LAPORAN PEMROSESAN PARALEL

(Bubble Sort Python Menggunakan MPI Secara Paralel)

Disusun Oleh:

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FAKULTAS ILMU KOMPUTER

PROGRAM STUDI SISTEM KOMPUTER

UNIVERSITAS SRIWIJAYA

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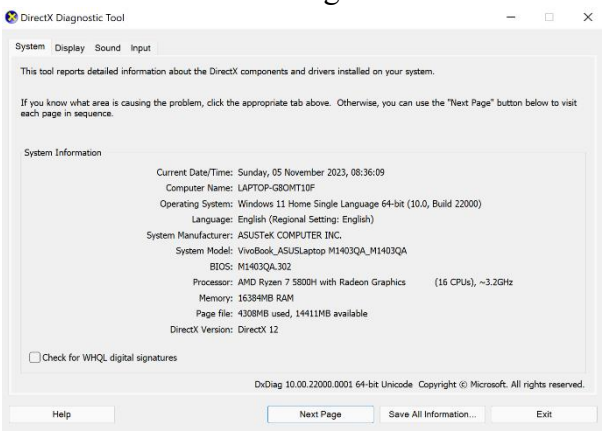
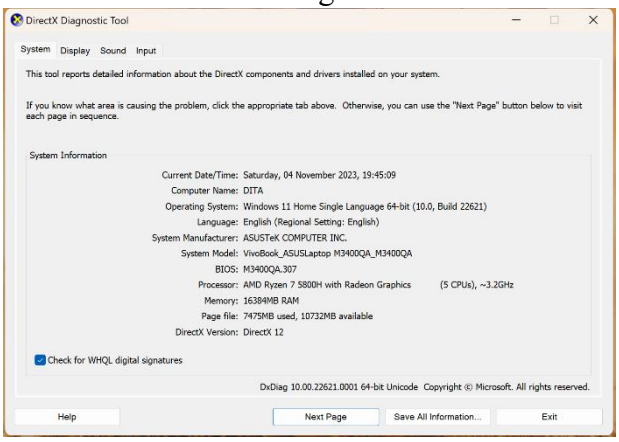
1. **Master dan Worker**

   Menentukan master dan worker dengan melihat spesifikasi masing masing device

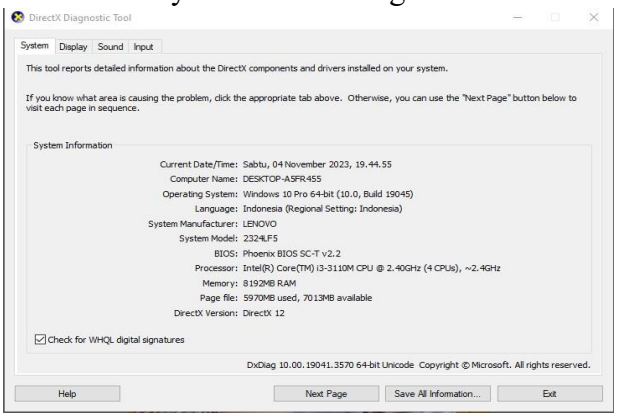
   - Khairunnisa Junaidi sebagai **master**



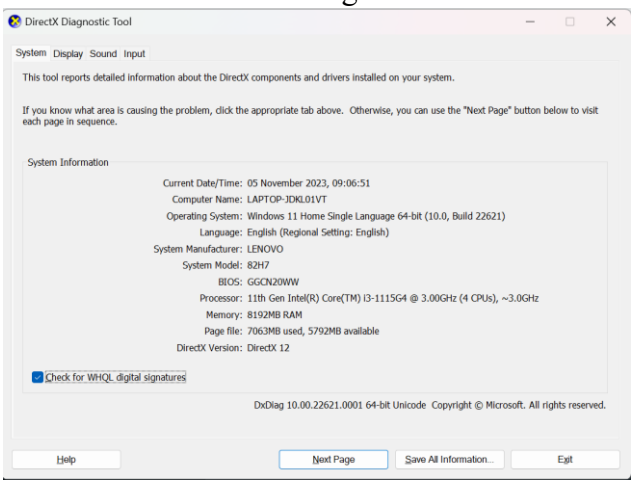
   - Eka Ratna Anindita sebagai **worker1**



   - Almirah Callysta Aurelie sebagai **worker2**



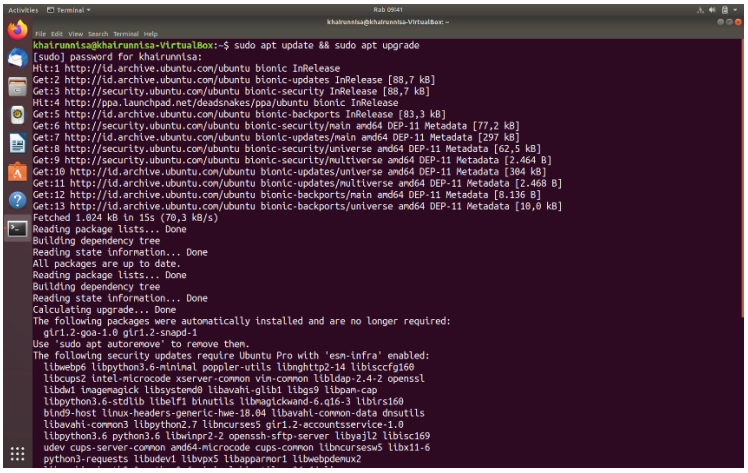
- Nabilla Suci Febriani sebagai **worker3**



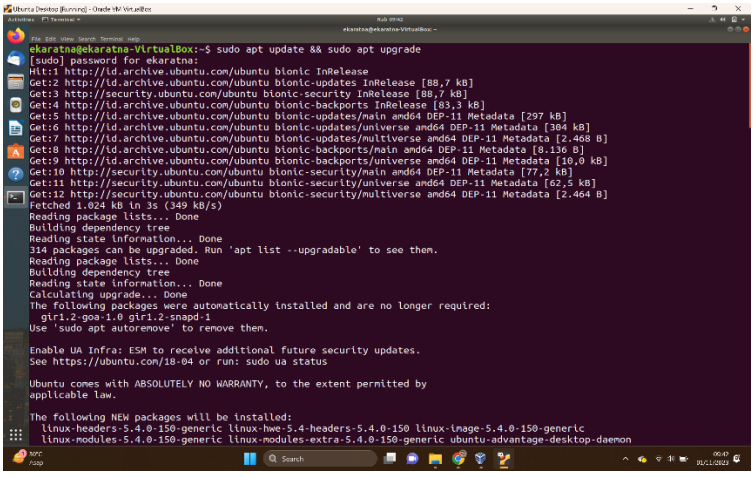
2. Upgrade OS

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

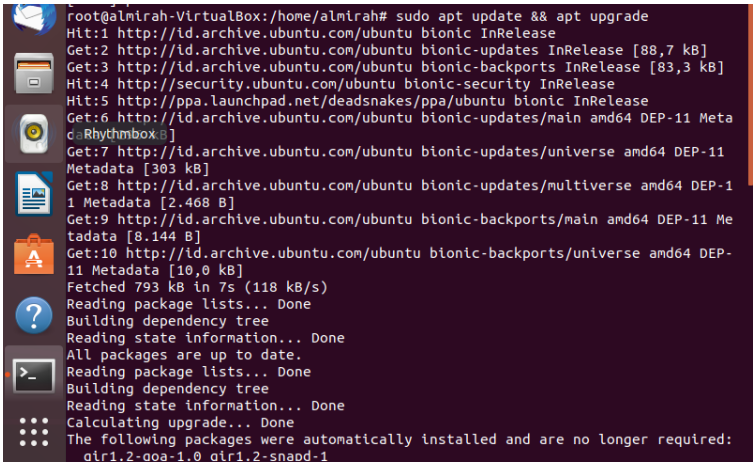
- Master



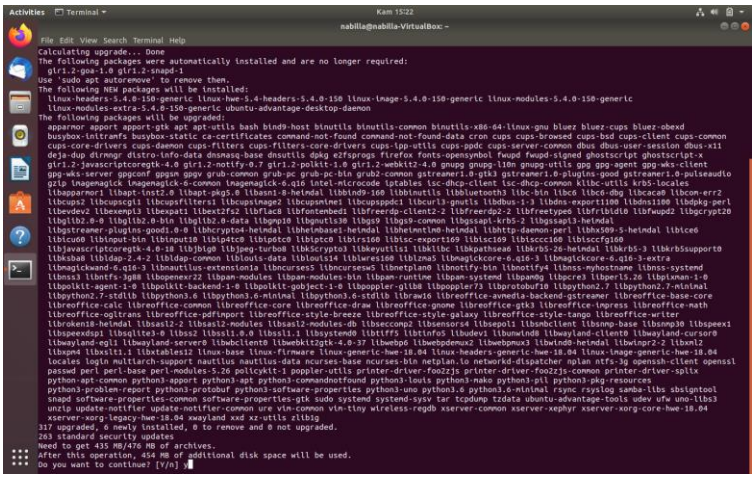
- Worker1



- Worker2



- Worker3



3. Install net-tools

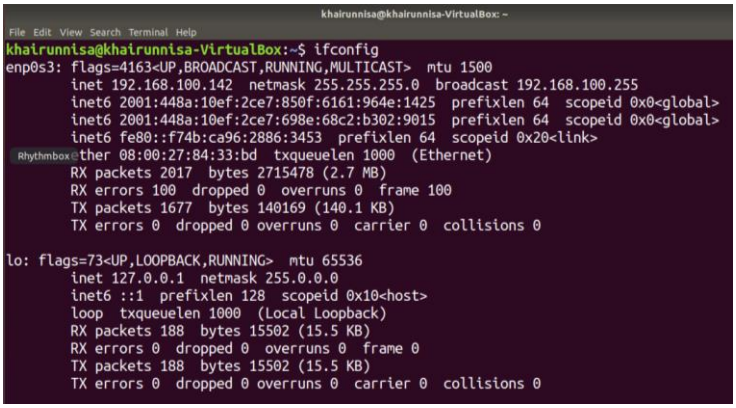
Melakukan penginstalan net-tools dengan menggunakan command ***'sudo apt install net-tools vim'*** untuk cek IP, vim sebagai teks editor

```
root@almirah-VirtualBox:/home/almirah# sudo apt install net-tools vim
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:
  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 0 not upgraded.
Need to get 6.790 kB of archives.
After this operation, 32,8 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 net-tools amd64 1.6
0+git20161116.90da8a0-1ubuntu1 [194 kB]
Get:2 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 vim-runtime
 all 2:8.0.1453-1ubuntu1.13 [5.439 kB]
Get:3 http://id.archive.ubuntu.com/ubuntu bionic-updates/main amd64 vim amd64 2
:8.0.1453-1ubuntu1.13 [1.156 kB]
Fetched 6.790 kB in 12s (544 kB/s)
Selecting previously unselected package net-tools.
(Reading database ... 164777 files and directories currently installed.)
Preparing to unpack .../net-tools_1.60+git20161116.90da8a0-1ubuntu1_amd64.deb .
..
Unpacking net-tools (1.60+git20161116.90da8a0-1ubuntu1) ...
```

4. **Cek ip**

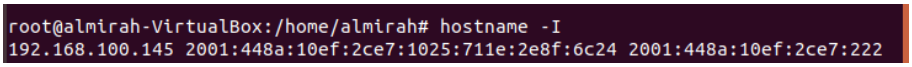
   Menggunakan command ***'ifconfig'*** atau ***'hostname –I'*** untuk mengecek IP masing masing device

   - Master

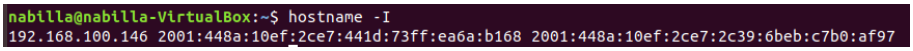


   - Worker1

   - Worker2

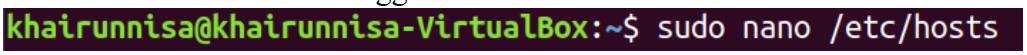


   - Worker3



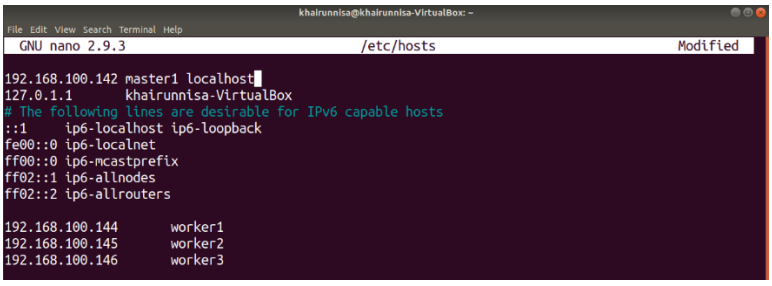
5. **Konfigurasi file**

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

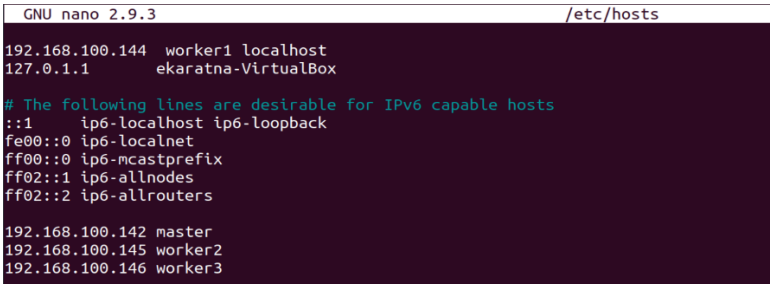


   Lalu mengedit file dengan menambahkan IP dan peran.

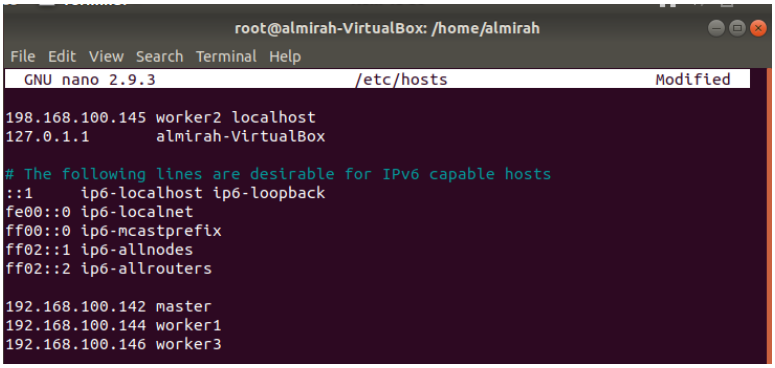
   - Master



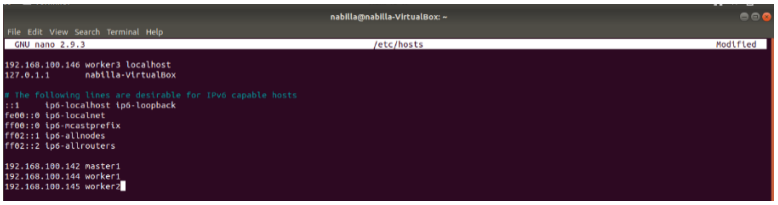
   - Worker1



- Worker2

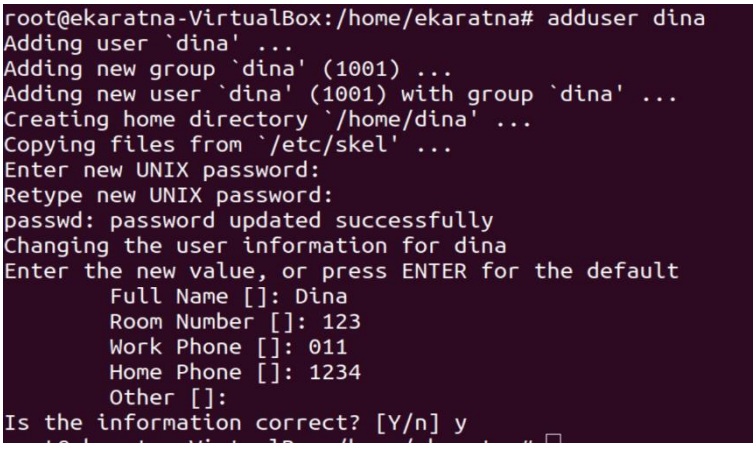


- Worker3



6. **User bersama**

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



➢ **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+aOw7nfFscE+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 klient**

  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"
```

```
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'***

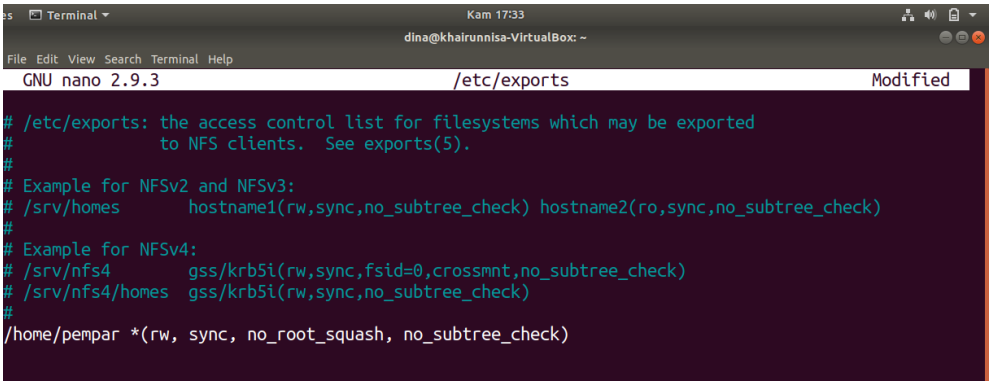
```
dina@khairunnisa-VirtualBox:~$ sudo apt install nfs-kernel-server
[sudo] password for dina:
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following packages were automatically installed and are no longer required:
  gir1.2-goa-1.0 gir1.2-snapd-1
Use '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)*



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@nabilla-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 'sudo apt autoremove' to remove them.
The following additional packages will be installed:
  autotools-dev gcc gcc-7 ibverbs-providers libasan4 libatomic1 libc-dev-bin libc6-dev libcilkrts5 libfabric1 libgcc-7-dev libhwloc-dev
  libhwloc-plugins libhwloc5 libibverbs-dev libibverbs1 libitm1 liblsan0 libltdl-dev libmpx2 libnl-route-3-200 libnuma-dev libopenmpi2
  libpsm-infinipath1 libquadmath0 librdmacm1 libtool libtsan0 libubsan0 linux-libc-dev manpages-dev ocl-icd-libopencl1 openmpi-common
Suggested packages:
  gcc-multilib make autoconf automake flex bison gcc-doc gcc-7-multilib gcc-7-doc gcc-7-locales 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 automaken gfortran | fortran95-compiler gcj-jdk opencl-icd gfortran
The following NEW packages will be installed:
  autotools-dev gcc gcc-7 ibverbs-providers libasan4 libatomic1 libc-dev-bin libc6-dev libcilkrts5 libfabric1 libgcc-7-dev libhwloc-dev
  libhwloc-plugins libhwloc5 libibverbs-dev libibverbs1 libitm1 liblsan0 libltdl-dev libmpx2 libnl-route-3-200 libnuma-dev libopenmpi-dev libopenmpi2
  libpsm-infinipath1 libquadmath0 librdmacm1 libtool libtsan0 libubsan0 linux-libc-dev manpages-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 [358 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]
10% [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@khairunnisa-VirtualBox:/home/pempar$ sudo chmod -R 777 /home/pempar
dina@khairunnisa-VirtualBox:/home/pempar$ touch test.py
dina@khairunnisa-VirtualBox:/home/pempar$
```

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

```
dina@khairunnisa-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/1393e69df9cf7b04143a51776727dd048586781
bca82543594ab439e2eb4/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/68998a0c10a3a307e55777b41b3da359a4742f
087eff53acce
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/
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
```

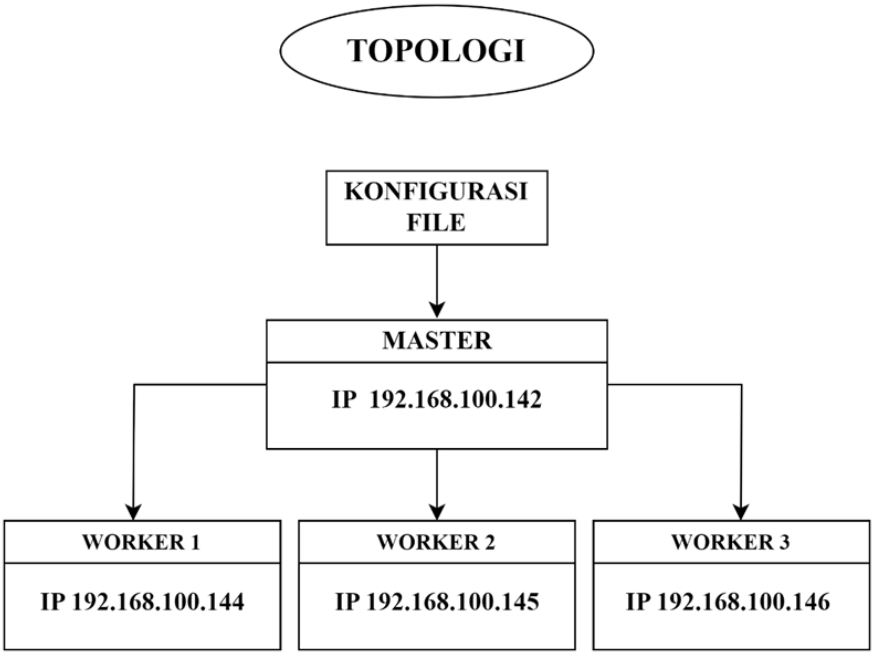
➢ **Testing**

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.
```

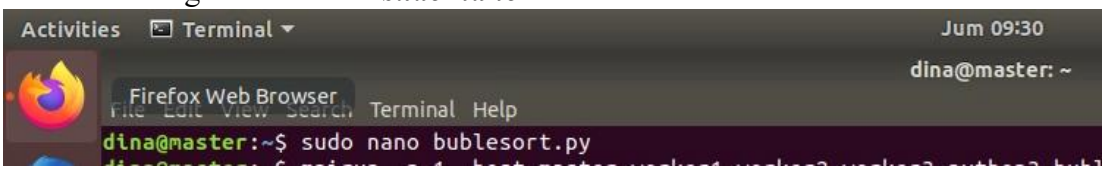
11. Bubble Sort

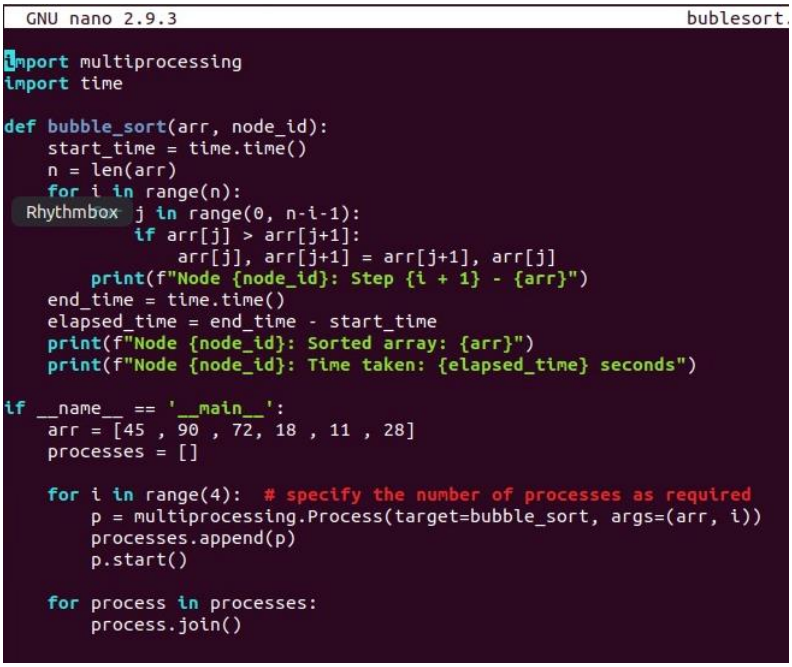
Bubble Sort adalah salah satu algoritma pengurutan sederhana yang digunakan dalam pemrograman. Algoritma ini bekerja dengan membandingkan dan menukar elemen-elemen dalam daftar satu per satu hingga seluruh daftar terurut.



- **Input coding**

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





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 bublesort.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:~$
```