

Pemrosesan Paralel



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FAKULTAS ILMU KOMPUTER
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2023**

Install net-tools untuk cek IP, vim untuk teks editor.

```
zahrans@zahrans-VirtualBox:~$ sudo apt install net-tools vim
[sudo] password for zahrans:
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
net-tools is already the newest version (1.60+git20181103.0eebece-1ubuntu5).
Suggested packages:
  ctags vim-doc vim-scripts
The following NEW packages will be installed:
  vim vim-runtime
0 upgraded, 2 newly installed, 0 to remove and 0 not upgraded.
Need to get 8.568 kB of archives.
After this operation, 37,6 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 vim-runtime all
2:8.2.3995-1ubuntu2.13 [6.834 kB]
Get:2 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 vim amd64 2:8.2.
3995-1ubuntu2.13 [1.734 kB]
Fetched 8.568 kB in 8s (1.134 kB/s)
Selecting previously unselected package vim-runtime.
[Reading database ... 85%
```

Salin kode cloudmesh-mpi dari github ke linux

```
zahrans@zahrans-VirtualBox:~$ git clone https://github.com/cloudmesh/cloudmesh-mpi.git
Cloning into 'cloudmesh-mpi'...
remote: Enumerating objects: 9875, done.
remote: Counting objects: 100% (9875/9875), done.
remote: Compressing objects: 100% (2145/2145), done.
Receiving objects: 75% (7407/9875), 20.72 MiB | 5.12 MiB/s
```

Kemudian install virtual environment pada linux

```
zahrans@zahrans-VirtualBox:~$ sudo apt install python3.10 python3.10-dev python3
-dev python3.10-venv
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
python3.10 is already the newest version (3.10.12-1~22.04.2).
The following additional packages will be installed:
  javascript-common libexpat1-dev libjs-jquery libjs-sphinxdoc
  libjs-underscore libpython3-dev libpython3.10-dev python3-distutils
  python3-lib2to3 python3-pip-whl python3-setuptools-whl zlib1g-dev
Suggested packages:
  apache2 | lighttpd | httpd
The following NEW packages will be installed:
  javascript-common libexpat1-dev libjs-jquery libjs-sphinxdoc
  libjs-underscore libpython3-dev libpython3.10-dev python3-dev
  python3-distutils python3-lib2to3 python3-pip-whl python3-setuptools-whl
  python3.10-dev python3.10-venv zlib1g-dev
0 upgraded, 15 newly installed, 0 to remove and 0 not upgraded.
Need to get 8.888 kB of archives.
After this operation, 28,5 MB of additional disk space will be used.
Do you want to continue? [Y/n]
```

Lalu membuat virtual environment nya dan menghitung jumlah cpu

```
zahrans@zahrans-VirtualBox:~$ python3 -m venv ~/env3
zahrans@zahrans-VirtualBox:~$ source env3/bin/activate
(env3) zahrans@zahrans-VirtualBox:~$ nano cpu.py
```

```
zahrans@zahrans-VirtualBox: ~  
File Edit View Search Terminal Help  
GNU nano 6.2      cpu.py *  
import multiprocessing  
multiprocessing.cpu_count()  
  
zahrans@zahrans-VirtualBox:~$ python3 -m venv ~/env3  
zahrans@zahrans-VirtualBox:~$ source env3/bin/activate  
(env3) zahrans@zahrans-VirtualBox:~$ nano cpu.py  
(env3) zahrans@zahrans-VirtualBox:~$ python -c "import multiprocessing; print(mu  
ltiprocessing.cpu_count())"  
1
```

Setelah itu install mpi4py

```
(env3) zahrans@zahrans-VirtualBox:~$ pip install mpi4py -U  
Collecting mpi4py  
  Using cached mpi4py-3.1.5.tar.gz (2.5 MB)  
  Installing build dependencies ... done  
  Getting requirements to build wheel ... done  
  Preparing metadata (pyproject.toml) ... done  
Building wheels for collected packages: mpi4py  
  Building wheel for mpi4py (pyproject.toml) ... /
```

Buat file count.py

```
zahrans@zahrans-VirtualBox: ~  
File Edit View Search Terminal Help  
zahrans@zahrans-VirtualBox:~$ source env3/bin/activate  
(env3) zahrans@zahrans-VirtualBox:~$ nano count.py
```

Isi dari file count.py

```
zahrans@zahrans-VirtualBox: ~  
File Edit View Search Terminal Help  
GNU nano 6.2      count.py  
import os  
import random  
from mpi4py import MPI  
# Get the input values or set them to a default  
n = int(os.environ.get("N") or 20)  
max_number = int(os.environ.get("MAX") or 10)  
find = int(os.environ.get("FIND") or 8)  
  
comm = MPI.COMM_WORLD # Communicator  
size = comm.Get_size() # Number of processes  
rank = comm.Get_rank() # Rank of this process  
  
# Each process gets different data, depending on its rank number  
data = []  
for i in range(n):  
    r = random.randint(1, max_number)  
    data.append(r)  
count = data.count(find)  
  
print(rank, count, data) # Print data from each process  
[ Read 20 lines ]  
^G Help      ^O Write Out ^W Where Is  ^K Cut       ^T Execute   ^C Location  
^X Exit      ^R Read File ^\ Replace   ^U Paste     ^J Justify   ^_ Go To Line
```

Hasil dari perhitungan

```
zahrans@zahrans-VirtualBox: ~  
File Edit View Search Terminal Help  
zahrans@zahrans-VirtualBox:~$ source env3/bin/activate  
(env3) zahrans@zahrans-VirtualBox:~$ nano count.py  
(env3) zahrans@zahrans-VirtualBox:~$ nano count.py  
(env3) zahrans@zahrans-VirtualBox:~$ mpiexec -n 4 python count.py  
3 4 [8, 8, 10, 8, 5, 9, 9, 5, 9, 7, 3, 6, 7, 8, 4, 10, 5, 7, 6, 10]  
2 1 [9, 7, 5, 8, 1, 1, 9, 7, 4, 10, 5, 1, 9, 6, 2, 4, 9, 5, 6, 2]  
0 2 [3, 3, 3, 2, 9, 10, 2, 1, 10, 10, 9, 7, 10, 8, 1, 8, 5, 1, 2, 10]  
1 2 [8, 5, 5, 7, 10, 7, 1, 4, 3, 8, 2, 6, 5, 4, 3, 10, 10, 5, 5, 5]  
(env3) zahrans@zahrans-VirtualBox:~$
```

MPI

Cek IP Pada Server dan Client

```
zahrans@master: ~  
File Edit View Search Terminal Help  
zahrans@master:~$ ifconfig  
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500  
    inet 192.168.1.6 netmask 255.255.255.0 broadcast 192.168.1.255  
    inet6 fe80::4ba7:6889:a5b0:a40c prefixlen 64 scopeid 0x20<link>  
    ether 08:00:27:f8:06:4e txqueuelen 1000 (Ethernet)  
    RX packets 282 bytes 35292 (35.2 KB)  
    RX errors 0 dropped 0 overruns 0 frame 0  
    TX packets 154 bytes 16500 (16.5 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 116 bytes 9678 (9.6 KB)  
    RX errors 0 dropped 0 overruns 0 frame 0  
    TX packets 116 bytes 9678 (9.6 KB)  
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

```
zahrans@workers: ~  
File Edit View Search Terminal Help  
zahrans@workers:~$ ifconfig  
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500  
    inet 192.168.1.7 netmask 255.255.255.0 broadcast 192.168.1.255  
    inet6 fe80::c5db:6ec4:5d6e:eb84 prefixlen 64 scopeid 0x20<link>  
    ether 08:00:27:6d:30:6f txqueuelen 1000 (Ethernet)  
    RX packets 252 bytes 30759 (30.7 KB)  
    RX errors 0 dropped 0 overruns 0 frame 0  
    TX packets 147 bytes 15910 (15.9 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 113 bytes 9519 (9.5 KB)  
    RX errors 0 dropped 0 overruns 0 frame 0  
    TX packets 113 bytes 9519 (9.5 KB)  
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

Buka file /etc/hosts

```
zahrn@master:~$ sudo nano /etc/hosts
```

tambahkan isinya dengan IP Server dan Client

```
zahrn@master: ~
File Edit View Search Terminal Help
GNU nano 6.2 /etc/hosts
127.0.0.1 localhost
127.0.1.1 zahrn-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

192.168.1.6 master
192.168.1.7 workers
```

Buat user baru di Server dan Client

```
zahrn@master:~$ sudo adduser klompok1
```

Beri akses root dan masuk ke user kemudian install ssh

```
zahrn@master:~$ sudo usermod -aG sudo klompok1
```

Hubungkan Server dan Client

```
klompok1@master: ~
File Edit View Search Terminal Help
klompok1@master:~$ ssh klompok1@workers
The authenticity of host 'workers (192.168.1.6)' can't be established.
ED25519 key fingerprint is SHA256:ULhuSn8sFcUG4D70w9N9oXrqWGYISnsqsryCEYYW7M.
This key is not known by any other names
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added 'workers' (ED25519) to the list of known hosts.
klompok1@workers's password:
```

Lakukan hal yang sama pada worker

```
klompok1@workers:~$ sudo apt install openssh-server
[sudo] password for klompok1:
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
openssh-server is already the newest version (1:8.9p1-3ubuntu0.4).
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
```

Generate keygen pada server

```
klompok1@master:~$ ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (/home/klompok1/.ssh/id_rsa):
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/klompok1/.ssh/id_rsa
Your public key has been saved in /home/klompok1/.ssh/id_rsa.pub
The key fingerprint is:
SHA256:hg4ITUw8Zq0VwYN8Ezb1tqywsMczqI10kydU/w75gHw klompok1@master
The key's randomart image is:
+---[RSA 3072]-----+
|  =o+B=.      |
|  o0oBo .    |
| .oo= o. o    |
|  o.+ . = .   |
|   * = E S    |
| . + + * .    |
| .   oo. +    |
| .  o.=.      |
|  o.o.oo      |
+---[SHA256]-----+
```

Copy key pulik ke client pada server kemudian buat shared folder dan install NFS Server

```
klompok1@master: ~
File Edit View Search Terminal Help
klompok1@master:~$ cd .ssh
klompok1@master:~/.ssh$ cat id_rsa.pub | ssh klompok1@master "mkdir .ssh; cat >>
.ssh/authorized_keys"
klompok1@master's password:
mkdir: cannot create directory '.ssh': File exists
klompok1@master:~/.ssh$ cd
klompok1@master:~$ mkdir cloud
klompok1@master:~$ sudo apt install nfs-kernel-server
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following NEW packages will be installed:
  nfs-kernel-server
0 upgraded, 1 newly installed, 0 to remove and 43 not upgraded.
Need to get 140 kB of archives.
After this operation, 526 kB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 nfs-kernel-server amd64 1:2.6.1-1ubuntu1.2 [140 kB]
Fetched 140 kB in 2s (68,1 kB/s)
Selecting previously unselected package nfs-kernel-server.
(Reading database ... 332992 files and directories currently installed.)
Preparing to unpack .../nfs-kernel-server_1%3a2.6.1-1ubuntu1.2_amd64.deb ...
Unpacking nfs-kernel-server (1:2.6.1-1ubuntu1.2) ...
Setting up nfs-kernel-server (1:2.6.1-1ubuntu1.2) ...
```

Buat shared folder pada Server dan Client serta lakukan install NFS Server pada Server

```
klompok1@master:~$ mkdir cloud
klompok1@master:~$ sudo apt install nfs-kernel-server
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following NEW packages will be installed:
  nfs-kernel-server
0 upgraded, 1 newly installed, 0 to remove and 43 not upgraded.
Need to get 140 kB of archives.
After this operation, 526 kB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu jammy-updates/main amd64 nfs-kernel-server amd64 1:2.6.1-1ubuntu1.2 [140 kB]
Fetched 140 kB in 2s (68,1 kB/s)
Selecting previously unselected package nfs-kernel-server.
(Reading database ... 332992 files and directories currently installed.)
Preparing to unpack .../nfs-kernel-server_1%3a2.6.1-1ubuntu1.2_amd64.deb ...
Unpacking nfs-kernel-server (1:2.6.1-1ubuntu1.2) ...
Setting up nfs-kernel-server (1:2.6.1-1ubuntu1.2) ...
```

```
klompok1@workers:~$ mkdir cloud
klompok1@workers:~$ sudo apt install nfs-common
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 5 not upgraded.
```

Konfigurasi file /etc/exports pada server

```
klompok1@master:~$ sudo nano /etc/exports
```

```
klompok1@master: ~
File Edit View Search Terminal Help
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/klompok1/cloud *(rw,sync,no_root_squash,no_subtree_check)

[ Read 12 lines ]
^G Help ^O Write Out ^W Where Is ^K Cut ^T Execute ^C Location
^X Exit ^R Read File ^N Replace ^U Paste ^J Justify ^_ Go To Line
```

Selanjutnya ketikkan perintah berikut

```
klompok1@master: ~
File Edit View Search Terminal Help
klompok1@master:~$ sudo exportfs -a
klompok1@master:~$ sudo systemctl restart nfs-kernel-server
```

Mounting pada Client lalu install MPI pada Server dan Client

```
klompok1@workers: ~/cloud
File Edit View Search Terminal Help
klompok1@workers:~$ sudo mount master:/home/klompok1/cloud /home/klompok1/cloud
klompok1@workers:~$ sudo apt install openmpi-bin libopenmpi-dev
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 5 not upgraded.
```

Lakukan testing di server Buat file touch.py

```
klompok1@master:~/cloud$ touch test.py
klompok1@master:~/cloud$ ls
test.py
```

Edit barisnya dengan print("Hello World")

```
klompok1@master: ~/cloud
File Edit View Search Terminal Help
GNU nano 6.2 test.py
print("Hello World")
```

Jalankan file menggunakan MPI

```
klompok1@master:~/cloud$ mpirun -np 1 python3 test.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Hello World
```

Buat file bubblesort.py

```
klompok1@master:~/cloud$ sudo nano bubblesort.py
```

Mengisi file dengan kode berikut

```
klompok1@master: ~/cloud
File Edit View Search Terminal Help
GNU nano 6.2 bubblesort.py
from mpi4py import MPI

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

    local_data = data[rank:size]
    local_data.sort()

    for step in range(1, size):
        if rank % 2 == 0:
            if rank < size - 1:
                comm.send(local_data, dest=rank+1)
                received_data = comm.recv(source=rank+1)
                local_data = merge(local_data, received_data)
            else:
                comm.send(local_data, dest=rank-1)
                received_data = comm.recv(source=rank-1)
                local_data = merge(local_data, received_data)
```

```
merged_array.extend(arr2[j:])
return merged_array

def merge_sorted_arrays(arrays):
    merged_array = []
    for array in arrays:
        merged_array = merge(merged_array, array)
    return merged_array

if __name__ == "__main__":
    data = [5, 2, 9, 1, 5, 6]
    comm = MPI.COMM_WORLD
    rank = comm.Get_rank()

    if rank == 0:
        sorted_data = bubble_sort_parallel(data)
        print("Sorted Data:", sorted_data)
    else:
        bubble_sort_parallel(data)
```



```

GNU nano 6.2      bubblesort.py
sorted_data = comm.gather(local_data, root=0)
if rank == 0:
    sorted_data = merge_sorted_arrays(sorted_data)
    return sorted_data
else:
    return None

def merge(arr1, arr2):
    merged_array = []
    i = j = 0
    while i < len(arr1) and j < len(arr2):
        if arr1[i] < arr2[j]:
            merged_array.append(arr1[i])
            i += 1
        else:
            merged_array.append(arr2[j])
            j += 1
    merged_array.extend(arr1[i:])
    merged_array.extend(arr2[j:])
    return merged_array

```

Jalankan file bubblesort.py Menggunakan MPI

```

klompok1@master:~/cloud$ mpirun -np 1 --host master python3 bubblesort.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Sorted Data: [1, 2, 5, 5, 6, 9]
klompok1@master:~/cloud$

```

Membuat file numeric.py

```

klompok1@master:~/cloud$ touch numeric.py

```

```

klompok1@master:~/cloud$ sudo nano numeric.py

```

Mengisi File dengan kode berikut

```

klompok1@master: ~/cloud
File Edit View Search Terminal Help
GNU nano 6.2      numeric.py
from mpi4py import MPI
import numpy as np

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

    # Bagi data di antara proses
    local_data = np.array_split(data, size)[rank]

    # Hitung jumlah lokal
    local_sum = np.sum(local_data)

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

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

if __name__ == '__main__':
    # Data numerik (gunakan data sesuai kebutuhan Anda)
    data = np.array([1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12])

    # Panggil fungsi untuk menjalankan program secara paralel
    parallel_sum(data)

```

Jalankan file numeric.py Menggunakan MPI

```
klompoki@master:~/cloud$ mpirun -np 1 --host master python3 numeric.py
Authorization required, but no authorization protocol specified
Authorization required, but no authorization protocol specified
Total sum: 78
klompoki@master:~/cloud$
```