

PEMROSESAN PARALEL

MPI



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Kelas

Sistem Komputer 5B Indralaya

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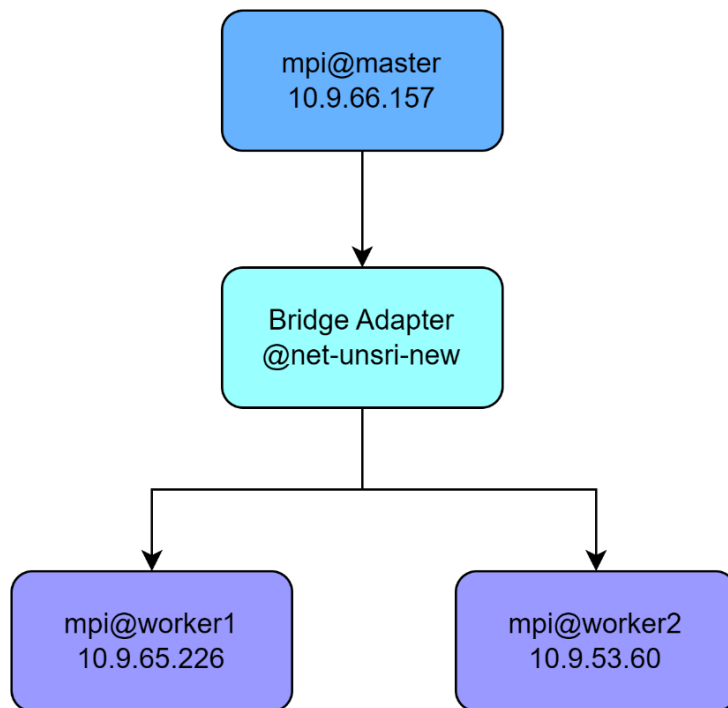
PROGRAM STUDI SISTEM KOMPUTER

FAKULTAS ILMU KOMPUTER

UNIVERSITAS SRIWIJAYA

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TOPOLOGI MPI



SETUP MASTER & WORKER

1. 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”.
2. Untuk melakukan setup master dan worker, ketik command “sudo nano /etc/hosts”, namun sebelum itu, lebih baik ubah terlebih dahulu hostnamanya menggunakan command “sudo nano /etc/hostname” seperti dibawah ini:

The screenshot shows two terminal windows. The top window is titled 'hamase@master: ~' and shows the command 'sudo nano /etc/hostname' being executed, with the output 'master' displayed. The bottom window is titled 'rafie@worker1: ~' and shows the command 'sudo nano /etc/hostname' being executed, with the output 'worker1' displayed.

3. Cek ip pada vm master dan worker

```
hamase@master: ~  
hamase@master:~$ sudo nano /etc/hostname  
hamase@master:~$ ip a  
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000  
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00  
    inet 127.0.0.1/8 scope host lo  
        valid_lft forever preferred_lft forever  
    inet6 ::1/128 scope host  
        valid_lft forever preferred_lft forever  
2: ens33: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP group default qlen 1000  
    link/ether 00:0c:29:c9:c2:73 brd ff:ff:ff:ff:ff:ff  
    altname enp2s1  
    inet 10.9.66.157/22 brd 10.9.67.255 scope global dynamic noprefixroute ens33  
        valid_lft 167sec preferred_lft 167sec  
    inet6 fe80::e635:ea7f:7f9a:fea7/64 scope link noprefixroute  
        valid_lft forever preferred_lft forever  
  
rafie@worker1: ~  
rafie@worker1:~$ ip a  
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000  
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00  
    inet 127.0.0.1/8 scope host lo  
        valid_lft forever preferred_lft forever  
    inet6 ::1/128 scope host  
        valid_lft forever preferred_lft forever  
2: ens33: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP group default qlen 1000  
    link/ether 00:0c:29:0a:ac:df brd ff:ff:ff:ff:ff:ff  
    altname enp2s1  
    inet 10.9.65.226/22 brd 10.9.67.255 scope global dynamic noprefixroute ens33  
        valid_lft 41sec preferred_lft 41sec  
    inet6 fe80::12cb:da3d:21c9:e91d/64 scope link noprefixroute  
        valid_lft forever preferred_lft forever
```

4. Kemudian, sambungkan ip pada master dan worker menggunakan perintah sebelumnya

- Pada master

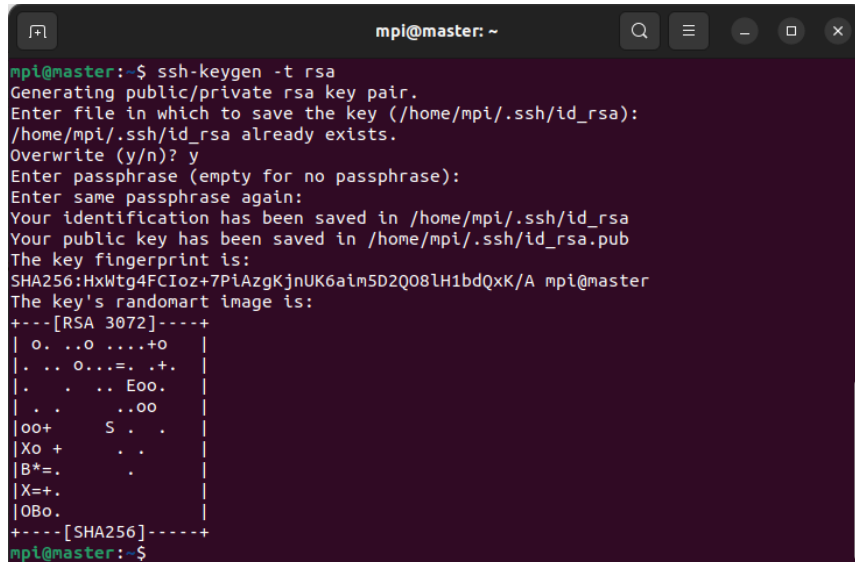
```
hamase@master: ~  
GNU nano 6.2 /etc/hosts *  
127.0.0.1 localhost  
127.0.1.1 hamas  
  
10.9.66.157 master  
10.9.65.226 worker1  
10.9.53.60 worker2  
  
# The following lines are desirable for IPv6 capable hosts  
::1 ip6-localhost ip6-loopback  
fe00::0 ip6-localnet  
ff00::0 ip6-mcastprefix  
ff02::1 ip6-allnodes  
ff02::2 ip6-allrouters
```

- Pada worker

```
rafie@worker1: ~  
GNU nano 6.2 /etc/hosts *  
127.0.0.1 localhost  
127.0.1.1 Hamase  
  
10.9.66.157 master  
10.9.65.226 worker1  
  
# The following lines are desirable for IPv6 capable hosts  
::1 ip6-localhost ip6-loopback  
fe00::0 ip6-localnet  
ff00::0 ip6-mcastprefix  
ff02::1 ip6-allnodes  
ff02::2 ip6-allrouters
```

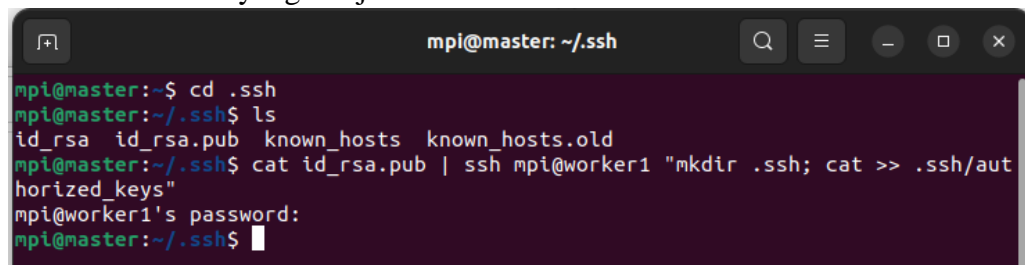
SETUP SSH

1. Masuk ke user baru terlebih dahulu pada master dan workernya menggunakan command “su – mpi”
2. Install SSH dahulu menggunakan command “sudo apt install openssh-server” di master dan worker.
3. Selesai dari install, bisa lakukan keygen menggunakan command “ssh-keygen -t rsa” pada masternya



```
mpi@master: ~  
mpi@master:~$ ssh-keygen -t rsa  
Generating public/private rsa key pair.  
Enter file in which to save the key (/home/mpi/.ssh/id_rsa):  
/home/mpi/.ssh/id_rsa already exists.  
Overwrite (y/n)? y  
Enter passphrase (empty for no passphrase):  
Enter same passphrase again:  
Your identification has been saved in /home/mpi/.ssh/id_rsa  
Your public key has been saved in /home/mpi/.ssh/id_rsa.pub  
The key fingerprint is:  
SHA256:HxWtg4FCIoZ+7PiAzgKjnUK6aim5D2Q08lH1bdQxK/A mpi@master  
The key's randomart image is:  
+---[RSA 3072]-----+  
|  o  ..o  ....+o  |  
| .  .. 0...=.. .+  |  
| .    .. Eoo.    |  
| .    ..oo       |  
|oo+   S . .      |  
|Xo +   . .       |  
|B*=.   .         |  
|X=+.            |  
|OBo.           |  
+---[SHA256]-----+  
mpi@master:~$
```

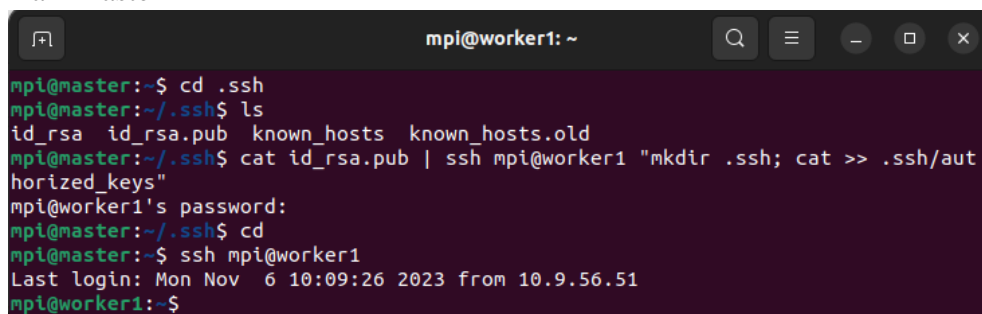
4. Kemudian lakukan command seperti gambar dibawah untuk memindahkan file dari master ke worker yang dituju.



```
mpi@master: ~/.ssh  
mpi@master:~$ cd .ssh  
mpi@master:~/.ssh$ ls  
id_rsa id_rsa.pub known_hosts known_hosts.old  
mpi@master:~/.ssh$ cat id_rsa.pub | ssh mpi@worker1 "mkdir .ssh; cat >> .ssh/authorized_keys"  
mpi@worker1's password:  
mpi@master:~/.ssh$
```

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

- Dari Master



```
mpi@master:~$ cd .ssh  
mpi@master:~/.ssh$ ls  
id_rsa id_rsa.pub known_hosts known_hosts.old  
mpi@master:~/.ssh$ cat id_rsa.pub | ssh mpi@worker1 "mkdir .ssh; cat >> .ssh/authorized_keys"  
mpi@worker1's password:  
mpi@master:~/.ssh$ cd  
mpi@master:~$ ssh mpi@worker1  
Last login: Mon Nov  6 10:09:26 2023 from 10.9.56.51  
mpi@worker1:~$
```

Bisa langsung masuk tanpa memasukkan password worker yang dituju

- Dari Worker

```
mpi@master: ~  
mpi@worker1:~$ ssh mpi@master  
The authenticity of host 'master (10.9.66.157)' can't be established.  
ED25519 key fingerprint is SHA256:tpIAYRsBzFVhWZ9qBc5vHVsz6Re0czTvn486lLiHBc.  
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.  
  
7 additional security updates can be applied with ESM Apps.  
Learn more about enabling ESM Apps service at https://ubuntu.com/esm  
  
Last login: Mon Nov  6 10:09:42 2023 from 10.9.56.51  
mpi@master:~$  
  
mpi@master:~$ exit  
logout  
Connection to master closed.  
mpi@worker1:~$ ssh mpi@master  
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.  
  
7 additional security updates can be applied with ESM Apps.  
Learn more about enabling ESM Apps service at https://ubuntu.com/esm  
  
Last login: Wed Nov  8 11:16:38 2023 from 10.9.65.226  
mpi@master:~$
```

Jika dari worker ke master, harus memasukkan password dari master setiap kali worker ingin masuk.

SETUP NFS

1. Selanjutnya membuat shared folder menggunakan NFS agar master dan worker dapat mengolah data dari folder yang sama secara langsung.
2. Pertama, buat folder baru di master dan worker dengan nama yang sama.
3. Pada master, lakukan instalasi NFS server menggunakan command “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  
nfs-kernel-server is already the newest version (1:2.6.1-1ubuntu1.2).  
0 upgraded, 0 newly installed, 0 to remove and 2 not upgraded.
```

4. Buka dan edit file yang ada di /etc/exports menggunakan command sudo nano /etc/exports dan tambahkan path direktori dari folder yang baru dibuat tadi.

```
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_sub  
#  
# Example for NFSv4:  
# /srv/nfs4 gss/krb5i(rw,sync,fsid=0,crossmnt,no_subtree_check)  
# /srv/nfs4/homes gss/krb5i(rw,sync,no_subtree_check)  
#  
/home/mpi/cloud *(rw,sync,no_root_squash,no_subtree_check)
```

Disini folder yang dibuat pada master dan worker memiliki nama sebagai “cloud”

5. Selanjutnya lakukan command seperti berikut

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

6. Kemudian, pada worker lakukan 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  
nfs-common is already the newest version (1:2.6.1-1ubuntu1.2).  
0 upgraded, 0 newly installed, 0 to remove and 25 not upgraded.  
mpi@worker1:~$
```

7. Kemudian, lakukan mount di worker untuk menghubungkan folder yang sudah dibuat agar terhubung satu sama lain antara master dan worker.

```
mpi@worker1:~$ sudo mount master:/home/mpi/cloud /home/mpi/cloud  
mpi@worker1:~$ ls  
cloud snap  
mpi@worker1:~$
```

```
mpi@master:~$ ls  
cloud snap
```

8. Cek isi folder cloud dan coba buat suatu file ataupun direktori

- Pada master

```
mpi@master:~$ ls  
cloud snap  
mpi@master:~$ cd cloud  
mpi@master:~/cloud$ ls  
bs.py hehe my_host test.py  
bubblesort.py Metode-Numerik-main Newton_Raphson.ipynb  
Eliminasi_Gauss.ipynb mn.py test1.py  
mpi@master:~/cloud$ mkdir hehe  
mkdir: cannot create directory 'hehe': File exists  
mpi@master:~/cloud$ mkdir hehehe  
mpi@master:~/cloud$ ls  
bs.py hehe mn.py test1.py  
bubblesort.py hehehe my_host test.py  
Eliminasi_Gauss.ipynb Metode-Numerik-main Newton_Raphson.ipynb  
mpi@master:~/cloud$
```

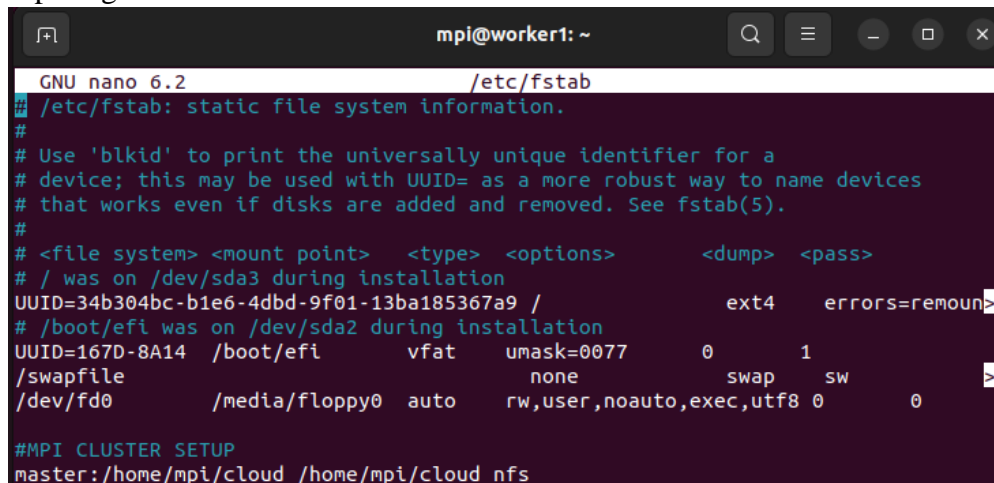
Dibuat folder baru dengan nama hehehe

- Pada worker

```
mpi@worker1:~$ sudo mount master:/home mpi/cloud /home mpi/cloud
mpi@worker1:~$ ls
cloud snap
mpi@worker1:~$ cd cloud
mpi@worker1:~/cloud$ ls
bs.py             hehe             mn.py            test1.py
bubblesort.py     hehehe          my_host         test.py
Eliminasi_Gauss.ipynb Metode-Numerik-main Newton_Raphson.ipynb
mpi@worker1:~/cloud$
```

Dapat dilihat pada gambar diatas, folder hehehe juga muncul.

9. Kemudian pada worker lagi, buka dan edit file pada /etc/fstab dan tambahkan perintah seperti gambar dibawah ini



```
GNU nano 6.2 /etc/fstab
# /etc/fstab: static file system information.
#
# Use 'blkid' to print the universally unique identifier for a
# device; this may be used with UUID= as a more robust way to name devices
# that works even if disks are added and removed. See fstab(5).
#
# <file system> <mount point> <type> <options> <dump> <pass>
# / was on /dev/sda3 during installation
UUID=34b304bc-b1e6-4dbd-9f01-13ba185367a9 / ext4 errors=remoun
# /boot/efi was on /dev/sda2 during installation
UUID=167D-8A14 /boot/efi vfat umask=0077 0 1
/swapfile none swap sw 0
/dev/fd0 /media/floppy0 auto rw,user,noauto,exec,utf8 0 0

#MPI CLUSTER SETUP
master:/home mpi/cloud /home mpi/cloud nfs
```

Yang ditambah adalah perintah pada baris bawah sekali. Hal ini dilakukan agar ketika worker dimatikan, tidak diperlukan proses mounting lagi.

SETUP MPI

1. Ada 3 hal yang harus di download pada bagian ini, yaitu sebagai berikut:

```
mpi@master:~$ sudo apt install openmpi-bin libopenmpi-dev
[sudo] password for mpi:
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
libopenmpi-dev is already the newest version (4.1.2-2ubuntu1).
openmpi-bin is already the newest version (4.1.2-2ubuntu1).
0 upgraded, 0 newly installed, 0 to remove and 2 not upgraded.
mpi@master:~$ sudo apt install python3-pip
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
python3-pip is already the newest version (22.0.2+dfsg-1ubuntu0.3).
0 upgraded, 0 newly installed, 0 to remove and 2 not upgraded.
mpi@master:~$ pip install mpi4py
Defaulting to user installation because normal site-packages is not writeable
Requirement already satisfied: mpi4py in ~/.local/lib/python3.10/site-packages (3.1.5)
mpi@master:~$
```

- Pertama ialah tentu saja menginstall mpi nya
- Selanjutnya adalah menginstall python3 agar dapat digunakan pada mpi
- Dan diakhir ada library mpi4py untuk mpi dan python

2. Dan kodingan yang digunakan untuk menjalankan MPI adalah sebagai berikut:
- Bubblesort:

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

start = time.time()

def bubbleSort(arr):
    n = len(arr)
    swapped = False

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

        if not swapped:
            return

if __name__ == '__main__':
    comm = MPI.COMM_WORLD
    size = comm.Get_size()
    rank = comm.Get_rank()

    n = 20 # Jumlah elemen dalam array
    max_number = 100 # Rentang angka acak
    local_data = []

    # Setiap proses mendapatkan data yang berbeda
    for i in range(n):
        local_data.append(random.randint(1, max_number))

    local_data = comm.gather(local_data, root=0)
```

- Numerik:

```
GNU nano 6.2 mn.py
from mpi4py import MPI
import time

start = time.time()

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

    # Data yang akan dihitung
    data = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]

    # Bagi data di antara proses
    chunk_size = len(data) // size
    start = rank * chunk_size
    end = (rank + 1) * chunk_size

    if rank == size - 1:
        # Pastikan semua data terhitung jika panjang data tidak habis dibagi oleh jumlah proses
        end = len(data)

    local_sum = sum(data[start:end])

    # Kumpulkan hasil dari semua proses
    total_sum = comm.reduce(local_sum, op=MPI.SUM, root=0)

    if rank == 0:
        print("Total hasil perhitungan:", total_sum)

if __name__ == '__main__':
    main()

end = time.time()
print("waktu dikerjakan", end-start)
```

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

TESTING

- Bubblesort

```
mpi@master: ~/cloud
mpi@master:~/cloud$ python3 bs.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Unsorted array is : [16, 56, 26, 30, 80, 50, 31, 53, 10, 66, 70, 95, 92, 68, 87, 14, 90, 40, 82, 51]
Sorted array is: [10, 14, 16, 26, 30, 31, 40, 50, 51, 53, 56, 66, 68, 70, 80, 82, 87, 90, 92, 95]
Waktu dikerjakan 0.001232147216796875
mpi@master:~/cloud$ mpirun -np 1 -host master,worker1 python3 bs.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Unsorted array is : [16, 65, 7, 96, 51, 22, 22, 69, 86, 91, 3, 78, 46, 15, 57, 54, 71, 87, 1, 23]
Sorted array is: [1, 3, 7, 15, 16, 22, 22, 23, 46, 51, 54, 57, 65, 69, 71, 78, 86, 87, 91, 96]
Waktu dikerjakan 0.0008807182312011719
mpi@master:~/cloud$
```

- Numerik

```
mpi@master: ~/cloud
mpi@master:~/cloud$ python3 mn.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Total hasil perhitungan: 55
waktu dikerjakan 0.0019352436065673828
mpi@master:~/cloud$ mpirun -np 1 -host master,worker1 python3 mn.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Total hasil perhitungan: 55
waktu dikerjakan 0.0007488727569580078
mpi@master:~/cloud$
```

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.