1.

```
INFO:host_tracker:Learned 3 1 00:00:00:00:00:01
INFO:host_tracker:Learned 3 1 00:00:00:00:00:01 got IP 10.0.0.1
INFO:host_tracker:Learned 6 1 00:00:00:00:00:05
INFO:host_tracker:Learned 6 1 00:00:00:00:00:05 got IP 10.0.0.5
DEBUG:forwarding.l2_learning:installing flow for 00:00:00:00:00:05.1 -> 00:00:00:00:00:01.3
DEBUG:forwarding.l2_learning:installing flow for 00:00:00:00:00:05.1 -> 00:00:00:00:00:01.3
DEBUG:forwarding.l2_learning:installing flow for 00:00:00:00:00:05.2 -> 00:00:00:00:00:01.1
DEBUG:forwarding.l2_learning:installing flow for 00:00:00:00:00:05.3 -> 00:00:00:00:00:01.1
DEBUG:forwarding.l2_learning:installing flow for 00:00:00:00:00:05.3 -> 00:00:00:00:00:01.1
DEBUG:forwarding.l2_learning:installing flow for 00:00:00:00:00:01.1 -> 00:00:00:00:00:05.3
DEBUG:forwarding.l2_learning:installing flow for 00:00:00:00:00:01.1 -> 00:00:00:00:00:05.3
DEBUG:forwarding.l2_learning:installing flow for 00:00:00:00:00:01.1 -> 00:00:00:00:00:05.2
DEBUG:forwarding.l2_learning:installing flow for 00:00:00:00:00:01.3 -> 00:00:00:00:00:05.1
DEBUG:forwarding.l2_learning:installing flow for 00:00:00:00:00:01.3 -> 00:00:00:00:00:05.1
```

POX logs following “h1 ping h5” cmd on mininet

Once the command “h1 ping h5” was sent to mininet, POV outputted4 lines to recognize the 2 flows installed on s1, one directing packets to “s1-eth1” and another to “s1-eth2”

POX logs then have 10 lines, 2 lines for each one of the 5 switches amongst the path forwarding from h1 to h5. One of the 2 lines is for the echo request when sending a ping and the second line is the echo reply from receiving a ping

2.

```
mininet> h1 ping h5
PING 10.0.0.5 (10.0.0.5) 56(84) bytes of data.
64 bytes from 10.0.0.5: icmp_seq=1 ttl=64 time=21.4 ms
64 bytes from 10.0.0.5: icmp_seq=2 ttl=64 time=0.053 ms
64 bytes from 10.0.0.5: icmp_seq=3 ttl=64 time=0.045 ms
64 bytes from 10.0.0.5: icmp_seq=4 ttl=64 time=0.082 ms
64 bytes from 10.0.0.5: icmp_seq=5 ttl=64 time=0.044 ms
```

Mininet logs RTT times for the first 5 ping messages

When comparing the RTT of the first ping to the remaining 4 there is a clear difference, the first ping took significantly longer. This difference can be explained because when the first ping was being sent, the controller would have had to calculate the route from h1 to h5 as well as install the flow rules at each bridge, but by the 2nd ping and onward, there rules would not have to be install again until they expire, shortening the RTT for the remaining pings.

3.

```
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s1
 cookie=0x0, duration=9.259s, table=0, n_packets=6, n_bytes=246,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
 cookie=0x0, duration=9.217s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s2
 cookie=0x0, duration=19.009s, table=0, n_packets=13, n_bytes=533,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
 cookie=0x0, duration=18.967s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s3
 cookie=0x0, duration=22.160s, table=0, n_packets=5, n_bytes=205,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
 cookie=0x0, duration=22.118s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s4
 cookie=0x0, duration=25.120s, table=0, n_packets=6, n_bytes=246,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
 cookie=0x0, duration=25.081s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s5
 cookie=0x0, duration=26.991s, table=0, n_packets=17, n_bytes=697,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
 cookie=0x0, duration=26.949s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s6
 cookie=0x0, duration=29.583s, table=0, n_packets=7, n_bytes=287,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
 cookie=0x0, duration=29.555s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s7
 cookie=0x0, duration=31.776s, table=0, n_packets=7, n_bytes=287,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
 cookie=0x0, duration=31.735s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
```

flow rules on all the switches both **before** the ping,

```
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s1
 cookie=0x0, duration=9.828s, table=0, n_packets=4, n_bytes=280, hard_timeout=1800,
priority=65001,dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"
 cookie=0x0, duration=9.823s, table=0, n_packets=3, n_bytes=238, hard_timeout=1800,
priority=65001,dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:05 actions=output:"s1-eth2"
 cookie=0x0, duration=88.414s, table=0, n_packets=38, n_bytes=1558,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
 cookie=0x0, duration=88.372s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s2
 cookie=0x0, duration=13.077s, table=0, n_packets=4, n_bytes=280, hard_timeout=1800,
priority=65001,dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:01 actions=output:"s2-eth1"
 cookie=0x0, duration=13.074s, table=0, n_packets=3, n_bytes=238, hard_timeout=1800,
priority=65001,dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:05 actions=output:"s2-eth3"
 cookie=0x0, duration=91.620s, table=0, n_packets=57, n_bytes=2337,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
```

```
 cookie=0x0, duration=91.578s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s3
 cookie=0x0, duration=15.201s, table=0, n_packets=4, n_bytes=280, hard_timeout=1800,
priority=65001,dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:01 actions=output:"s3-eth1"
 cookie=0x0, duration=15.201s, table=0, n_packets=3, n_bytes=238, hard_timeout=1800,
priority=65001,dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:05 actions=output:"s3-eth3"
 cookie=0x0, duration=93.746s, table=0, n_packets=20, n_bytes=820,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
 cookie=0x0, duration=93.704s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s4
 cookie=0x0, duration=95.888s, table=0, n_packets=20, n_bytes=820,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
 cookie=0x0, duration=95.849s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s5
 cookie=0x0, duration=18.951s, table=0, n_packets=4, n_bytes=280, hard_timeout=1800,
priority=65001,dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:01 actions=output:"s5-eth3"
 cookie=0x0, duration=18.942s, table=0, n_packets=3, n_bytes=238, hard_timeout=1800,
priority=65001,dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:05 actions=output:"s5-eth1"
 cookie=0x0, duration=97.490s, table=0, n_packets=59, n_bytes=2419,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
 cookie=0x0, duration=97.448s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s6
 cookie=0x0, duration=21.081s, table=0, n_packets=4, n_bytes=280, hard_timeout=1800,
priority=65001,dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:01 actions=output:"s6-eth3"
 cookie=0x0, duration=21.069s, table=0, n_packets=3, n_bytes=238, hard_timeout=1800,
priority=65001,dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:05 actions=output:"s6-eth1"
 cookie=0x0, duration=99.695s, table=0, n_packets=21, n_bytes=861,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
 cookie=0x0, duration=99.667s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s7
 cookie=0x0, duration=104.368s, table=0, n_packets=22, n_bytes=902,
priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
 cookie=0x0, duration=104.327s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef
actions=CONTROLLER:65535
```

flow rules on all the switches both **after** the ping,

The initial rules establish the connection with each switch and the controller as well as establish arp routing.

No, not all switches have newly installed flow rules after the ping, the ones that do are the ones on the routing path from h1 to h5, namly s1, s2, s3, s5, 56. Since s4 and s7 were not on the forwarding route, they do not have any newly installed flow rules.

These rules differ from those defined in part A, as these ones define a hard_timeout and a priority which will set the time limit to delete this flow after as well as the priority when overlapping rules are present. Additionally the dl_src and dl_dst do not get modified as the switches here are L2 instead of L3 as in part A.