 90]
Node 1: Step 4 - [11, 18, 28, 45, 72, 90]
Node 2: Step 3 - [18, 11, 28, 45, 72, 90]
Node 1: Step 5 - [11, 18, 28, 45, 72, 90]
Node 2: Step 4 - [11, 18, 28, 45, 72, 90]
Node 2: Step 5 - [11, 18, 28, 45, 72, 90]
Node 1: Step 6 - [11, 18, 28, 45, 72, 90]
Node 2: Step 6 - [11, 18, 28, 45, 72, 90]
Node 2: Sorted array: [11, 18, 28, 45, 72, 90]
Node 1: Sorted array: [11, 18, 28, 45, 72, 90]
Node 2: Time taken: 0.0028581619262695312 seconds
Node 1: Time taken: 0.004815101623535156 seconds
Node 3: Step 1 - [45, 72, 18, 11, 28, 90]
Node 3: Step 2 - [45, 18, 11, 28, 72, 90]
Node 3: Step 3 - [18, 11, 28, 45, 72, 90]
Node 3: Step 4 - [11, 18, 28, 45, 72, 90]
Node 3: Step 5 - [11, 18, 28, 45, 72, 90]
Node 3: Step 6 - [11, 18, 28, 45, 72, 90]
Node 3: Sorted array: [11, 18, 28, 45, 72, 90]
Node 3: Time taken: 0.0043201446533203125 seconds
dina@master:~$
```