

# Experiment 00

## Q1

We can do this in two different ways:

1. We can send ECHO requests to desired websites from our VM.

We use commands below:

```
ping google.com -c 3
```

```
ping digikala.com -c 3
```

```
Ping linux.com -c 3
```

```
ping wireshark.com -c 3
```

```
ping yahoo.com -c 3
```

```

:~$ echo -e 'google.com\ndigikala.com\nlinux.com\nwireshark.com\nyahoo.com' > list.txt
:~$ for ip in $(cat list.txt); do ping $ip -c 3; done
PING google.com (142.250.185.46) 56(84) bytes of data.
64 bytes from mct01s19-in-f14.1e100.net (142.250.185.46): icmp_seq=1 ttl=105 time=149 ms
64 bytes from mct01s19-in-f14.1e100.net (142.250.185.46): icmp_seq=2 ttl=105 time=266 ms
64 bytes from mct01s19-in-f14.1e100.net (142.250.185.46): icmp_seq=3 ttl=105 time=167 ms

--- google.com ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2003ms
rtt min/avg/max/mdev = 149.023/193.916/265.537/51.183 ms
PING digikala.com (185.188.104.10) 56(84) bytes of data.
64 bytes from 185.188.104.10 (185.188.104.10): icmp_seq=1 ttl=49 time=35.9 ms
64 bytes from 185.188.104.10 (185.188.104.10): icmp_seq=2 ttl=49 time=35.1 ms
64 bytes from 185.188.104.10 (185.188.104.10): icmp_seq=3 ttl=49 time=37.2 ms

--- digikala.com ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2003ms
rtt min/avg/max/mdev = 35.059/36.041/37.173/0.869 ms
PING linux.com (23.185.0.3) 56(84) bytes of data.
64 bytes from 23.185.0.3 (23.185.0.3): icmp_seq=1 ttl=48 time=112 ms
64 bytes from 23.185.0.3 (23.185.0.3): icmp_seq=2 ttl=48 time=104 ms
64 bytes from 23.185.0.3 (23.185.0.3): icmp_seq=3 ttl=48 time=106 ms

--- linux.com ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2003ms
rtt min/avg/max/mdev = 103.602/107.385/112.073/3.516 ms
PING wireshark.com (23.91.67.6) 56(84) bytes of data.
64 bytes from server.greenbaycrypto.com (23.91.67.6): icmp_seq=1 ttl=44 time=377 ms
64 bytes from server.greenbaycrypto.com (23.91.67.6): icmp_seq=2 ttl=44 time=240 ms
64 bytes from server.greenbaycrypto.com (23.91.67.6): icmp_seq=3 ttl=44 time=296 ms

--- wireshark.com ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2001ms
rtt min/avg/max/mdev = 239.574/304.346/377.378/56.560 ms
PING yahoo.com (98.137.11.163) 56(84) bytes of data.
64 bytes from media-router-fp74.prod.media.vip.gql.yahoo.com (98.137.11.163): icmp_seq=1 ttl=41 time=310 ms
64 bytes from media-router-fp74.prod.media.vip.gql.yahoo.com (98.137.11.163): icmp_seq=2 ttl=41 time=526 ms
64 bytes from media-router-fp74.prod.media.vip.gql.yahoo.com (98.137.11.163): icmp_seq=3 ttl=41 time=487 ms

--- yahoo.com ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2000ms
rtt min/avg/max/mdev = 309.965/441.259/526.467/94.202 ms
:~$

```

2. We can send ECHO requests to desired websites from our main machine (windows).

```
ping google.com -n 3
```

```
ping digikala.com -n 3
```

```
Ping linux.com -n 3
```

```
ping wireshark.com -n 3
```

```
ping yahoo.com -n 3
```

```
C:\Users\asus>ping google.com -n 3
```

```
Pinging google.com [142.250.185.46] with 32 bytes of data:
```

```
Reply from 142.250.185.46: bytes=32 time=72ms TTL=112
```

```
Reply from 142.250.185.46: bytes=32 time=70ms TTL=112
```

```
Reply from 142.250.185.46: bytes=32 time=69ms TTL=112
```

```
Ping statistics for 142.250.185.46:
```

```
    Packets: Sent = 3, Received = 3, Lost = 0 (0% loss),
```

```
Approximate round trip times in milli-seconds:
```

```
    Minimum = 69ms, Maximum = 72ms, Average = 70ms
```

```
C:\Users\asus>ping digikala.com -n 3
```

```
Pinging digikala.com [185.188.104.10] with 32 bytes of data:
```

```
Reply from 185.188.104.10: bytes=32 time=49ms TTL=55
```

```
Reply from 185.188.104.10: bytes=32 time=49ms TTL=55
```

```
Reply from 185.188.104.10: bytes=32 time=48ms TTL=55
```

```
Ping statistics for 185.188.104.10:
```

```
    Packets: Sent = 3, Received = 3, Lost = 0 (0% loss),
```

```
Approximate round trip times in milli-seconds:
```

```
    Minimum = 48ms, Maximum = 49ms, Average = 48ms
```

```
C:\Users\asus>ping linux.com -n 3
```

```
Pinging linux.com [23.185.0.3] with 32 bytes of data:
```

```
Reply from 23.185.0.3: bytes=32 time=125ms TTL=50
```

```
Reply from 23.185.0.3: bytes=32 time=123ms TTL=50
```

```
Reply from 23.185.0.3: bytes=32 time=122ms TTL=50
```

```
Ping statistics for 23.185.0.3:
```

```
    Packets: Sent = 3, Received = 3, Lost = 0 (0% loss),
```

```
Approximate round trip times in milli-seconds:
```

```
    Minimum = 122ms, Maximum = 125ms, Average = 123ms
```

```
C:\Users\asus>ping wireshark.com -n 3
```

```
Pinging wireshark.com [23.91.67.6] with 32 bytes of data:
```

```
Reply from 23.91.67.6: bytes=32 time=236ms TTL=50
```

```
Reply from 23.91.67.6: bytes=32 time=233ms TTL=50
```

```
Reply from 23.91.67.6: bytes=32 time=307ms TTL=50
```

```
Ping statistics for 23.91.67.6:
```

```
    Packets: Sent = 3, Received = 3, Lost = 0 (0% loss),
```

```
Approximate round trip times in milli-seconds:
```

```
    Minimum = 233ms, Maximum = 307ms, Average = 258ms
```

```

C:\Users\asus>ping yahoo.com -n 3

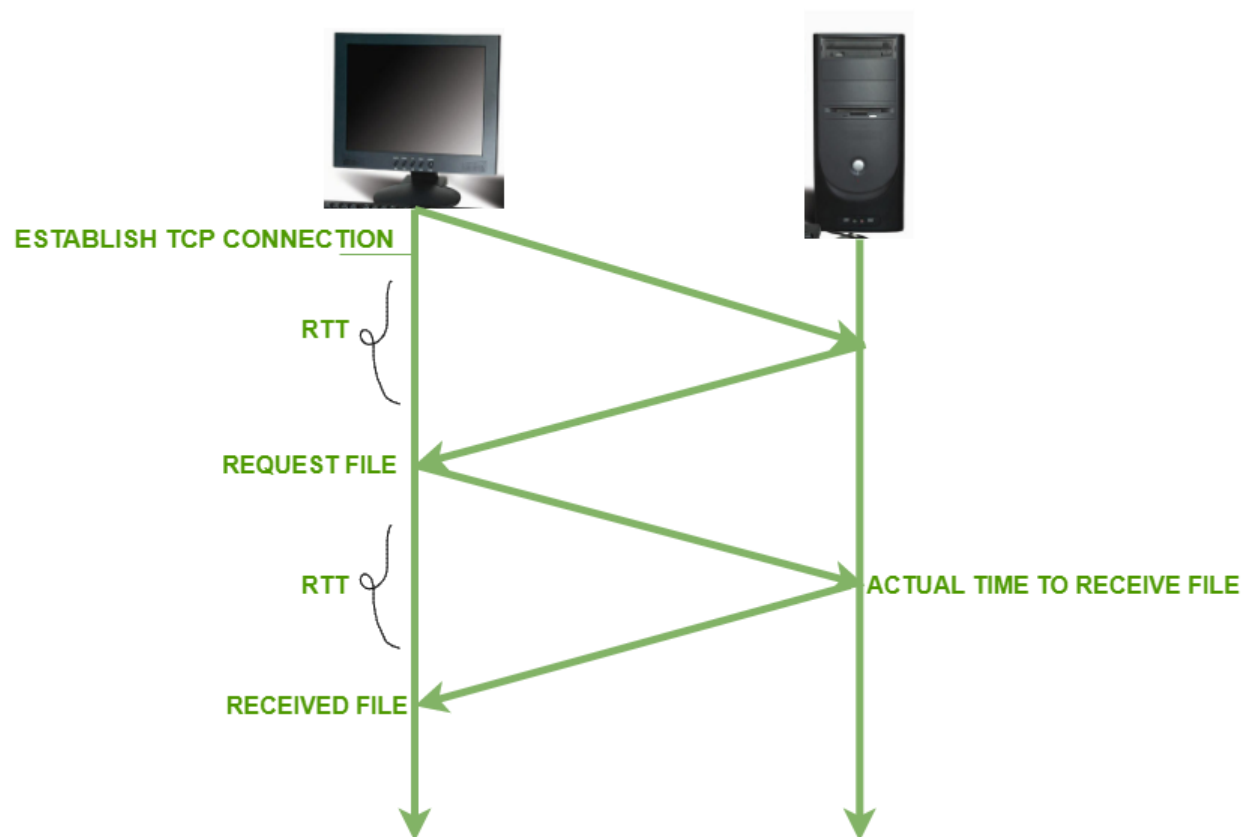
Pinging yahoo.com [98.137.11.163] with 32 bytes of data:
Reply from 98.137.11.163: bytes=32 time=285ms TTL=47
Reply from 98.137.11.163: bytes=32 time=283ms TTL=47
Reply from 98.137.11.163: bytes=32 time=284ms TTL=47

Ping statistics for 98.137.11.163:
    Packets: Sent = 3, Received = 3, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 283ms, Maximum = 285ms, Average = 284ms

```

RTTs and TTLs are in the result images above.

- **RTT(round trip time):** in the computer network, RTT is the time it takes to send the request to the receiver and receive an acknowledgment from the receiver.

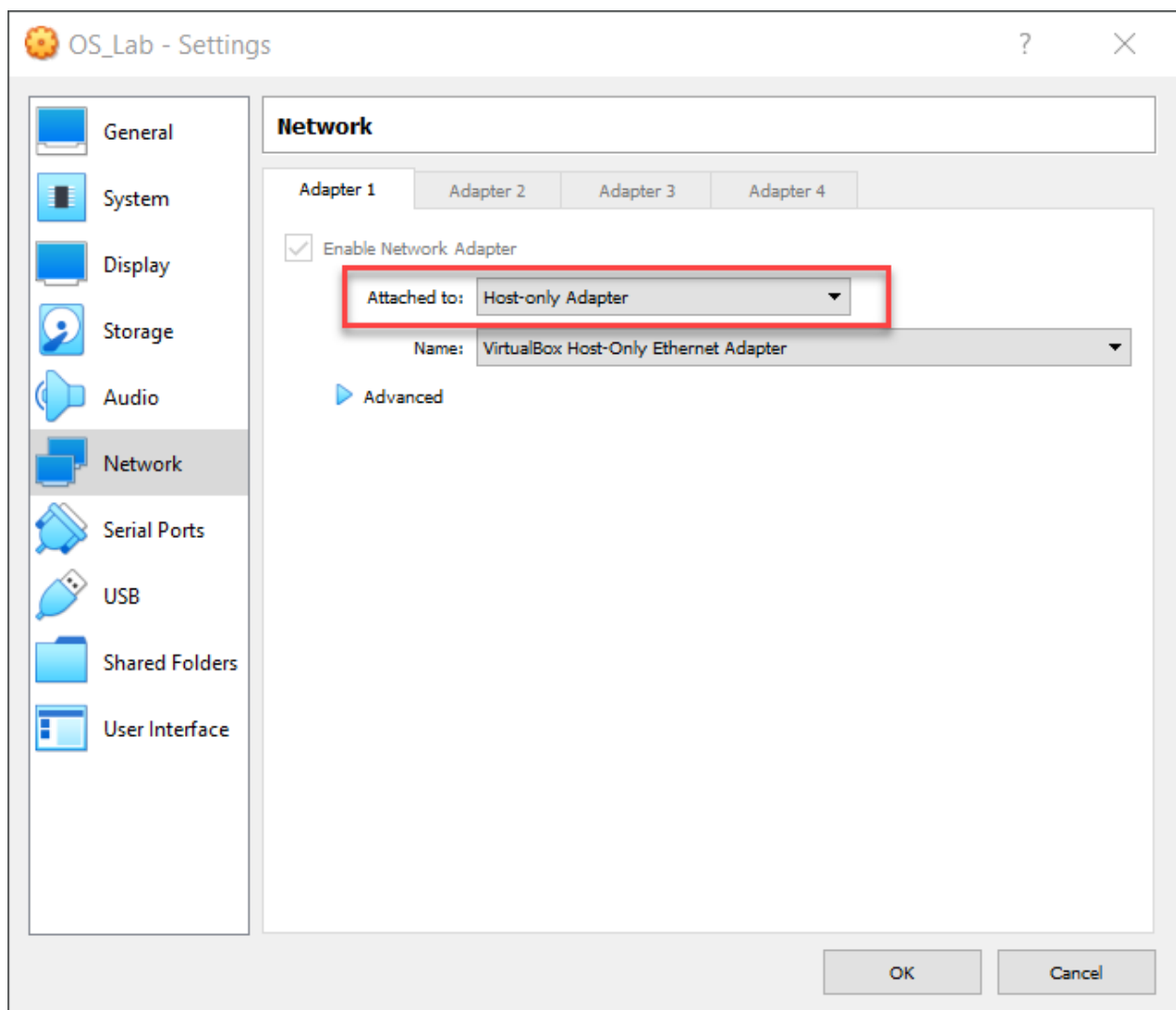


- **TTL(time to live):** Time to live or hop limit is a mechanism that limits the lifespan or lifetime of data in a computer or network. TTL may be implemented as a counter or timestamp attached to or embedded in the data. Once the prescribed event count or timespan has elapsed, data is discarded or revalidated.

*RTT and TTL do not have any relationship because their metrics are not related.*

## Q2

We must first change our VM settings. In network settings, we must change the “Attached to” option from “NAT” to “Host-only Adapter.”



With this option, our VM only connects to our main machine.

```
~$ ifconfig
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.56.101 netmask 255.255.255.0 broadcast 192.168.56.255
    inet6 fe80::d9f3:d6cd:e1b4:d1f7 prefixlen 64 scopeid 0x20<link>
    ether 08:00:27:b9:e2:68 txqueuelen 1000 (Ethernet)
    RX packets 3618 bytes 4809240 (4.8 MB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 2287 bytes 214166 (214.1 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

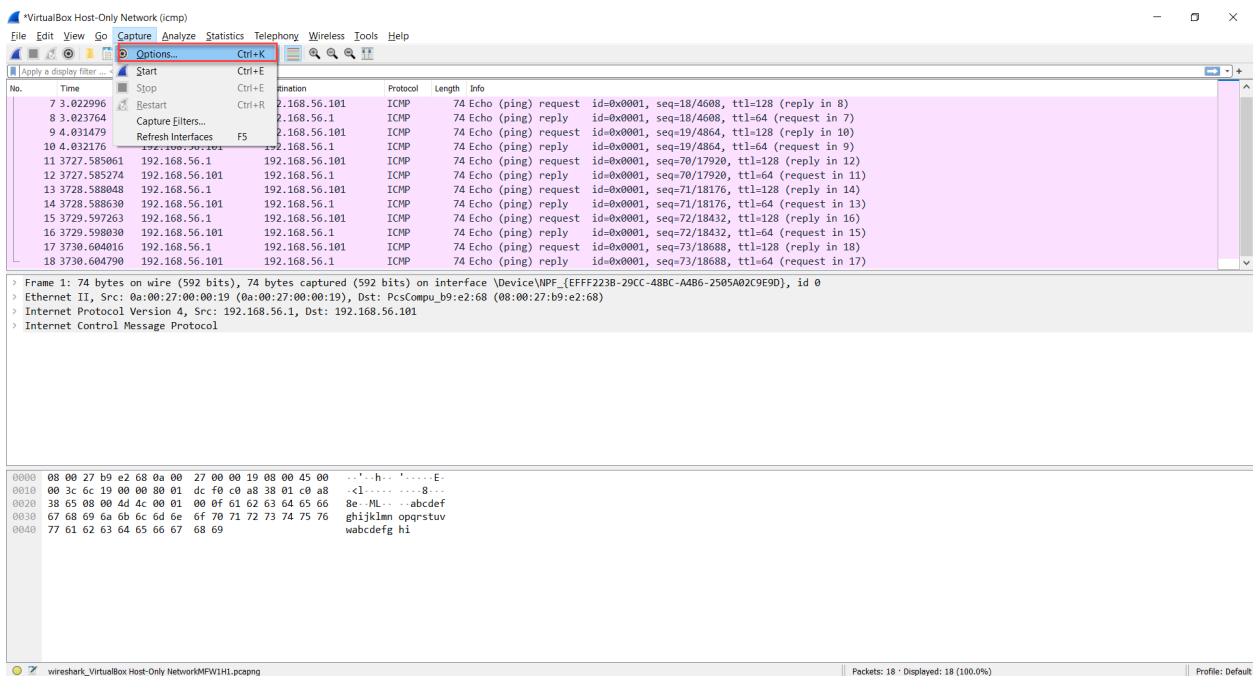
lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    inet6 ::1 prefixlen 128 scopeid 0x10<host>
    loop txqueuelen 1000 (Local Loopback)
    RX packets 469 bytes 40253 (40.2 KB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 469 bytes 40253 (40.2 KB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

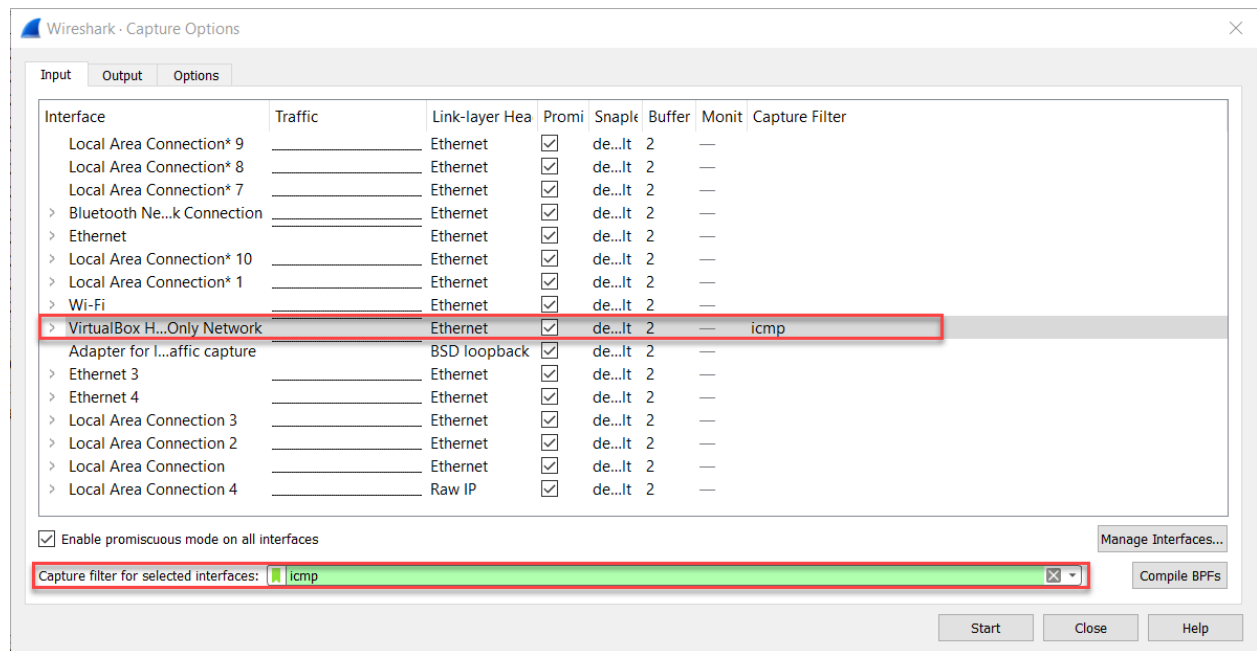
~$
```

We must use this IP to ping.

After that, we use Wireshark to capture packets.

From the “capture” option we must filter our packets to only show the ping requests. For doing this, we use the ICMP filter in the “Virtualbox host-only network” interface because ping uses ICMP protocol.





After that we must send ECHO requests from our main machine to our VM using the command below:

```
ping 192.168.56.101 -n 5
```

```
C:\Users\asus>ping 192.168.56.101 -n 5

Pinging 192.168.56.101 with 32 bytes of data:
Reply from 192.168.56.101: bytes=32 time<1ms TTL=64
Reply from 192.168.56.101: bytes=32 time<1ms TTL=64
Reply from 192.168.56.101: bytes=32 time<1ms TTL=64
Reply from 192.168.56.101: bytes=32 time<1ms TTL=64
Reply from 192.168.56.101: bytes=32 time<1ms TTL=64

Ping statistics for 192.168.56.101:
    Packets: Sent = 5, Received = 5, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 0ms, Average = 0ms
```

We got results below:

Capturing from VirtualBox Host-Only Network (icmp)

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

Apply a display filter ... <Ctrl-F>

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	192.168.56.1	192.168.56.101	ICMP	74	Echo (ping) request id=0x0001, seq=79/20224, ttl=128 (reply in 2)
2	0.000242	192.168.56.101	192.168.56.1	ICMP	74	Echo (ping) reply id=0x0001, seq=79/20224, ttl=64 (request in 1)
3	1.002129	192.168.56.1	192.168.56.101	ICMP	74	Echo (ping) request id=0x0001, seq=80/20480, ttl=128 (reply in 4)
4	1.002489	192.168.56.101	192.168.56.1	ICMP	74	Echo (ping) reply id=0x0001, seq=80/20480, ttl=64 (request in 3)
5	2.006902	192.168.56.1	192.168.56.101	ICMP	74	Echo (ping) request id=0x0001, seq=81/20736, ttl=128 (reply in 6)
6	2.007569	192.168.56.101	192.168.56.1	ICMP	74	Echo (ping) reply id=0x0001, seq=81/20736, ttl=64 (request in 5)
7	3.015170	192.168.56.1	192.168.56.101	ICMP	74	Echo (ping) request id=0x0001, seq=82/20992, ttl=128 (reply in 8)
8	3.015829	192.168.56.101	192.168.56.1	ICMP	74	Echo (ping) reply id=0x0001, seq=82/20992, ttl=64 (request in 7)
9	4.024335	192.168.56.1	192.168.56.101	ICMP	74	Echo (ping) request id=0x0001, seq=83/21248, ttl=128 (reply in 10)
10	4.024648	192.168.56.101	192.168.56.1	ICMP	74	Echo (ping) reply id=0x0001, seq=83/21248, ttl=64 (request in 9)

> Frame 1: 74 bytes on wire (592 bits), 74 bytes captured (592 bits) on interface \Device\NPF\_{EFFF223B-29CC-48BC-A486-2505A02C9E9D}, id 0  
 > Ethernet II, Src: 0a:00:27:00:00:19 (0a:00:27:00:00:19), Dst: PcsCompu\_b9:e2:68 (08:00:27:b9:e2:68)  
 > Internet Protocol Version 4, Src: 192.168.56.1, Dst: 192.168.56.101  
 > Internet Control Message Protocol

```

0000  08 00 27 b9 e2 68 0a 00 27 00 00 19 08 00 45 00  ...h...E:
0010  00 3c 6c 27 00 00 80 01 4c e2 c0 a8 38 01 c0 a8  ...l...8:
0020  38 65 08 00 4d 0c 00 01 00 4f 61 62 63 64 65 66  8e-M...Dabcde
0030  67 68 69 6a 6b 6c 6d 6e 6f 70 71 72 73 74 75 76  ghijklm opqrstu
0040  77 61 62 63 64 65 66 67 68 69                    wabcdegh i

```

VirtualBox Host-Only Network: <live capture in progress> Packets: 10 · Displayed: 10 (100.0%) Profile: Default

## Q3

a) We use the command below to create such network:

- o **sudo mn -topo minimal**

```

~$ sudo mn --topo minimal
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(h1, s1) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Starting CLI:
mininet>

```



b) We use the command below to create such network:

- **sudo mn -topo linear,2,2**

```
~$ sudo mn --topo linear,2,2
*** Creating network
*** Adding controller
*** Adding hosts:
h1s1 h1s2 h2s1 h2s2
*** Adding switches:
s1 s2
*** Adding links:
(h1s1, s1) (h1s2, s2) (h2s1, s1) (h2s2, s2) (s2, s1)
*** Configuring hosts
h1s1 h1s2 h2s1 h2s2
*** Starting controller
c0
*** Starting 2 switches
s1 s2 ...
*** Starting CLI:
mininet>
```

c) We use the command below to create such network:

- **sudo mn --topo tree,depth=2,fanout=3**

```
~$ sudo mn --topo tree,depth=2,fanout=3
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2 h3 h4 h5 h6 h7 h8 h9
*** Adding switches:
s1 s2 s3 s4
*** Adding links:
(s1, s2) (s1, s3) (s1, s4) (s2, h1) (s2, h2) (s2, h3) (s3, h4) (s3, h5) (s3, h6) (s4, h7) (s4, h8) (s4, h9)
*** Configuring hosts
h1 h2 h3 h4 h5 h6 h7 h8 h9
*** Starting controller
c0
*** Starting 4 switches
s1 s2 s3 s4 ...
*** Starting CLI:
mininet>
```

## Q4

```
root@kali:~# sudo mn --topo minimal --link tc,bw=100,delay=0.01ms
[sudo] password for root:
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(100.00Mbit 0.01ms delay) (100.00Mbit 0.01ms delay) (h1, s1) (100.00Mbit 0.01ms delay) (100.00Mbit 0.01ms delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (100.00Mbit 0.01ms delay) (100.00Mbit 0.01ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data:
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=3.96 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=2.22 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=1.62 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2002ms
rtt min/avg/max/mdev = 1.616/2.598/3.960/0.993 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['67.5 Mbits/sec', '69.0 Mbits/sec']
mininet>
```

```
root@kali:~# sudo mn --topo minimal --link tc,bw=100,delay=0.05ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(100.00Mbit 0.05ms delay) (100.00Mbit 0.05ms delay) (h1, s1) (100.00Mbit 0.05ms delay) (100.00Mbit 0.05ms delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (100.00Mbit 0.05ms delay) (100.00Mbit 0.05ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data:
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=4.45 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=6.72 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=4.90 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2006ms
rtt min/avg/max/mdev = 4.449/5.356/6.716/0.979 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['63.9 Mbits/sec', '66.2 Mbits/sec']
mininet>
```

```

:~$ sudo mn --topo minimal --link tc,bw=100,delay=0.1ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(100.00Mbit 0.1ms delay) (100.00Mbit 0.1ms delay) (h1, s1) (100.00Mbit 0.1ms delay) (100.00Mbit 0.1ms delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (100.00Mbit 0.1ms delay) (100.00Mbit 0.1ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=7.71 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=1.62 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=6.98 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2004ms
rtt min/avg/max/mdev = 1.618/5.432/7.705/2.713 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['58.6 Mbits/sec', '68.3 Mbits/sec']
mininet>

```

```

:~$ sudo mn --topo minimal --link tc,bw=100,delay=0.5ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(100.00Mbit 0.5ms delay) (100.00Mbit 0.5ms delay) (h1, s1) (100.00Mbit 0.5ms delay) (100.00Mbit 0.5ms delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (100.00Mbit 0.5ms delay) (100.00Mbit 0.5ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=9.55 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=4.45 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=6.81 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2018ms
rtt min/avg/max/mdev = 4.448/6.935/9.546/2.083 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['59.6 Mbits/sec', '74.0 Mbits/sec']
mininet>

```

```

$ sudo mn --topo minimal --link tc,bw=100,delay=1.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(100.00Mbit 1.0ms delay) (100.00Mbit 1.0ms delay) (h1, s1) (100.00Mbit 1.0ms delay) (100.00Mbit 1.0ms delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (100.00Mbit 1.0ms delay) (100.00Mbit 1.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=17.4 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=5.92 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=9.78 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2004ms
rtt min/avg/max/mdev = 5.917/11.026/17.380/4.761 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['44.1 Mbits/sec', '53.9 Mbits/sec']
mininet>

```

```

$ sudo mn --topo minimal --link tc,bw=100,delay=5.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(100.00Mbit 5.0ms delay) (100.00Mbit 5.0ms delay) (h1, s1) (100.00Mbit 5.0ms delay) (100.00Mbit 5.0ms delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (100.00Mbit 5.0ms delay) (100.00Mbit 5.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=72.9 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=31.1 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=85.4 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2050ms
rtt min/avg/max/mdev = 31.055/63.110/85.362/23.229 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['30.5 Mbits/sec', '35.9 Mbits/sec']
mininet>

```

```

:~$ sudo mn --topo minimal --link tc,bw=100,delay=10.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(100.00Mbit 10.0ms delay) (100.00Mbit 10.0ms delay) (h1, s1) (100.00Mbit 10.0ms delay) (100.00Mbit 10.0ms delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (100.00Mbit 10.0ms delay) (100.00Mbit 10.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=92.1 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=72.8 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=57.8 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2010ms
rtt min/avg/max/mdev = 57.767/74.193/92.057/14.035 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['25.3 Mbits/sec', '26.0 Mbits/sec']
mininet>

```

```

:~$ sudo mn --topo minimal --link tc,bw=100,delay=50.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(100.00Mbit 50.0ms delay) (100.00Mbit 50.0ms delay) (h1, s1) (100.00Mbit 50.0ms delay) (100.00Mbit 50.0ms delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (100.00Mbit 50.0ms delay) (100.00Mbit 50.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=409 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=202 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=221 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2004ms
rtt min/avg/max/mdev = 202.050/277.289/408.587/93.171 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['25.5 Mbits/sec', '28.5 Mbits/sec']
mininet>

```

```
~$ sudo mn --topo minimal --link tc,bw=100,delay=100.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(100.00Mbit 100.0ms delay) (100.00Mbit 100.0ms delay) (h1, s1) (100.00Mbit 100.0ms delay) (100.00Mbit 100.0ms delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (100.00Mbit 100.0ms delay) (100.00Mbit 100.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=830 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=421 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=439 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2098ms
rtt min/avg/max/mdev = 421.357/563.496/830.016/188.597 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['4.00 Mbits/sec', '4.89 Mbits/sec']
mininet>
```

```
~$ sudo mn --topo minimal --link tc,bw=100,delay=500.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(100.00Mbit 500.0ms delay) (100.00Mbit 500.0ms delay) (h1, s1) (100.00Mbit 500.0ms delay) (100.00Mbit 500.0ms delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (100.00Mbit 500.0ms delay) (100.00Mbit 500.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=4064 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=3055 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=2039 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2025ms
rtt min/avg/max/mdev = 2038.507/3052.278/4063.597/826.741 ms, pipe 3
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['371 Kbits/sec', '521 Kbits/sec']
mininet>
```

---

Delay (ms)	RTT (ms)	Measured Bandwidth (Mb/sec)
0.01	2.598	67.5, 69.0
0.05	5.356	63.9, 66.2
0.1	5.432	58.6, 68.3
0.5	6.935	59.6, 74.0
1.0	11.026	44.1, 53.9
5.0	63.110	30.5, 35.9
10.0	74.193	25.3, 26.0
50.0	277.289	25.5, 28.5
100.0	563.496	4.00, 4.89
500.0	3052.278	0.371, 0.521

- ***The higher the delay, the higher the RTT and the lower the bandwidth.***

```

:~$ sudo mn --topo minimal --link tc,bw=0.01,delay=1.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(0.01Mbit 1.0ms delay) (0.01Mbit 1.0ms delay) (h1, s1) (0.01Mbit 1.0ms delay) (0.01Mbit 1.0ms delay) (
h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...(0.01Mbit 1.0ms delay) (0.01Mbit 1.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=18.1 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=8.51 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=10.6 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2015ms
rtt min/avg/max/mdev = 8.511/12.414/18.096/4.110 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['9.56 Kbits/sec', '123 Kbits/sec']
mininet>

```

```

:~$ sudo mn --topo minimal --link tc,bw=0.05,delay=1.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(0.05Mbit 1.0ms delay) (0.05Mbit 1.0ms delay) (h1, s1) (0.05Mbit 1.0ms delay) (0.05Mbit 1.0ms delay) (
h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...(0.05Mbit 1.0ms delay) (0.05Mbit 1.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=13.1 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=18.1 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=6.83 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2019ms
rtt min/avg/max/mdev = 6.830/12.652/18.068/4.596 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['48.1 Kbits/sec', '337 Kbits/sec']
mininet>

```



```

:~$ sudo mn --topo minimal --link tc,bw=0.1,delay=1.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(0.10Mbit 1.0ms delay) (0.10Mbit 1.0ms delay) (h1, s1) (0.10Mbit 1.0ms delay) (0.10Mbit 1.0ms delay) (
h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...(0.10Mbit 1.0ms delay) (0.10Mbit 1.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=18.5 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=10.0 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=14.0 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2020ms
rtt min/avg/max/mdev = 10.031/14.163/18.473/3.448 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['96.3 Kbits/sec', '352 Kbits/sec']
mininet>

```

```

:~$ sudo mn --topo minimal --link tc,bw=0.5,delay=1.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(0.50Mbit 1.0ms delay) (0.50Mbit 1.0ms delay) (h1, s1) (0.50Mbit 1.0ms delay) (0.50Mbit 1.0ms delay) (
h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...(0.50Mbit 1.0ms delay) (0.50Mbit 1.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=14.8 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=8.82 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=14.4 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2010ms
rtt min/avg/max/mdev = 8.821/12.650/14.756/2.712 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['470 Kbits/sec', '989 Kbits/sec']
mininet>

```

```

:~$ sudo mn --topo minimal --link tc,bw=1.0,delay=1.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(1.00Mbit 1.0ms delay) (1.00Mbit 1.0ms delay) (h1, s1) (1.00Mbit 1.0ms delay) (1.00Mbit 1.0ms delay) (
h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (1.00Mbit 1.0ms delay) (1.00Mbit 1.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=16.8 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=11.6 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=64.4 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2008ms
rtt min/avg/max/mdev = 11.627/30.925/64.369/23.741 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['933 Kbits/sec', '1.56 Mbits/sec']
mininet>

```

```

:~$ sudo mn --topo minimal --link tc,bw=5.0,delay=1.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(5.00Mbit 1.0ms delay) (5.00Mbit 1.0ms delay) (h1, s1) (5.00Mbit 1.0ms delay) (5.00Mbit 1.0ms delay) (
h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (5.00Mbit 1.0ms delay) (5.00Mbit 1.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=17.8 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=10.6 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=33.6 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2009ms
rtt min/avg/max/mdev = 10.563/20.665/33.614/9.623 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['4.25 Mbits/sec', '5.46 Mbits/sec']
mininet>

```

```

:~$ sudo mn --topo minimal --link tc,bw=10.0,delay=1.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(10.00Mbit 1.0ms delay) (10.00Mbit 1.0ms delay) (h1, s1) (10.00Mbit 1.0ms delay) (10.00Mbit 1.0ms delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (10.00Mbit 1.0ms delay) (10.00Mbit 1.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=15.0 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=18.5 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=45.4 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2025ms
rtt min/avg/max/mdev = 15.005/26.294/45.389/13.576 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['5.92 Mbits/sec', '7.60 Mbits/sec']
mininet>

```

```

:~$ sudo mn --topo minimal --link tc,bw=50.0,delay=1.0ms
*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(50.00Mbit 1.0ms delay) (50.00Mbit 1.0ms delay) (h1, s1) (50.00Mbit 1.0ms delay) (50.00Mbit 1.0ms delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ... (50.00Mbit 1.0ms delay) (50.00Mbit 1.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=15.8 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=9.52 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=8.12 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2043ms
rtt min/avg/max/mdev = 8.115/11.157/15.836/3.357 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['26.0 Mbits/sec', '30.4 Mbits/sec']
mininet>

```

```

*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(100.00Mbit 1.0ms delay) (100.00Mbit 1.0ms delay) (h1, s1) (100.00Mbit 1.0ms delay) (100.00Mbit 1.0ms
delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...(100.00Mbit 1.0ms delay) (100.00Mbit 1.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=18.9 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=12.5 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=20.3 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2020ms
rtt min/avg/max/mdev = 12.455/17.199/20.282/3.404 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['46.1 Mbits/sec', '52.3 Mbits/sec']
mininet>

```

```

*** Creating network
*** Adding controller
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(500.00Mbit 1.0ms delay) (500.00Mbit 1.0ms delay) (h1, s1) (500.00Mbit 1.0ms delay) (500.00Mbit 1.0ms
delay) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...(500.00Mbit 1.0ms delay) (500.00Mbit 1.0ms delay)
*** Starting CLI:
mininet> h1 ping h2 -c 3
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=15.2 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=8.86 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=10.7 ms

--- 10.0.0.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2038ms
rtt min/avg/max/mdev = 8.859/11.615/15.245/2.679 ms
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['184 Mbits/sec', '214 Mbits/sec']
mininet>

```

---

Bandwidth (Mbits / sec)	RTT (ms)	Measured Bandwidth (Kb/s)
0.01	12.414	9.56, 123
0.05	12.652	48.1, 337
0.1	14.163	96.3, 352
0.5	12.650	470, 989
1.0	30.925	933, 1560
5.0	20.665	4250, 5460
10.0	26.294	5920, 7600
50.0	11.157	26000, 30400
100.0	17.199	46100, 52300
500.0	11.615	184000, 214000