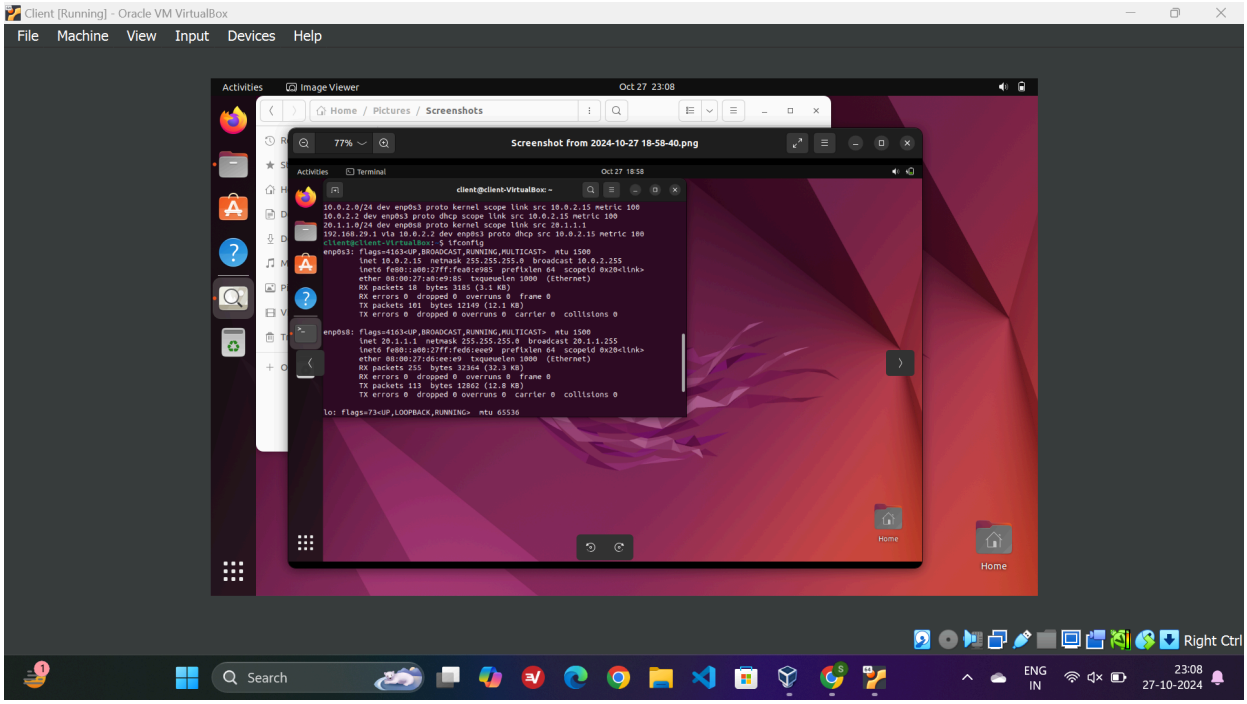
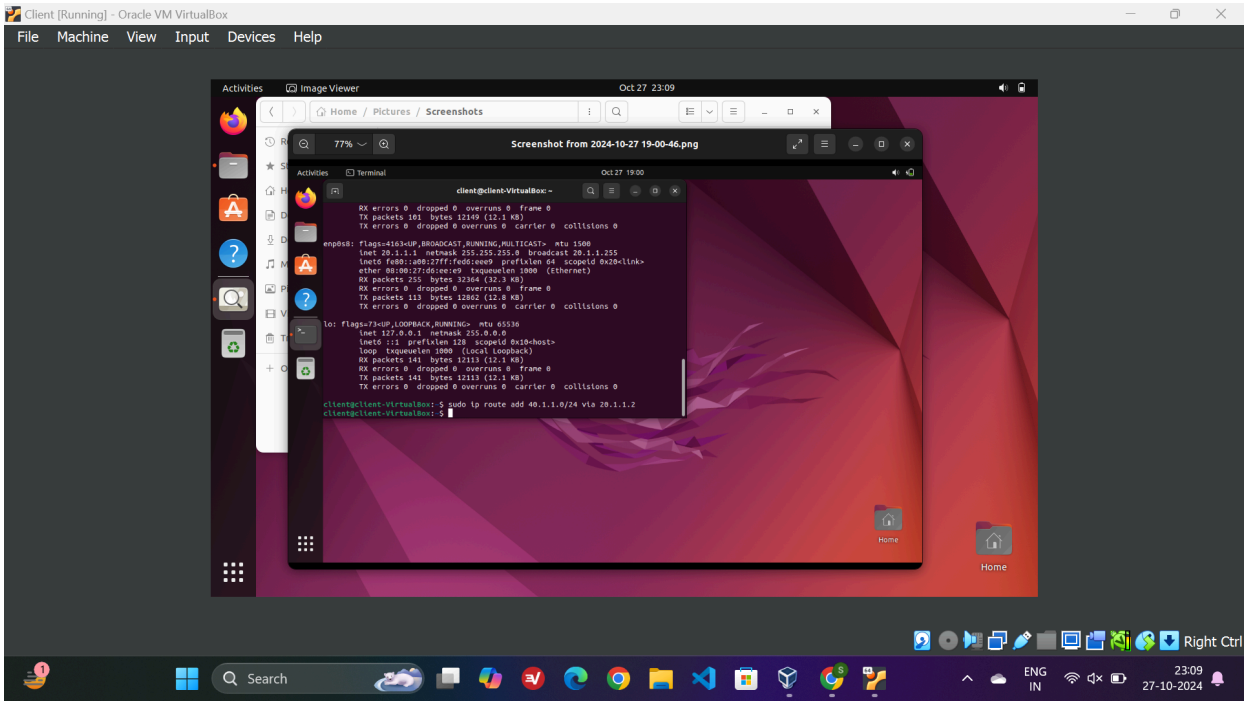
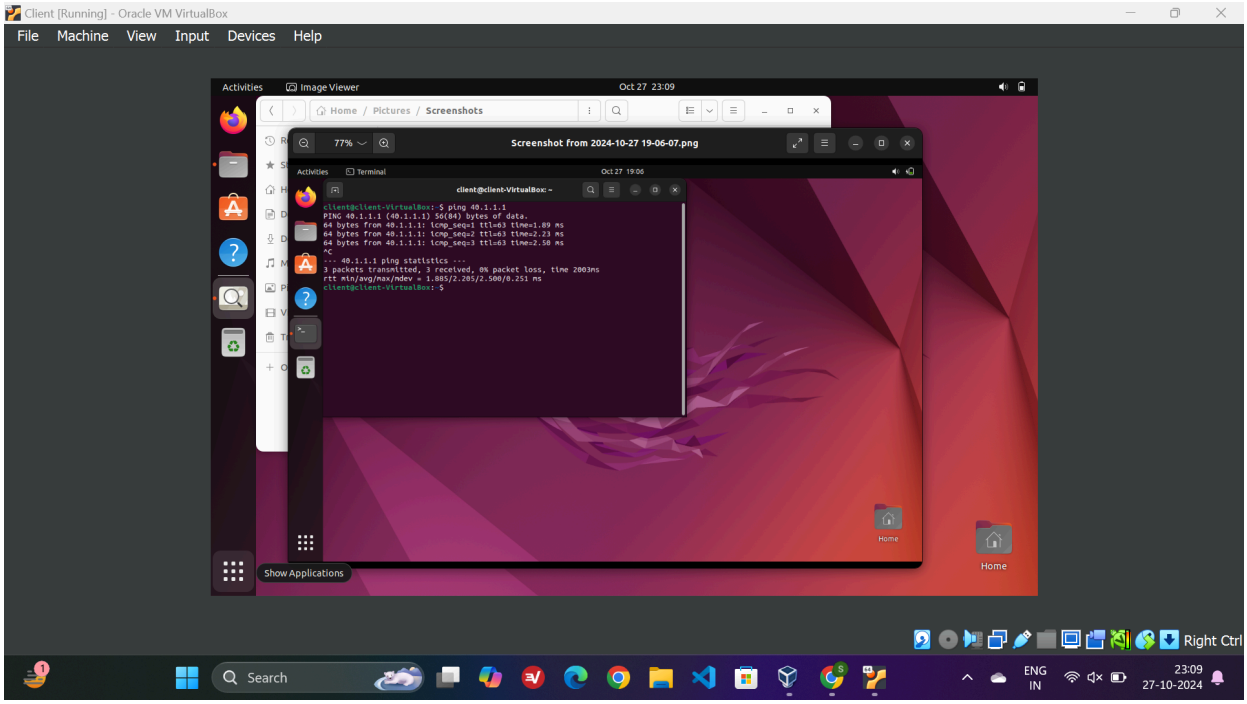
Q-1:

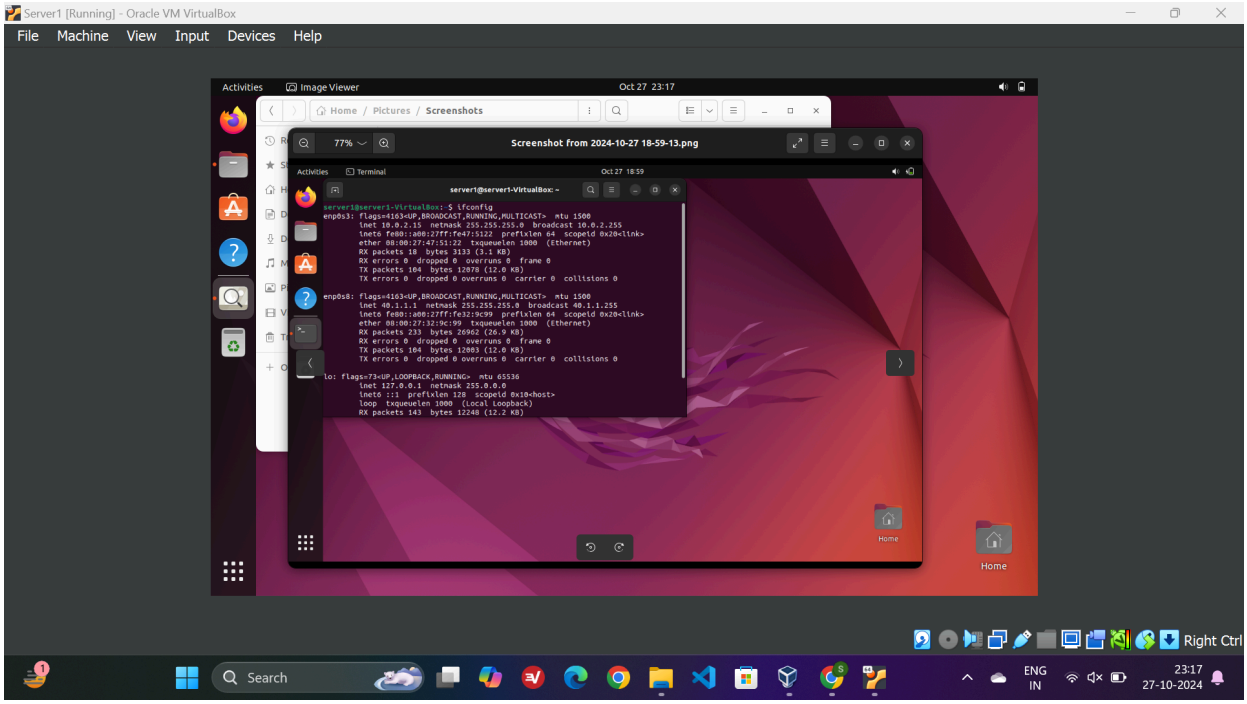
a) I followed the tutorial steps to configure the four VMs: client, gateway, server 1, server 2, along with necessary Ip addresse and routes.

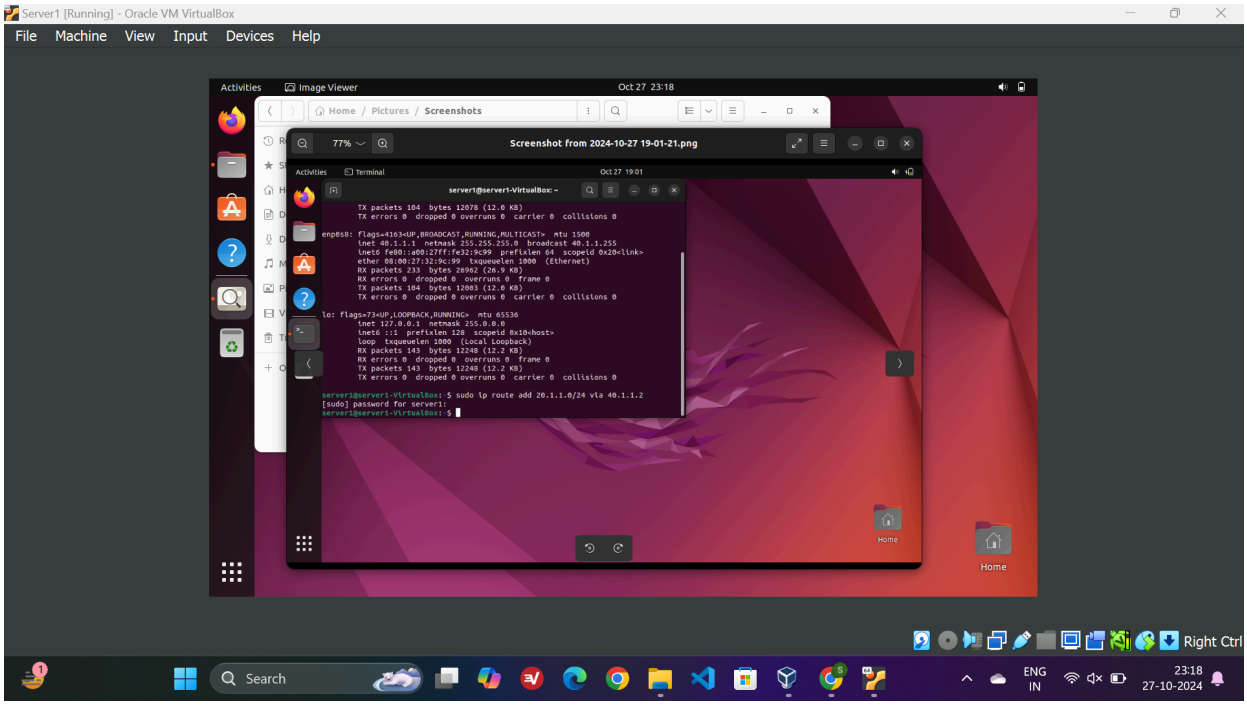
b) Forwarding functionality was added and tested by successfully pinging the servers from the client.

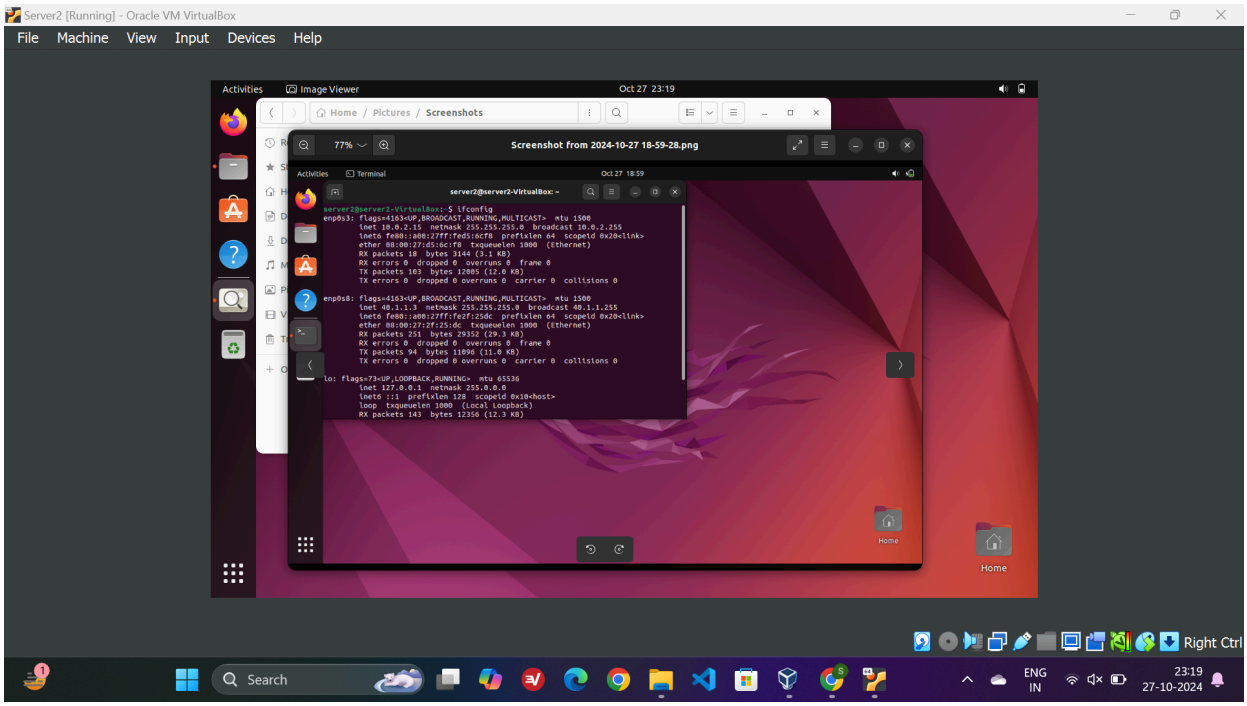


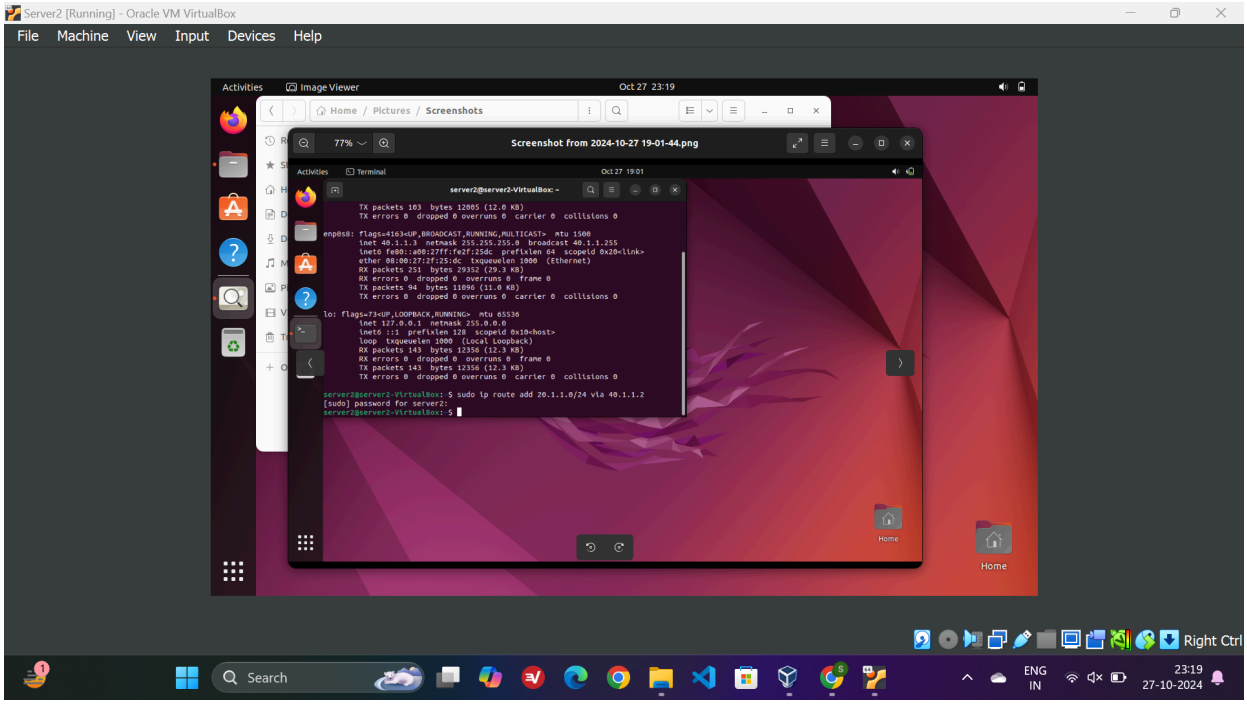



Client [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Image Viewer Oct 27 23:09
Home / Pictures / Screenshots
Screenshot from 2024-10-27 19-06-07.png
Activities Terminal Oct 27 19:06
client@client-VirtualBox: ~
client@client-VirtualBox:~$ ping 40.1.1.1
PING 40.1.1.1 (40.1.1.1) 56(84) bytes of data.
64 bytes from 40.1.1.1: icmp_seq=1 ttl=63 time=1.89 ms
64 bytes from 40.1.1.1: icmp_seq=2 ttl=63 time=2.23 ms
64 bytes from 40.1.1.1: icmp_seq=3 ttl=63 time=2.50 ms
^C
--- 40.1.1.1 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2003ms
rtt min/avg/max/mdev = 1.885/2.205/2.500/0.251 ms
client@client-VirtualBox:~$
Home
Show Applications
Right Ctrl
Search
ENG IN
23:09 27-10-2024


Server1 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Image Viewer Oct 27 23:17
Home / Pictures / Screenshots
Screenshot from 2024-10-27 18-59-13.png
Activities Terminal Oct 27 18:59
server1@server1-VirtualBox: ~
server1@server1-VirtualBox:~$ ifconfig
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 10.0.2.15 netmask 255.255.255.0 broadcast 10.0.2.255
inet6 fe80::a00:27ff:fe47:5122 prefixlen 64 scopeid 0x20<link>
ether 08:00:27:47:51:22 txqueuelen 1000 (Ethernet)
RX packets 18 bytes 3133 (3.1 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 104 bytes 12078 (12.0 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
enp0s8: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 40.1.1.1 netmask 255.255.255.0 broadcast 40.1.1.255
inet6 fe80::a00:27ff:fe32:9c99 prefixlen 64 scopeid 0x20<link>
ether 08:00:27:32:9c:99 txqueuelen 1000 (Ethernet)
RX packets 233 bytes 26962 (26.9 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 104 bytes 12003 (12.0 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 143 bytes 12248 (12.2 KB)
Home
Right Ctrl
Search
ENG IN
23:17 27-10-2024

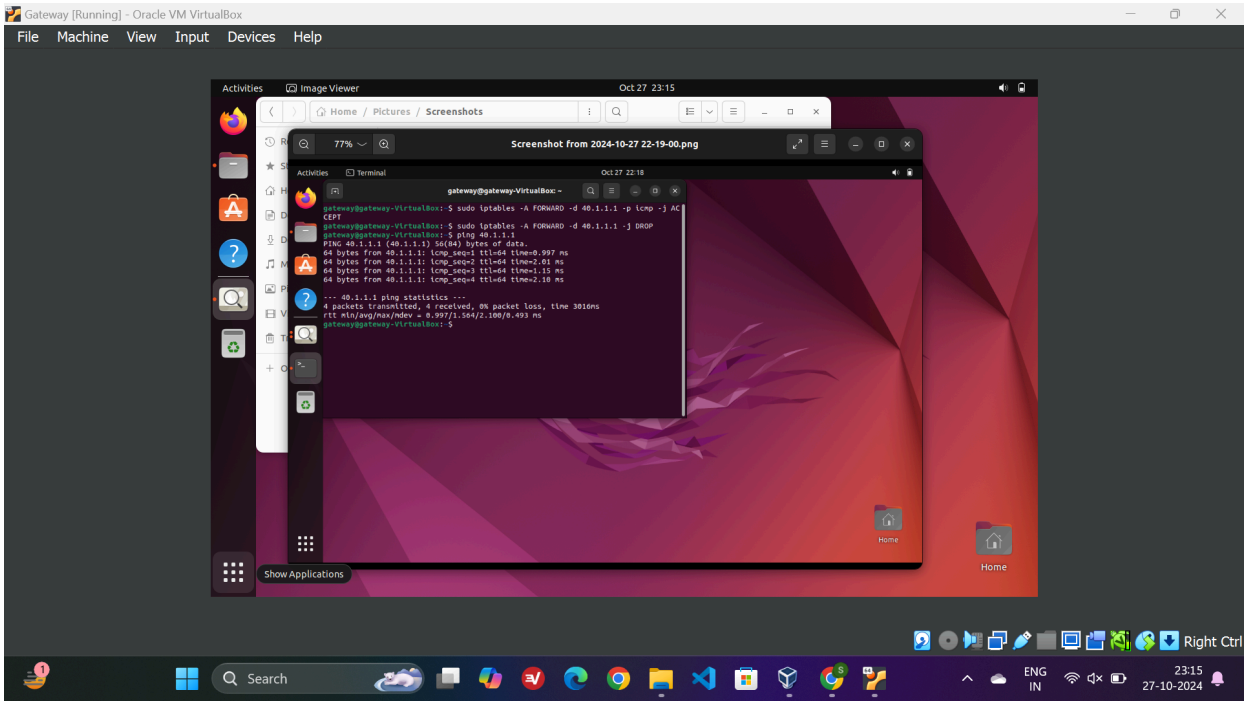

Server1 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Image Viewer Oct 27 23:18
Home / Pictures / Screenshots
Screenshot from 2024-10-27 19-01-21.png
Activities Terminal Oct 27 19:01
server1@server1-VirtualBox: ~
TX packets 104 bytes 12078 (12.0 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
enp0s8: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 40.1.1.1 netmask 255.255.255.0 broadcast 40.1.1.255
inet6 fe80::a00:27ff:fe32:9c99 prefixlen 64 scopeid 0x20<link>
ether 08:00:27:32:9c:99 txqueuelen 1000 (Ethernet)
RX packets 233 bytes 26962 (26.9 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 104 bytes 12083 (12.0 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 143 bytes 12248 (12.2 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 143 bytes 12248 (12.2 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
server1@server1-VirtualBox:~$ sudo ip route add 20.1.1.0/24 via 40.1.1.2
[sudo] password for server1:
server1@server1-VirtualBox:~$
Home
Right Ctrl
Search
ENG IN
23:18 27-10-2024


Server2 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Image Viewer Oct 27 23:19
Home / Pictures / Screenshots
Screenshot from 2024-10-27 18-59-28.png
Activities Terminal Oct 27 18:59
server2@server2-VirtualBox: ~
server2@server2-VirtualBox:~$ ifconfig
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 10.0.2.15 netmask 255.255.255.0 broadcast 10.0.2.255
inet6 fe80::a00:27ff:fed5:6cf8 prefixlen 64 scopeid 0x20<link>
ether 08:00:27:d5:6c:f8 txqueuelen 1000 (Ethernet)
RX packets 18 bytes 3144 (3.1 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 103 bytes 12005 (12.0 KB)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
enp0s8: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 40.1.1.3 netmask 255.255.255.0 broadcast 40.1.1.255
inet6 fe80::a00:27ff:fe2f:25dc prefixlen 64 scopeid 0x20<link>
ether 08:00:27:2f:25:dc txqueuelen 1000 (Ethernet)
RX packets 251 bytes 29352 (29.3 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 94 bytes 11696 (11.6 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 143 bytes 12356 (12.3 KB)
Home
Right Ctrl
Search
ENG IN
23:19 27-10-2024

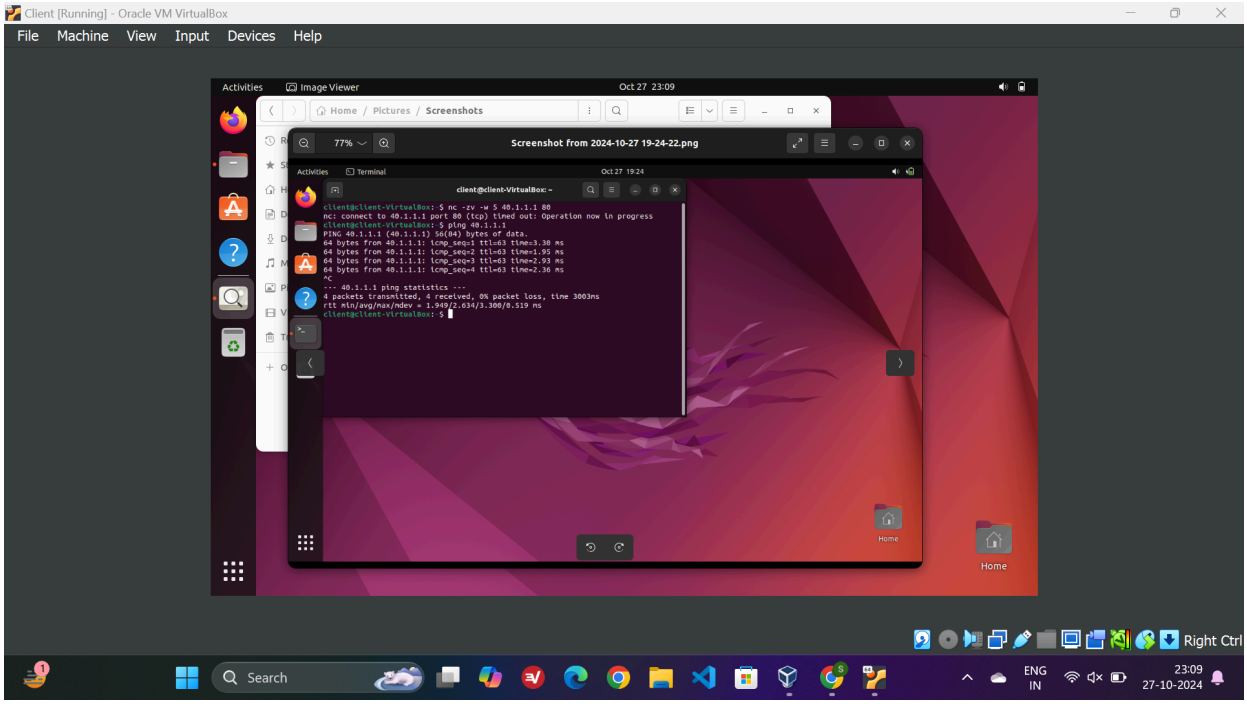


Command to enable forwardin on the gateway VM:
sudo sysctl -w net.ipv4.ip_forward=1

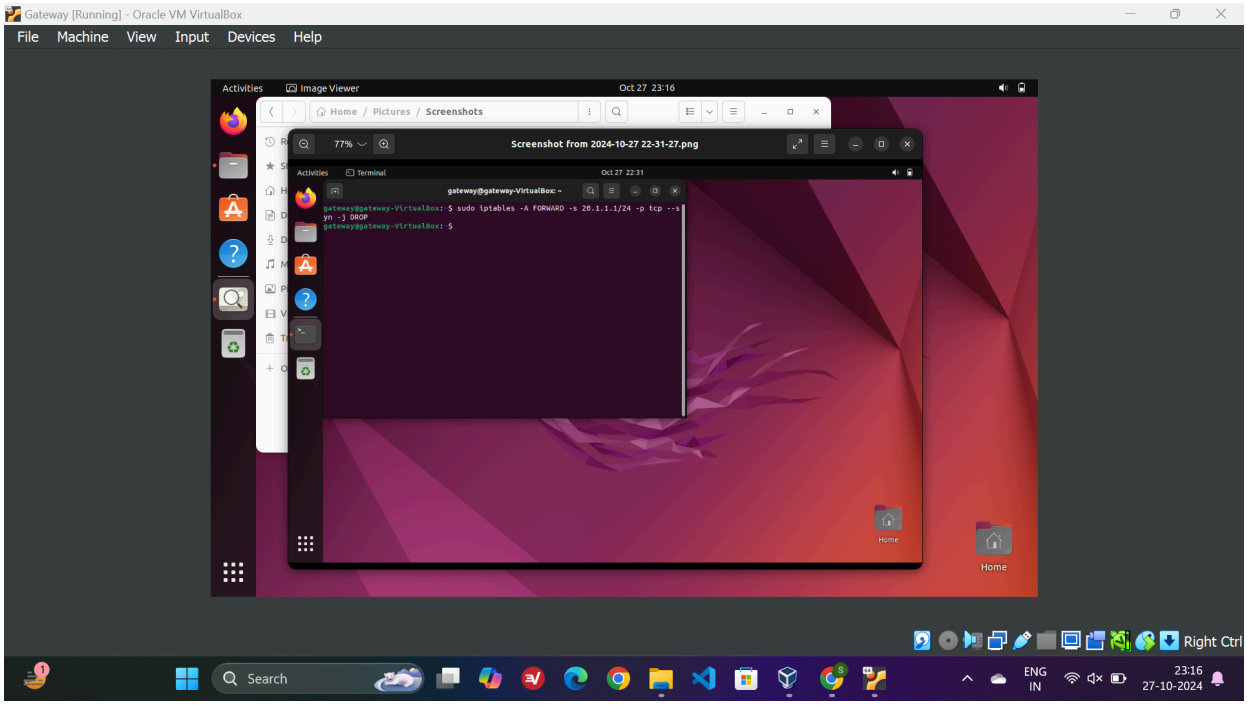
Q.2 a)
The following commands were executed on the Gateway:



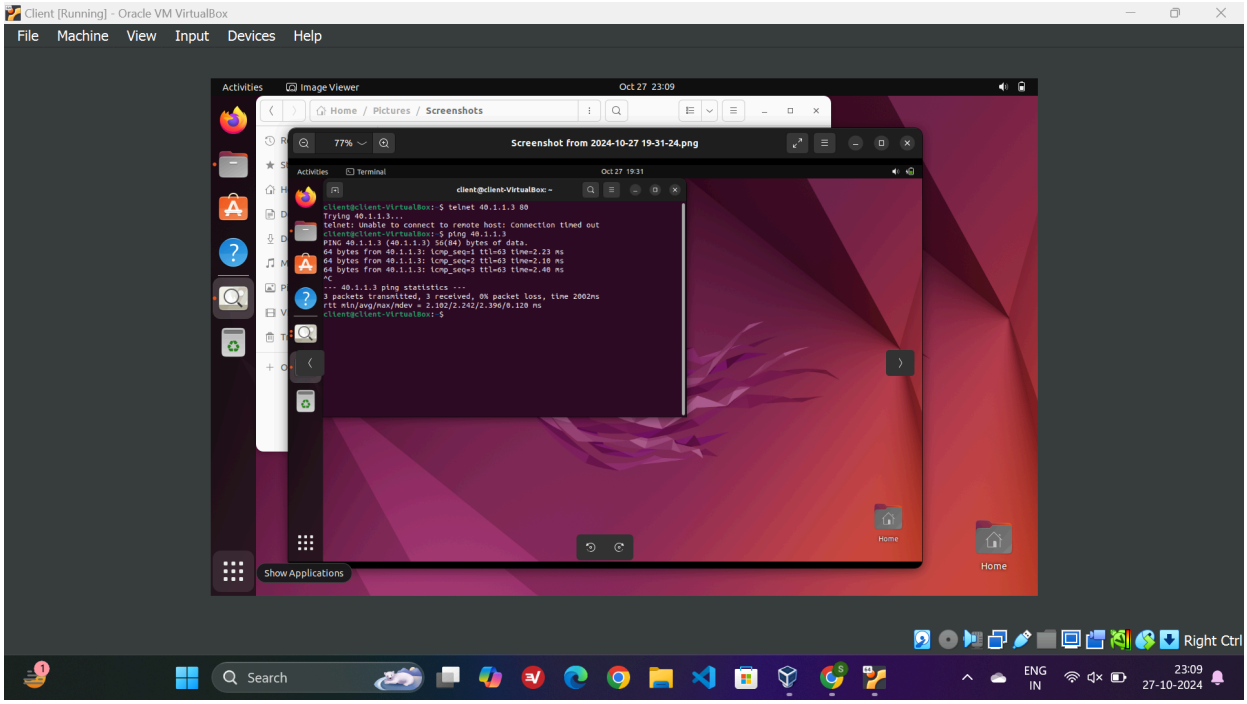
It is evident that the command is functioning as intended, as shown in the following screenshots.

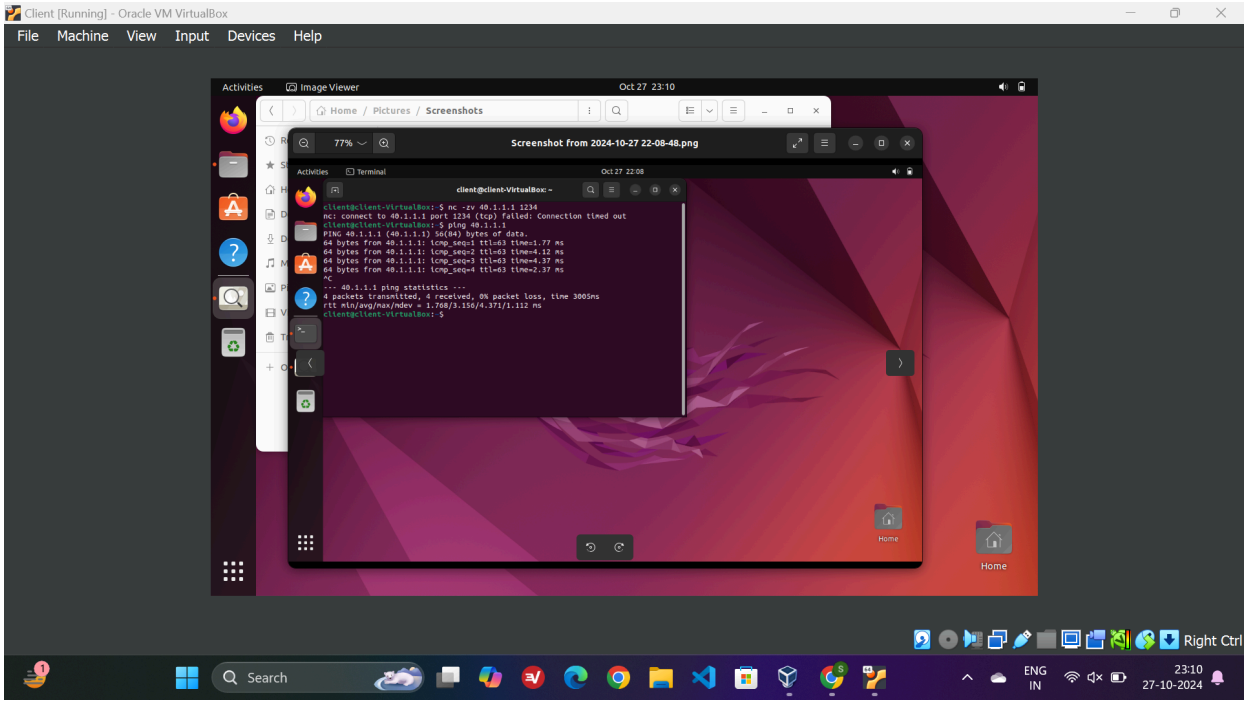


b) The following commands were executed on the on Gateway

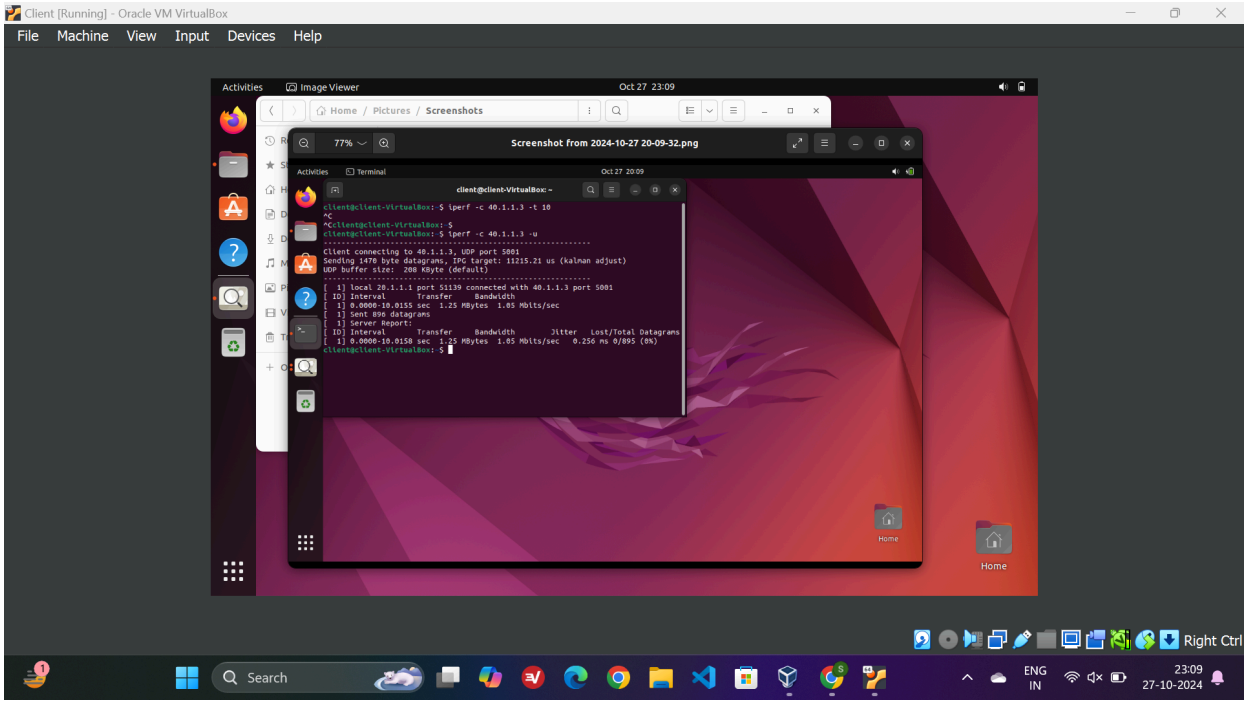


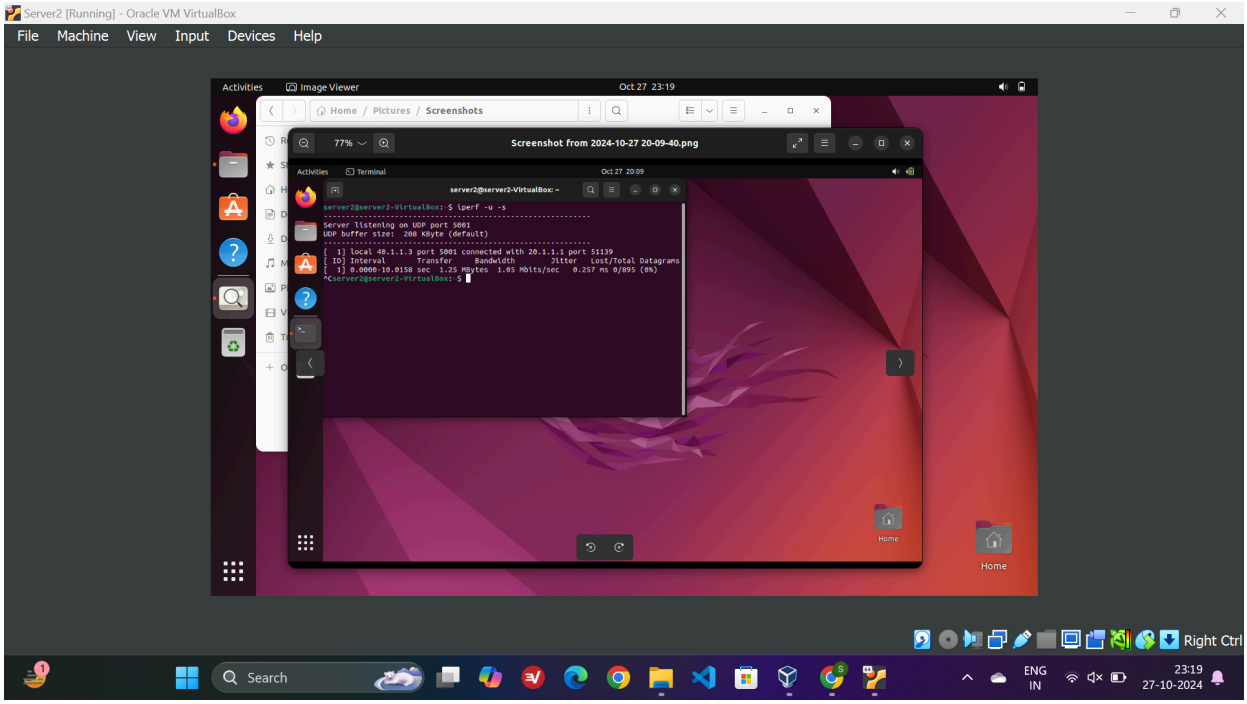
It can be observed that it is working as intended through the following.



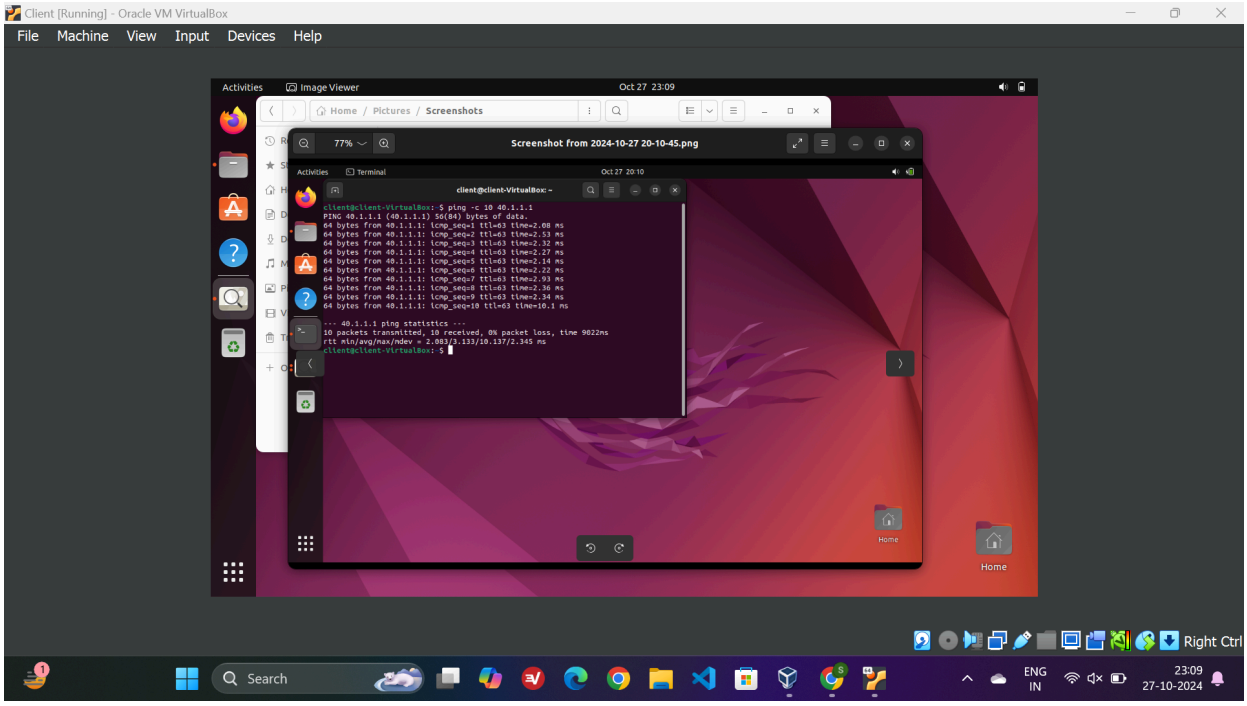


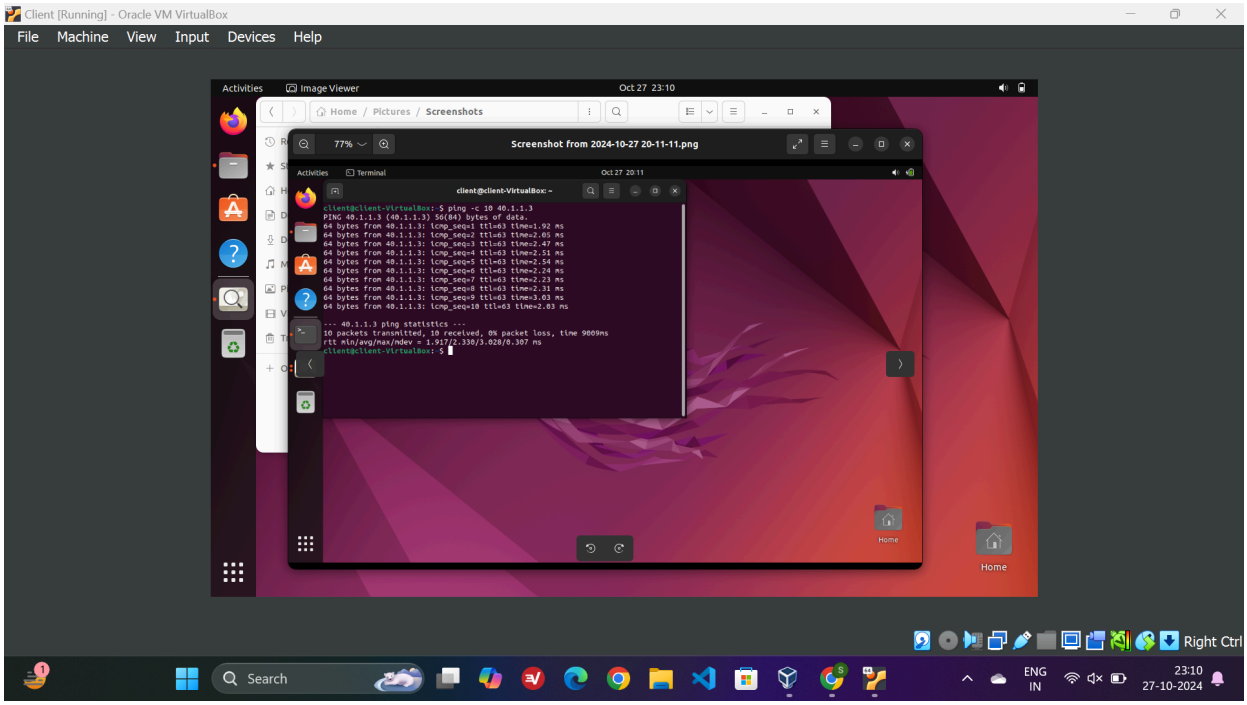
Q3 a) a) Using the same setup as Q.2, iperf does not work for TCP. For UDP, the measured bandwidth is 1.05 Mbits/sec.


Client [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Image Viewer Oct 27 23:09
Home / Pictures / Screenshots
Screenshot from 2024-10-27 20-09-32.png
Activities Terminal Oct 27 20:09
client@client-VirtualBox: ~
client@client-VirtualBox: $ iperf -c 40.1.1.3 -t 10
^C
client@client-VirtualBox: $
client@client-VirtualBox: $ iperf -c 40.1.1.3 -u
Client connecting to 40.1.1.3, UDP port 5001
Sending 1470 byte datagrams, IPG target: 11215.21 us (kalman adjust)
UDP buffer size: 208 KByte (default)
[1] local 20.1.1.1 port 51139 connected with 40.1.1.3 port 5001
[ID] Interval Transfer Bandwidth
[1] 0.0000-10.0155 sec 1.25 MBytes 1.05 Mbits/sec
[1] Sent 896 datagrams
[1] Server Report:
[ID] Interval Transfer Bandwidth Jitter Lost/Total Datagrams
[1] 0.0000-10.0158 sec 1.25 MBytes 1.05 Mbits/sec 0.256 ms 0/895 (0%)
client@client-VirtualBox: $
Home
Right Ctrl
Search
ENG IN
23:09 27-10-2024


Server2 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Image Viewer Oct 27 23:19
Home / Pictures / Screenshots
Screenshot from 2024-10-27 20-09-40.png
Activities Terminal Oct 27 20:09
server2@server2-VirtualBox: ~
server2@server2-VirtualBox: $ iperf -u -s
Server listening on UDP port 5001
UDP buffer size: 208 KByte (default)
[1] local 40.1.1.3 port 5001 connected with 20.1.1.1 port 51139
[ID] Interval Transfer Bandwidth Jitter Lost/Total Datagrams
[1] 0.0000-10.0158 sec 1.25 MBytes 1.05 Mbits/sec 0.257 ms 0/895 (0%)
^Cserver2@server2-VirtualBox: $
Home
Right Ctrl
Search
ENG IN
23:19 27-10-2024

b)





iii) For server1:

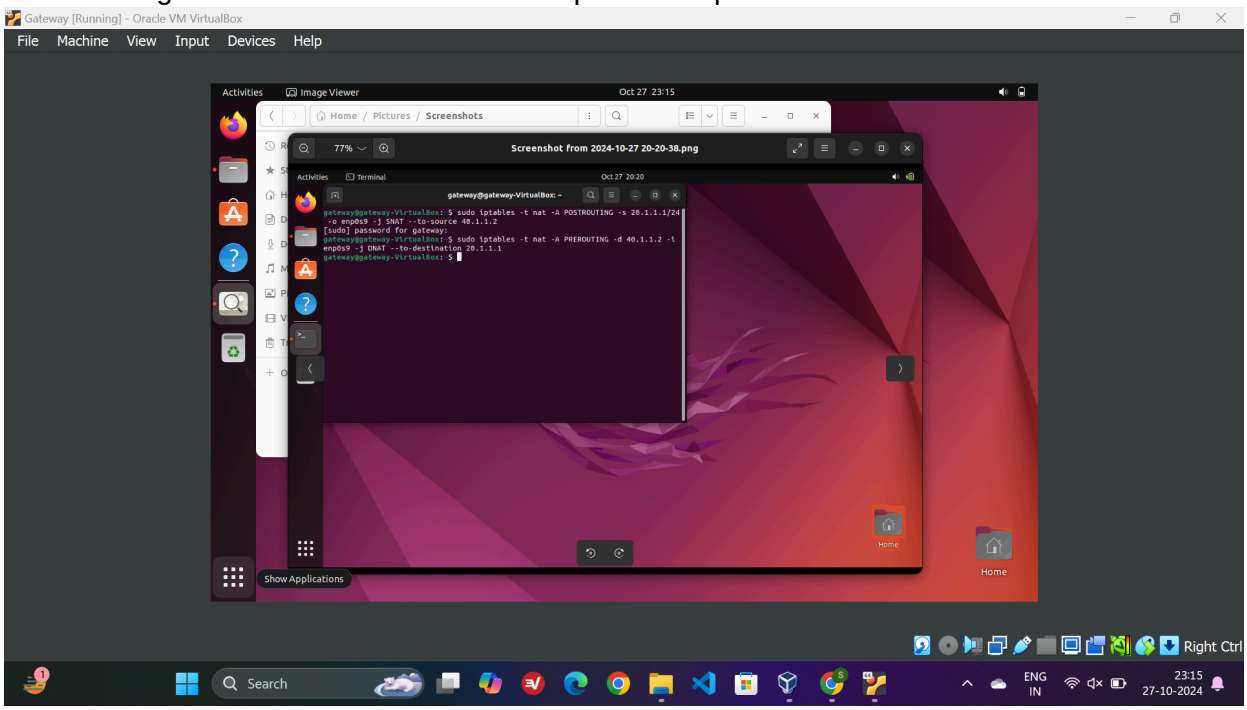
Min RTT: 2.083, Avg RTT: 3.133, Max RTT: 10.137

For server2:

MinRTT: 1.917, Avg RTT: 2.330, Max RTT: 3.028

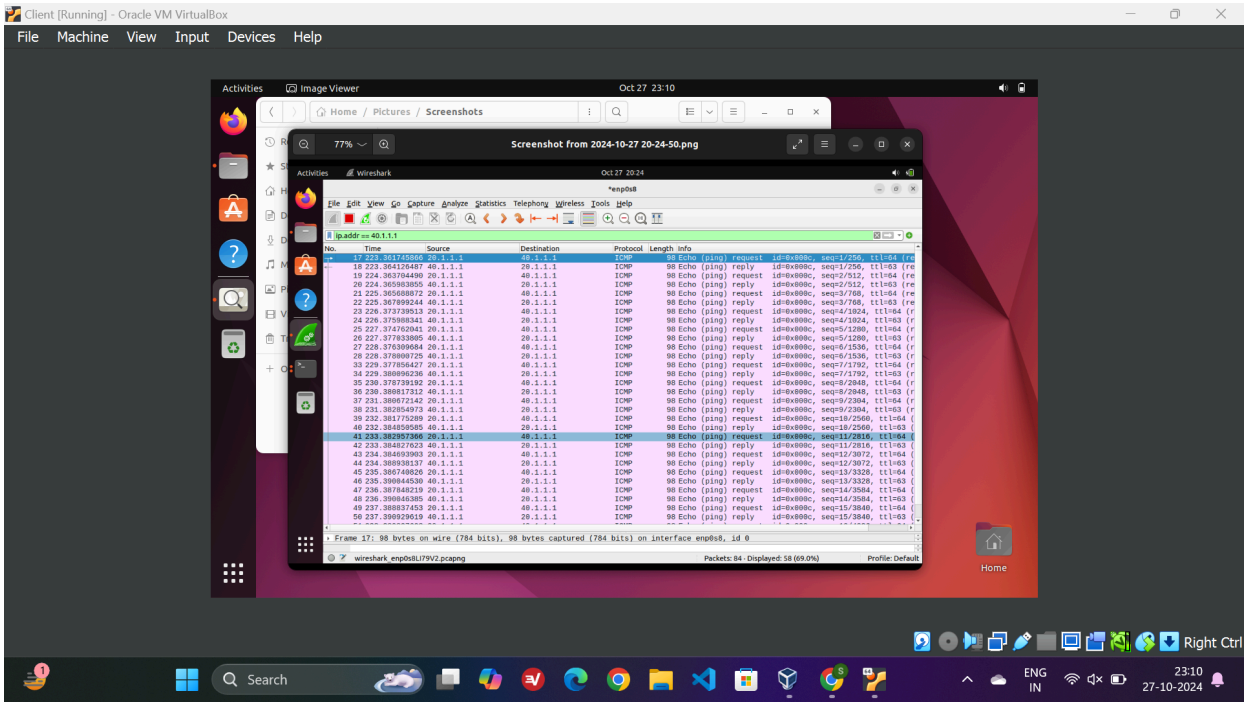
The results are similar for both servers with no significant difference, as traffic is being forwarded correctly. Both servers are on the same network and connected to the same gateway.

Q-4:
The following commands were executed for part a and part b.

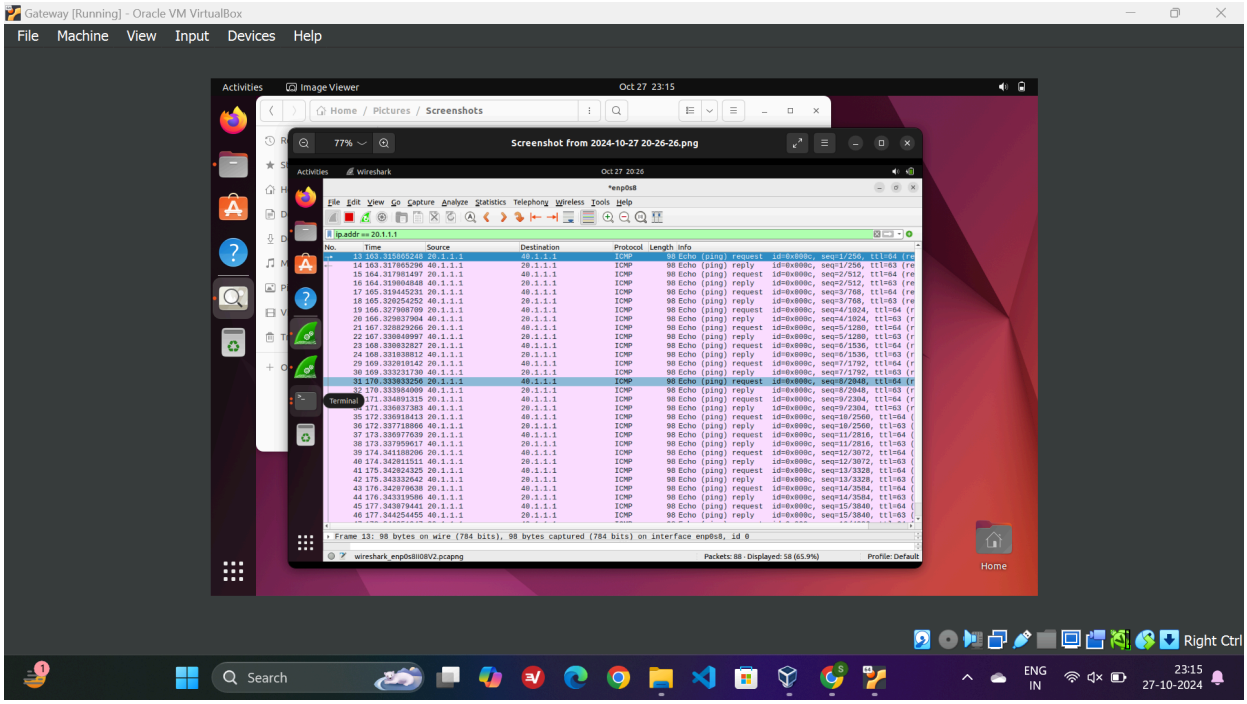


ICMP packets were sent using the ping command, and the results matched the expected outcome. This is evident from the following Wireshark captures for the various VMs.

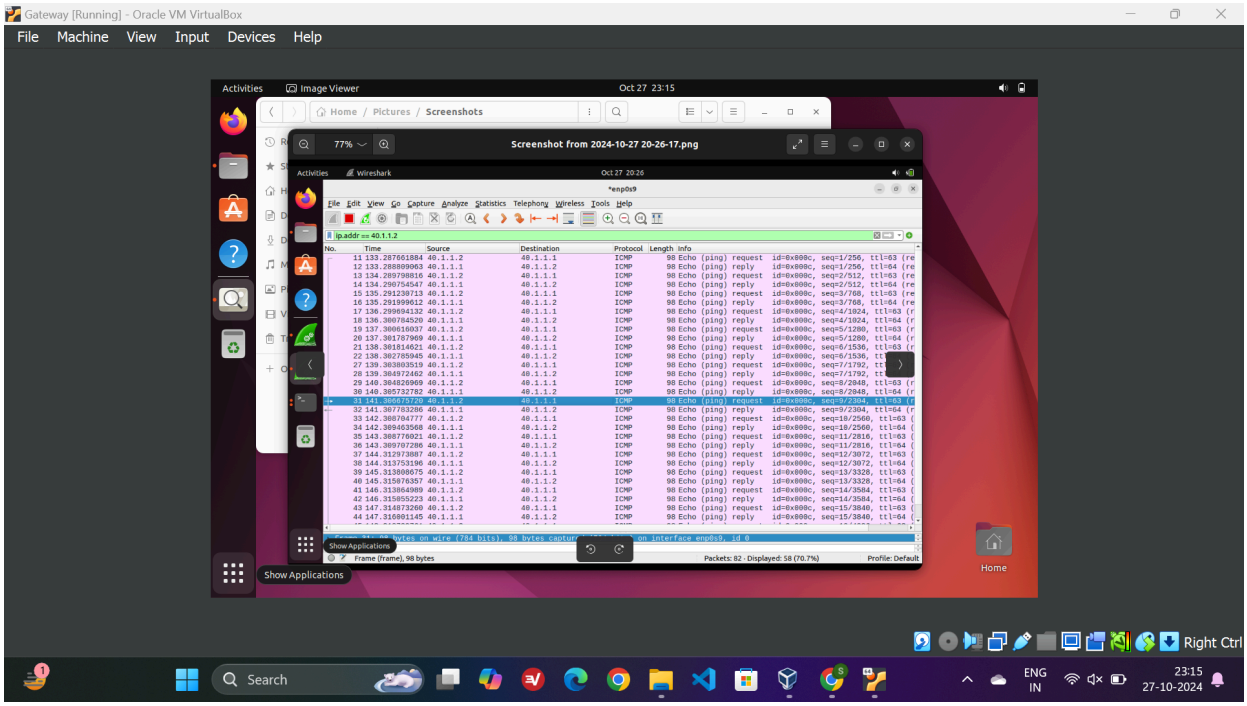
Client:



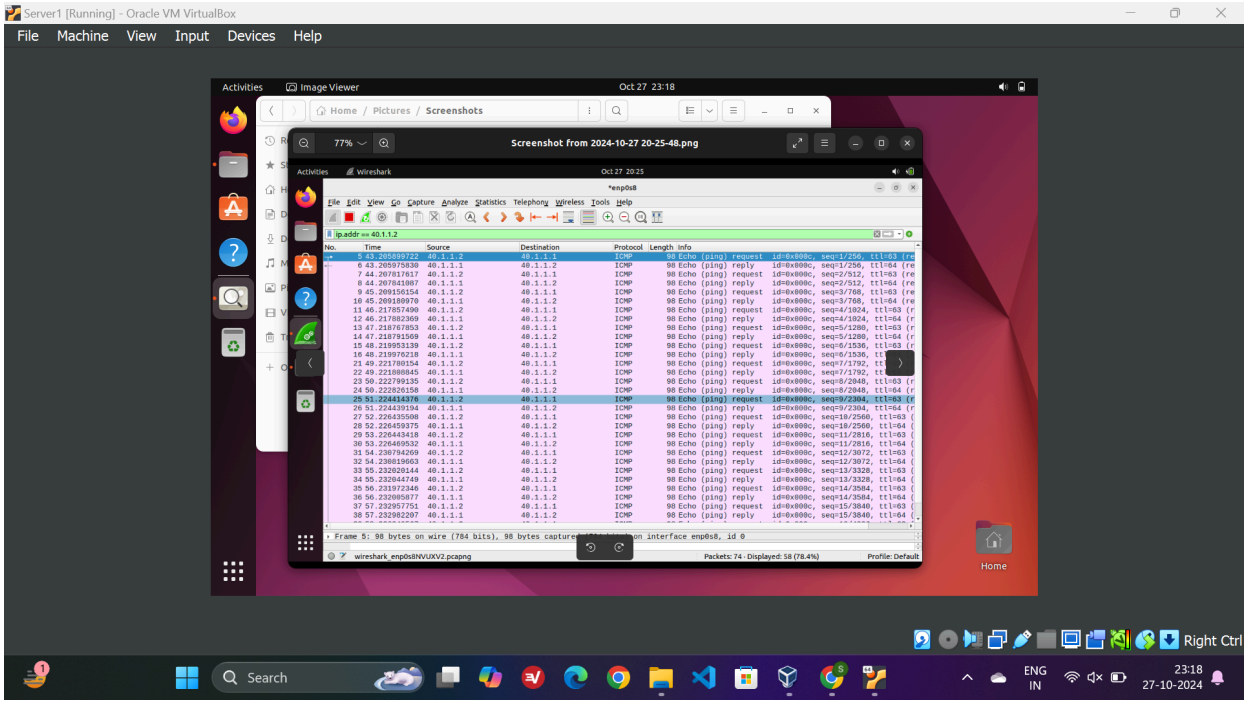
Gateway (Client Side):



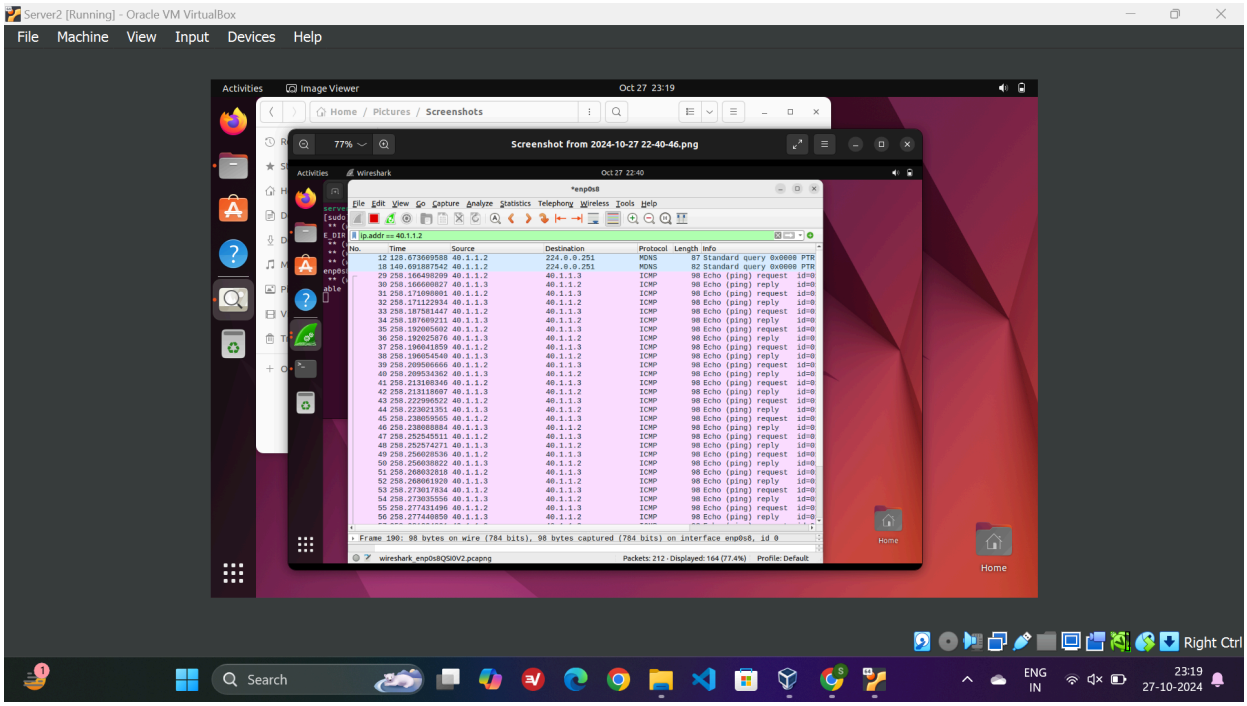
Gateway (Server Side):



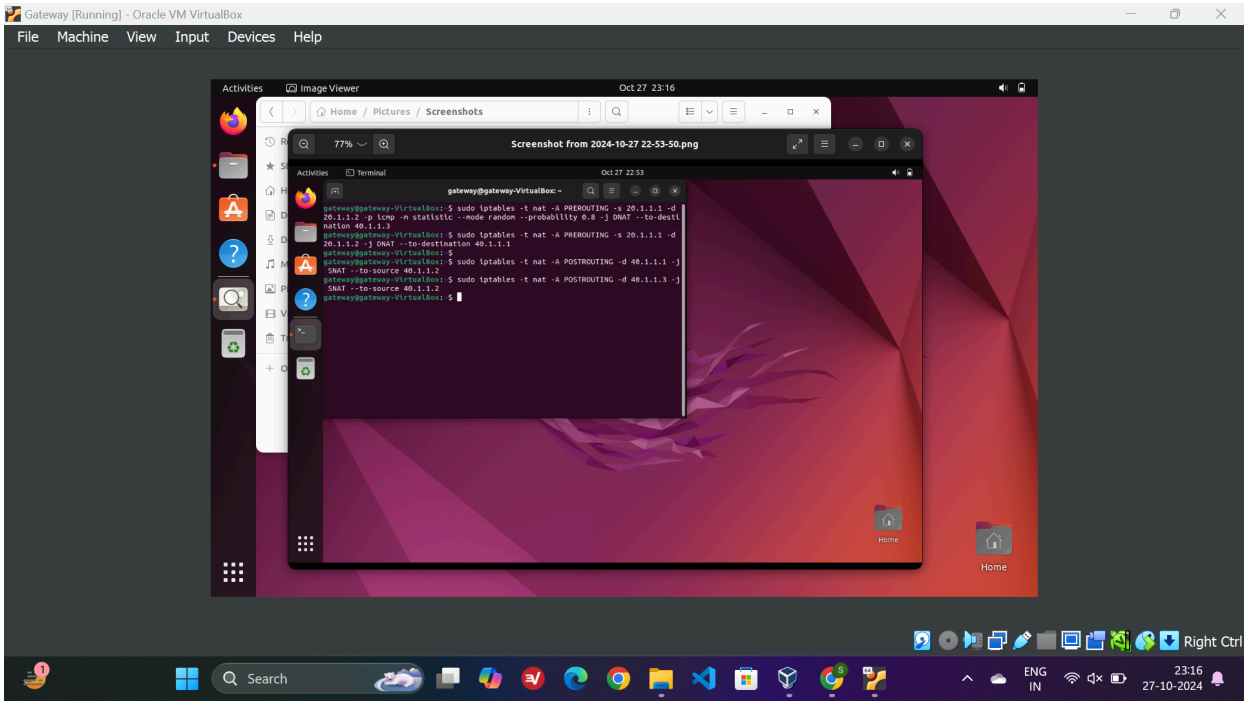
Server1:



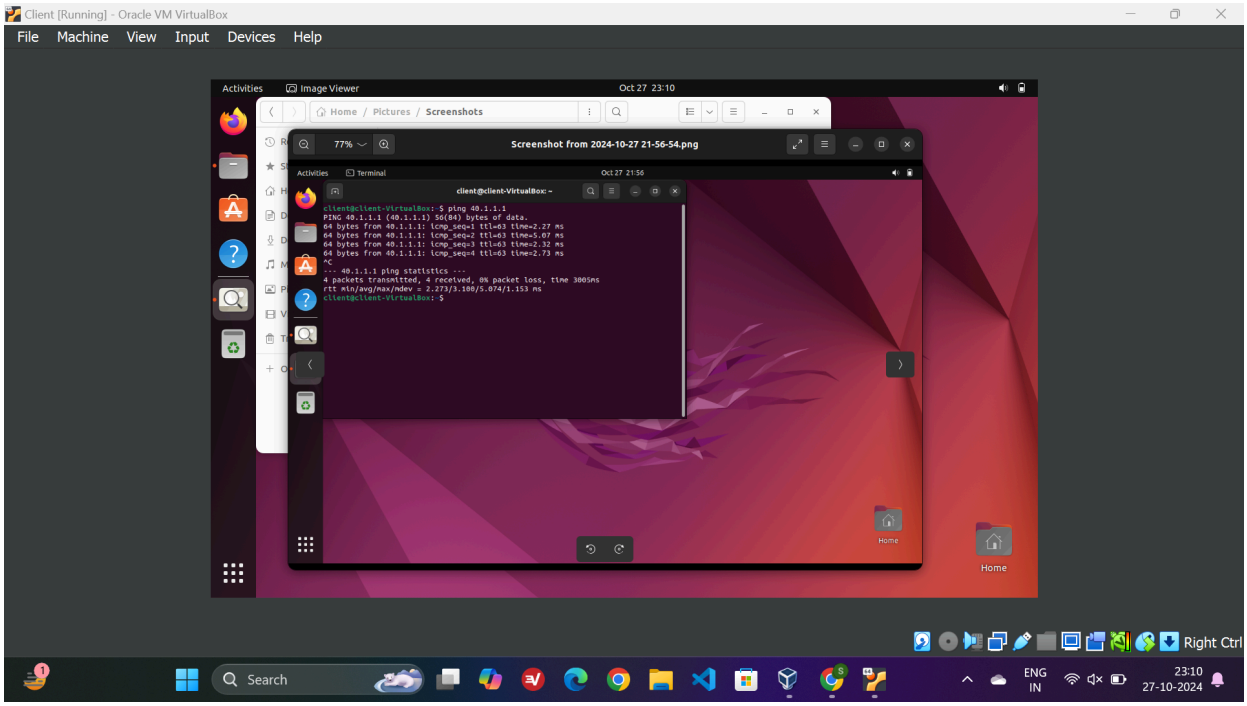
Server-2:

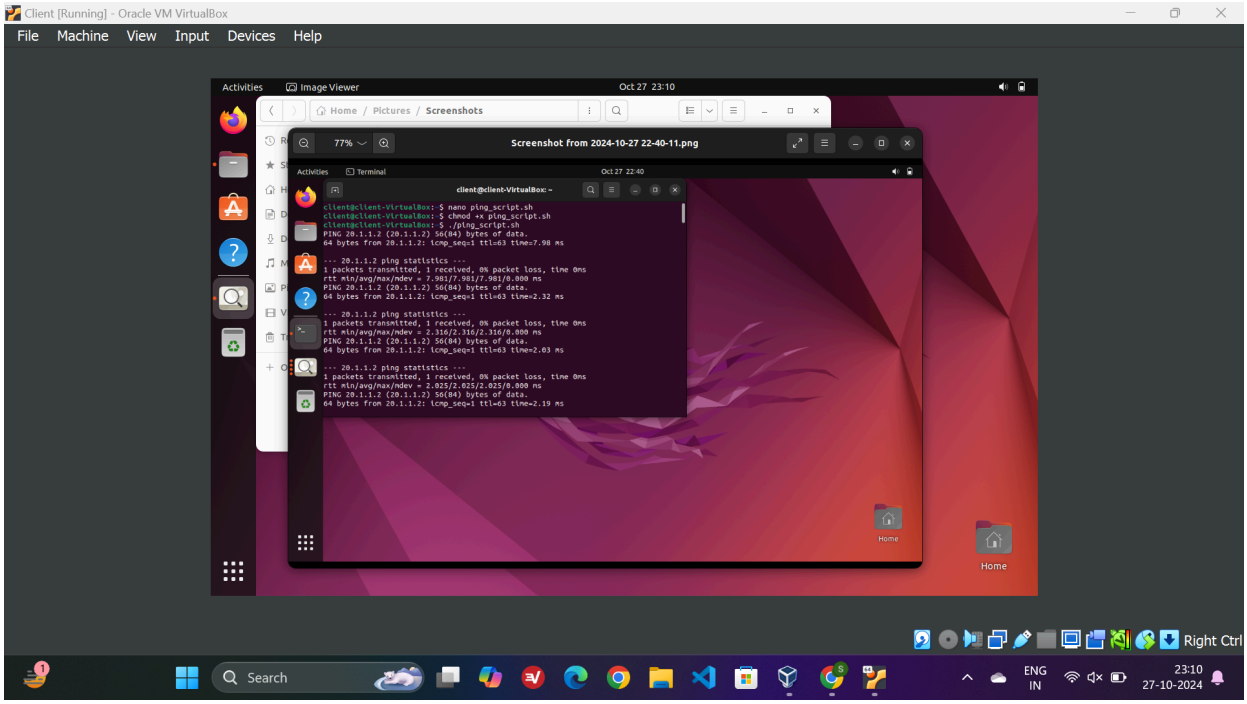


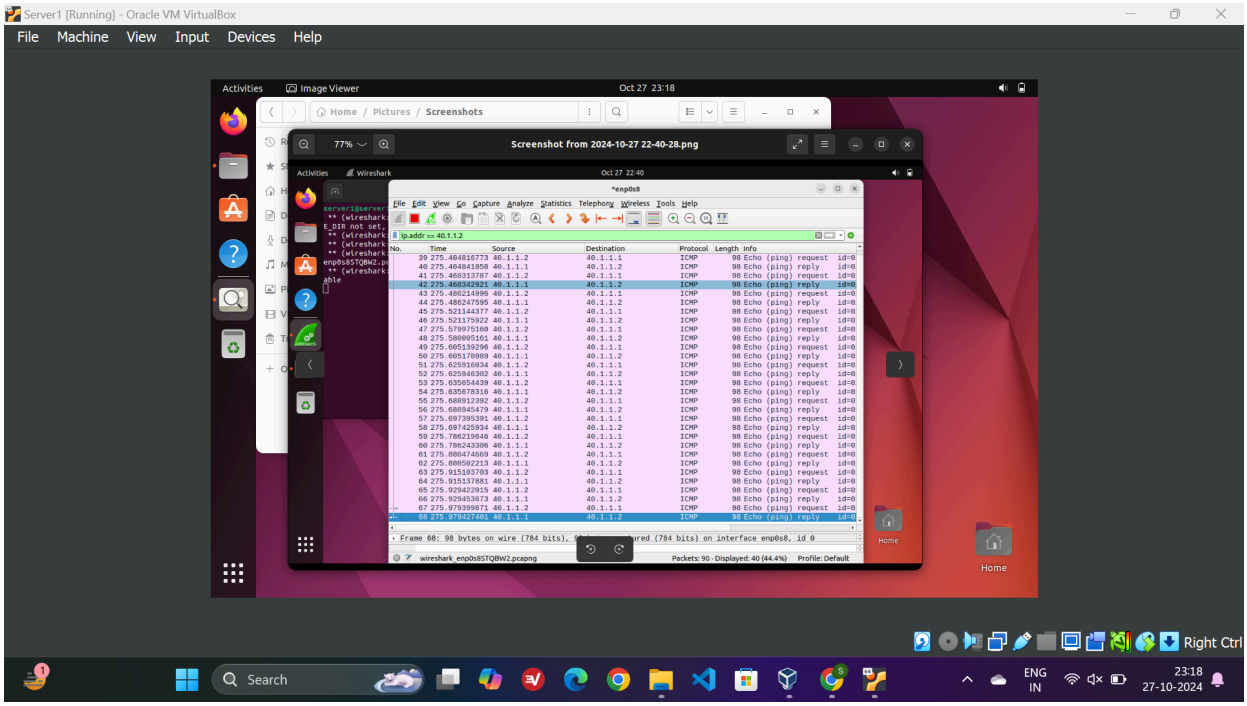
Q5 Since the RTT for server 2 was slightly lower, packets will be sent to server 2 with an 80% probability and the remaining packets to server 1.
This was accomplished using the following commands.

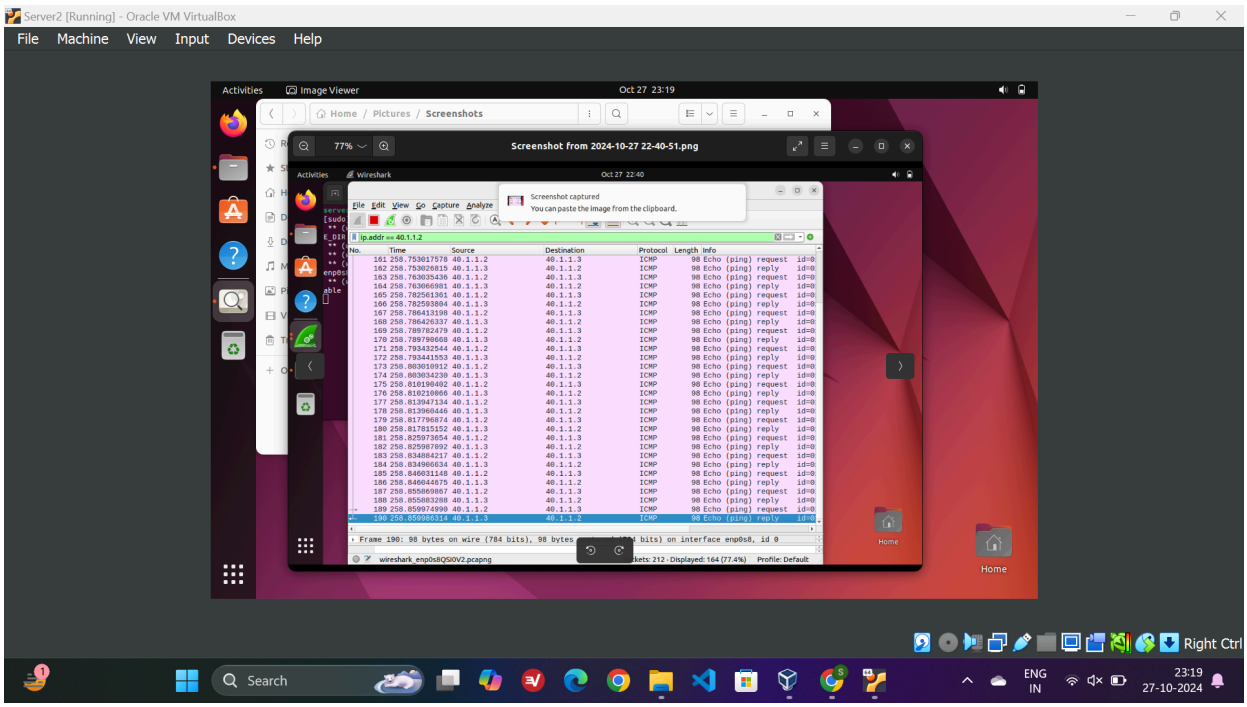


I then tested it by creating a bash script to ping 20.1.1.2 100 times and capturing the results. approximately 80% of the packets were sent to server 2 and 20% to server 1, which matched the expected result.


Client [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Image Viewer Oct 27 23:10
Home / Pictures / Screenshots
Screenshot from 2024-10-27 21-56-54.png
Activities Terminal Oct 27 21:56
client@client-VirtualBox: ~
client@client-VirtualBox: $ ping 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=2.27 ms
64 bytes from 40.1.1.1: icmp_seq=2 ttl=63 time=5.07 ms
64 bytes from 40.1.1.1: icmp_seq=3 ttl=63 time=2.32 ms
64 bytes from 40.1.1.1: icmp_seq=4 ttl=63 time=2.73 ms
^C
--- 40.1.1.1 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3005ms
rtt min/avg/max/mdev = 2.273/3.100/5.074/1.153 ms
client@client-VirtualBox: $
Home
Right Ctrl
Search
ENG IN
23:10 27-10-2024


Client [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Activities Image Viewer Oct 27 23:10
Home / Pictures / Screenshots
Screenshot from 2024-10-27 22-40-11.png
Activities Terminal Oct 27 22:40
client@client-VirtualBox: ~
client@client-VirtualBox: $ nano ping_script.sh
client@client-VirtualBox: $ chmod +x ping_script.sh
client@client-VirtualBox: $ ./ping_script.sh
PING 20.1.1.2 (20.1.1.2) 56(84) bytes of data.
64 bytes from 20.1.1.2: icmp_seq=1 ttl=63 time=7.98 ms
--- 20.1.1.2 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 7.981/7.981/7.981/0.000 ms
PING 20.1.1.2 (20.1.1.2) 56(84) bytes of data.
64 bytes from 20.1.1.2: icmp_seq=1 ttl=63 time=2.32 ms
--- 20.1.1.2 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 2.316/2.316/2.316/0.000 ms
PING 20.1.1.2 (20.1.1.2) 56(84) bytes of data.
64 bytes from 20.1.1.2: icmp_seq=1 ttl=63 time=2.03 ms
--- 20.1.1.2 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 2.025/2.025/2.025/0.000 ms
PING 20.1.1.2 (20.1.1.2) 56(84) bytes of data.
64 bytes from 20.1.1.2: icmp_seq=1 ttl=63 time=2.19 ms
Home
Right Ctrl
Search
ENG IN
23:10 27-10-2024





Bash Script:

```
#!/bin/bash
# Loop to ping 100 times with a single packet each time
 for i in {1..100}
do
        ping -c 1 20.1.1.2
done
```