IP addr used

Container Name	T1_master	T1_slave01	T1_slave02	T1_slave03	T1_slave04	T1_slave05
IP Addr Used	172.17.0.2	172.17.0.3	172.17.0.4	172.17.0.5	172.17.0.6	172.17.0.7

Shared Storage Path

Source:/home/rajat/sheesh/DSD6231/Lab/Assignments/Assignment2

Target:/T2_files

Question	Execution time	Number of Slaves
Q1	20.54	3
Q2	20.33	3
Q3	24.18	3
Q4	26.21	3

Master Section

1)rajat@rajat:~$ docker run --name T2_master --mount type=bind,source=/home/rajat/sheesh/DSD6231/Lab/Assignments/Assignment2,target=/T2_files -it husseinabdallah2/mpi4py-cluster:master
docker run command first creates a writeable container layer over the specified image
--name Assign a name to the container (**T2_master**)
--mount flag allows you to mount volumes, host-directories and tmpfs mounts in a container.
source is the mount point location in the host file system
target is the mount point location inside the container.(**T2_files**)
-it instructs Docker to allocate a pseudo-TTY connected to the container's stdin; creating an interactive **bash** shell in the container

2)root@f36a2b313128:/# service ssh start
Enabling the ssh service on master node.

3)root@f36a2b313128:/# ssh root@172.17.0.3

```
The authenticity of host '172.17.0.3 (172.17.0.3)' can't be established.
ECDSA key fingerprint is SHA256:Sb7YRN1066NNPdEdoQLXTA4r5IUTIC+XrRRlddjoWzs.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added '172.17.0.3' (ECDSA) to the list of known hosts.
root@172.17.0.3's password:
```

```
Welcome to Ubuntu 20.04 LTS (GNU/Linux 5.19.0-23-generic x86_64)

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


This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.
Last login: Mon Oct 17 17:00:04 2022 from 172.17.0.9
```

Explanation:- sshing into ip addr of slave1(172.17.0.3)

4)root@c54985eaa559:~# exit

```
logout
Connection to 172.17.0.3 closed.
```

Explanation:- exiting from T1_slave01

5)root@f36a2b313128:/# ssh root@172.17.0.4

```
The authenticity of host '172.17.0.4 (172.17.0.4)' can't be established.
ECDSA key fingerprint is SHA256:Sb7YRN1066NNPdEdoQLXTA4r5IUTIC+XrRRlddjoWzs.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added '172.17.0.4' (ECDSA) to the list of known hosts.
root@172.17.0.4's password:
Welcome to Ubuntu 20.04 LTS (GNU/Linux 5.19.0-23-generic x86_64)

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


This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.
Last login: Mon Oct 17 17:00:04 2022 from 172.17.0.9
```

Explanation:- sshing into ip addr of slave2(172.17.0.4)

6)root@31fc24850572:~# exit

logout
Connection to 172.17.0.4 closed.

Explanation:- exiting from T1_slave02

7)root@f36a2b313128:/# ssh root@172.17.0.5

```
The authenticity of host '172.17.0.5 (172.17.0.5)' can't be established.
ECDSA key fingerprint is SHA256:Sb7YRN1066NNPdEdoQLXTA4r5IUTIC+XrRRlddjoWzs.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added '172.17.0.5' (ECDSA) to the list of known hosts.
root@172.17.0.5's password:
Welcome to Ubuntu 20.04 LTS (GNU/Linux 5.19.0-23-generic x86_64)

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


This system has been minimized by removing packages and content that are
not required on a system that users do not log into.
```

```
To restore this content, you can run the 'unminimize' command.
Last login: Mon Oct 17 17:00:04 2022 from 172.17.0.9
```

Explanation:- sshing into ip addr of slave3(172.17.0.5)

8)root@117b87a8dd5b:~# exit

```
logout
Connection to 172.17.0.5 closed.
```

Explanation:- exiting from T1_slave03

9)root@f36a2b313128:/# nano ~/machinefile

Editing the machinefile to have the ip addr of Master,Slave01,Slave02,Slave03 in this particular order.

10)root@f36a2b313128:/# ssh-keygen -t rsa

```
Generating public/private rsa key pair.
Enter file in which to save the key (/root/.ssh/id_rsa):
/root/.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 /root/.ssh/id_rsa
Your public key has been saved in /root/.ssh/id_rsa.pub
The key fingerprint is:
SHA256:4E9o8S1jcpxO7eSwpBlaJ8+WqD4gGUcpX4KCbVea1IE root@f36a2b313128
The key's randomart image is:
+---[RSA 3072]----+
|.o ..+o.         |
|= *.Eo.          |
|.= +o o          |
|. o  . * +       |
| +    O S +      |
|o .  + ^ X       |
| . .. + O o      |
|    .. .         |
|   .o.           |
+----[SHA256]-----+
```

Explanation:- Generating SSH keys on Linux system using RSA algorithm.

11)root@f36a2b313128:/# ssh-copy-id -i ~/.ssh/id_rsa.pub root@172.17.0.3

```
/usr/bin/ssh-copy-id: INFO: Source of key(s) to be installed: "/root/.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 prompted now it is to install
the new keys
root@172.17.0.3's password:

Number of key(s) added: 1

Now try logging into the machine, with:   "ssh 'root@172.17.0.3'"
and check to make sure that only the key(s) you wanted were added.
```

Explanation:- Copying the rsa key generated to slave01 to enable password-less login.

12)root@f36a2b313128:/# ssh-copy-id -i ~/.ssh/id_rsa.pub root@172.17.0.4

```
/usr/bin/ssh-copy-id: INFO: Source of key(s) to be installed: "/root/.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 prompted now it is to install
the new keys
root@172.17.0.4's password:

Number of key(s) added: 1

Now try logging into the machine, with:   "ssh 'root@172.17.0.4'"
and check to make sure that only the key(s) you wanted were added.
```

Explanation:- Copying the rsa key generated to slave02 to enable password-less login.

13)root@f36a2b313128:/# ssh-copy-id -i ~/.ssh/id_rsa.pub root@172.17.0.5

```
/usr/bin/ssh-copy-id: INFO: Source of key(s) to be installed: "/root/.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 prompted now it is to install
the new keys
root@172.17.0.5's password:

Number of key(s) added: 1

Now try logging into the machine, with:   "ssh 'root@172.17.0.5'"
and check to make sure that only the key(s) you wanted were added.
```

Explanation:- Copying the rsa key generated to slave03 to enable password-less login.

14)root@f36a2b313128:/# eval 'ssh-agent'

```
SSH_AUTH_SOCK=/tmp/ssh-HdRQE5xFuE5i/agent.103; export SSH_AUTH_SOCK;
SSH_AGENT_PID=104; export SSH_AGENT_PID;
echo Agent pid 104;
```

This command tells the shell to run the output of ssh-agent as shell commands; thereafter, processes run by this shell inherit the environment variables and have access to the agent.

15)root@f36a2b313128:/# cd T2_files/implementation/Q1

Changing directory to Q1.

16)root@f36a2b313128:/T2_files/implementation/Q1# mpiexec -n 4 -machinefile ~/machinefile python -m mpi4py T3.py

mpiexec Run an MPI program
-n Specify the number of processes to use
-machinefile Machinefile to use. Equal to –hostfile.
~/machinefile Location of machinefile
-m Merge identical output lines from all processes.
-m mpi4py to execute Python code on the command line resembles that of the Python interpreter.

```
Log:
Worker 1 is assigned chunk info [2103956, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [2103957, 2103957] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
                                          0     1
0                       Southwest Airlines Co.  2326
1                       American Airlines Inc.   759
2                            Republic Airlines   704
3                        United Air Lines Inc.   633
4                              JetBlue Airways   487
5    GoJet Airlines, LLC d/b/a United Express   428
6                              Spirit Air Lines   316
```

```
7                       SkyWest Airlines Inc.   297
8                        Delta Air Lines Inc.   295
9                  Air Wisconsin Airlines Corp   286
10                                Comair Inc.   202
11  Commutair Aka Champlain Enterprises, Inc.   202
12                           Mesa Airlines Inc.   160
13                                 Envoy Air   135
14                  Capital Cargo International   132
15                         Alaska Airlines Inc.   127
16                            Endeavor Air Inc.    80
17                       Frontier Airlines Inc.    79
18                                Allegiant Air    50
19                                  Horizon Air    42
20                       Hawaiian Airlines Inc.    36
0    Southwest Airlines Co.
1                        2326
Name: 18, dtype: object
time taken with 3 slaves (MPI execution): 20.54 second(s)
Worker 3 is assigned chunk info [None, 4207914] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
```

17)root@f36a2b313128:/T2_files/implementation/Q1# cd ../Q2/
Changing directory to Q2.

18)root@f36a2b313128:/T2_files/implementation/Q2# mpiexec -n 4 -machinefile ~/machinefile python -m mpi4py T3.py
mpiexec Run an MPI program
-n Specify the number of processes to use
-machinefile Machinefile to use. Equal to –hostfile.
~/machinefile Location of machinefile
-m Merge identical output lines from all processes.
-m mpi4py to execute Python code on the command line resembles that of the Python interpreter.

```
Log:
Worker 1 is assigned chunk info [2103956, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [2103957, 2103957] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
263
time taken with 3 slaves (MPI execution): 20.33 second(s)
Worker 3 is assigned chunk info [None, 4207914] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
```

19)root@f36a2b313128:/T2_files/implementation/Q2# cd ../Q3/
Changing directory to Q3.

20)root@f36a2b313128:/T2_files/implementation/Q3# mpiexec -n 4 -machinefile ~/machinefile python -m mpi4py T3.py
mpiexec Run an MPI program
-n Specify the number of processes to use
-machinefile Machinefile to use. Equal to –hostfile.
~/machinefile Location of machinefile
-m Merge identical output lines from all processes.
-m mpi4py to execute Python code on the command line resembles that of the Python interpreter.

```
Log:
Worker 1 is assigned chunk info [1577966, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [1577967, 1577967] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
72.73409801876956
time taken with 3 slaves (MPI execution): 24.18 second(s)
Worker 3 is assigned chunk info [None, 3155934] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
```

21)root@f36a2b313128:/T2_files/implementation/Q3# cd ../Q4/
Changing directory to Q4.

22)root@f36a2b313128:/T2_files/implementation/Q4# mpiexec -n 4 -machinefile ~/machinefile python -m mpi4py T3.py
mpiexec Run an MPI program
-n Specify the number of processes to use
-machinefile Machinefile to use. Equal to –hostfile.
~/machinefile Location of machinefile
-m Merge identical output lines from all processes.
-m mpi4py to execute Python code on the command line resembles that of the Python interpreter.

```
Log:
Worker 1 is assigned chunk info [2103956, 1] ../../Combined_Flights_2021.csv
Worker slave 1 is done. Sending back to master
Worker 2 is assigned chunk info [2103957, 2103957] ../../Combined_Flights_2021.csv
Worker slave 2 is done. Sending back to master
Worker 3 is assigned chunk info [None, 4207914] ../../Combined_Flights_2021.csv
Worker slave 3 is done. Sending back to master
received from Worker slave 1
received from Worker slave 2
received from Worker slave 3
365
time taken with 3 slaves (MPI execution): 26.21 second(s)
```

Slave01 Section

23)rajat@rajat:~$ docker run --name T2_slave01 --mount type=bind,source=/home/rajat/sheesh/DSD6231/Lab/Assignments/Assignment2,target=/T2_files -it husseinabdallah2/mpi4py-cluster:master
docker run command first creates a writeable container layer over the specified image
--name Assign a name to the container (**T2_slave01**)
--mount flag allows you to mount volumes, host-directories and tmpfs mounts in a container.
source is the mount point location in the host file system
target is the mount point location inside the container.(**T2_files**)
-it instructs Docker to allocate a pseudo-TTY connected to the container’s stdin; creating an interactive **bash** shell in the container

24)root@c54985eaa559:/# service ssh start
*** Starting OpenBSD Secure Shell server sshd**
Enabling the ssh service on slave node.

Slave02 Section

25)rajat@rajat:~$ docker run --name T2_slave02 --mount type=bind,source=/home/rajat/sheesh/DSD6231/Lab/Assignments/Assignment2,target=/T2_files -it husseinabdallah2/mpi4py-cluster:master

docker run command first creates a writeable container layer over the specified image
--name Assign a name to the container (**T2_slave02**)
--mount flag allows you to mount volumes, host-directories and tmpfs mounts in a container.
source is the mount point location in the host file system
target is the mount point location inside the container.(**T2_files**)
-it instructs Docker to allocate a pseudo-TTY connected to the container's stdin; creating an interactive **bash** shell in the container

26)root@31fc24850572:/# service ssh start
*** Starting OpenBSD Secure Shell server sshd**
Enabling the ssh service on slave node.

Slave03 Section

27)rajat@rajat:~$ docker run --name T2_slave03 --mount type=bind,source=/home/rajat/sheesh/DSD6231/Lab/Assignments/Assignment2,target=/T2_files -it husseinabdallah2/mpi4py-cluster:master

docker run command first creates a writeable container layer over the specified image
--name Assign a name to the container (**T2_slave03**)
--mount flag allows you to mount volumes, host-directories and tmpfs mounts in a container.
source is the mount point location in the host file system
target is the mount point location inside the container.(**T2_files**)
-it instructs Docker to allocate a pseudo-TTY connected to the container's stdin; creating an interactive **bash** shell in the container

28)root@117b87a8dd5b:/# service ssh start
*** Starting OpenBSD Secure Shell server sshd**
Enabling the ssh service on slave node.