

Tugas Pemrosesan Paralel

“MPI”



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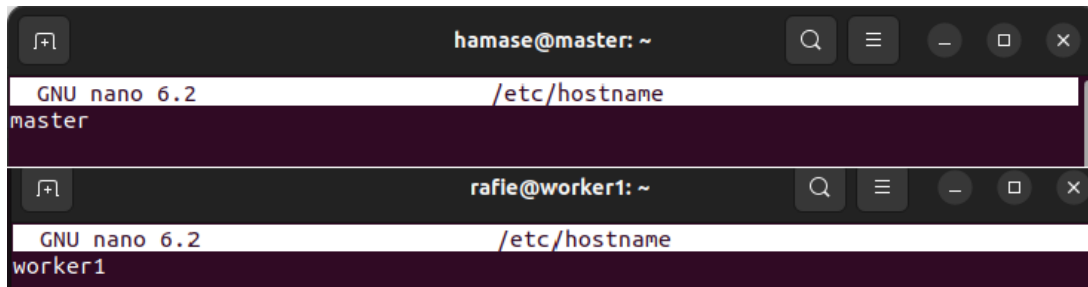
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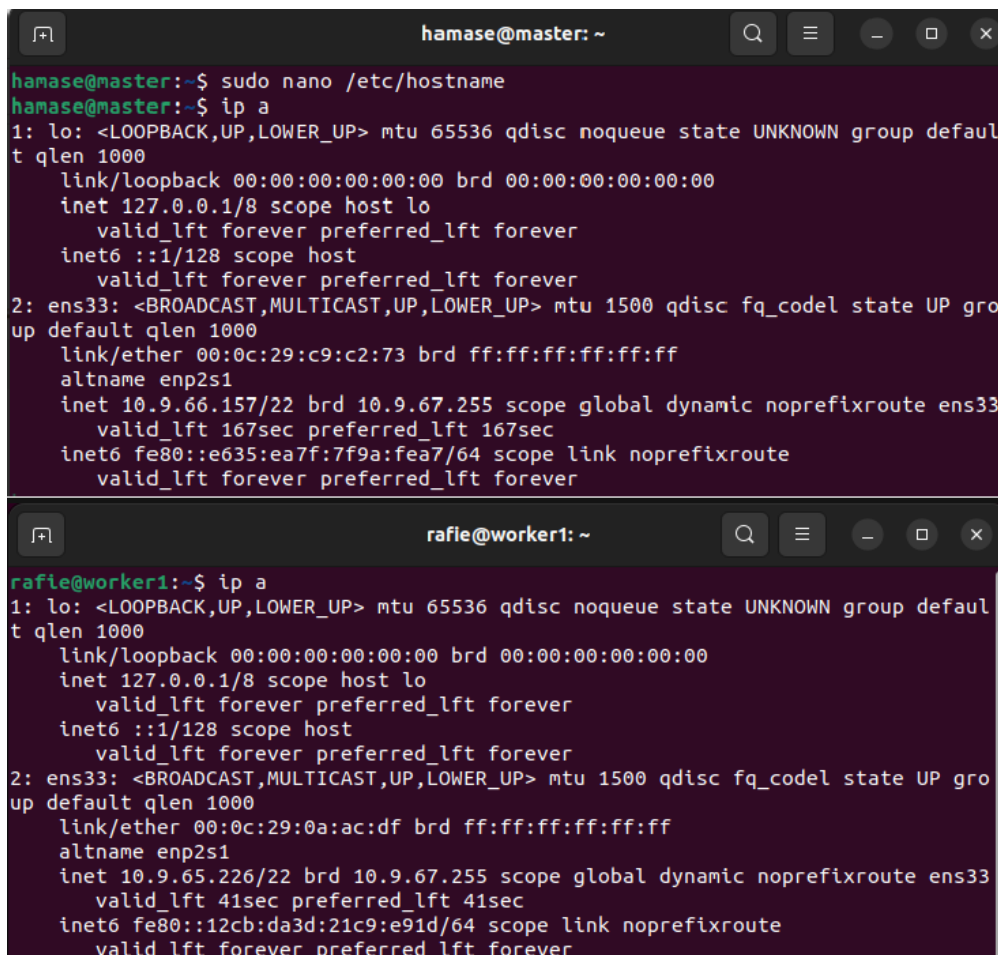
1. Setup Master dan Worker

Pertama-tama gunakan perintah "sudo adduser mpi" untuk membuat pengguna baru dengan nama "mpi" pada kandidat master dan worker. Setelah itu, berikan akses root ke pengguna yang baru dibuat dengan menggunakan perintah "sudo usermod -aG sudo mpi". Kemudian mengubah hostname sebagai berikut :



```
hamase@master: ~  
GNU nano 6.2 /etc/hostname  
master  
  
rafie@worker1: ~  
GNU nano 6.2 /etc/hostname  
worker1
```

Kemudian pada file etc/hosts masukan ip master dan worker, untuk mengecek ip bisa digunakan command sebagai berikut :



```
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:~$ 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
```

Tuliskan IP pada file hosts sebagai berikut

- 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
```

- 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
```

2. Setup SSH (Secure Shell)

Pertama-tama masuk ke user terlebih dahulu kemudian install SSH dengan menggunakan command “Sudo apt install openssh-server” pada node master dan node worker. Setelah SSH terinstall berikan command keygen pada node master “ssh-keygen -t rsa”.

```
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 |  
| . . . O . . = . . + |  
| . . . . Eoo. |  
| . . . .oo |  
|oo+ S . . |  
|Xo + . . |  
|B* . . |  
|X=. . |  
|OBo. |  
+----[SHA256]-----+  
mpi@master:~$
```

Kemudian hubungkan SSH dari master ke worker atau sebaliknya dengan memindahkan file menggunakan command sebagai berikut

```
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$
```

Untuk pengecekan apakah sudah terhubung bisa menggunakan command berikut

```
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:~$
```

Ketika menghubungkan dari master kita tidak perlu menggunakan password sedangkan sebaliknya ketika menghubungkan dari worker kita perlu menggunakan password

```
mpi@worker1:~$ ssh mpi@master
The authenticity of host 'master (10.9.66.157)' can't be established.
ED25519 key fingerprint is SHA256:tpIAYRsBzFVhWZ9qBc5vHVsz6Re0czTvn486lfLiHBc.
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:~$
```

3. Setup NFS

Agar master dan worker bisa mengolah data pada folder yang sama secara langsung diperlukan shared folder yang bisa dibuat menggunakan NFS. Pertama-tama buat folder dengan nama yang sama pada master dan worker.

Pada node master lakukan instalasi NFS dengan 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.
```

Setelah nfs terinstall buka file /etc/exports untuk menambahkan path direktori dari folder yang sudah dibuat. Kemudian restart nfs

```
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/mpi/cloud *(rw,sync,no_root_squash,no_subtree_check)

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

Selanjutnya pada node worker lakukan instalasi 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:~$
```

Setelah nfs terinstall pada node worker lakukan mount dengan menggunakan command berikut folder yang sudah dibuat bisa terhubung 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
```

Untuk mengetes apakah worker dan master sudah terhubung bisa kita coba buat file atau direktori seperti contoh berikut

```
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 test1.py
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$
```

Kemudian pada node worker dilakukan pengecekan dengan command ls untuk melihat apakah shared folder sudah berfungsi. Bisa dilihat jika folder yang sudah dibuat pada node master sudah muncul pada node 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$
```

Terakhir pada file /etc/fstab tambahkan command sebagai berikut agar ketika node worker dimatikan kita tidak perlu melakukan mounting lagi

```
mpi@worker1: ~
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
```

4. Setup MPI

Pertama tama lakukan instalasi mpi, python3, dan library mpi4py untuk mpi dan python. Bisa dilihat pada command berikut :

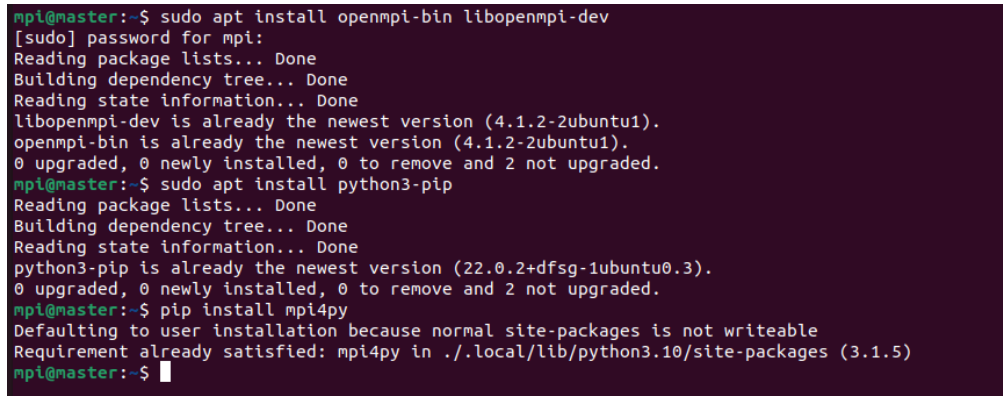
```

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:~$

```

Setelah semua terinstall jalankan kodingan 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


```
mpi@master: ~/cloud
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)
```

5. Menjalankan kodingan dengan MPI

- 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, 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
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
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$
```

Kesimpulan

Setelah program dijalankan bisa disimpulkan bahwa Program yang dijalankan dengan MPI menghasilkan kinerja yang lebih cepat daripada yang tidak menggunakan MPI berdasarkan hasil dari implementasi bubblesort dan operasi numerik. Oleh karena itu, untuk tugas yang lebih kompleks dan berat, disarankan untuk menggunakan pendekatan multi-processing karena dapat mengurangi waktu eksekusi secara signifikan.