

Part-C: Introducing the Controller

1. In the POX output, after creating the network topology, the controller will try to connect to each of the switches created.

When we try to ping h5 from h1 (h1 ping h5), we observe that POX tries to install the flow rules on each of the switches so that the switch will know where to forward the received packet. These rules include an echo request and an echo reply.

```
DEBUG:openflow.discovery:Installing flow for 00-00-00-00-00-05
DEBUG:forwarding.l2_learning:Connection [00-00-00-00-00-05 8]
INFO:openflow.discovery:link detected: 00-00-00-00-00-06.3 -> 00-00-00-00-00-05.1
INFO:openflow.discovery:link detected: 00-00-00-00-00-03.3 -> 00-00-00-00-00-02.1
INFO:openflow.discovery:link detected: 00-00-00-00-00-02.3 -> 00-00-00-00-00-01.1
INFO:openflow.discovery:link detected: 00-00-00-00-00-02.1 -> 00-00-00-00-00-03.3
INFO:openflow.discovery:link detected: 00-00-00-00-00-04.3 -> 00-00-00-00-00-02.2
INFO:openflow.discovery:link detected: 00-00-00-00-00-02.2 -> 00-00-00-00-00-04.3
INFO:openflow.discovery:link detected: 00-00-00-00-00-07.3 -> 00-00-00-00-00-05.2
INFO:openflow.discovery:link detected: 00-00-00-00-00-05.3 -> 00-00-00-00-00-01.2
INFO:openflow.discovery:link detected: 00-00-00-00-00-05.1 -> 00-00-00-00-00-06.3
INFO:openflow.discovery:link detected: 00-00-00-00-00-05.2 -> 00-00-00-00-00-07.3
INFO:openflow.discovery:link detected: 00-00-00-00-00-01.1 -> 00-00-00-00-00-02.3
INFO:openflow.discovery:link detected: 00-00-00-00-00-01.2 -> 00-00-00-00-00-05.3
DEBUG:openflow.of_01:1 connection aborted
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
```

2. As seen from logs below, The first ping took much longer than the subsequent RTTs. This is because in the first ping, the controller computes a route to route the message from one host to other (h1 to h5) and install the appropriate OVS flow rules on the switches on the route(h1->s3 -> s2 -> s1-> s5->s6->h5). However, once the rules are installed on the switches, they are not needed to reinstall until it expires, hence the shorter RTT for rest of the pings. The timeframe is in ms, since the control plane operates in milliseconds.

```
s1 s2 s3 s4 s5 s6 s7 ...
*** Starting CLI:
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=46.4 ms
64 bytes from 10.0.0.5: icmp_seq=2 ttl=64 time=0.158 ms
64 bytes from 10.0.0.5: icmp_seq=3 ttl=64 time=0.159 ms
64 bytes from 10.0.0.5: icmp_seq=4 ttl=64 time=0.107 ms
64 bytes from 10.0.0.5: icmp_seq=5 ttl=64 time=0.079 ms
64 bytes from 10.0.0.5: icmp_seq=6 ttl=64 time=0.118 ms
64 bytes from 10.0.0.5: icmp_seq=7 ttl=64 time=0.107 ms
```

3. Route traversed is: h1->s3 -> s2 -> s1-> s5->s6->-h5, hence S4 and s7 are not learned as when h5 is pinged from h1.

The rules in s4 and s7 are empty, because sending a message between h1 and h5, it only needs to go through switches s1, s2, s3, s5 and s6.

The rules defined in the switches (s1, s2, s3, s5 and s6) are like the ones defined in part A.

For example, in s1: the first rule lets the switch forward the packet sent from source 10.0.0.1 (h1) which arrives from the "s1-eth1" interface to dest 10.0.0.5 (h2) via the "s1-eth2" interface. It also defined hard_timeout and idle_timeout which will delete this flow entry after the specified interval. The src and dest MAC addresses are not modified since these are L2 switches and not L3.

The first rule sends in forward direction (echo request) and second rule is in backward direction (echo reply). The flow entry also identified the type of message the switch receives as denoted by icmp_type and icmp_code.

Before ping:

Switches: dump-flow (s1, s2, s3, s4, s5, s6, s7)

```
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s1
cookie=0x0, duration=30.036s, table=0, n_packets=16, n_bytes=656, priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
cookie=0x0, duration=29.902s, 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=87.177s, table=0, n_packets=54, n_bytes=2214, priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
cookie=0x0, duration=87.138s, 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=89.459s, table=0, n_packets=19, n_bytes=779, priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
cookie=0x0, duration=89.458s, 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=92.689s, table=0, n_packets=18, n_bytes=738, priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
cookie=0x0, duration=92.689s, 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=96.209s, table=0, n_packets=58, n_bytes=2378, priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
cookie=0x0, duration=96.153s, 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=98.607s, 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=98.572s, 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=101.861s, 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=101.861s, 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:~$
```

After Ping:

```
mininet@mininet-vm:~$ sudo ovs-ofctl dump-flows s1
cookie=0x0, duration=49.396s, table=0, n_packets=35, n_bytes=3262, hard_timeout=1800, priority=65001,dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:0
1 actions=output:"s1-eth1"
cookie=0x0, duration=49.380s, table=0, n_packets=34, n_bytes=3220, hard_timeout=1800, priority=65001,dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:0
5 actions=output:"s1-eth2"
cookie=0x0, duration=210.447s, table=0, n_packets=87, n_bytes=3567, priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
cookie=0x0, duration=210.313s, 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=52.976s, table=0, n_packets=35, n_bytes=3262, hard_timeout=1800, priority=65001,dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:0
1 actions=output:"s2-eth1"
cookie=0x0, duration=52.970s, table=0, n_packets=34, n_bytes=3220, hard_timeout=1800, priority=65001,dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:0
5 actions=output:"s2-eth3"
cookie=0x0, duration=213.880s, table=0, n_packets=129, n_bytes=5289, priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
cookie=0x0, duration=213.841s, 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=55.166s, table=0, n_packets=35, n_bytes=3262, hard_timeout=1800, priority=65001,dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:0
1 actions=output:"s3-eth1"
cookie=0x0, duration=55.164s, table=0, n_packets=34, n_bytes=3220, hard_timeout=1800, priority=65001,dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:0
5 actions=output:"s3-eth3"
cookie=0x0, duration=216.034s, table=0, n_packets=44, n_bytes=1804, priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
cookie=0x0, duration=216.033s, 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=218.384s, table=0, n_packets=0, n_bytes=0, priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
cookie=0x0, duration=218.384s, 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=60.243s, table=0, n_packets=35, n_bytes=3262, hard_timeout=1800, priority=65001,dl_src=00:00:00:00:05,dl_dst=00:00:00:00:00:00,actions=output:"s5-eth3"
1
cookie=0x0, duration=60.214s, table=0, n_packets=34, n_bytes=3220, hard_timeout=1800, priority=65001,dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:00,actions=output:"s5-eth1"
5
cookie=0x0, duration=221.097s, table=0, n_packets=132, n_bytes=5412, priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
cookie=0x0, duration=221.041s, 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=62.653s, table=0, n_packets=35, n_bytes=3262, hard_timeout=1800, priority=65001,dl_src=00:00:00:00:00:05,dl_dst=00:00:00:00:00:00,actions=output:"s6-eth3"
1
cookie=0x0, duration=62.619s, table=0, n_packets=34, n_bytes=3220, hard_timeout=1800, priority=65001,dl_src=00:00:00:00:00:01,dl_dst=00:00:00:00:00:00,actions=output:"s6-eth1"
5
cookie=0x0, duration=223.548s, table=0, n_packets=47, n_bytes=1927, priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
cookie=0x0, duration=223.513s, 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=225.865s, table=0, n_packets=47, n_bytes=1927, priority=65000,dl_dst=01:23:20:00:00:01,dl_type=0x88cc actions=CONTROLLER:65535
cookie=0x0, duration=225.865s, table=0, n_packets=0, n_bytes=0, priority=32769,arp,dl_dst=02:00:00:00:be:ef actions=CONTROLLER:65535
```