COEN 241 : Cloud Computing

Homework 3
Mininet

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Task 1 : Defining custom topologies

1. What is the output of “nodes” and “net”?

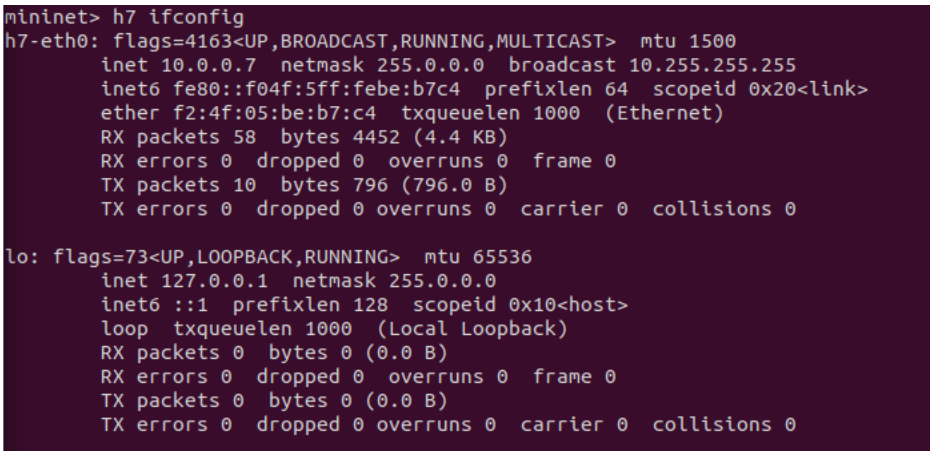
   a) nodes :

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

   b) net :

```
mininet>
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
```

2. What is the output of “h7 ifconfig” ?



```
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::f04f:5ff:febe:b7c4  prefixlen 64  scopeid 0x20<link>
        ether f2:4f:05:be:b7:c4  txqueuelen 1000  (Ethernet)
        RX packets 58  bytes 4452 (4.4 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 10  bytes 796 (796.0 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
```

Task 2 : Analyze the “of_tutorial” controller

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?

Ans → We begin by starting the POX Listener using the following command –

‘ ./pox.py log.level –DEBUG misc.of_tutorial ‘

By running the command, the ‘**start switch**’ is turned ON which calls the **_handle PacketIn()** method from the switch. The _handle PacketIn() method then calls the act like **hub()** function. The act like hub() function generates a behavior that sends packets to all ports except the input port, creating a hub like environment. Then, the resend packet() method is called which adds a packet to the message data and performs action on it. The switch is instructed to resend the packet to a specified port by the message.

The call graph of the controller is as follows –

start switch : _handle_PacketIn() -> act_like_hub() -> resend_packet() -> send(message)

2.

h1 ping -c100 h2

```
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=2.42 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=1.04 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=1.04 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=1.05 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=1.05 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=1.20 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=1.25 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=1.06 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=1.06 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=1.10 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=0.971 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=1.14 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=0.937 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=1.11 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=1.09 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=1.03 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=1.33 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=1.06 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=1.20 ms
64 bytes from 10.0.0.2: icmp_seq=21 ttl=64 time=1.11 ms
64 bytes from 10.0.0.2: icmp_seq=22 ttl=64 time=1.05 ms
64 bytes from 10.0.0.2: icmp_seq=23 ttl=64 time=1.98 ms
64 bytes from 10.0.0.2: icmp_seq=24 ttl=64 time=1.33 ms
64 bytes from 10.0.0.2: icmp_seq=25 ttl=64 time=1.26 ms
64 bytes from 10.0.0.2: icmp_seq=26 ttl=64 time=1.05 ms
64 bytes from 10.0.0.2: icmp_seq=27 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=28 ttl=64 time=1.06 ms
64 bytes from 10.0.0.2: icmp_seq=29 ttl=64 time=1.10 ms
64 bytes from 10.0.0.2: icmp_seq=30 ttl=64 time=1.41 ms
64 bytes from 10.0.0.2: icmp_seq=31 ttl=64 time=1.06 ms
64 bytes from 10.0.0.2: icmp_seq=32 ttl=64 time=1.33 ms
64 bytes from 10.0.0.2: icmp_seq=33 ttl=64 time=1.11 ms
64 bytes from 10.0.0.2: icmp_seq=34 ttl=64 time=1.09 ms
64 bytes from 10.0.0.2: icmp_seq=35 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=36 ttl=64 time=1.14 ms
64 bytes from 10.0.0.2: icmp_seq=37 ttl=64 time=1.11 ms
64 bytes from 10.0.0.2: icmp_seq=38 ttl=64 time=1.31 ms
64 bytes from 10.0.0.2: icmp_seq=39 ttl=64 time=1.21 ms
64 bytes from 10.0.0.2: icmp_seq=40 ttl=64 time=1.22 ms
64 bytes from 10.0.0.2: icmp_seq=41 ttl=64 time=1.15 ms
64 bytes from 10.0.0.2: icmp_seq=42 ttl=64 time=1.10 ms
64 bytes from 10.0.0.2: icmp_seq=43 ttl=64 time=1.43 ms
64 bytes from 10.0.0.2: icmp_seq=44 ttl=64 time=1.37 ms
64 bytes from 10.0.0.2: icmp_seq=45 ttl=64 time=1.37 ms
```

```
64 bytes from 10.0.0.2: icmp_seq=54 ttl=64 time=1.23 ms
64 bytes from 10.0.0.2: icmp_seq=55 ttl=64 time=1.23 ms
64 bytes from 10.0.0.2: icmp_seq=56 ttl=64 time=1.39 ms
64 bytes from 10.0.0.2: icmp_seq=57 ttl=64 time=1.10 ms
64 bytes from 10.0.0.2: icmp_seq=58 ttl=64 time=1.09 ms
64 bytes from 10.0.0.2: icmp_seq=59 ttl=64 time=1.09 ms
64 bytes from 10.0.0.2: icmp_seq=60 ttl=64 time=1.06 ms
64 bytes from 10.0.0.2: icmp_seq=61 ttl=64 time=1.29 ms
64 bytes from 10.0.0.2: icmp_seq=62 ttl=64 time=1.37 ms
64 bytes from 10.0.0.2: icmp_seq=63 ttl=64 time=1.06 ms
64 bytes from 10.0.0.2: icmp_seq=64 ttl=64 time=1.04 ms
64 bytes from 10.0.0.2: icmp_seq=65 ttl=64 time=1.33 ms
64 bytes from 10.0.0.2: icmp_seq=66 ttl=64 time=1.09 ms
64 bytes from 10.0.0.2: icmp_seq=67 ttl=64 time=1.14 ms
64 bytes from 10.0.0.2: icmp_seq=68 ttl=64 time=1.38 ms
64 bytes from 10.0.0.2: icmp_seq=69 ttl=64 time=1.19 ms
64 bytes from 10.0.0.2: icmp_seq=70 ttl=64 time=1.16 ms
64 bytes from 10.0.0.2: icmp_seq=71 ttl=64 time=1.12 ms
64 bytes from 10.0.0.2: icmp_seq=72 ttl=64 time=1.39 ms
64 bytes from 10.0.0.2: icmp_seq=73 ttl=64 time=1.09 ms
64 bytes from 10.0.0.2: icmp_seq=74 ttl=64 time=1.35 ms
64 bytes from 10.0.0.2: icmp_seq=75 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=76 ttl=64 time=1.02 ms
64 bytes from 10.0.0.2: icmp_seq=77 ttl=64 time=1.07 ms
64 bytes from 10.0.0.2: icmp_seq=78 ttl=64 time=1.39 ms
64 bytes from 10.0.0.2: icmp_seq=79 ttl=64 time=1.12 ms
64 bytes from 10.0.0.2: icmp_seq=80 ttl=64 time=1.34 ms
64 bytes from 10.0.0.2: icmp_seq=81 ttl=64 time=1.03 ms
64 bytes from 10.0.0.2: icmp_seq=82 ttl=64 time=1.11 ms
64 bytes from 10.0.0.2: icmp_seq=83 ttl=64 time=1.15 ms
64 bytes from 10.0.0.2: icmp_seq=84 ttl=64 time=1.19 ms
64 bytes from 10.0.0.2: icmp_seq=85 ttl=64 time=1.28 ms
64 bytes from 10.0.0.2: icmp_seq=86 ttl=64 time=1.50 ms
64 bytes from 10.0.0.2: icmp_seq=87 ttl=64 time=1.12 ms
64 bytes from 10.0.0.2: icmp_seq=88 ttl=64 time=1.20 ms
64 bytes from 10.0.0.2: icmp_seq=89 ttl=64 time=1.12 ms
64 bytes from 10.0.0.2: icmp_seq=90 ttl=64 time=1.59 ms
64 bytes from 10.0.0.2: icmp_seq=91 ttl=64 time=1.12 ms
64 bytes from 10.0.0.2: icmp_seq=92 ttl=64 time=1.35 ms
64 bytes from 10.0.0.2: icmp_seq=93 ttl=64 time=1.16 ms
64 bytes from 10.0.0.2: icmp_seq=94 ttl=64 time=1.25 ms
64 bytes from 10.0.0.2: icmp_seq=95 ttl=64 time=1.23 ms
64 bytes from 10.0.0.2: icmp_seq=96 ttl=64 time=1.17 ms
64 bytes from 10.0.0.2: icmp_seq=97 ttl=64 time=1.33 ms
64 bytes from 10.0.0.2: icmp_seq=98 ttl=64 time=1.40 ms
64 bytes from 10.0.0.2: icmp_seq=99 ttl=64 time=1.11 ms
64 bytes from 10.0.0.2: icmp_seq=100 ttl=64 time=1.14 ms

--- 10.0.0.2 ping statistics ---
100 packets transmitted, 100 received, 0% packet loss, time 99115ms
rtt min/avg/max/mdev = 0.937/1.200/2.423/0.200 ms
```

h1 ping -c100 h8

```
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=8.91 ms
64 bytes from 10.0.0.8: icmp_seq=2 ttl=64 time=4.05 ms
64 bytes from 10.0.0.8: icmp_seq=3 ttl=64 time=5.32 ms
64 bytes from 10.0.0.8: icmp_seq=4 ttl=64 time=4.14 ms
64 bytes from 10.0.0.8: icmp_seq=5 ttl=64 time=4.00 ms
64 bytes from 10.0.0.8: icmp_seq=6 ttl=64 time=3.99 ms
64 bytes from 10.0.0.8: icmp_seq=7 ttl=64 time=3.79 ms
64 bytes from 10.0.0.8: icmp_seq=8 ttl=64 time=3.89 ms
64 bytes from 10.0.0.8: icmp_seq=9 ttl=64 time=5.42 ms
64 bytes from 10.0.0.8: icmp_seq=10 ttl=64 time=4.05 ms
64 bytes from 10.0.0.8: icmp_seq=11 ttl=64 time=3.82 ms
64 bytes from 10.0.0.8: icmp_seq=12 ttl=64 time=4.14 ms
64 bytes from 10.0.0.8: icmp_seq=13 ttl=64 time=4.03 ms
64 bytes from 10.0.0.8: icmp_seq=14 ttl=64 time=3.45 ms
64 bytes from 10.0.0.8: icmp_seq=15 ttl=64 time=4.86 ms
64 bytes from 10.0.0.8: icmp_seq=16 ttl=64 time=3.76 ms
64 bytes from 10.0.0.8: icmp_seq=17 ttl=64 time=4.21 ms
64 bytes from 10.0.0.8: icmp_seq=18 ttl=64 time=3.72 ms
64 bytes from 10.0.0.8: icmp_seq=19 ttl=64 time=3.82 ms
64 bytes from 10.0.0.8: icmp_seq=20 ttl=64 time=3.73 ms
64 bytes from 10.0.0.8: icmp_seq=21 ttl=64 time=5.17 ms
64 bytes from 10.0.0.8: icmp_seq=22 ttl=64 time=3.96 ms
64 bytes from 10.0.0.8: icmp_seq=23 ttl=64 time=4.00 ms
64 bytes from 10.0.0.8: icmp_seq=24 ttl=64 time=3.87 ms
64 bytes from 10.0.0.8: icmp_seq=25 ttl=64 time=3.76 ms
64 bytes from 10.0.0.8: icmp_seq=26 ttl=64 time=3.80 ms
64 bytes from 10.0.0.8: icmp_seq=27 ttl=64 time=5.47 ms
64 bytes from 10.0.0.8: icmp_seq=28 ttl=64 time=3.89 ms
64 bytes from 10.0.0.8: icmp_seq=29 ttl=64 time=4.15 ms
64 bytes from 10.0.0.8: icmp_seq=30 ttl=64 time=4.04 ms
64 bytes from 10.0.0.8: icmp_seq=31 ttl=64 time=3.91 ms
64 bytes from 10.0.0.8: icmp_seq=32 ttl=64 time=4.06 ms
64 bytes from 10.0.0.8: icmp_seq=33 ttl=64 time=5.08 ms
64 bytes from 10.0.0.8: icmp_seq=34 ttl=64 time=3.93 ms
64 bytes from 10.0.0.8: icmp_seq=35 ttl=64 time=3.64 ms
64 bytes from 10.0.0.8: icmp_seq=36 ttl=64 time=3.39 ms
64 bytes from 10.0.0.8: icmp_seq=37 ttl=64 time=3.85 ms
64 bytes from 10.0.0.8: icmp_seq=38 ttl=64 time=3.84 ms
64 bytes from 10.0.0.8: icmp_seq=39 ttl=64 time=5.43 ms
64 bytes from 10.0.0.8: icmp_seq=40 ttl=64 time=3.90 ms
64 bytes from 10.0.0.8: icmp_seq=41 ttl=64 time=3.90 ms
64 bytes from 10.0.0.8: icmp_seq=42 ttl=64 time=4.01 ms
64 bytes from 10.0.0.8: icmp_seq=43 ttl=64 time=4.03 ms
64 bytes from 10.0.0.8: icmp_seq=44 ttl=64 time=4.08 ms
64 bytes from 10.0.0.8: icmp_seq=45 ttl=64 time=4.99 ms
```

```
64 bytes from 10.0.0.8: icmp_seq=54 ttl=64 time=4.02 ms
64 bytes from 10.0.0.8: icmp_seq=55 ttl=64 time=3.54 ms
64 bytes from 10.0.0.8: icmp_seq=56 ttl=64 time=3.64 ms
64 bytes from 10.0.0.8: icmp_seq=57 ttl=64 time=4.17 ms
64 bytes from 10.0.0.8: icmp_seq=58 ttl=64 time=4.11 ms
64 bytes from 10.0.0.8: icmp_seq=59 ttl=64 time=5.67 ms
64 bytes from 10.0.0.8: icmp_seq=60 ttl=64 time=3.99 ms
64 bytes from 10.0.0.8: icmp_seq=61 ttl=64 time=4.10 ms
64 bytes from 10.0.0.8: icmp_seq=62 ttl=64 time=4.24 ms
64 bytes from 10.0.0.8: icmp_seq=63 ttl=64 time=4.28 ms
64 bytes from 10.0.0.8: icmp_seq=64 ttl=64 time=4.18 ms
64 bytes from 10.0.0.8: icmp_seq=65 ttl=64 time=5.51 ms
64 bytes from 10.0.0.8: icmp_seq=66 ttl=64 time=4.22 ms
64 bytes from 10.0.0.8: icmp_seq=67 ttl=64 time=4.13 ms
64 bytes from 10.0.0.8: icmp_seq=68 ttl=64 time=3.92 ms
64 bytes from 10.0.0.8: icmp_seq=69 ttl=64 time=4.01 ms
64 bytes from 10.0.0.8: icmp_seq=70 ttl=64 time=3.61 ms
64 bytes from 10.0.0.8: icmp_seq=71 ttl=64 time=5.14 ms
64 bytes from 10.0.0.8: icmp_seq=72 ttl=64 time=3.69 ms
64 bytes from 10.0.0.8: icmp_seq=73 ttl=64 time=3.70 ms
64 bytes from 10.0.0.8: icmp_seq=74 ttl=64 time=3.73 ms
64 bytes from 10.0.0.8: icmp_seq=75 ttl=64 time=3.57 ms
64 bytes from 10.0.0.8: icmp_seq=76 ttl=64 time=3.98 ms
64 bytes from 10.0.0.8: icmp_seq=77 ttl=64 time=5.08 ms
64 bytes from 10.0.0.8: icmp_seq=78 ttl=64 time=4.05 ms
64 bytes from 10.0.0.8: icmp_seq=79 ttl=64 time=4.18 ms
64 bytes from 10.0.0.8: icmp_seq=80 ttl=64 time=4.05 ms
64 bytes from 10.0.0.8: icmp_seq=81 ttl=64 time=4.10 ms
64 bytes from 10.0.0.8: icmp_seq=82 ttl=64 time=4.07 ms
64 bytes from 10.0.0.8: icmp_seq=83 ttl=64 time=5.21 ms
64 bytes from 10.0.0.8: icmp_seq=84 ttl=64 time=4.20 ms
64 bytes from 10.0.0.8: icmp_seq=85 ttl=64 time=3.80 ms
64 bytes from 10.0.0.8: icmp_seq=86 ttl=64 time=4.00 ms
64 bytes from 10.0.0.8: icmp_seq=87 ttl=64 time=4.06 ms
64 bytes from 10.0.0.8: icmp_seq=88 ttl=64 time=4.12 ms
64 bytes from 10.0.0.8: icmp_seq=89 ttl=64 time=5.53 ms
64 bytes from 10.0.0.8: icmp_seq=90 ttl=64 time=3.58 ms
64 bytes from 10.0.0.8: icmp_seq=91 ttl=64 time=3.86 ms
64 bytes from 10.0.0.8: icmp_seq=92 ttl=64 time=3.63 ms
64 bytes from 10.0.0.8: icmp_seq=93 ttl=64 time=3.79 ms
64 bytes from 10.0.0.8: icmp_seq=94 ttl=64 time=3.83 ms
64 bytes from 10.0.0.8: icmp_seq=95 ttl=64 time=5.26 ms
64 bytes from 10.0.0.8: icmp_seq=96 ttl=64 time=3.85 ms
64 bytes from 10.0.0.8: icmp_seq=97 ttl=64 time=4.95 ms
64 bytes from 10.0.0.8: icmp_seq=98 ttl=64 time=3.58 ms
64 bytes from 10.0.0.8: icmp_seq=99 ttl=64 time=4.01 ms
64 bytes from 10.0.0.8: icmp_seq=100 ttl=64 time=3.87 ms

--- 10.0.0.8 ping statistics ---
100 packets transmitted, 100 received, 0% packet loss, time 99144ms
rtt min/avg/max/mdev = 3.395/4.241/8.911/0.834 ms
```

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

	Average Ping
h1 ping -c100 h2	**1.200 ms**
h1 ping -c100 h8	**4.241 ms**

b) What is the minimum and maximum ping you have observed?

	Minimum Ping	Maximum Ping
h1 ping -c100 h2	**0.937 ms**	**2.423 ms**
h1 ping -c100 h8	**3.395 ms**	**8.911 ms**

c) What is the difference, and why?

Ans -> The ping time is higher for h1 -> h8 (4.241 ms) as compared to h1 -> h2 (1.200 ms) because for h1 to reach h8 , it has to go through 5 switches i.e., s3, s2, s1, s5 and s7 but for h1 -> h2 there is only one switch is between. Hence the pinging time is higher in the case of h1 to h8.

3. Run “iperf h1 h2” and “iperf h1 h8”.

```
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['11.4 Mbits/sec', '11.7 Mbits/sec']
mininet> iperf h1 h8
*** Iperf: testing TCP bandwidth between h1 and h8
*** Results: ['2.90 Mbits/sec', '3.31 Mbits/sec']
```

a) What is “iperf” used for?

Ans→ iperf is an open-source free program that helps administrators to determine the bandwidth for line quality and network performance. It is used to calculate the amount of data transfer between any two nodes on a network line.

b) What is the throughput for each case?

i) iperf: testing TCP bandwidth between h1 and h2
Results: ['11.4 Mbits/sec', '11.7 Mbits/sec']

ii) iperf: testing TCP bandwidth between h1 and h8
Results: ['2.90 Mbits/sec', '3.31 Mbits/sec']

c) What is the difference and explain the reasons for the difference.
Ans→Throughput is higher between h1 -> h2 than h1 -> h8 due to the same reason as ping time being slower for h1 -> h8. Due to less network congestion, latency and less distance to traverse between h1 -> h2, more data can be sent in lesser time. Hence throughput is higher for h1 -> h2 than h1 -> h8.

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).

Ans→ We can probe the info that can helps us observe the traffic by adding loggers like log.info("Switch observing traffic : percent s" (self.connection)) to line 107 of the "of_tutorial" file of the controller. We can decipher from this that all switches are able to monitor and observe traffic when they are overloaded with packets. The event listener fuction _handle_PacketIn() is called whenever a packet is received.

Task 3 : MAC Learning Controller

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).

Ans→ The act_like_switch() function enables us to determine all the MAC addresses and their location. Whenever a sender wants to send a message to a particular MAC address, the controller having all the meta data can map the MAC address to its respective port. When the message is to be sent to the same address, it speeds/boosts up the process as we already know the port to where the packet is to be delivered.
The act_like_switch() function just sends the packet to all addresses if destination is unknown. Due to lower chances of flooding occurring, the MAC Learning Controller aids in improving pinging time and throughput.

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

h1 ping -c100 h2

```
*** Starting CLI:
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=3.00 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=1.13 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=1.19 ms
64 bytes from 10.0.0.2: icmp_seq=5 ttl=64 time=1.29 ms
64 bytes from 10.0.0.2: icmp_seq=6 ttl=64 time=1.21 ms
64 bytes from 10.0.0.2: icmp_seq=7 ttl=64 time=1.38 ms
64 bytes from 10.0.0.2: icmp_seq=8 ttl=64 time=1.05 ms
64 bytes from 10.0.0.2: icmp_seq=9 ttl=64 time=0.891 ms
64 bytes from 10.0.0.2: icmp_seq=10 ttl=64 time=1.02 ms
64 bytes from 10.0.0.2: icmp_seq=11 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=12 ttl=64 time=1.06 ms
64 bytes from 10.0.0.2: icmp_seq=13 ttl=64 time=1.28 ms
64 bytes from 10.0.0.2: icmp_seq=14 ttl=64 time=1.04 ms
64 bytes from 10.0.0.2: icmp_seq=15 ttl=64 time=1.09 ms
64 bytes from 10.0.0.2: icmp_seq=16 ttl=64 time=1.04 ms
64 bytes from 10.0.0.2: icmp_seq=17 ttl=64 time=1.07 ms
64 bytes from 10.0.0.2: icmp_seq=18 ttl=64 time=1.04 ms
64 bytes from 10.0.0.2: icmp_seq=19 ttl=64 time=1.30 ms
64 bytes from 10.0.0.2: icmp_seq=20 ttl=64 time=0.983 ms
64 bytes from 10.0.0.2: icmp_seq=21 ttl=64 time=1.04 ms
64 bytes from 10.0.0.2: icmp_seq=22 ttl=64 time=0.998 ms
64 bytes from 10.0.0.2: icmp_seq=23 ttl=64 time=1.05 ms
64 bytes from 10.0.0.2: icmp_seq=24 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=25 ttl=64 time=1.30 ms
64 bytes from 10.0.0.2: icmp_seq=26 ttl=64 time=1.03 ms
64 bytes from 10.0.0.2: icmp_seq=27 ttl=64 time=1.04 ms
64 bytes from 10.0.0.2: icmp_seq=28 ttl=64 time=1.11 ms
64 bytes from 10.0.0.2: icmp_seq=29 ttl=64 time=0.988 ms
64 bytes from 10.0.0.2: icmp_seq=30 ttl=64 time=1.05 ms
64 bytes from 10.0.0.2: icmp_seq=31 ttl=64 time=1.33 ms
64 bytes from 10.0.0.2: icmp_seq=32 ttl=64 time=1.06 ms
64 bytes from 10.0.0.2: icmp_seq=33 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=34 ttl=64 time=1.12 ms
64 bytes from 10.0.0.2: icmp_seq=35 ttl=64 time=1.06 ms
64 bytes from 10.0.0.2: icmp_seq=36 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=37 ttl=64 time=1.36 ms
64 bytes from 10.0.0.2: icmp_seq=38 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=39 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=40 ttl=64 time=1.07 ms
64 bytes from 10.0.0.2: icmp_seq=41 ttl=64 time=1.18 ms
64 bytes from 10.0.0.2: icmp_seq=42 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=43 ttl=64 time=1.37 ms
64 bytes from 10.0.0.2: icmp_seq=44 ttl=64 time=1.11 ms
64 bytes from 10.0.0.2: icmp_seq=45 ttl=64 time=1.10 ms
64 bytes from 10.0.0.2: icmp_seq=46 ttl=64 time=1.12 ms
64 bytes from 10.0.0.2: icmp_seq=47 ttl=64 time=1.09 ms
64 bytes from 10.0.0.2: icmp_seq=48 ttl=64 time=1.15 ms
64 bytes from 10.0.0.2: icmp_seq=49 ttl=64 time=1.33 ms
```

```
64 bytes from 10.0.0.2: icmp_seq=64 ttl=64 time=1.11 ms
64 bytes from 10.0.0.2: icmp_seq=65 ttl=64 time=1.10 ms
64 bytes from 10.0.0.2: icmp_seq=66 ttl=64 time=1.10 ms
64 bytes from 10.0.0.2: icmp_seq=67 ttl=64 time=1.35 ms
64 bytes from 10.0.0.2: icmp_seq=68 ttl=64 time=1.09 ms
64 bytes from 10.0.0.2: icmp_seq=69 ttl=64 time=1.17 ms
64 bytes from 10.0.0.2: icmp_seq=70 ttl=64 time=1.10 ms
64 bytes from 10.0.0.2: icmp_seq=71 ttl=64 time=1.06 ms
64 bytes from 10.0.0.2: icmp_seq=72 ttl=64 time=1.18 ms
64 bytes from 10.0.0.2: icmp_seq=73 ttl=64 time=1.29 ms
64 bytes from 10.0.0.2: icmp_seq=74 ttl=64 time=0.971 ms
64 bytes from 10.0.0.2: icmp_seq=75 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=76 ttl=64 time=1.14 ms
64 bytes from 10.0.0.2: icmp_seq=77 ttl=64 time=1.06 ms
64 bytes from 10.0.0.2: icmp_seq=78 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=79 ttl=64 time=1.22 ms
64 bytes from 10.0.0.2: icmp_seq=80 ttl=64 time=1.02 ms
64 bytes from 10.0.0.2: icmp_seq=81 ttl=64 time=1.05 ms
64 bytes from 10.0.0.2: icmp_seq=82 ttl=64 time=1.09 ms
64 bytes from 10.0.0.2: icmp_seq=83 ttl=64 time=1.06 ms
64 bytes from 10.0.0.2: icmp_seq=84 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=85 ttl=64 time=1.29 ms
64 bytes from 10.0.0.2: icmp_seq=86 ttl=64 time=1.05 ms
64 bytes from 10.0.0.2: icmp_seq=87 ttl=64 time=1.02 ms
64 bytes from 10.0.0.2: icmp_seq=88 ttl=64 time=1.09 ms
64 bytes from 10.0.0.2: icmp_seq=89 ttl=64 time=0.971 ms
64 bytes from 10.0.0.2: icmp_seq=90 ttl=64 time=1.07 ms
64 bytes from 10.0.0.2: icmp_seq=91 ttl=64 time=1.36 ms
64 bytes from 10.0.0.2: icmp_seq=92 ttl=64 time=1.08 ms
64 bytes from 10.0.0.2: icmp_seq=93 ttl=64 time=1.03 ms
64 bytes from 10.0.0.2: icmp_seq=94 ttl=64 time=1.04 ms
64 bytes from 10.0.0.2: icmp_seq=95 ttl=64 time=1.02 ms
64 bytes from 10.0.0.2: icmp_seq=96 ttl=64 time=1.04 ms
64 bytes from 10.0.0.2: icmp_seq=97 ttl=64 time=1.33 ms
64 bytes from 10.0.0.2: icmp_seq=98 ttl=64 time=1.07 ms
64 bytes from 10.0.0.2: icmp_seq=99 ttl=64 time=1.11 ms
64 bytes from 10.0.0.2: icmp_seq=100 ttl=64 time=1.10 ms

--- 10.0.0.2 ping statistics ---
100 packets transmitted, 100 received, 0% packet loss, time 99158ms
rtt min/avg/max/mdev = 0.890/1.147/3.007/0.238 ms
```

h1 ping -c100 h8

```
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=11.5 ms
64 bytes from 10.0.0.8: icmp_seq=2 ttl=64 time=3.82 ms
64 bytes from 10.0.0.8: icmp_seq=3 ttl=64 time=3.78 ms
64 bytes from 10.0.0.8: icmp_seq=4 ttl=64 time=4.09 ms
64 bytes from 10.0.0.8: icmp_seq=5 ttl=64 time=4.13 ms
64 bytes from 10.0.0.8: icmp_seq=6 ttl=64 time=3.86 ms
64 bytes from 10.0.0.8: icmp_seq=7 ttl=64 time=5.13 ms
64 bytes from 10.0.0.8: icmp_seq=8 ttl=64 time=4.03 ms
64 bytes from 10.0.0.8: icmp_seq=9 ttl=64 time=4.02 ms
64 bytes from 10.0.0.8: icmp_seq=10 ttl=64 time=4.23 ms
64 bytes from 10.0.0.8: icmp_seq=11 ttl=64 time=4.01 ms
64 bytes from 10.0.0.8: icmp_seq=12 ttl=64 time=4.22 ms
64 bytes from 10.0.0.8: icmp_seq=13 ttl=64 time=5.80 ms
64 bytes from 10.0.0.8: icmp_seq=14 ttl=64 time=3.99 ms
64 bytes from 10.0.0.8: icmp_seq=15 ttl=64 time=4.32 ms
64 bytes from 10.0.0.8: icmp_seq=16 ttl=64 time=3.55 ms
64 bytes from 10.0.0.8: icmp_seq=17 ttl=64 time=4.23 ms
64 bytes from 10.0.0.8: icmp_seq=18 ttl=64 time=3.91 ms
64 bytes from 10.0.0.8: icmp_seq=19 ttl=64 time=5.46 ms
64 bytes from 10.0.0.8: icmp_seq=20 ttl=64 time=4.11 ms
64 bytes from 10.0.0.8: icmp_seq=21 ttl=64 time=3.79 ms
64 bytes from 10.0.0.8: icmp_seq=22 ttl=64 time=3.84 ms
64 bytes from 10.0.0.8: icmp_seq=23 ttl=64 time=3.90 ms
64 bytes from 10.0.0.8: icmp_seq=24 ttl=64 time=3.75 ms
64 bytes from 10.0.0.8: icmp_seq=25 ttl=64 time=5.02 ms
64 bytes from 10.0.0.8: icmp_seq=26 ttl=64 time=3.59 ms
64 bytes from 10.0.0.8: icmp_seq=27 ttl=64 time=3.70 ms
64 bytes from 10.0.0.8: icmp_seq=28 ttl=64 time=3.86 ms
64 bytes from 10.0.0.8: icmp_seq=29 ttl=64 time=3.73 ms
64 bytes from 10.0.0.8: icmp_seq=30 ttl=64 time=4.26 ms
64 bytes from 10.0.0.8: icmp_seq=31 ttl=64 time=4.90 ms
64 bytes from 10.0.0.8: icmp_seq=32 ttl=64 time=3.95 ms
64 bytes from 10.0.0.8: icmp_seq=33 ttl=64 time=3.99 ms
64 bytes from 10.0.0.8: icmp_seq=34 ttl=64 time=4.20 ms
64 bytes from 10.0.0.8: icmp_seq=35 ttl=64 time=4.09 ms
64 bytes from 10.0.0.8: icmp_seq=36 ttl=64 time=4.17 ms
64 bytes from 10.0.0.8: icmp_seq=37 ttl=64 time=5.11 ms
64 bytes from 10.0.0.8: icmp_seq=38 ttl=64 time=3.39 ms
64 bytes from 10.0.0.8: icmp_seq=39 ttl=64 time=3.97 ms
64 bytes from 10.0.0.8: icmp_seq=40 ttl=64 time=3.57 ms
64 bytes from 10.0.0.8: icmp_seq=41 ttl=64 time=3.74 ms
64 bytes from 10.0.0.8: icmp_seq=42 ttl=64 time=3.68 ms
64 bytes from 10.0.0.8: icmp_seq=43 ttl=64 time=4.90 ms
64 bytes from 10.0.0.8: icmp_seq=44 ttl=64 time=3.69 ms
64 bytes from 10.0.0.8: icmp_seq=45 ttl=64 time=3.86 ms
```

```
64 bytes from 10.0.0.8: icmp_seq=54 ttl=64 time=4.20 ms
64 bytes from 10.0.0.8: icmp_seq=55 ttl=64 time=5.49 ms
64 bytes from 10.0.0.8: icmp_seq=56 ttl=64 time=4.20 ms
64 bytes from 10.0.0.8: icmp_seq=57 ttl=64 time=4.26 ms
64 bytes from 10.0.0.8: icmp_seq=58 ttl=64 time=4.21 ms
64 bytes from 10.0.0.8: icmp_seq=59 ttl=64 time=4.51 ms
64 bytes from 10.0.0.8: icmp_seq=60 ttl=64 time=4.06 ms
64 bytes from 10.0.0.8: icmp_seq=61 ttl=64 time=5.33 ms
64 bytes from 10.0.0.8: icmp_seq=62 ttl=64 time=4.07 ms
64 bytes from 10.0.0.8: icmp_seq=63 ttl=64 time=4.33 ms
64 bytes from 10.0.0.8: icmp_seq=64 ttl=64 time=4.33 ms
64 bytes from 10.0.0.8: icmp_seq=65 ttl=64 time=4.20 ms
64 bytes from 10.0.0.8: icmp_seq=66 ttl=64 time=4.24 ms
64 bytes from 10.0.0.8: icmp_seq=67 ttl=64 time=5.20 ms
64 bytes from 10.0.0.8: icmp_seq=68 ttl=64 time=4.18 ms
64 bytes from 10.0.0.8: icmp_seq=69 ttl=64 time=3.98 ms
64 bytes from 10.0.0.8: icmp_seq=70 ttl=64 time=3.96 ms
64 bytes from 10.0.0.8: icmp_seq=71 ttl=64 time=3.69 ms
64 bytes from 10.0.0.8: icmp_seq=72 ttl=64 time=3.99 ms
64 bytes from 10.0.0.8: icmp_seq=73 ttl=64 time=5.32 ms
64 bytes from 10.0.0.8: icmp_seq=74 ttl=64 time=3.73 ms
64 bytes from 10.0.0.8: icmp_seq=75 ttl=64 time=3.96 ms
64 bytes from 10.0.0.8: icmp_seq=76 ttl=64 time=4.00 ms
64 bytes from 10.0.0.8: icmp_seq=77 ttl=64 time=4.09 ms
64 bytes from 10.0.0.8: icmp_seq=78 ttl=64 time=3.80 ms
64 bytes from 10.0.0.8: icmp_seq=79 ttl=64 time=5.55 ms
64 bytes from 10.0.0.8: icmp_seq=80 ttl=64 time=4.36 ms
64 bytes from 10.0.0.8: icmp_seq=81 ttl=64 time=3.90 ms
64 bytes from 10.0.0.8: icmp_seq=82 ttl=64 time=3.89 ms
64 bytes from 10.0.0.8: icmp_seq=83 ttl=64 time=3.64 ms
64 bytes from 10.0.0.8: icmp_seq=84 ttl=64 time=4.04 ms
64 bytes from 10.0.0.8: icmp_seq=85 ttl=64 time=5.14 ms
64 bytes from 10.0.0.8: icmp_seq=86 ttl=64 time=4.43 ms
64 bytes from 10.0.0.8: icmp_seq=87 ttl=64 time=4.84 ms
64 bytes from 10.0.0.8: icmp_seq=88 ttl=64 time=4.09 ms
64 bytes from 10.0.0.8: icmp_seq=89 ttl=64 time=4.36 ms
64 bytes from 10.0.0.8: icmp_seq=90 ttl=64 time=4.55 ms
64 bytes from 10.0.0.8: icmp_seq=91 ttl=64 time=5.70 ms
64 bytes from 10.0.0.8: icmp_seq=92 ttl=64 time=4.44 ms
64 bytes from 10.0.0.8: icmp_seq=93 ttl=64 time=4.09 ms
64 bytes from 10.0.0.8: icmp_seq=94 ttl=64 time=4.16 ms
64 bytes from 10.0.0.8: icmp_seq=95 ttl=64 time=4.11 ms
64 bytes from 10.0.0.8: icmp_seq=96 ttl=64 time=3.92 ms
64 bytes from 10.0.0.8: icmp_seq=97 ttl=64 time=5.32 ms
64 bytes from 10.0.0.8: icmp_seq=98 ttl=64 time=4.17 ms
64 bytes from 10.0.0.8: icmp_seq=99 ttl=64 time=3.79 ms
64 bytes from 10.0.0.8: icmp_seq=100 ttl=64 time=3.97 ms

--- 10.0.0.8 ping statistics ---
100 packets transmitted, 100 received, 0% packet loss, time 99138ms
rtt min/avg/max/mdev = 3.393/4.293/11.505/0.903 ms
```

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

	Average Ping
h1 ping -c100 h2	**1.147 ms**
h1 ping -c100 h8	**4.293 ms**

b. What is the minimum and maximum ping you have observed?

	Minimum Ping	Maximum Ping
h1 ping -c100 h2	**0.890 ms**	**3.007 ms**
h1 ping -c100 h8	**3.393 ms**	**11.505 ms**

c. Any difference from Task 2 and why do you think there is a change if there is?

Ans→ The time taken by task 3 to perform operations is less than task 2, although the difference is not that huge. The difference in ping is because in task 3 the switches will only resend the packet that is mapped in the "mac to port" mapping after the first entry of that address goes into the map. Whenever in future, a packet is to be sent to same address it becomes substantially faster because the port and address are already known as well as lack of network congestion.

3. Run "iperf h1 h2" and "iperf h1 h8".

```
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['18.7 Mbits/sec', '19.2 Mbits/sec']
mininet> iperf h1 h8
*** Iperf: testing TCP bandwidth between h1 and h8
*** Results: ['4.02 Mbits/sec', '4.75 Mbits/sec']
```

a) What is the throughput for each case?

i) iperf: testing TCP bandwidth between h1 and h2
Results: ['18.7 Mbits/sec', '19.2 Mbits/sec']

ii) iperf: testing TCP bandwidth between h1 and h8
Results: ['4.02 Mbits/sec', '4.75 Mbits/sec']

b) What is the difference and explain the reasons for the difference.

Ans→ The throughput of task 3 is higher than that of task 2 in the both cases because the mac to port mapping results in lesser network congestion. Also no flooding will occur as the address and their ports are already known when packet was sent the first time. Due to this the switches will not be over-burdened with requests. In the case of h1 -> h2, we can see that task 3 has significant improvement over task 2 due to less congestion whereas from h1 -> h8, there is not that significant change due to packet dropping and more distance.