Task 1: Defining custom topologies

Questions -

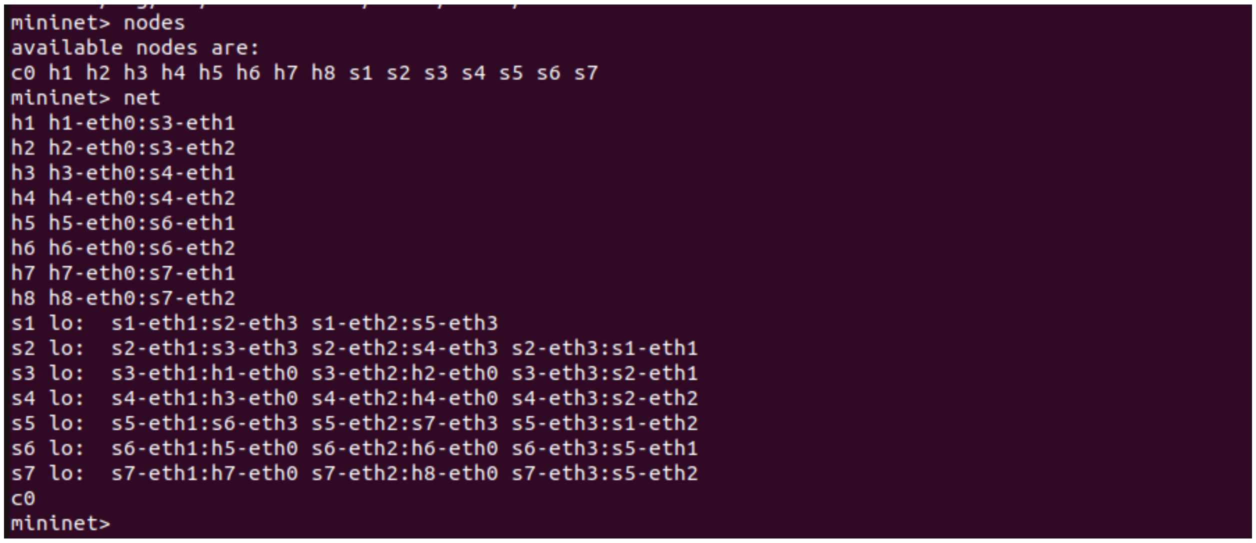
1. What is the output of “nodes” and “net”
<u>Answer</u> -
Output of command “nodes” -

```
available nodes are:
c0 h1 h2 h3 h4 h5 h6 h7 h8 s1 s2 s3 s4 s5 s6 s7
```

Output of command “net” -

```
mininet> net
h1 h1-eth0:s3-eth1
h2 h2-eth0:s3-eth2
h3 h3-eth0:s4-eth1
h4 h4-eth0:s4-eth2
h5 h5-eth0:s6-eth1
h6 h6-eth0:s6-eth2
h7 h7-eth0:s7-eth1
h8 h8-eth0:s7-eth2
s1 lo:  s1-eth1:s2-eth3 s1-eth2:s5-eth3
s2 lo:  s2-eth1:s3-eth3 s2-eth2:s4-eth3 s2-eth3:s1-eth1
s3 lo:  s3-eth1:h1-eth0 s3-eth2:h2-eth0 s3-eth3:s2-eth1
s4 lo:  s4-eth1:h3-eth0 s4-eth2:h4-eth0 s4-eth3:s2-eth2
s5 lo:  s5-eth1:s6-eth3 s5-eth2:s7-eth3 s5-eth3:s1-eth2
s6 lo:  s6-eth1:h5-eth0 s6-eth2:h6-eth0 s6-eth3:s5-eth1
s7 lo:  s7-eth1:h7-eth0 s7-eth2:h8-eth0 s7-eth3:s5-eth2
C0
```

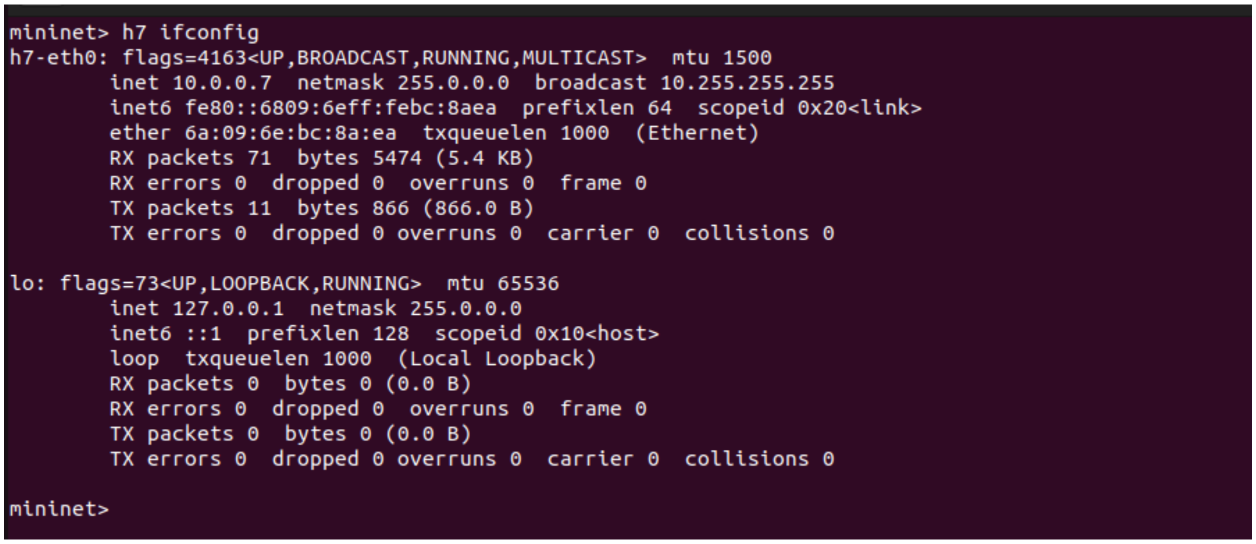
Screenshot -



```
mininet> nodes
available nodes are:
c0 h1 h2 h3 h4 h5 h6 h7 h8 s1 s2 s3 s4 s5 s6 s7
mininet> net
h1 h1-eth0:s3-eth1
h2 h2-eth0:s3-eth2
h3 h3-eth0:s4-eth1
h4 h4-eth0:s4-eth2
h5 h5-eth0:s6-eth1
h6 h6-eth0:s6-eth2
h7 h7-eth0:s7-eth1
h8 h8-eth0:s7-eth2
s1 lo:  s1-eth1:s2-eth3 s1-eth2:s5-eth3
s2 lo:  s2-eth1:s3-eth3 s2-eth2:s4-eth3 s2-eth3:s1-eth1
s3 lo:  s3-eth1:h1-eth0 s3-eth2:h2-eth0 s3-eth3:s2-eth1
s4 lo:  s4-eth1:h3-eth0 s4-eth2:h4-eth0 s4-eth3:s2-eth2
s5 lo:  s5-eth1:s6-eth3 s5-eth2:s7-eth3 s5-eth3:s1-eth2
s6 lo:  s6-eth1:h5-eth0 s6-eth2:h6-eth0 s6-eth3:s5-eth1
s7 lo:  s7-eth1:h7-eth0 s7-eth2:h8-eth0 s7-eth3:s5-eth2
c0
mininet>
```

2. What is the output of "h7 ifconfig"

<u>Answer</u> -



```
mininet> h7 ifconfig
h7-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 10.0.0.7  netmask 255.0.0.0  broadcast 10.255.255.255
        inet6 fe80::6809:6eff:febc:8aea  prefixlen 64  scopeid 0x20<link>
        ether 6a:09:6e:bc:8a:ea  txqueuelen 1000  (Ethernet)
        RX packets 71  bytes 5474 (5.4 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 11  bytes 866 (866.0 B)
        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 0  bytes 0 (0.0 B)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 0  bytes 0 (0.0 B)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0

mininet>
```

Task 2: Analyze the "of_tutorial' controller

Questions -

1. Draw the function call graph of this controller. For example, once a packet comes to the controller, which function is the first to be called, which one is the second, and so forth?

<u>Answer</u> -

```
Firstly, start the POX listener using `./pox.py log.level --DEBUG
misc.of_tutorial` command, which then turns on the `start switch`.
Now, The _handle PacketIn() method is called by the `start switch` to
handle the packet in messages from the switch.
```

```
After this, the act like hub() function is then called by the _handle
PacketIn() function. The act like hub() function generates a behavior that
sends packets to all ports except the input port, simulating a hub
environment.
Now, the resend packet() method is then called. The resend packet()
function adds a packet to the message data and performs the action on
it.The switch is then instructed to resend the packet to a specified port
by this message.
The graph is shown as below:
start switch : _handle_PacketIn() -> act_like_hub() -> resend_packet() ->
send(msg)
```

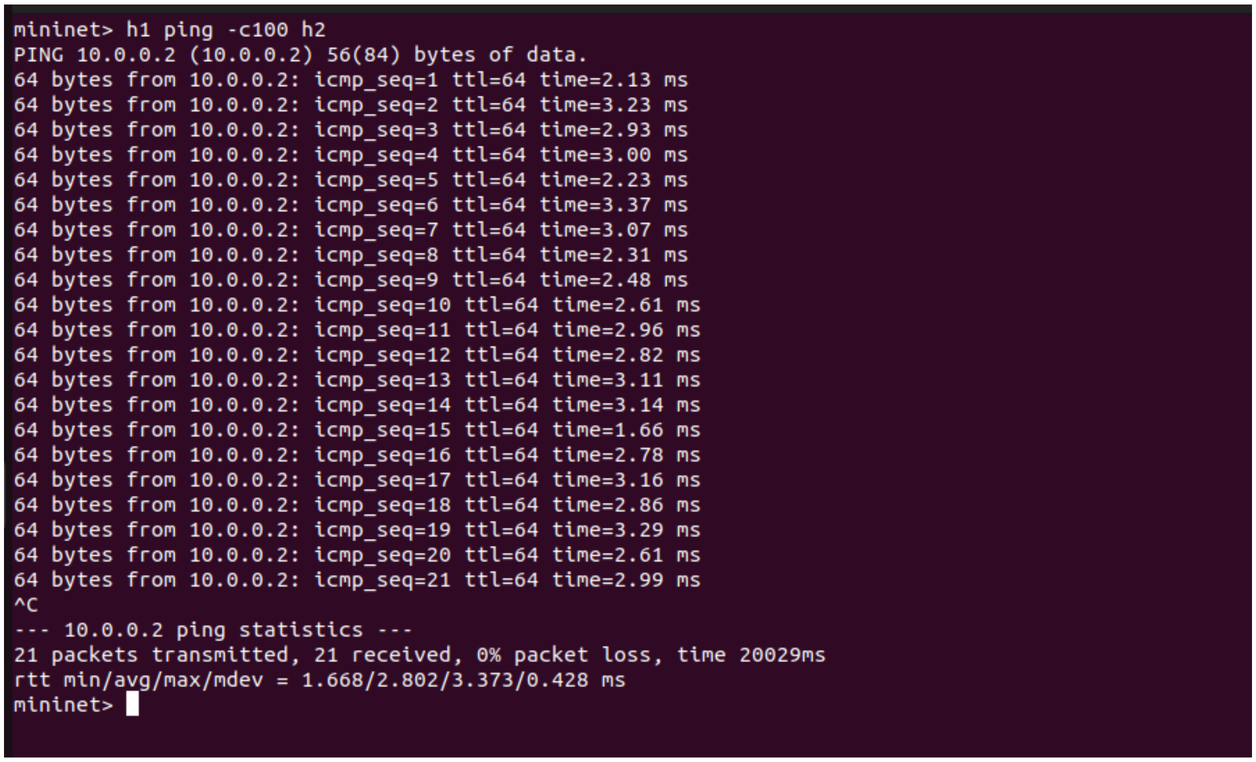
2. Have h1 ping h2, and h1 ping h8 for 100 times (e.g., h1 ping -c100 p2).

a. How long does it take (on average) to ping for each case?

<u>Answer</u> -

For h1 ping -c100 h2 -

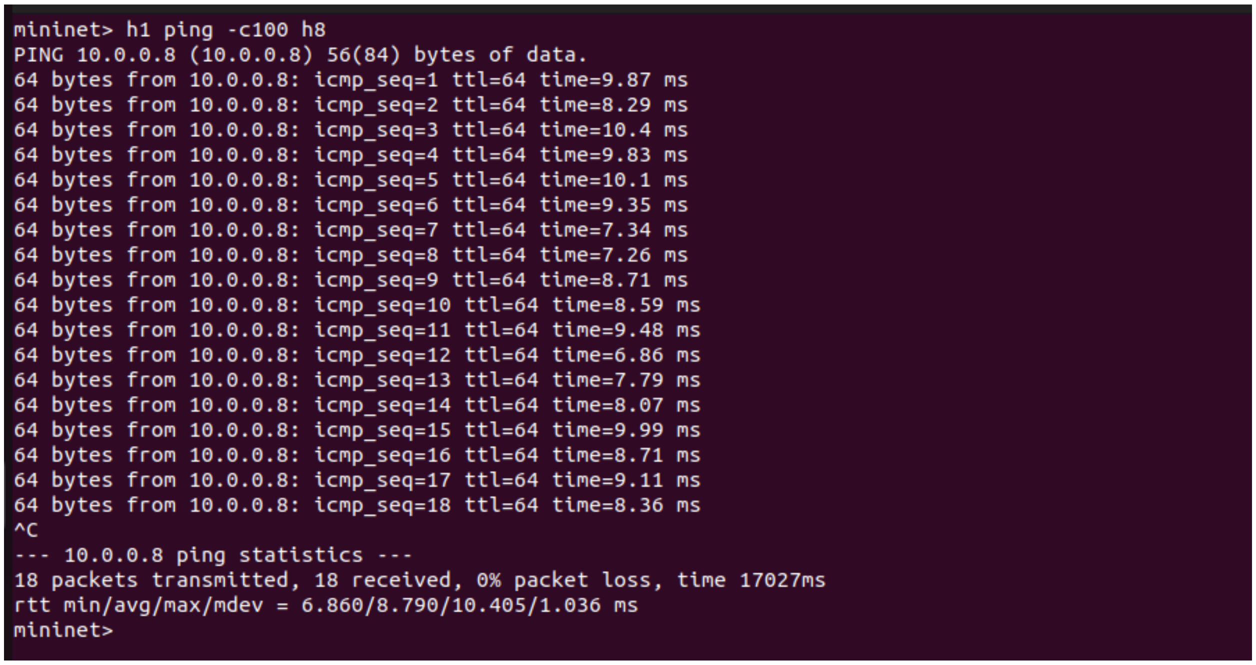
Average time to ping in case of h1 ping h2 is 2.802ms as shown in below screenshot -



```
mininet> h1 ping -c100 h2
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=2.13 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=3.23 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=2.93 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=3.00 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=2.23 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=3.37 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=3.07 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=2.31 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=2.48 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=2.61 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=2.96 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=2.82 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=3.11 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=3.14 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=1.66 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=2.78 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=3.16 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=2.86 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=3.29 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=2.61 ms
64 bytes from 10.0.0.2: icmp_seq=21 ttl=64 time=2.99 ms
^C
--- 10.0.0.2 ping statistics ---
21 packets transmitted, 21 received, 0% packet loss, time 20029ms
rtt min/avg/max/mdev = 1.668/2.802/3.373/0.428 ms
mininet>
```

For h1 ping -c100 h8 -

Average time to ping in case of h1 ping h2 is 8.790ms as shown in below screenshot -



```
mininet> h1 ping -c100 h8
PING 10.0.0.8 (10.0.0.8) 56(84) bytes of data.
64 bytes from 10.0.0.8: icmp_seq=1 ttl=64 time=9.87 ms
64 bytes from 10.0.0.8: icmp_seq=2 ttl=64 time=8.29 ms
64 bytes from 10.0.0.8: icmp_seq=3 ttl=64 time=10.4 ms
64 bytes from 10.0.0.8: icmp_seq=4 ttl=64 time=9.83 ms
64 bytes from 10.0.0.8: icmp_seq=5 ttl=64 time=10.1 ms
64 bytes from 10.0.0.8: icmp_seq=6 ttl=64 time=9.35 ms
64 bytes from 10.0.0.8: icmp_seq=7 ttl=64 time=7.34 ms
64 bytes from 10.0.0.8: icmp_seq=8 ttl=64 time=7.26 ms
64 bytes from 10.0.0.8: icmp_seq=9 ttl=64 time=8.71 ms
64 bytes from 10.0.0.8: icmp_seq=10 ttl=64 time=8.59 ms
64 bytes from 10.0.0.8: icmp_seq=11 ttl=64 time=9.48 ms
64 bytes from 10.0.0.8: icmp_seq=12 ttl=64 time=6.86 ms
64 bytes from 10.0.0.8: icmp_seq=13 ttl=64 time=7.79 ms
64 bytes from 10.0.0.8: icmp_seq=14 ttl=64 time=8.07 ms
64 bytes from 10.0.0.8: icmp_seq=15 ttl=64 time=9.99 ms
64 bytes from 10.0.0.8: icmp_seq=16 ttl=64 time=8.71 ms
64 bytes from 10.0.0.8: icmp_seq=17 ttl=64 time=9.11 ms
64 bytes from 10.0.0.8: icmp_seq=18 ttl=64 time=8.36 ms
^C
--- 10.0.0.8 ping statistics ---
18 packets transmitted, 18 received, 0% packet loss, time 17027ms
rtt min/avg/max/mdev = 6.860/8.790/10.405/1.036 ms
mininet>
```

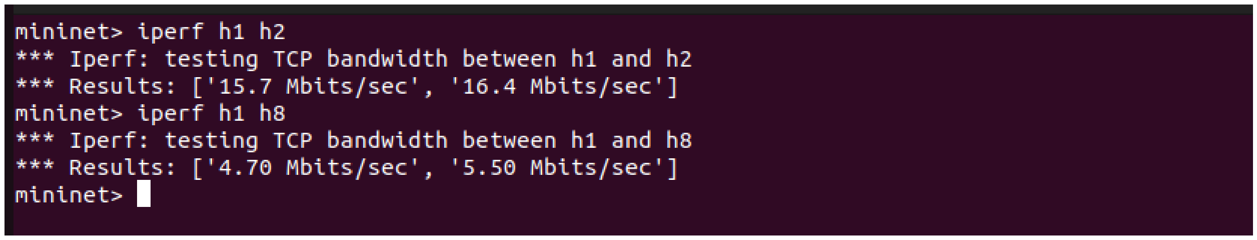
b. What is the minimum and maximum ping you have observed?
<u>Answer</u> -
Minimum ping -
For h1 ping -c100 h2 - 1.668ms
For h1 ping -c100 h8 - 3.373ms
Maximum ping -
For h1 ping -c100 h2 - 6.860ms
For h1 ping -c100 h8 - 10.405ms

c. What is the difference, and why?
<u>Answer</u> -
Ping time is higher for h1 to h8 (8.790ms as shown in above screenshot) compared with h1 to h2 (2.802ms as shown in above screenshot). h1 has to traverse through s3,s2,s1,s5 and s7 to reach h8 while there is only one switch between h1 and h2. Therefore, the ping time is higher in the second case i.e. for h1 to h8.

3. Run “iperf h1 h2” and “iperf h1 h8”
a. What is “iperf” used for?
<u>Answer</u> -
Iperf is an open source program that assists administrators in determining bandwidth for network performance and line quality.Two hosts running iperf are limiting the network link.It is used to determine the amount of data transferred between any two nodes on a network line.

b. What is the throughput for each case?

Answer -
Throughput for h1 to h2 - Results: ['15.7 Mbits/sec', '16.4 Mbits/sec']
Throughput for h1 to h2 - Results: ['4.70 Mbits/sec', '5.50 Mbits/sec']
Screenshot -



```
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['15.7 Mbits/sec', '16.4 Mbits/sec']
mininet> iperf h1 h8
*** Iperf: testing TCP bandwidth between h1 and h8
*** Results: ['4.70 Mbits/sec', '5.50 Mbits/sec']
mininet> 
```

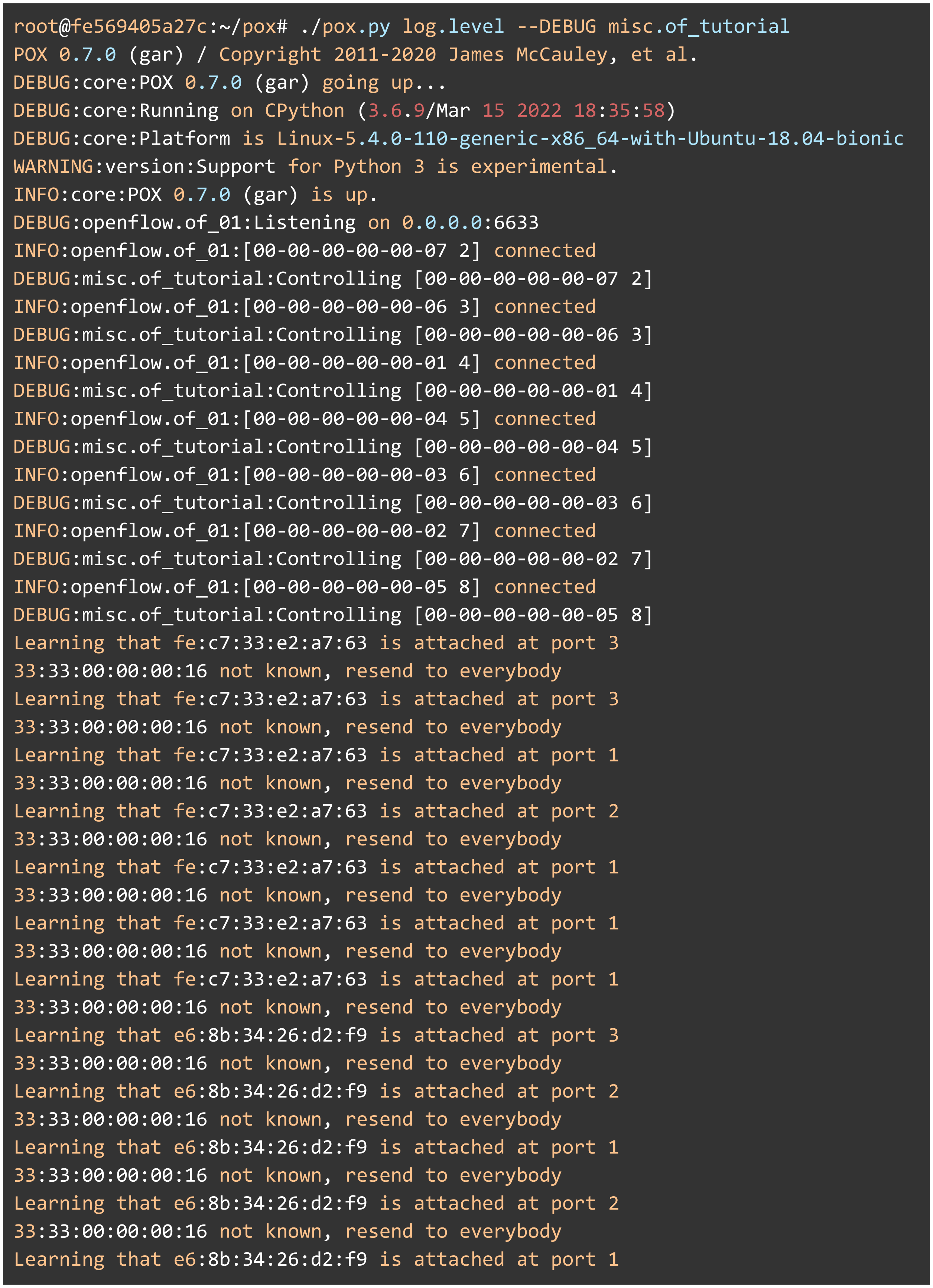
c. What is the difference, and explain the reasons for the difference.
Answer -
Because of less network congestion and latency, throughput is higher between h1 and h2 than between h1 and h8 (same as ping time being slower). Because the number of hops between h1 and h2 is lower, more data can be sent in less time. Since, the number of hops between h1 and h8 is higher, less data throughput may be transferred in a given amount of time.

4. Which of the switches observe traffic? Please describe your way for observing such traffic on switches (e.g., adding some functions in the “of_tutorial” controller).
Answer -
We may inspect the information that lets us observe the traffic by adding log.info("Switch observing traffic: percent s" percent (self.connection) to the line number 107 "of tutorial" controller.As a result of this, we can deduce that all switches monitor traffic, particularly when they are overloaded with packets.The event listener function _handle PacketIn is invoked whenever a packet is received.

Task 3: MAC Learning Controller

Questions -

1. Describe how the above code works, such as how the "MAC to Port" map is established.
You could use a ‘ping’ example to describe the establishment process (e.g., h1 ping h2).
Answer -
The functionality of the act like switch function in our code allows us to determine where MAC addresses are located.
As a result, when a MAC address is determined to be the address to which a sender wishes to send a message, the controller can map that MAC address to a port for convenience.This also aids the controller's speed when delivering packets to already known addresses, as the packet is simply directed to that known port.The function just floods the packet to all destinations if the destination is unknown.Because flooding occurs less frequently, the MAC Learning Controller helps to improve ping times and throughput.



```
root@fe569405a27c:~/pox# ./pox.py log.level --DEBUG misc.of_tutorial
POX 0.7.0 (gar) / Copyright 2011-2020 James McCauley, et al.
DEBUG:core:POX 0.7.0 (gar) going up...
DEBUG:core:Running on CPython (3.6.9/Mar 15 2022 18:35:58)
DEBUG:core:Platform is Linux-5.4.0-110-generic-x86_64-with-Ubuntu-18.04-bionic
WARNING:version:Support for Python 3 is experimental.
INFO:core:POX 0.7.0 (gar) is up.
DEBUG:openflow.of_01:Listening on 0.0.0.0:6633
INFO:openflow.of_01:[00-00-00-00-00-07 2] connected
DEBUG:misc.of_tutorial:Controlling [00-00-00-00-00-07 2]
INFO:openflow.of_01:[00-00-00-00-00-06 3] connected
DEBUG:misc.of_tutorial:Controlling [00-00-00-00-00-06 3]
INFO:openflow.of_01:[00-00-00-00-00-01 4] connected
DEBUG:misc.of_tutorial:Controlling [00-00-00-00-00-01 4]
INFO:openflow.of_01:[00-00-00-00-00-04 5] connected
DEBUG:misc.of_tutorial:Controlling [00-00-00-00-00-04 5]
INFO:openflow.of_01:[00-00-00-00-00-03 6] connected
DEBUG:misc.of_tutorial:Controlling [00-00-00-00-00-03 6]
INFO:openflow.of_01:[00-00-00-00-00-02 7] connected
DEBUG:misc.of_tutorial:Controlling [00-00-00-00-00-02 7]
INFO:openflow.of_01:[00-00-00-00-00-05 8] connected
DEBUG:misc.of_tutorial:Controlling [00-00-00-00-00-05 8]
Learning that fe:c7:33:e2:a7:63 is attached at port 3
33:33:00:00:00:16 not known, resend to everybody
Learning that fe:c7:33:e2:a7:63 is attached at port 3
33:33:00:00:00:16 not known, resend to everybody
Learning that fe:c7:33:e2:a7:63 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that fe:c7:33:e2:a7:63 is attached at port 2
33:33:00:00:00:16 not known, resend to everybody
Learning that fe:c7:33:e2:a7:63 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that fe:c7:33:e2:a7:63 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that fe:c7:33:e2:a7:63 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that e6:8b:34:26:d2:f9 is attached at port 3
33:33:00:00:00:16 not known, resend to everybody
Learning that e6:8b:34:26:d2:f9 is attached at port 2
33:33:00:00:00:16 not known, resend to everybody
Learning that e6:8b:34:26:d2:f9 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that e6:8b:34:26:d2:f9 is attached at port 2
33:33:00:00:00:16 not known, resend to everybody
Learning that e6:8b:34:26:d2:f9 is attached at port 1
```

```
33:33:00:00:00:16 not known, resend to everybody
Learning that e6:8b:34:26:d2:f9 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that e6:8b:34:26:d2:f9 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that 12:3b:c3:3e:0b:62 is attached at port 2
33:33:00:00:00:16 not known, resend to everybody
Learning that 12:3b:c3:3e:0b:62 is attached at port 2
33:33:00:00:00:16 not known, resend to everybody
Learning that 12:3b:c3:3e:0b:62 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that 12:3b:c3:3e:0b:62 is attached at port 2
33:33:00:00:00:16 not known, resend to everybody
Learning that 12:3b:c3:3e:0b:62 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that 12:3b:c3:3e:0b:62 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that 12:3b:c3:3e:0b:62 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
33:33:ff:26:d2:f9 not known, resend to everybody
33:33:ff:26:d2:f9 not known, resend to everybody
33:33:ff:26:d2:f9 not known, resend to everybody
33:33:ff:26:d2:f9 not known, resend to everybody
33:33:ff:26:d2:f9 not known, resend to everybody
33:33:ff:26:d2:f9 not known, resend to everybody
33:33:ff:26:d2:f9 not known, resend to everybody
33:33:ff:3e:0b:62 not known, resend to everybody
33:33:ff:3e:0b:62 not known, resend to everybody
33:33:ff:3e:0b:62 not known, resend to everybody
33:33:ff:3e:0b:62 not known, resend to everybody
33:33:ff:3e:0b:62 not known, resend to everybody
33:33:ff:3e:0b:62 not known, resend to everybody
33:33:ff:3e:0b:62 not known, resend to everybody
Learning that 0a:fa:38:0c:09:dc is attached at port 2
33:33:00:00:00:16 not known, resend to everybody
Learning that 0a:fa:38:0c:09:dc is attached at port 3
33:33:00:00:00:16 not known, resend to everybody
Learning that 0a:fa:38:0c:09:dc is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that 0a:fa:38:0c:09:dc is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that 0a:fa:38:0c:09:dc is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that 0a:fa:38:0c:09:dc is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
```

```
Learning that 0a:fa:38:0c:09:dc is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that fa:f1:d1:80:0c:b9 is attached at port 3
33:33:ff:80:0c:b9 not known, resend to everybody
Learning that fa:f1:d1:80:0c:b9 is attached at port 3
33:33:ff:80:0c:b9 not known, resend to everybody
Learning that fa:f1:d1:80:0c:b9 is attached at port 1
33:33:ff:80:0c:b9 not known, resend to everybody
Learning that fa:f1:d1:80:0c:b9 is attached at port 1
33:33:ff:80:0c:b9 not known, resend to everybody
Learning that fa:f1:d1:80:0c:b9 is attached at port 1
33:33:ff:80:0c:b9 not known, resend to everybody
Learning that fa:f1:d1:80:0c:b9 is attached at port 1
33:33:ff:80:0c:b9 not known, resend to everybody
Learning that fa:f1:d1:80:0c:b9 is attached at port 1
33:33:ff:80:0c:b9 not known, resend to everybody
Learning that a6:e8:e9:dd:39:24 is attached at port 2
33:33:00:00:00:16 not known, resend to everybody
Learning that a6:e8:e9:dd:39:24 is attached at port 2
33:33:00:00:00:16 not known, resend to everybody
Learning that a6:e8:e9:dd:39:24 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that a6:e8:e9:dd:39:24 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that a6:e8:e9:dd:39:24 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that a6:e8:e9:dd:39:24 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that a6:e8:e9:dd:39:24 is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
33:33:ff:0c:09:dc not known, resend to everybody
33:33:ff:0c:09:dc not known, resend to everybody
33:33:ff:0c:09:dc not known, resend to everybody
33:33:ff:0c:09:dc not known, resend to everybody
33:33:ff:0c:09:dc not known, resend to everybody
33:33:ff:0c:09:dc not known, resend to everybody
33:33:ff:0c:09:dc not known, resend to everybody
Learning that 1a:d1:21:83:fe:bb is attached at port 3
33:33:00:00:00:16 not known, resend to everybody
Learning that 1a:d1:21:83:fe:bb is attached at port 2
33:33:00:00:00:16 not known, resend to everybody
Learning that 1a:d1:21:83:fe:bb is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that 1a:d1:21:83:fe:bb is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
```

```
Learning that 1a:d1:21:83:fe:bb is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that 1a:d1:21:83:fe:bb is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
Learning that 1a:d1:21:83:fe:bb is attached at port 1
33:33:00:00:00:16 not known, resend to everybody
33:33:ff:e2:a7:63 not known, resend to everybody
Learning that fa:94:b9:5b:2f:4d is attached at port 2
33:33:ff:5b:2f:4d not known, resend to everybody
33:33:ff:e2:a7:63 not known, resend to everybody
Learning that fa:94:b9:5b:2f:4d is attached at port 3
33:33:ff:5b:2f:4d not known, resend to everybody
33:33:ff:e2:a7:63 not known, resend to everybody
Learning that fa:94:b9:5b:2f:4d is attached at port 1
33:33:ff:5b:2f:4d not known, resend to everybody
33:33:ff:e2:a7:63 not known, resend to everybody
Learning that fa:94:b9:5b:2f:4d is attached at port 2
33:33:ff:5b:2f:4d not known, resend to everybody
33:33:ff:e2:a7:63 not known, resend to everybody
Learning that fa:94:b9:5b:2f:4d is attached at port 1
33:33:ff:5b:2f:4d not known, resend to everybody
33:33:ff:e2:a7:63 not known, resend to everybody
Learning that fa:94:b9:5b:2f:4d is attached at port 1
33:33:ff:5b:2f:4d not known, resend to everybody
33:33:ff:e2:a7:63 not known, resend to everybody
Learning that fa:94:b9:5b:2f:4d is attached at port 1
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a6:e8:e9:dd:39:24 destination known. only send message to it
DEBUG:openflow.of_01:1 connection aborted
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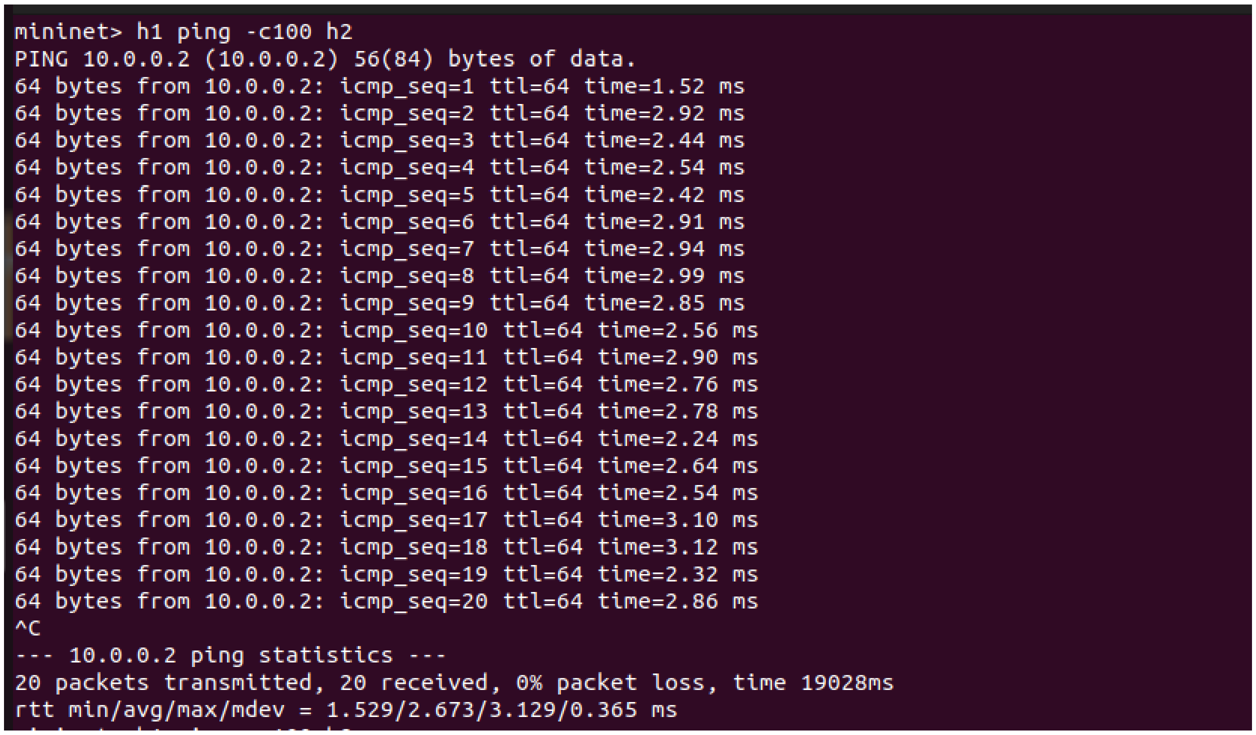
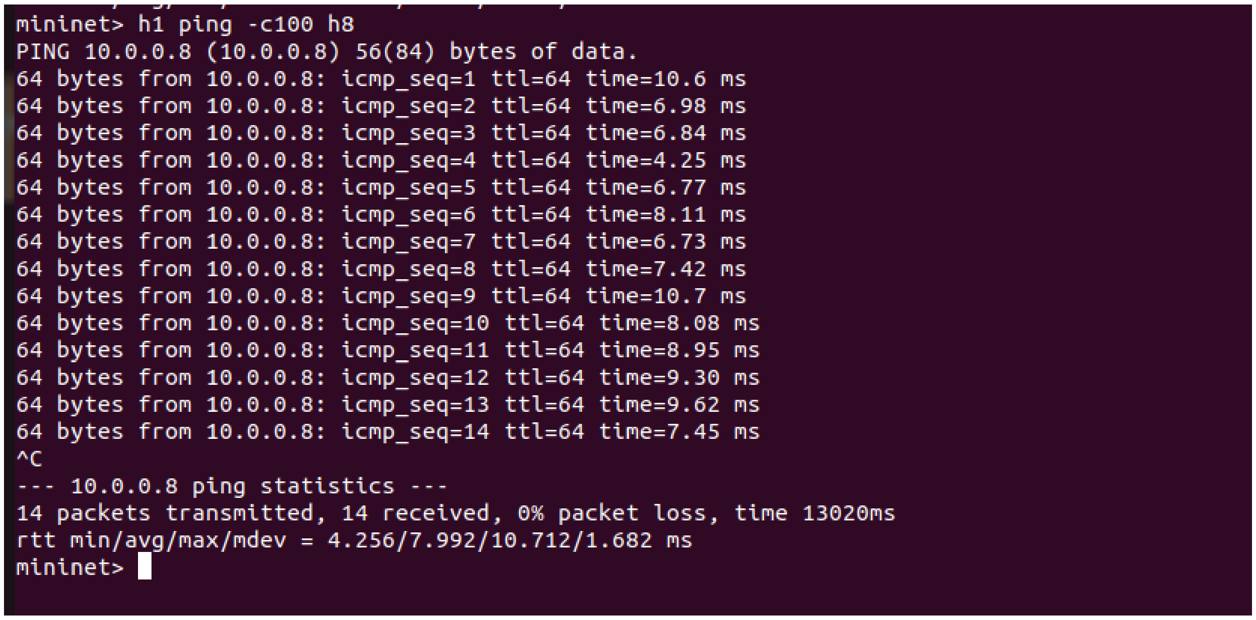
2. (Comment out all prints before doing this experiment) Have h1 ping h2, and h1 ping h8 for 100 times (e.g., h1 ping -c100 p2).
a. How long did it take (on average) to ping for each case?
Answer -
For h1 ping -c100 h2 -
Average time to ping in case of h1 ping h2 is 2.673ms as shown in below screenshot -



```
mininet> h1 ping -c100 h2
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=1.52 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=2.92 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=2.44 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=2.54 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=2.42 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=2.91 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=2.94 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=2.99 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=2.85 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=2.56 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=2.90 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=2.76 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=2.78 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=2.24 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=2.64 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=2.54 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=3.10 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=3.12 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=2.32 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=2.86 ms
^C
--- 10.0.0.2 ping statistics ---
20 packets transmitted, 20 received, 0% packet loss, time 19028ms
rtt min/avg/max/mdev = 1.529/2.673/3.129/0.365 ms
```

For h1 ping -c100 h8 -
Average time to ping in case of h1 ping h2 is 7.992ms as shown in below screenshot -



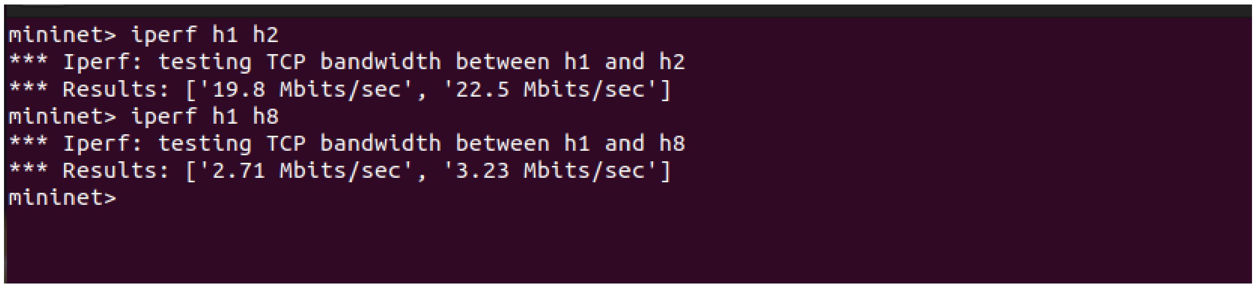
```
mininet> h1 ping -c100 h8
PING 10.0.0.8 (10.0.0.8) 56(84) bytes of data.
64 bytes from 10.0.0.8: icmp_seq=1 ttl=64 time=10.6 ms
64 bytes from 10.0.0.8: icmp_seq=2 ttl=64 time=6.98 ms
64 bytes from 10.0.0.8: icmp_seq=3 ttl=64 time=6.84 ms
64 bytes from 10.0.0.8: icmp_seq=4 ttl=64 time=4.25 ms
64 bytes from 10.0.0.8: icmp_seq=5 ttl=64 time=6.77 ms
64 bytes from 10.0.0.8: icmp_seq=6 ttl=64 time=8.11 ms
64 bytes from 10.0.0.8: icmp_seq=7 ttl=64 time=6.73 ms
64 bytes from 10.0.0.8: icmp_seq=8 ttl=64 time=7.42 ms
64 bytes from 10.0.0.8: icmp_seq=9 ttl=64 time=10.7 ms
64 bytes from 10.0.0.8: icmp_seq=10 ttl=64 time=8.08 ms
64 bytes from 10.0.0.8: icmp_seq=11 ttl=64 time=8.95 ms
64 bytes from 10.0.0.8: icmp_seq=12 ttl=64 time=9.30 ms
64 bytes from 10.0.0.8: icmp_seq=13 ttl=64 time=9.62 ms
64 bytes from 10.0.0.8: icmp_seq=14 ttl=64 time=7.45 ms
^C
--- 10.0.0.8 ping statistics ---
14 packets transmitted, 14 received, 0% packet loss, time 13020ms
rtt min/avg/max/mdev = 4.256/7.992/10.712/1.682 ms
mininet> 
```

b. What is the minimum and maximum ping you have observed?
<u>Answer</u> -
Minimum ping -
For h1 ping -c100 h2 - 1.529ms
For h1 ping -c100 h8 - 3.129ms

Maximum ping -
For h1 ping -c100 h2 - 4.256ms
For h1 ping -c100 h8 - 10.712ms

c. Any difference from Task 2 and why do you think there is a change if there is?
Answer -
Task 3 takes somewhat less time than task 2 for the value for h1 ping h2, while the difference is not substantial. In the instance of h1 and h8, the difference in ping time figures is large because it needs to go through a lot more changes.Because only the first few packets are flooded in job 3, it is clear that task 3 is considerably faster/ or has less ping time.The switches will only resend the packet to the corresponding port that is mapped to in the "mac to port" mapping after the destination MAC address is identified in the map.As a result, future pings are substantially faster due to the lack of network congestion.

3. Q.3 Run "iperf h1 h2" and "iperf h1 h8".
a. What is the throughput for each case?
Answer -
Output of throughput in both h1 h2 and h1 h8 is shown below -



```
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['19.8 Mbits/sec', '22.5 Mbits/sec']
mininet> iperf h1 h8
*** Iperf: testing TCP bandwidth between h1 and h8
*** Results: ['2.71 Mbits/sec', '3.23 Mbits/sec']
mininet>
```

b. What is the difference from Task 2 and why do you think there is a change if there is?
Answer -
In both cases, the throughput for task 3 is higher than that of task 2.This is because, unlike task 3, there will be less network congestion since when mac to port. Map has learned all the ports, there will be no flooding of packets and the switches will be less burdened.Given that the routes are more pre-computed and learned with changes in controller, we can see in h1 and h2, task 2 and 3 had significant improvement in throughputs.There is no significant improvement in the case of h1 and h8, due to the number of hops and packet dropping.