Task 1

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

The output of "nodes" is:
available nodes are:
h1 h2 h3 h4 h5 h6 h7 h8 s1 s2 s3 s4 s5 s6 s7

The output of "net" is:
h1 h1-eth0:s3-eth2
h2 h2-eth0:s3-eth3
h3 h3-eth0:s4-eth2
h4 h4-eth0:s4-eth3
h5 h5-eth0:s6-eth2
h6 h6-eth0:s6-eth3
h7 h7-eth0:s7-eth2
h8 h8-eth0:s7-eth3
s1 lo: s1-eth1:s2-eth1 s1-eth2:s5-eth1
s2 lo: s2-eth1:s1-eth1 s2-eth2:s3-eth1 s2-eth3:s4-eth1
s3 lo: s3-eth1:s2-eth2 s3-eth2:h1-eth0 s3-eth3:h2-eth0
s4 lo: s4-eth1:s2-eth3 s4-eth2:h3-eth0 s4-eth3:h4-eth0
s5 lo: s5-eth1:s1-eth2 s5-eth2:s6-eth1 s5-eth3:s7-eth1
s6 lo: s6-eth1:s5-eth2 s6-eth2:h5-eth0 s6-eth3:h6-eth0
s7 lo: s7-eth1:s5-eth3 s7-eth2:h7-eth0 s7-eth3:h8-eth0

2. What is the output of “h7 ifconfig”

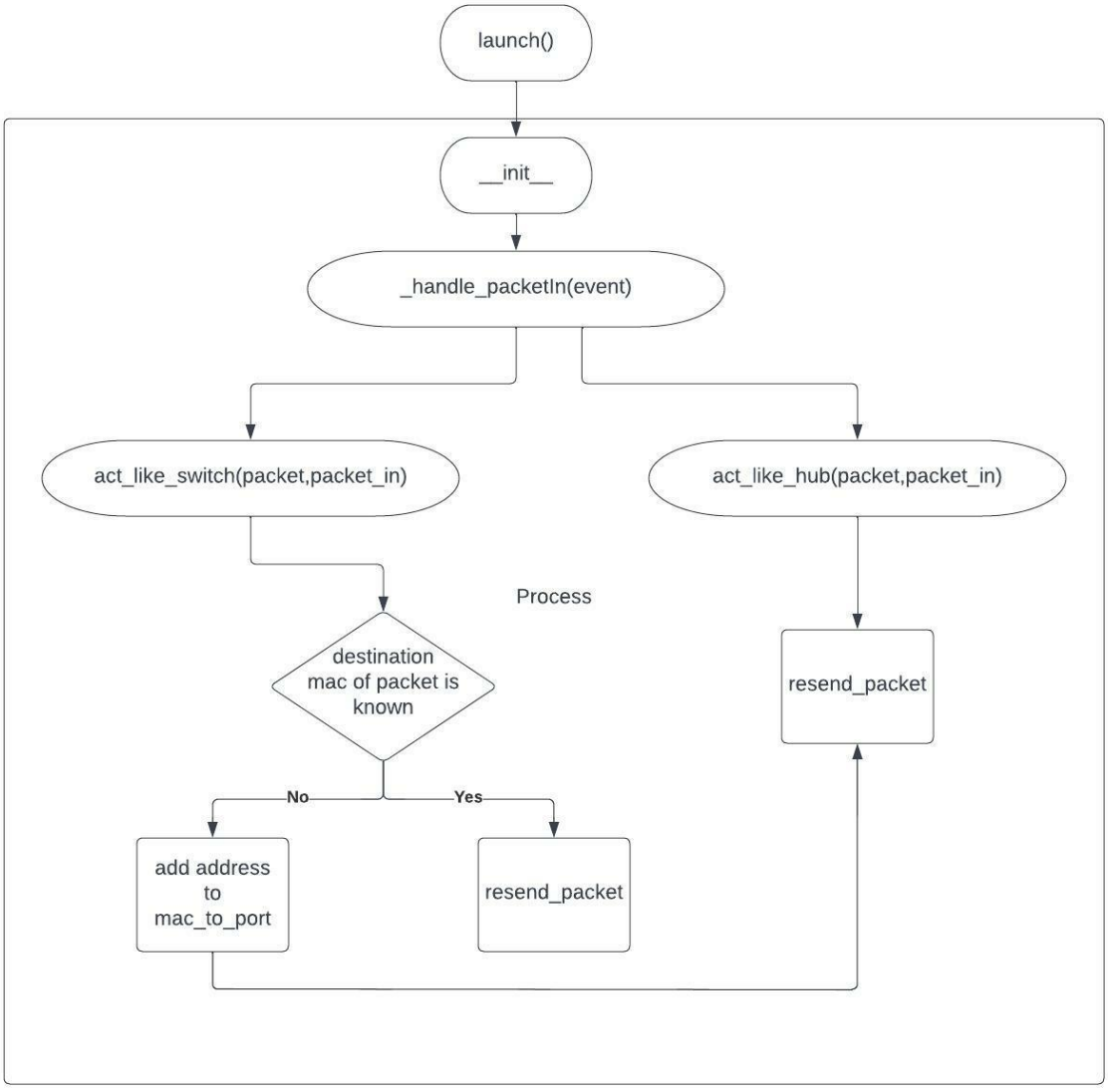
The output of "h7 ifconfig" is:
h7-eth0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
inet 10.0.0.7 netmask 255.0.0.0 broadcast 10.255.255.255
inet6 fe80::202d:4ff:fe61:ea78 prefixlen 64 scopeid 0x20<link>
ether 22:2d:04:61:ea:78 txqueuelen 1000 (Ethernet)
RX packets 237 bytes 36730 (36.7 KB)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 11 bytes 886 (886.0 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

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?



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?
b. What is the minimum and maximum ping you have observed?
c. What is the difference, and why?

h1 ping -c100 h2
--- 10.0.0.2 ping statistics ---
100 packets transmitted, 100 received, 0% packet loss, time 99179ms
rtt min/avg/max/mdev = 1.024/1.552/3.417/0.599 ms

h1 ping -c100 h8
--- 10.0.0.8 ping statistics ---
100 packets transmitted, 100 received, 0% packet loss, time 99175ms
rtt min/avg/max/mdev = 4.506/5.962/12.121/1.509 ms

Ans 2.a. h1 ping h2 - Average ping is 1.555 ms
h1 ping h8 - Average ping is 5.961 ms

Ans 2.b. h1 ping h2 - Minimum ping observed is 1.025 ms
h1 ping h8 - Minimum ping observed is 4.511 ms

h1 ping h2 - Maximum ping observed is 3.420 ms
h1 ping h8 - Maximum ping observed is 12.130 ms

Ans 2.c.
The ping times are much longer for h1 to h8 than h1 to h2, because h1 only has one switch in between itself and h2,i.e.s3, where as there are several hops between h1 and h8,i.e., s3,s2,s1,s5,s7.

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

a. What is “iperf” used for?
b. What is the throughput for each case?
c. What is the difference, and explain the reasons for the difference.

Ans 3.a.
Iperf is an open source tool for helping the administrators measure the bandwidth for the network performance and quality of a network line. The network link is restricted by two hosts running iperf. It is used to measure the throughput between any two nodes in a network line.

Ans 3.b.
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['10.8 Mbits/sec', '12.9 Mbits/sec']

mininet> iperf h1 h8
*** Iperf: testing TCP bandwidth between h1 and h8
*** Results: ['3.15 Mbits/sec', '3.73 Mbits/sec'

Ans 3.c.
The throughput is higher between h1 and h2 than h1 and h8 because of network congestion and latency (same as ping time being slower). The number of hops between h1 and h2 are less and therefore more data can be transmitted in a shorter time. While the number of hops between h1 and h8 are more, and therefore less data can be transmitted in a given 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).

By adding log.info("Switch observing traffic: %s" % (self.connection) in the line number 107 "of_tutorial" controller we can view the information which helps us to observe the traffic. After seeing that, we can conclude that all the switches view the traffic, specifically when all are flooded with packets. The _handle_PacketIn function is the event listener so it's called every time a packet is received.

Task 3

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).

In the case of operation h1 ping h2, the packet must be routed through switch's3'. When a packet p arrives from h1 on one of its input ports, mac to port checks for the presence of packet.src as the key and value as the input port. This means that the port can be used each time a packet is sent to the host specified in the key.
If the pair exists, the packet is routed to the specified port. If not, the switch learns by appending the key,value pair to mac to port and sending the packet to all ports except the input port.

2. 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?
b. What is the minimum and maximum ping you have observed?
c. Any difference from Task 2 and why do you think there is a change if there is?

h1 ping -c100 h2
--- 10.0.0.2 ping statistics ---
100 packets transmitted, 100 received, 0% packet loss, time 99170ms
rtt min/avg/max/mdev = 1.099/1.458/2.797/0.261 ms

h1 ping -c100 h8
--- 10.0.0.8 ping statistics ---
100 packets transmitted, 100 received, 0% packet loss, time 99155ms
rtt min/avg/max/mdev = 3.722/4.676/13.912/1.6534ms

Ans 2.a. h1 ping h2 - Average ping is 1.450 ms
h1 ping h8 - Average ping is 4.621 ms

Ans 2.b. h1 ping h2 - Minimum ping observed is 1.034 ms
h1 ping h8 - Minimum ping observed is 3.766 ms

h1 ping h2 - Maximum ping observed is 2.823 ms
h1 ping h8 - Maximum ping observed is 13.913 ms

Ans 2.c.
In task 3, the value for h1 ping h2 takes slightly less time than in task 2, though the difference is not statistically significant. In the case of h1 and h8, the difference in ping time values is significant because it has to go through a lot more switches. Clearly, task 3 is much faster/ has a lower ping time, because only the first few packets are flooded in task 3. Once the destination MAC address is found in the map, the switches will only resend the packet to the port that is mapped to in the "mac to port" mapping. As a result, subsequent pings are much faster because there will be less network congestion.

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

a. What is the throughput for each case?
b. What is the difference from Task 2 and why do you think there is a change if there is?

Ans 3.a
mininet> iperf h1 h2
*** Iperf: testing TCP bandwidth between h1 and h2
*** Results: ['30.1 Mbits/sec', '36.7 Mbits/sec']
mininet> iperf h1 h8
*** Iperf: testing TCP bandwidth between h1 and h8
*** Results: ['3.76 Mbits/sec', '4.29 Mbits/sec']

b.
In both cases, the throughput for task 3 is greater than that of task 2. This is due to less network congestion, as there will be no flooding of packets after mac to port map has learned all the ports, and the switches will be less burdened.
We can see in h1 and h2, task 1 and 2, that the throughput improved by approximately three times the average, given that the routes are more pre-computed and learned with controller

changes. While there is no significant improvement in the case of h1 and h8, there is a slight improvement due to the number of hops and dropped packets.