Programming Assignment 3
Report

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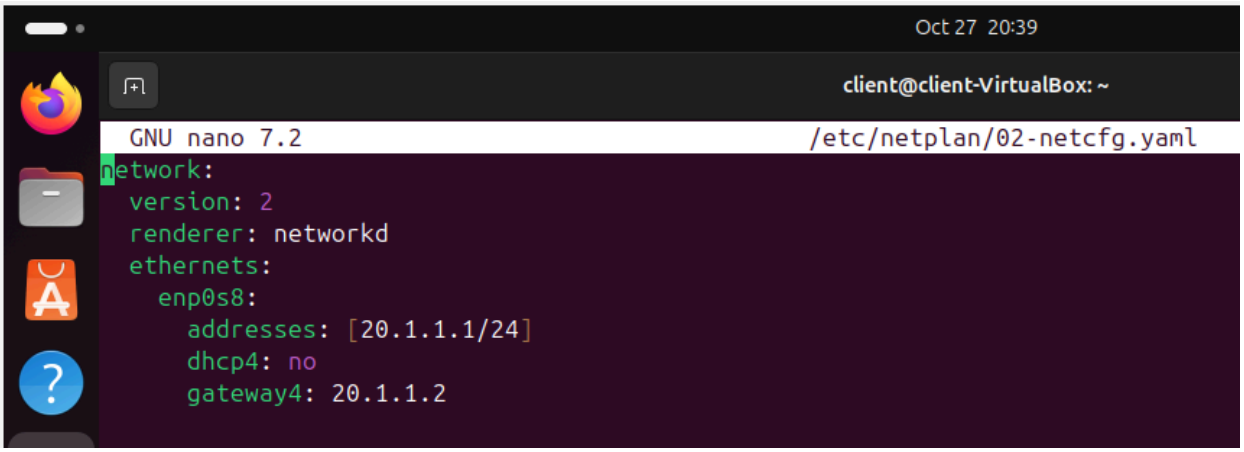
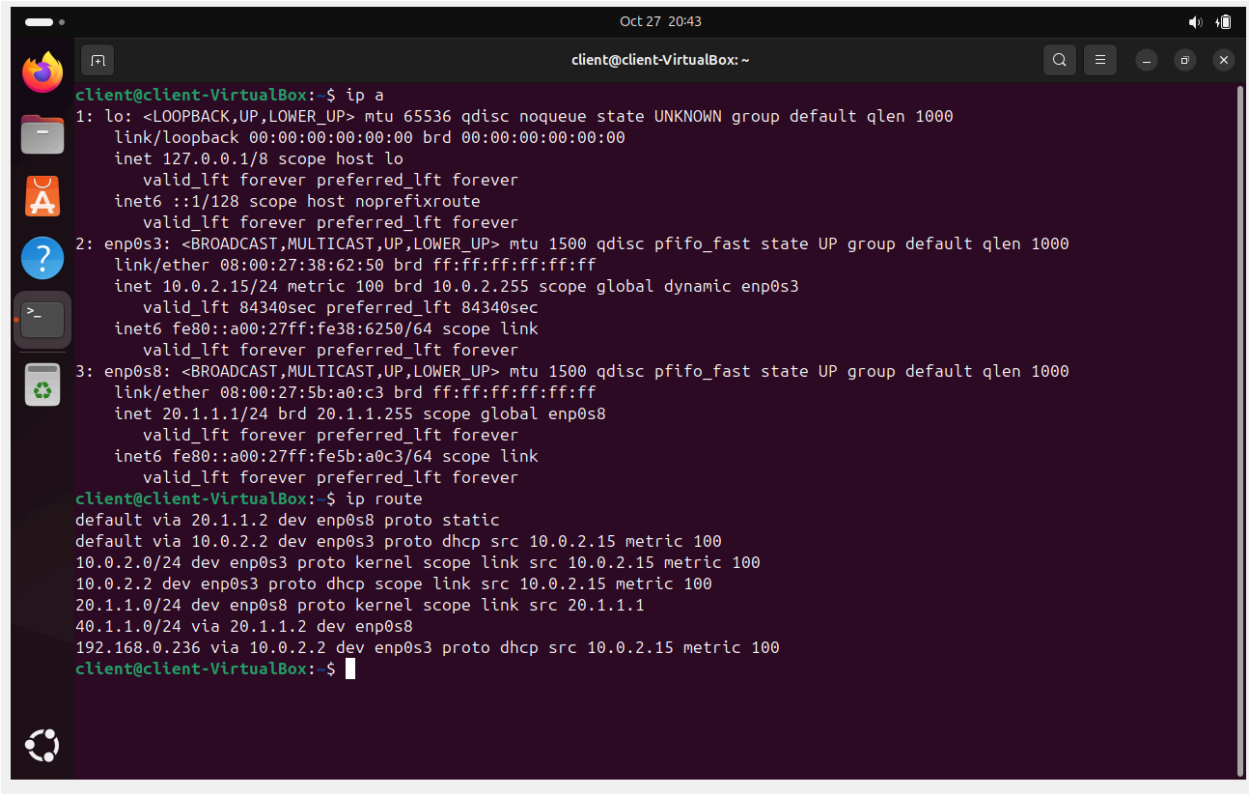
Ans1. (a) Configure the IP addresses and routes for all VMs, as shown in the figure

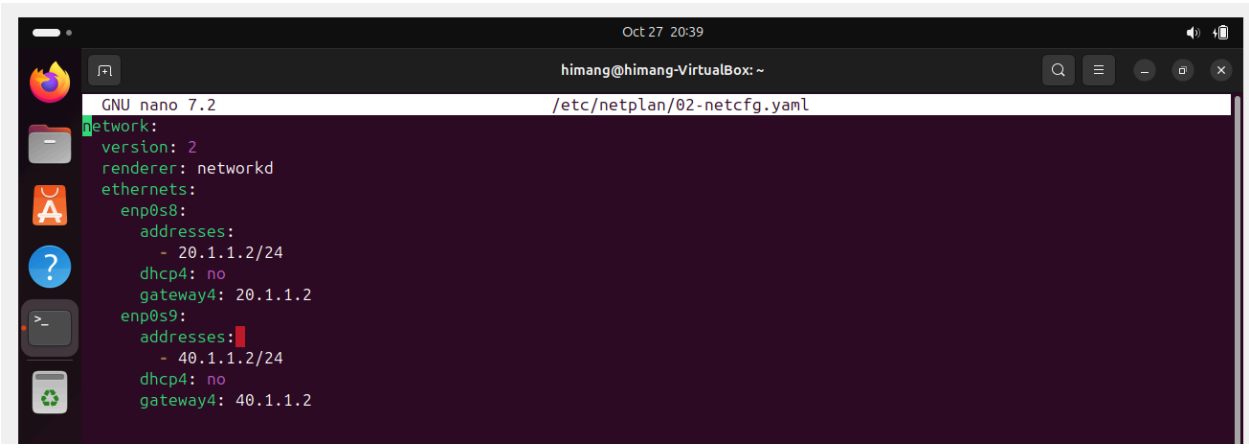
I have created a new host-only adaptor for client, server 1 and server 2 and 2 new host-only adaptor for the gateway. I have used the command sudo nano /etc/netplan/02-netcfg.yaml to configure the ip addresses and gateways. The code is attached in the below screenshot. The current ip address and routes are also shown below:

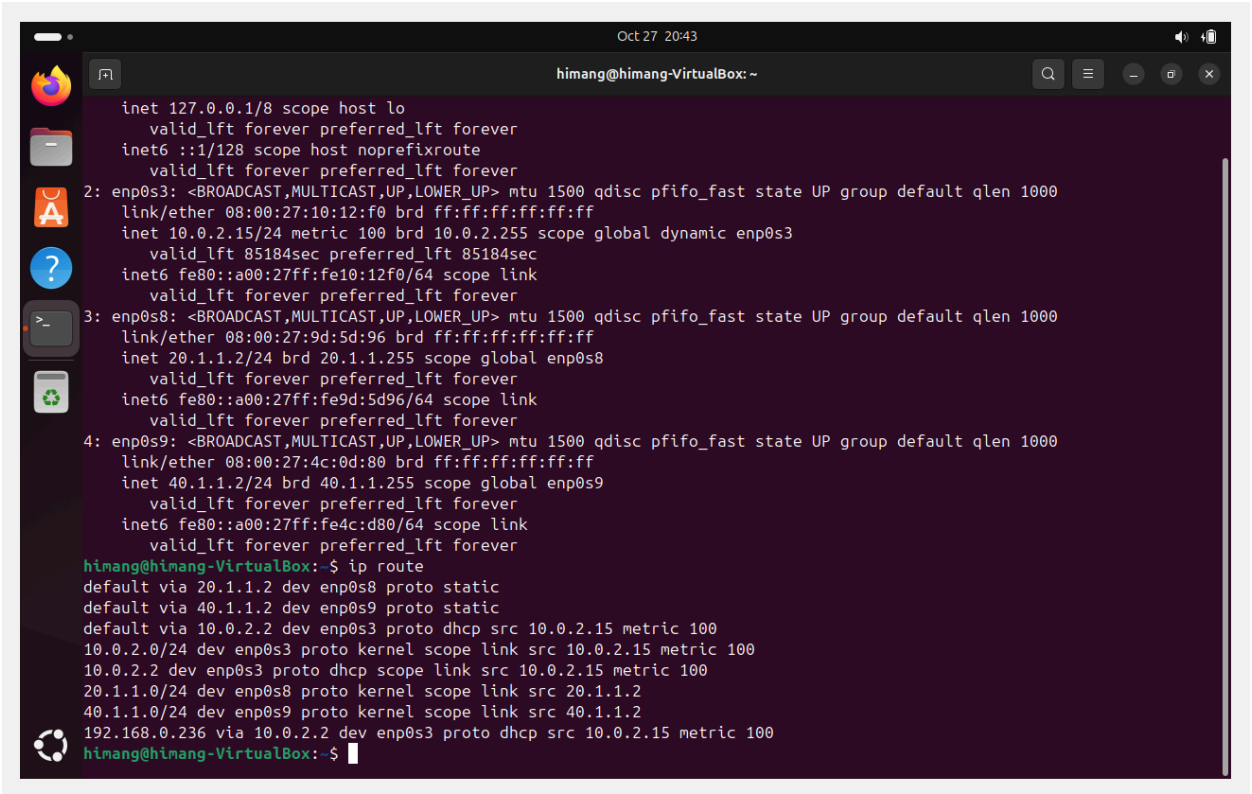
Client:



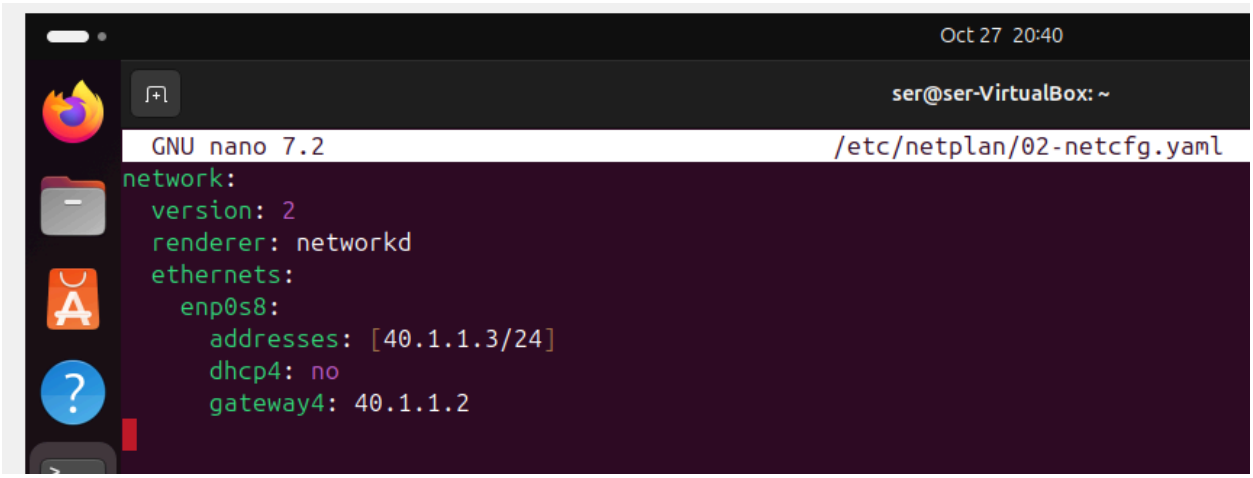

Oct 27 20:43
client@client-VirtualBox: ~
client@client-VirtualBox:~$ ip a
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000
link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
inet 127.0.0.1/8 scope host lo
valid_lft forever preferred_lft forever
inet6 ::1/128 scope host noprefixroute
valid_lft forever preferred_lft forever
2: enp0s3: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP group default qlen 1000
link/ether 08:00:27:38:62:50 brd ff:ff:ff:ff:ff:ff
inet 10.0.2.15/24 metric 100 brd 10.0.2.255 scope global dynamic enp0s3
valid_lft 84340sec preferred_lft 84340sec
inet6 fe80::a00:27ff:fe38:6250/64 scope link
valid_lft forever preferred_lft forever
3: enp0s8: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP group default qlen 1000
link/ether 08:00:27:5b:a0:c3 brd ff:ff:ff:ff:ff:ff
inet 20.1.1.1/24 brd 20.1.1.255 scope global enp0s8
valid_lft forever preferred_lft forever
inet6 fe80::a00:27ff:fe5b:a0c3/64 scope link
valid_lft forever preferred_lft forever
client@client-VirtualBox:~$ ip route
default via 20.1.1.2 dev enp0s8 proto static
default via 10.0.2.2 dev enp0s3 proto dhcp src 10.0.2.15 metric 100
10.0.2.0/24 dev enp0s3 proto kernel scope link src 10.0.2.15 metric 100
10.0.2.2 dev enp0s3 proto dhcp scope link src 10.0.2.15 metric 100
20.1.1.0/24 dev enp0s8 proto kernel scope link src 20.1.1.1
40.1.1.0/24 via 20.1.1.2 dev enp0s8
192.168.0.236 via 10.0.2.2 dev enp0s3 proto dhcp src 10.0.2.15 metric 100
client@client-VirtualBox:~$

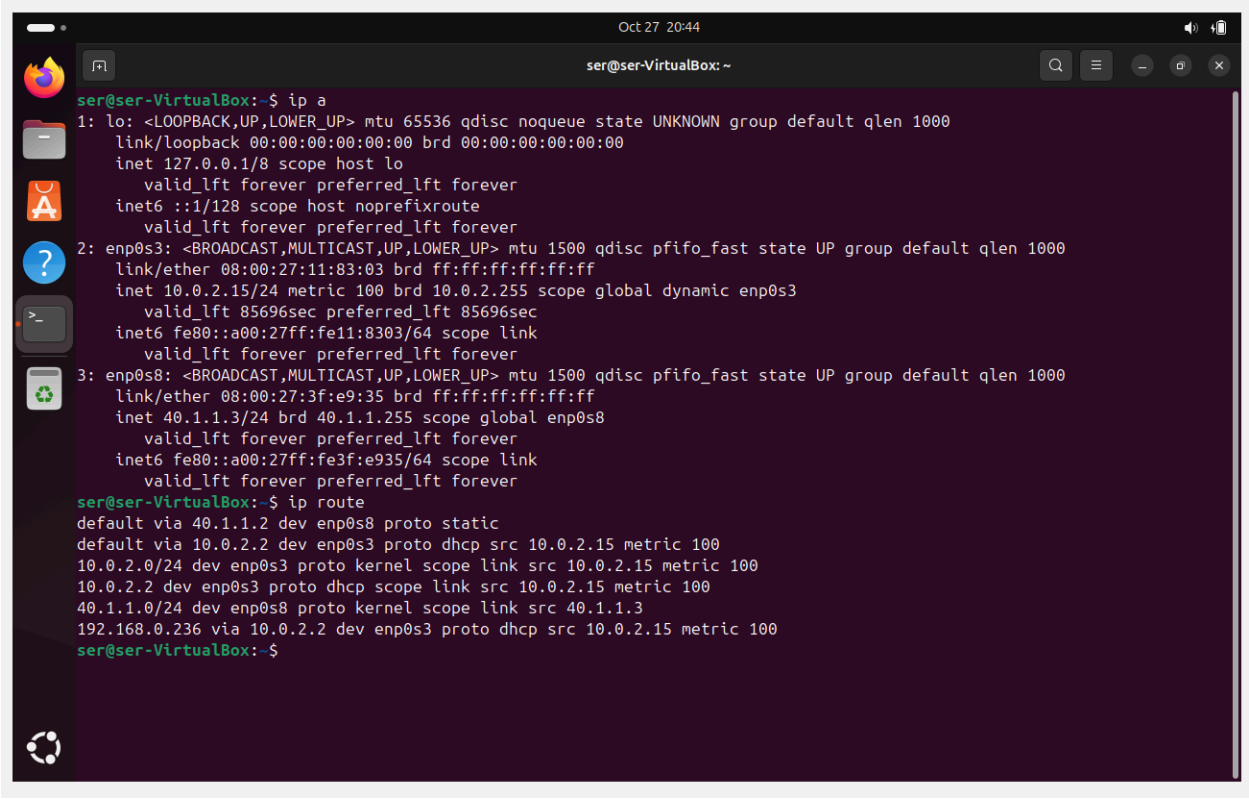
Gateway:


Oct 27 20:39
himang@himang-VirtualBox: ~
GNU nano 7.2 /etc/netplan/02-netcfg.yaml
network:
version: 2
renderer: networkd
ethernets:
enp0s8:
addresses:
- 20.1.1.2/24
dhcp4: no
gateway4: 20.1.1.2
enp0s9:
addresses:
- 40.1.1.2/24
dhcp4: no
gateway4: 40.1.1.2

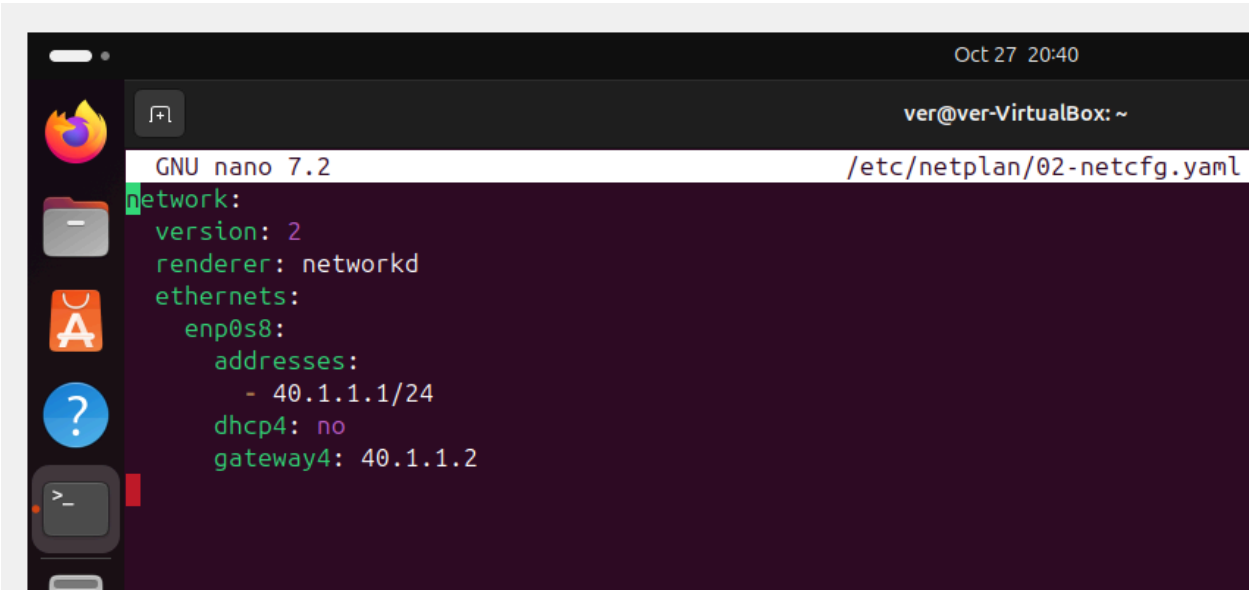

Oct 27 20:43
himang@himang-VirtualBox: ~
inet 127.0.0.1/8 scope host lo
valid_lft forever preferred_lft forever
inet6 ::1/128 scope host noprefixroute
valid_lft forever preferred_lft forever
2: enp0s3: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP group default qlen 1000
link/ether 08:00:27:10:12:f0 brd ff:ff:ff:ff:ff:ff
inet 10.0.2.15/24 metric 100 brd 10.0.2.255 scope global dynamic enp0s3
valid_lft 85184sec preferred_lft 85184sec
inet6 fe80::a00:27ff:fe10:12f0/64 scope link
valid_lft forever preferred_lft forever
3: enp0s8: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP group default qlen 1000
link/ether 08:00:27:9d:5d:96 brd ff:ff:ff:ff:ff:ff
inet 20.1.1.2/24 brd 20.1.1.255 scope global enp0s8
valid_lft forever preferred_lft forever
inet6 fe80::a00:27ff:fe9d:5d96/64 scope link
valid_lft forever preferred_lft forever
4: enp0s9: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP group default qlen 1000
link/ether 08:00:27:4c:0d:80 brd ff:ff:ff:ff:ff:ff
inet 40.1.1.2/24 brd 40.1.1.255 scope global enp0s9
valid_lft forever preferred_lft forever
inet6 fe80::a00:27ff:fe4c:d80/64 scope link
valid_lft forever preferred_lft forever
himang@himang-VirtualBox:~$ ip route
default via 20.1.1.2 dev enp0s8 proto static
default via 40.1.1.2 dev enp0s9 proto static
default via 10.0.2.2 dev enp0s3 proto dhcp src 10.0.2.15 metric 100
10.0.2.0/24 dev enp0s3 proto kernel scope link src 10.0.2.15 metric 100
10.0.2.2 dev enp0s3 proto dhcp scope link src 10.0.2.15 metric 100
20.1.1.0/24 dev enp0s8 proto kernel scope link src 20.1.1.2
40.1.1.0/24 dev enp0s9 proto kernel scope link src 40.1.1.2
192.168.0.236 via 10.0.2.2 dev enp0s3 proto dhcp src 10.0.2.15 metric 100
himang@himang-VirtualBox:~$

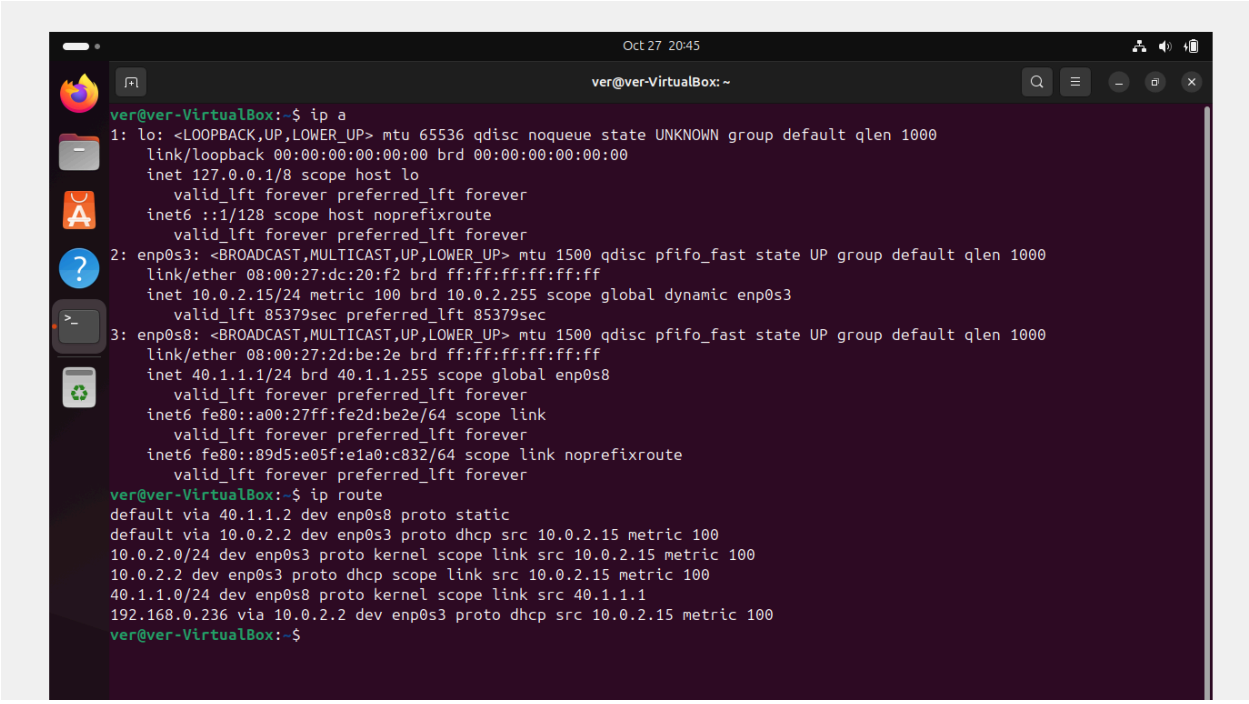
Server 1:


Oct 27 20:40
ser@ser-VirtualBox: ~
GNU nano 7.2
/etc/netplan/02-netcfg.yaml
network:
version: 2
renderer: networkd
ethernets:
enp0s8:
addresses: [40.1.1.3/24]
dhcp4: no
gateway4: 40.1.1.2


Oct 27 20:44
ser@ser-VirtualBox: ~
ser@ser-VirtualBox:~$ 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 noprefixroute
valid_lft forever preferred_lft forever
2: enp0s3: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP group default qlen 1000
link/ether 08:00:27:11:83:03 brd ff:ff:ff:ff:ff:ff
inet 10.0.2.15/24 metric 100 brd 10.0.2.255 scope global dynamic enp0s3
valid_lft 85696sec preferred_lft 85696sec
inet6 fe80::a00:27ff:fe11:8303/64 scope link
valid_lft forever preferred_lft forever
3: enp0s8: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP group default qlen 1000
link/ether 08:00:27:3f:e9:35 brd ff:ff:ff:ff:ff:ff
inet 40.1.1.3/24 brd 40.1.1.255 scope global enp0s8
valid_lft forever preferred_lft forever
inet6 fe80::a00:27ff:fe3f:e935/64 scope link
valid_lft forever preferred_lft forever
ser@ser-VirtualBox:~$ ip route
default via 40.1.1.2 dev enp0s8 proto static
default via 10.0.2.2 dev enp0s3 proto dhcp src 10.0.2.15 metric 100
10.0.2.0/24 dev enp0s3 proto kernel scope link src 10.0.2.15 metric 100
10.0.2.2 dev enp0s3 proto dhcp scope link src 10.0.2.15 metric 100
40.1.1.0/24 dev enp0s8 proto kernel scope link src 40.1.1.3
192.168.0.236 via 10.0.2.2 dev enp0s3 proto dhcp src 10.0.2.15 metric 100
ser@ser-VirtualBox:~$

Server 2:

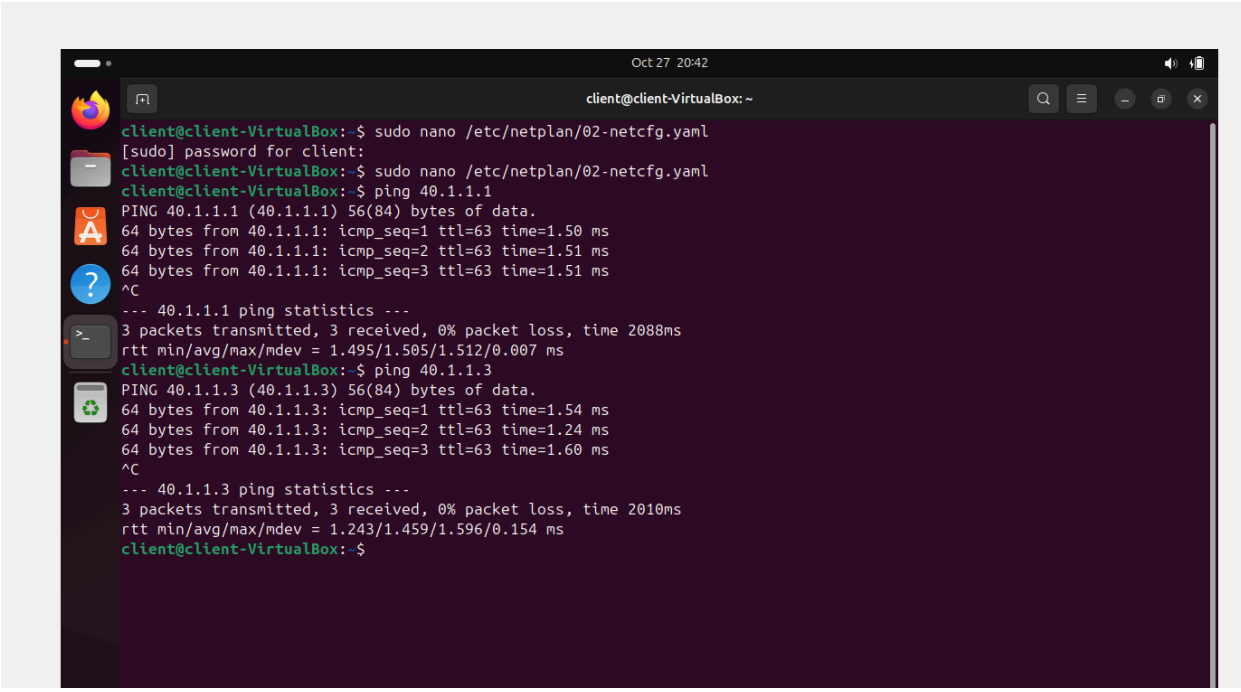

Oct 27 20:40
ver@ver-VirtualBox: ~
GNU nano 7.2
/etc/netplan/02-netcfg.yaml
network:
version: 2
renderer: networkd
ethernets:
enp0s8:
addresses:
- 40.1.1.1/24
dhcp4: no
gateway4: 40.1.1.2



(b) Configure VM2 as the gateway such that it can forward the incoming traffic to one of the servers – add forwarding functionality

I have added the forwarding functionality using this command: sudo sysctl -w net.ipv4.ip_forward=1on the gateway

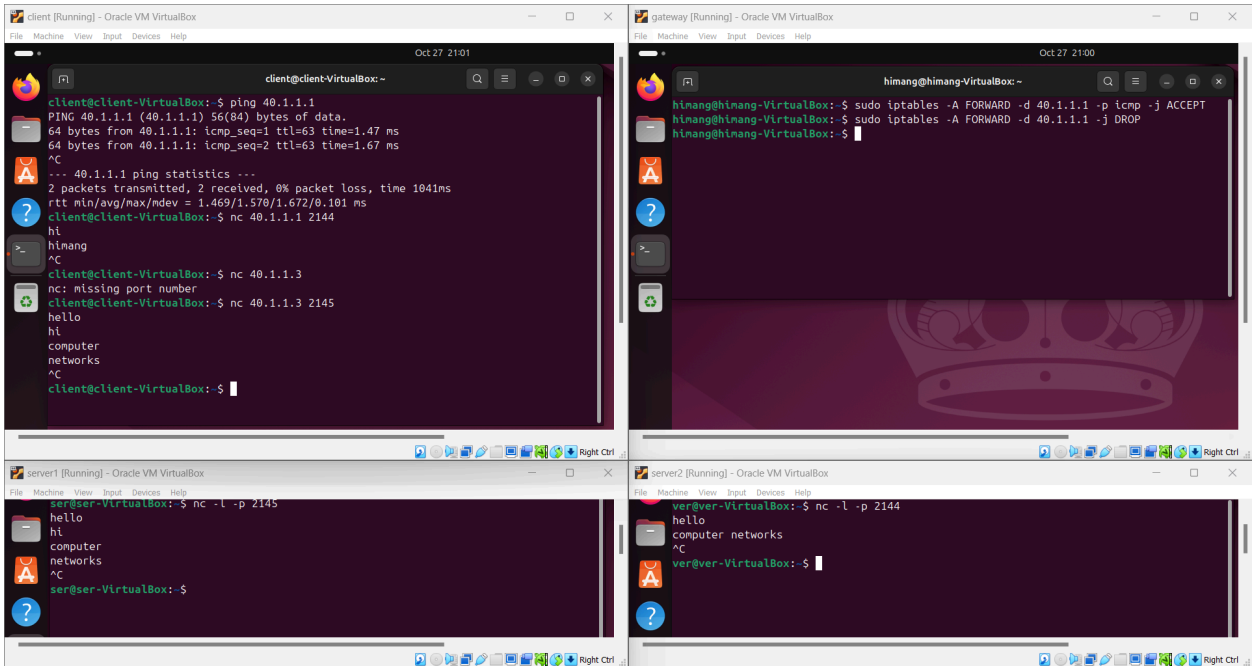
Thus the connection is established as shown below:



Ans2. (a) The gateway must block all traffic (except for ping) destined to the server 40.1.1.1/24.

I have used the following command to only accept ping to 40.1.1.1 and block all other:
sudo iptables -A FORWARD -d 40.1.1.1 -p icmp -j ACCEPT
sudo iptables -A FORWARD -d 40.1.1.1 -j DROP

As shown in the screenshot below ping is working for 40.1.1.1, but netcat is not working for 40.1.1.1 and showing different outputs. It can be seen that netcat is working for the other server which is 40.1.1.3 :

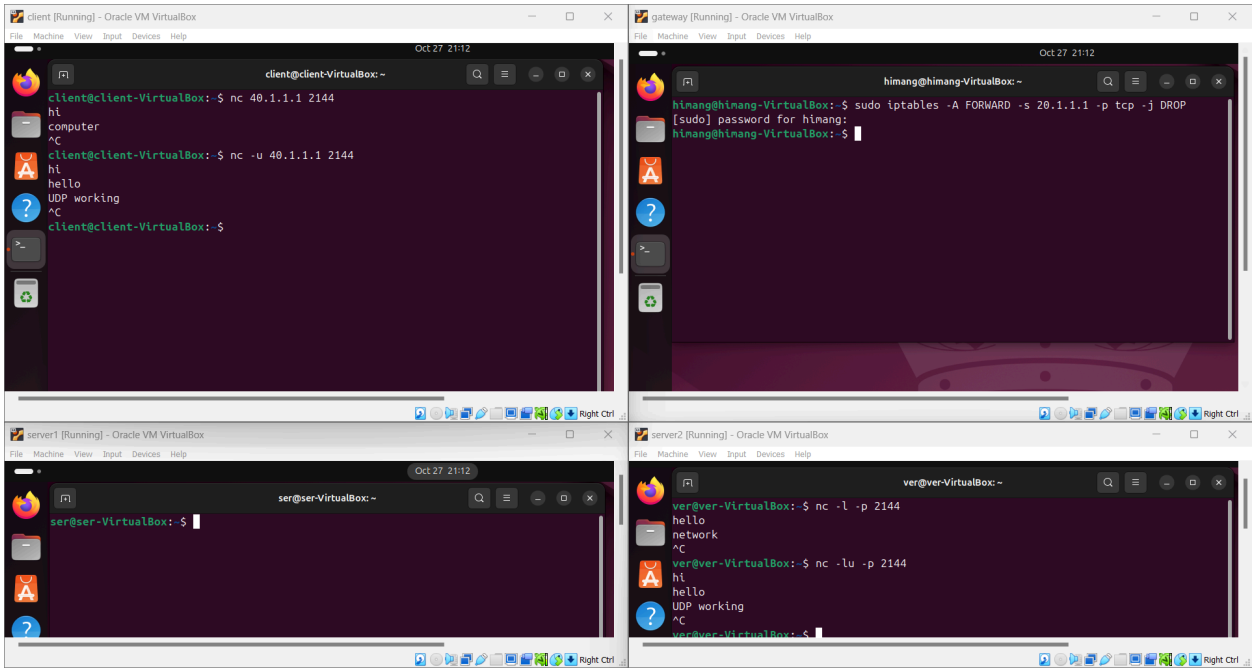


(b) The gateway must block only TCP traffic initiated by 20.1.1.1/24.

I have used the following command to block TCP traffic initiated by 20.1.1.1:

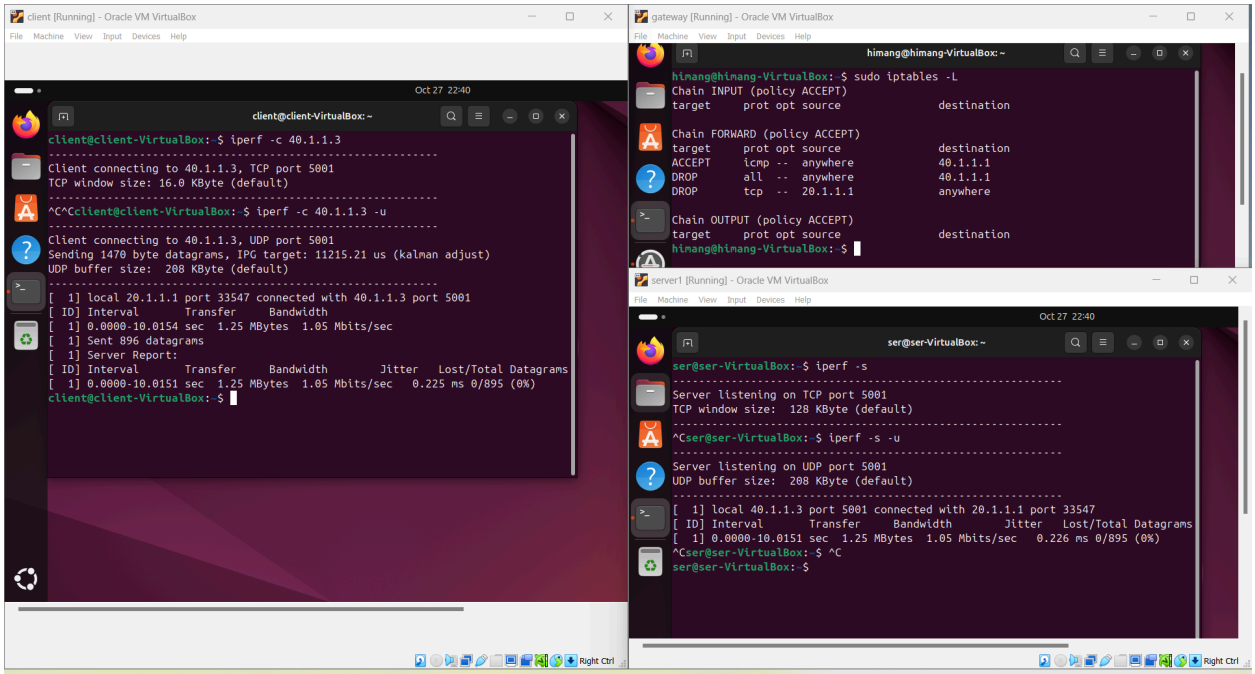
sudo iptables -A FORWARD -s 20.1.1.1 -p tcp -j DROP

The result can be seen in the following screenshot that the netcat command works only for UDP connection but not for TCP.



Ans 3.
(a)Use “iperf2” tool to test the TCP and UDP bandwidth between 20.1.1.1/24 and 40.1.1.3/24.

TCP connection can’t be established because of the configurations made in question 2 but a UDP connection can be established as shown below:



(b) What is the minimum, average, and maximum RTT

(i) from 20.1.1.1/24 to 40.1.1.1/24
Minimum RTT = 1.068 ms
Average RTT = 1.746 ms
Maximum RTT = 2.087 ms

```
client@client-VirtualBox:~$ ping -c 10 40.1.1.1
PING 40.1.1.1 (40.1.1.1) 56(84) bytes of data.
64 bytes from 40.1.1.1: icmp_seq=1 ttl=63 time=1.67 ms
64 bytes from 40.1.1.1: icmp_seq=2 ttl=63 time=1.64 ms
64 bytes from 40.1.1.1: icmp_seq=3 ttl=63 time=1.82 ms
64 bytes from 40.1.1.1: icmp_seq=4 ttl=63 time=1.07 ms
64 bytes from 40.1.1.1: icmp_seq=5 ttl=63 time=1.70 ms
64 bytes from 40.1.1.1: icmp_seq=6 ttl=63 time=1.69 ms
64 bytes from 40.1.1.1: icmp_seq=7 ttl=63 time=1.91 ms
64 bytes from 40.1.1.1: icmp_seq=8 ttl=63 time=2.01 ms
64 bytes from 40.1.1.1: icmp_seq=9 ttl=63 time=1.86 ms
64 bytes from 40.1.1.1: icmp_seq=10 ttl=63 time=2.09 ms

--- 40.1.1.1 ping statistics ---
10 packets transmitted, 10 received, 0% packet loss, time 9092ms
rtt min/avg/max/mdev = 1.068/1.746/2.087/0.266 ms
```

(ii) from 20.1.1.1/24 to 40.1.1.3/24

Minimum RTT = 1.415 ms
Average RTT = 1.637 ms
Maximum RTT = 1.940 ms

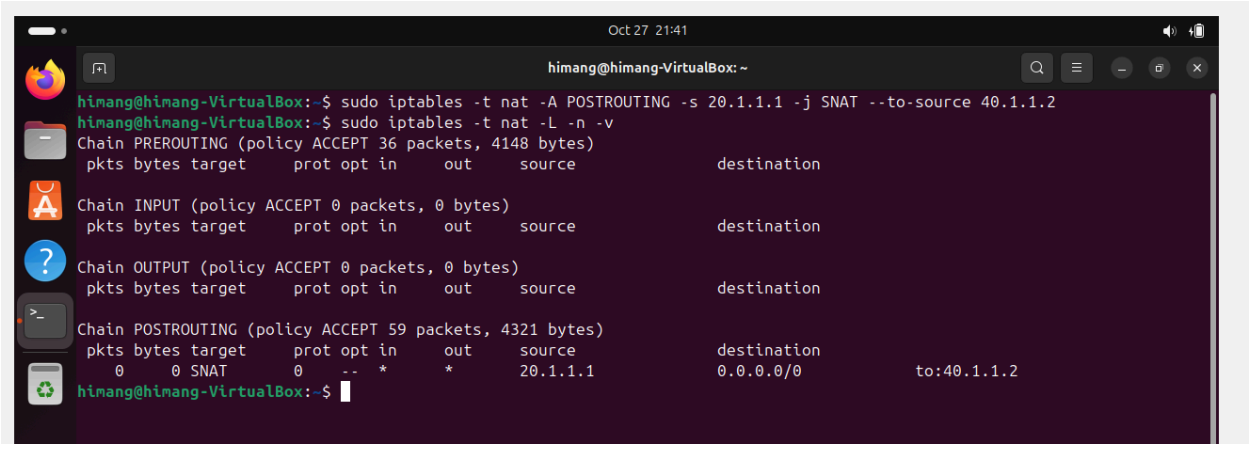
```
client@client-VirtualBox:~$ ping -c 10 40.1.1.3
PING 40.1.1.3 (40.1.1.3) 56(84) bytes of data.
64 bytes from 40.1.1.3: icmp_seq=1 ttl=63 time=1.80 ms
64 bytes from 40.1.1.3: icmp_seq=2 ttl=63 time=1.67 ms
64 bytes from 40.1.1.3: icmp_seq=3 ttl=63 time=1.94 ms
64 bytes from 40.1.1.3: icmp_seq=4 ttl=63 time=1.70 ms
64 bytes from 40.1.1.3: icmp_seq=5 ttl=63 time=1.69 ms
64 bytes from 40.1.1.3: icmp_seq=6 ttl=63 time=1.72 ms
64 bytes from 40.1.1.3: icmp_seq=7 ttl=63 time=1.46 ms
64 bytes from 40.1.1.3: icmp_seq=8 ttl=63 time=1.53 ms
64 bytes from 40.1.1.3: icmp_seq=9 ttl=63 time=1.46 ms
64 bytes from 40.1.1.3: icmp_seq=10 ttl=63 time=1.42 ms

--- 40.1.1.3 ping statistics ---
10 packets transmitted, 10 received, 0% packet loss, time 11184ms
rtt min/avg/max/mdev = 1.415/1.637/1.940/0.160 ms
```

(iii) Did you find a significant difference between (i) and (ii)? If so, why?
The average and maximum RTT for 40.1.1.3 is less than that of 40.1.1.1. This is due to the configurations made in Question 2. Since all the rules have to be checked, the packed has to spend more time in kernel space and an increase in time can seen.

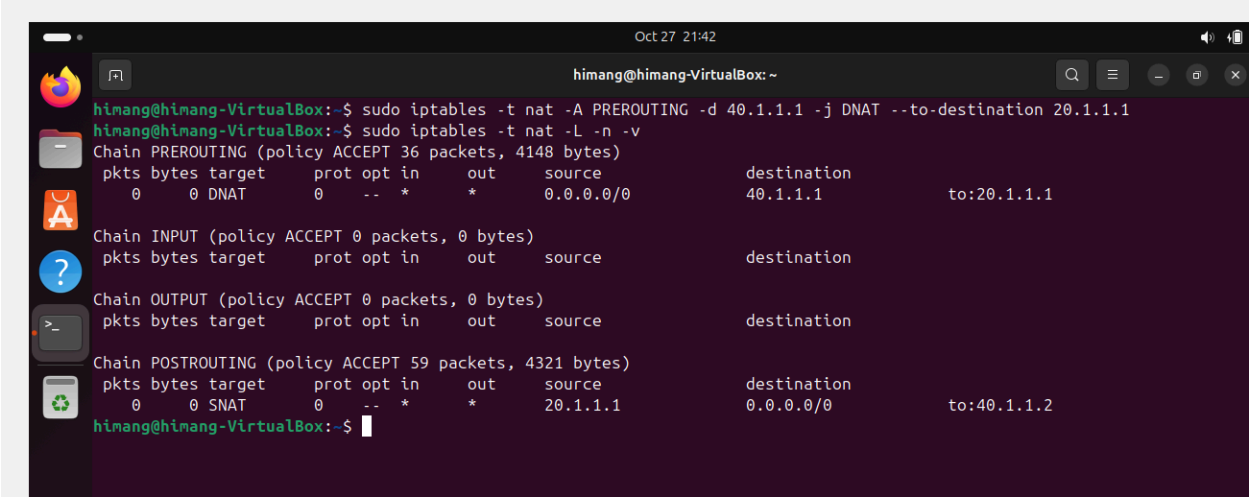
Ans 4.
(a) Change the source IP address of every packet from 20.1.1.1/24 to 40.1.1.2/24

I have the used the below command:
sudo iptables -t nat -A POSTROUTING -s 20.1.1.1 -j SNAT --to-source 40.1.1.2



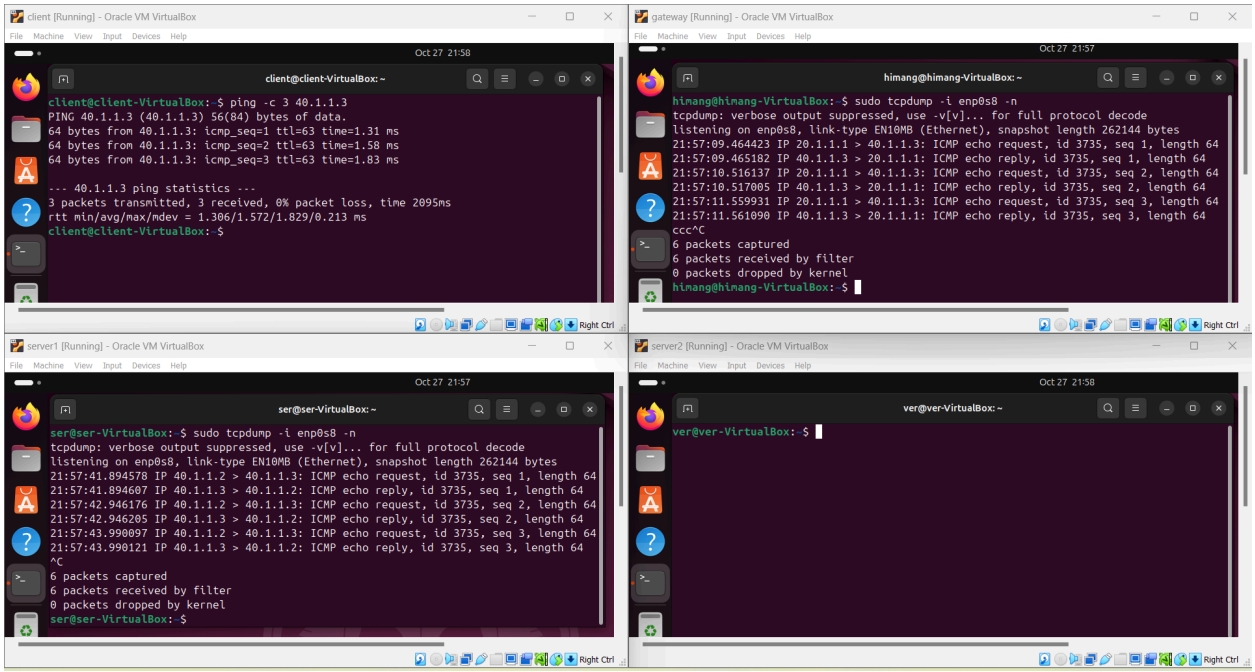
(b) When the packet response for the packet from step “a” arrives at the gateway, revert the destination IP address to the original.

I have used the command below:
sudo iptables -t nat -A PREROUTING -d 40.1.1.2 -j DNAT --to-destination 20.1.1.1



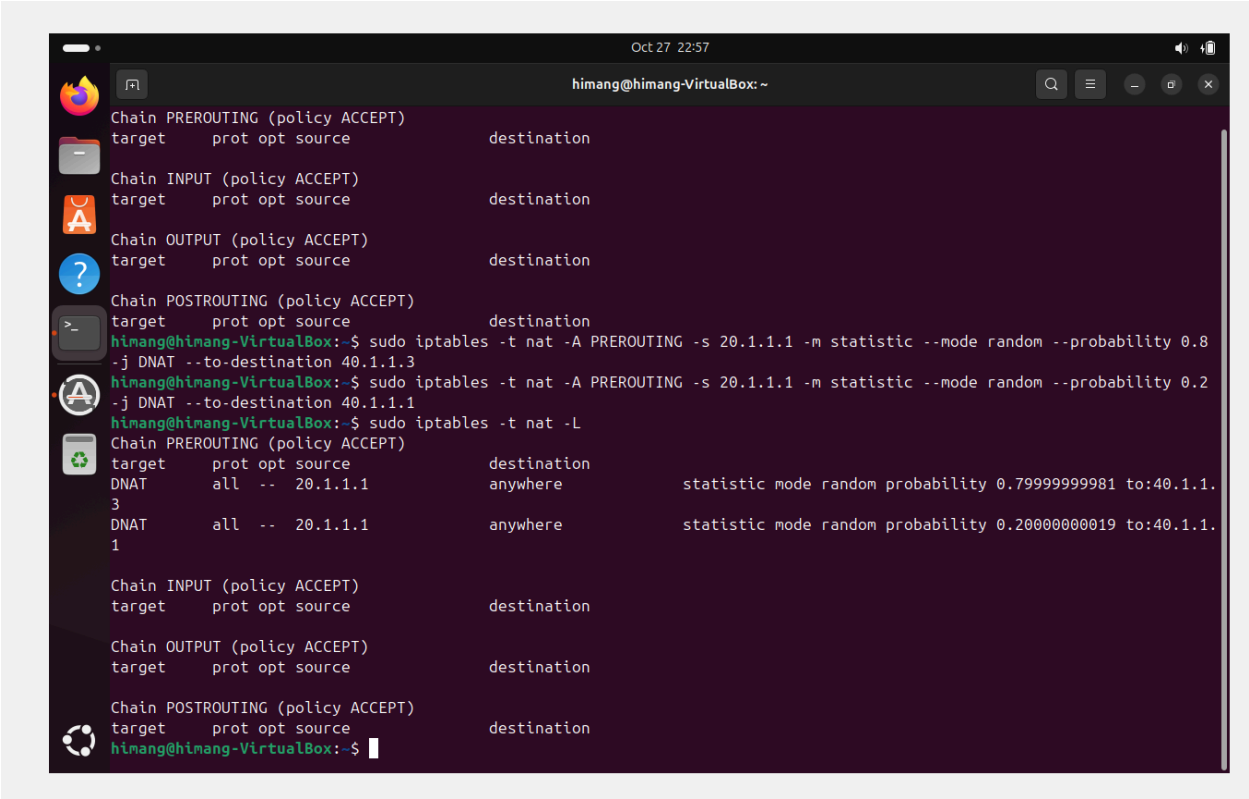
(c) Validate the above by sending traffic and observing the packets at each VM using Wireshark/tcpdump.

The below screenshot can validate the above result.



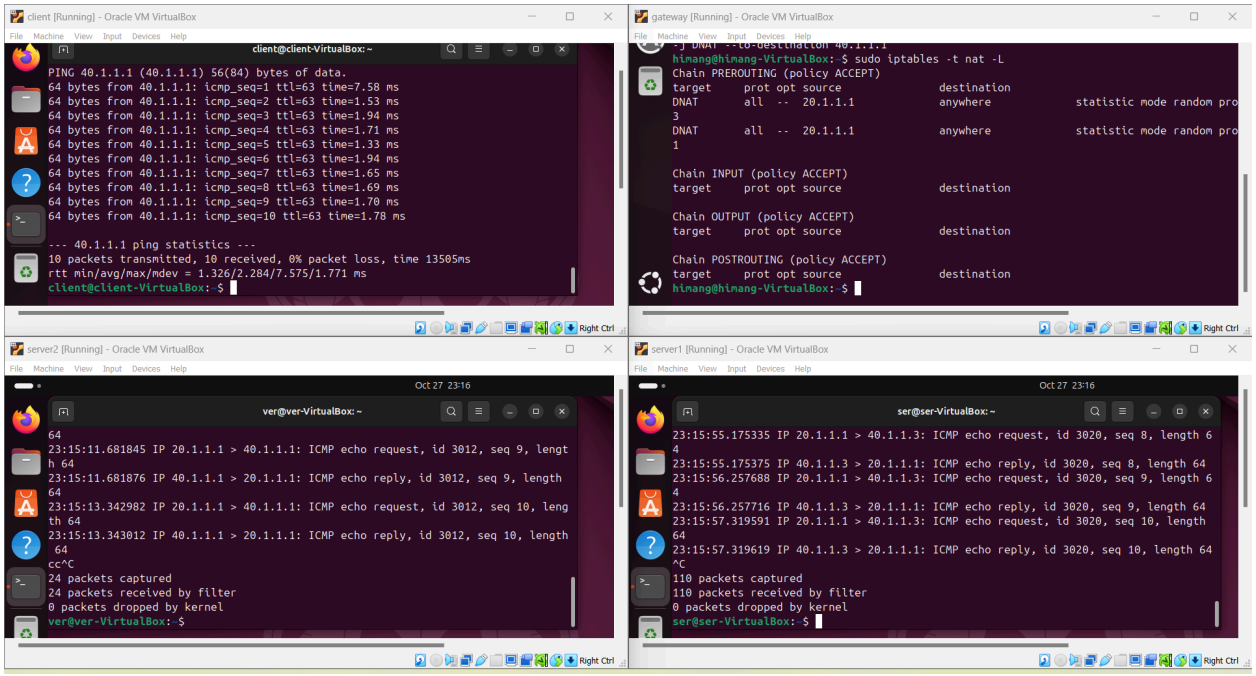
Ans 5.
(a) Using the information obtained from Q.3.b., balance the traffic from 20.1.1.1/24 to the servers, 40.1.1.1/24 and 40.1.1.3/24. The probability of assigning the packet to the servers is 0.8 and 0.2, i.e., assign a high probability to the server with lower RTT.

Since we found that the average RTT for 40.1.1.3 is lower than that of 40.1.1.1 we will give a higher probability to 40.1.1.3 using the following commands:



(b)

After pinging 40.1.1.1 several times, we can see that a ratio of 1:4 is visible as shown in the screenshot below:


client [Running] - Oracle VM VirtualBox
client@client-VirtualBox: ~
PING 40.1.1.1 (40.1.1.1) 56(84) bytes of data.
64 bytes from 40.1.1.1: icmp_seq=1 ttl=63 time=7.58 ms
64 bytes from 40.1.1.1: icmp_seq=2 ttl=63 time=1.53 ms
64 bytes from 40.1.1.1: icmp_seq=3 ttl=63 time=1.94 ms
64 bytes from 40.1.1.1: icmp_seq=4 ttl=63 time=1.71 ms
64 bytes from 40.1.1.1: icmp_seq=5 ttl=63 time=1.33 ms
64 bytes from 40.1.1.1: icmp_seq=6 ttl=63 time=1.94 ms
64 bytes from 40.1.1.1: icmp_seq=7 ttl=63 time=1.65 ms
64 bytes from 40.1.1.1: icmp_seq=8 ttl=63 time=1.69 ms
64 bytes from 40.1.1.1: icmp_seq=9 ttl=63 time=1.70 ms
64 bytes from 40.1.1.1: icmp_seq=10 ttl=63 time=1.78 ms
--- 40.1.1.1 ping statistics ---
10 packets transmitted, 10 received, 0% packet loss, time 13505ms
rtt min/avg/max/mdev = 1.326/2.284/7.575/1.771 ms
client@client-VirtualBox:~$
gateway [Running] - Oracle VM VirtualBox
himang@himang-VirtualBox:~$ sudo iptables -t nat -L
Chain PREROUTING (policy ACCEPT)
target prot opt source destination
DNAT all -- 20.1.1.1 anywhere statistic mode random pro
3
DNAT all -- 20.1.1.1 anywhere statistic mode random pro
1
Chain INPUT (policy ACCEPT)
target prot opt source destination
Chain OUTPUT (policy ACCEPT)
target prot opt source destination
Chain POSTROUTING (policy ACCEPT)
target prot opt source destination
himang@himang-VirtualBox:~$
server2 [Running] - Oracle VM VirtualBox
Oct 27 23:16
ver@ver-VirtualBox: ~
64
23:15:11.681845 IP 20.1.1.1 > 40.1.1.1: ICMP echo request, id 3012, seq 9, lengt
h 64
23:15:11.681876 IP 40.1.1.1 > 20.1.1.1: ICMP echo reply, id 3012, seq 9, length
64
23:15:13.342982 IP 20.1.1.1 > 40.1.1.1: ICMP echo request, id 3012, seq 10, leng
th 64
23:15:13.343012 IP 40.1.1.1 > 20.1.1.1: ICMP echo reply, id 3012, seq 10, length
64
cc^C
24 packets captured
24 packets received by filter
0 packets dropped by kernel
ver@ver-VirtualBox:~$
server1 [Running] - Oracle VM VirtualBox
Oct 27 23:16
ser@ser-VirtualBox: ~
23:15:55.175335 IP 20.1.1.1 > 40.1.1.3: ICMP echo request, id 3020, seq 8, length 6
4
23:15:55.175375 IP 40.1.1.3 > 20.1.1.1: ICMP echo reply, id 3020, seq 8, length 64
23:15:56.257688 IP 20.1.1.1 > 40.1.1.3: ICMP echo request, id 3020, seq 9, length 6
4
23:15:56.257716 IP 40.1.1.3 > 20.1.1.1: ICMP echo reply, id 3020, seq 9, length 64
23:15:57.319591 IP 20.1.1.1 > 40.1.1.3: ICMP echo request, id 3020, seq 10, length
64
23:15:57.319619 IP 40.1.1.3 > 20.1.1.1: ICMP echo reply, id 3020, seq 10, length 64
^C
110 packets captured
110 packets received by filter
0 packets dropped by kernel
ser@ser-VirtualBox:~$