TRƯỜNG ĐẠI HỌC KHOA HỌC TỰ NHIÊN

ĐẠI HỌC QUỐC GIA THÀNH PHỐ HỒ CHÍ MINH

- KHOA CÔNG NGHỆ THÔNG TIN -

BÁO CÁO ĐỒ ÁN NHÓM

Môn: Mạng máy tính nâng cao

ĐỒ ÁN SDN

|MÃ MÔN HỌC|

CSC11004

Mục lục

1. Thông tin nhóm

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2. Cài đặt

Cài đặt Topo Linear với 4 switch (mỗi switch 1 host)

```
mininet@mininet-vm:~$ sudo -E mn --controller=remote,ip=127.0.0.1 --mac -i 10.1.1.0/24
--switch=ovsk --topo=linear,4
*** Creating network
*** Adding controller
Unable to contact the remote controller at 127.0.0.1:6653
Unable to contact the remote controller at 127.0.0.1:6633
Setting remote controller to 127.0.0.1:6653
*** Adding hosts:
h1 h2 h3 h4
*** Adding switches:
s1 s2 s3 s4
*** Adding links:
(h1, s1) (h2, s2) (h3, s3) (h4, s4) (s2, s1) (s3, s2) (s4, s3)
*** Configuring hosts
h1 h2 h3 h4
*** Starting controller
c0
*** Starting 4 switches
s1 s2 s3 s4 ...
*** Starting CLI:
mininet>
```

Chạy POX controllervới l2_pairs

```
mininet@mininet-vm:~$      sudo      ~/pox/pox.py      forwarding.l2_pairs      info.packet_dump
samples.pretty_log log.level --DEBUG
POX 0.7.0 (gar) / Copyright 2011-2020 James McCauley, et al.
INFO:forwarding.l2_pairs:Pair-Learning switch running.
INFO:info.packet_dump:Packet dumper running
[core                    ] POX 0.7.0 (gar) going up...
[core                    ] Running on CPython (3.8.5/Jul 28 2020 12:59:40)
[core                    ] Platform is Linux-5.4.0-42-generic-x86_64-with-glibc2.29
[version                 ] Support for Python 3 is experimental.
[core                    ] POX 0.7.0 (gar) is up.
[openflow.of_01          ] Listening on 0.0.0.0:6633
[openflow.of_01          ] [00-00-00-00-00-04 2] connected
[openflow.of_01          ] [00-00-00-00-00-01 3] connected
[openflow.of_01          ] [00-00-00-00-00-03 4] connected
[openflow.of_01          ] [00-00-00-00-00-02 5] connected
```

3. Đánh giá nội dung thực hiện

Yêu cầu 1: sửa l2_pairs.py thành ứng dụng chạy theo kịch bản của phần 3.5.2.
Đánh giá: hoàn thành 100%

Theo như quá trình trao đổi giữa 2 host **h1** và **h2** trong phần 3.5.2 được tóm tắt theo sơ đồ dưới, ta thấy controller chỉ cài flow khi đã biết được chính xác nguồn và đích. Và flow chỉ cài 1 chiều từ nguồn tới đích (không như l2_pairs.py gốc, cài 2 chiều)
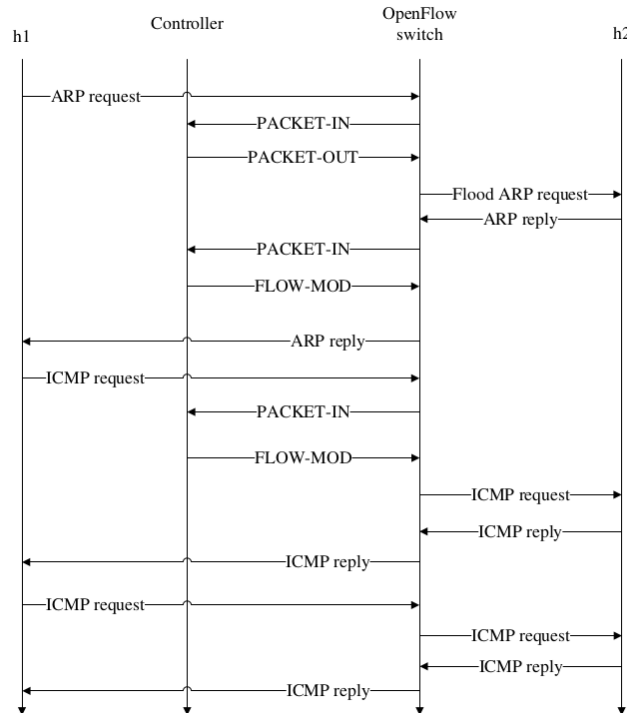
Đây là code cài đặt flow khi controller biết rõ thông tin của nguồn và đích

```
79  else:
80      # This is the packet that just came in -- we want to
81      # install the rule
82      log.debug('>> FLOW MOD')
83      msg = of.ofp_flow_mod()
84      msg.data = event.ofp # Forward the incoming packet
85      msg.match.dl_src = packet.src
86      msg.match.dl_dst = packet.dst
87
88      msg.hard_timeout = 20 # REQUIRE 2: every rule has hard_timeout = 20s
89
90      msg.actions.append(of.ofp_action_output(port = dst_port))
91      event.connection.send(msg)
92
93      log.debug("Installing %s -> %s" % (packet.src, packet.dst))
94
```

Yêu cầu 2 : Thêm thời gian "hard timeout" của mỗi luật là 20s
Đánh giá: hoàn thành 100%

Ở dòng 88 thêm dòng lệnh **msg.hard_timeout=20** để cài đặt cho thời gian hard time out cho flow khi nó mới được cài

```
88      msg.hard_timeout = 20 # REQUIRE 2: every rule has hard_timeout = 20s
```

Yêu cầu 3: với tất cả các gói tin từ h1 thì switch sẽ FLOOD mà không quan tâm gói tin đó như thế nào

Đánh giá: hoàn thành 100%

Để xác định gói tin đó từ **h1**, em thêm điều kiện kiểm tra `if packet.src == "00:00:00:00:00:01"`, nếu đúng thì sẽ **FLOOD** ngoài ra nếu destination port không xác định, em cũng sẽ **FLOOD**

```
63    if packet.src == "00:00:00:00:00:01" or dst_port is None:
64        # REQUIRE 3: all packet from 'h1'  -> FLOOD
65        # We don't know where the destination is yet or this packet from 'h1'.
66        # So, we'll just send the packet out all ports (except the one it
67        # came in on!) and hope the destination is out there somewhere. :)
68        msg = of.ofp_packet_out(data = event.ofp)
69        msg.actions.append(of.ofp_action_output(port = all_ports))
70        event.connection.send(msg)
71        log.debug('>> FLOOD')
```

Yêu cầu 4: Switch chỉ chấp nhận chuyển tiếp đến host "h2" khi port đến h2 là cổng 80, ngoài port 80 thì switch ko chấp nhân và hủy gói tin.

Đánh giá: hoàn thành 100%

Ở đây em điều kiện để xác định đích đến là **h2** và có phải có **port 80** không thì em thêm diều kiện `elif packet.dst == "00:00:00:00:00:02" and dst_port != 80:`, nếu đích đến đúng là **h2** nhưng **port khác 80** thì sẽ **drop packet** đó, ngược lại sẽ **gửi đi**

```
73    elif packet.dst == "00:00:00:00:00:02" and dst_port != 80:
74        # REQUIRE 4: only allow transmit packet to 'h2' when its dst port is 80
75        # otherwise, drop this packet
76        log.debug('>> H2 - DROP')
77        drop(event)
```

4. Kiểm tra

h1 ping h2

```
mininet> h1 ping h2 -c 1
PING 10.1.1.2 (10.1.1.2) 56(84) bytes of data.
64 bytes from 10.1.1.2: icmp_seq=1 ttl=64 time=10.7 ms

--- 10.1.1.2 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 10.675/10.675/10.675/0.000 ms

mininet> dpctl dump-flows
*** s1 ------------------------------------------------------------------------
 cookie=0x0,   duration=9.920s,   table=0,   n_packets=3,   n_bytes=182,   hard_timeout=20,
dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"
*** s2 ------------------------------------------------------------------------
 cookie=0x0,   duration=9.936s,   table=0,   n_packets=3,   n_bytes=182,   hard_timeout=20,
dl_src=00:00:00:00:00:02,dl_dst=00:00:00:00:00:01 actions=output:"s2-eth2"
*** s3 ------------------------------------------------------------------------
*** s4 ------------------------------------------------------------------------
```

Sau 20s dump lại:

```
mininet> dpctl dump-flows
*** s1 ------------------------------------------------------------------
*** s2 ------------------------------------------------------------------
*** s3 ------------------------------------------------------------------
*** s4 ------------------------------------------------------------------
```

Log của controller

```
mininet@mininet-vm:~$    sudo    ~/pox/pox.py    forwarding.l2_pairs    info.packet_dump
samples.pretty_log log.level --DEBUG
POX 0.7.0 (gar) / Copyright 2011-2020 James McCauley, et al.
INFO:forwarding.l2_pairs:Pair-Learning switch running.
INFO:info.packet_dump:Packet dumper running
[core                      ] POX 0.7.0 (gar) going up...
[core                      ] Running on CPython (3.8.5/Jul 28 2020 12:59:40)
[core                      ] Platform is Linux-5.4.0-42-generic-x86_64-with-glibc2.29
[version                   ] Support for Python 3 is experimental.
[core                      ] POX 0.7.0 (gar) is up.
[openflow.of_01            ] Listening on 0.0.0.0:6633
[openflow.of_01            ] [00-00-00-00-00-04 2] connected
[openflow.of_01            ] [00-00-00-00-00-01 3] connected
[openflow.of_01            ] [00-00-00-00-00-03 4] connected
[openflow.of_01            ] [00-00-00-00-00-02 5] connected
[forwarding.l2_pairs       ] ----------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:01 -- port: 1
[forwarding.l2_pairs       ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs       ] >> FLOOD
[dump:00-00-00-00-00-01 ] [ethernet][arp]
[forwarding.l2_pairs       ] ----------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs       ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs       ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][arp]
[forwarding.l2_pairs       ] ----------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs       ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs       ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs       ] ----------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:02 -- port: 1
[forwarding.l2_pairs       ] Packet dest    : 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs       ] >> FLOW MOD
[forwarding.l2_pairs       ] Installing 00:00:00:00:00:02 -> 00:00:00:00:00:01
[dump:00-00-00-00-00-02 ] [ethernet][arp]
[forwarding.l2_pairs       ] ----------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs       ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs       ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][arp]
[forwarding.l2_pairs       ] ----------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs       ] Packet dest    : 00:00:00:00:00:01 -- port: 1
[forwarding.l2_pairs       ] >> FLOW MOD
[forwarding.l2_pairs       ] Installing 00:00:00:00:00:02 -> 00:00:00:00:00:01
[dump:00-00-00-00-00-01 ] [ethernet][arp]
[forwarding.l2_pairs       ] ----------------------------------------
```

```
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 1
[forwarding.l2_pairs      ] Packet dest   : 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-01 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs      ] ----------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest   : 00:00:00:00:00:02 -- port: 1
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs      ] ----------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest   : 00:00:00:00:00:02 -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs      ] ----------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest   : 00:00:00:00:00:02 -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs      ] ----------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 1
[forwarding.l2_pairs      ] Packet dest   : 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-01 ] [ethernet][arp]
[forwarding.l2_pairs      ] ----------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest   : 00:00:00:00:00:02 -- port: 1
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][arp]
[forwarding.l2_pairs      ] ----------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest   : 00:00:00:00:00:02 -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs      ] ----------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest   : 00:00:00:00:00:02 -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][arp]
```

h1 ping h3

```
mininet> h1 ping h3 -c 1
PING 10.1.1.3 (10.1.1.3) 56(84) bytes of data.
64 bytes from 10.1.1.3: icmp_seq=1 ttl=64 time=10.0 ms

--- 10.1.1.3 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 10.025/10.025/10.025/0.000 ms

mininet> dpctl dump-flows
*** s1 ------------------------------------------------------------------
 cookie=0x0,    duration=9.888s,    table=0,    n_packets=3,    n_bytes=182,    hard_timeout=20,
dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"
*** s2 ------------------------------------------------------------------
 cookie=0x0,    duration=9.892s,    table=0,    n_packets=3,    n_bytes=182,    hard_timeout=20,
```

```
dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:01 actions=output:"s2-eth2"
*** s3 ------------------------------------------------------------------
  cookie=0x0,    duration=9.898s,    table=0,    n_packets=3,    n_bytes=182,    hard_timeout=20,
dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:01 actions=output:"s3-eth2"
*** s4 ------------------------------------------------------------------
```

Log của controller

```
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 1
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-01 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:03 -- port: 1
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] >> FLOW MOD
[forwarding.l2_pairs      ] Installing 00:00:00:00:00:03 -> 00:00:00:00:00:01
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:03 -- port: 3
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] >> FLOW MOD
[forwarding.l2_pairs      ] Installing 00:00:00:00:00:03 -> 00:00:00:00:00:01
[dump:00-00-00-00-00-02 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:03 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:01 -- port: 1
[forwarding.l2_pairs      ] >> FLOW MOD
[forwarding.l2_pairs      ] Installing 00:00:00:00:00:03 -> 00:00:00:00:00:01
[dump:00-00-00-00-00-01 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 1
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:03 -- port: 2
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-01 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:03 -- port: 3
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs      ] ------------------------------------------
```

```
[forwarding.l2_pairs    ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs    ] Packet dest    : 00:00:00:00:00:03 -- port: 1
[forwarding.l2_pairs    ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs    ] ----------------------------------------
[forwarding.l2_pairs    ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs    ] Packet dest    : 00:00:00:00:00:03 -- port: None
[forwarding.l2_pairs    ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs    ] ----------------------------------------
[forwarding.l2_pairs    ] Packet source: 00:00:00:00:00:01 -- port: 1
[forwarding.l2_pairs    ] Packet dest    : 00:00:00:00:00:03 -- port: 2
[forwarding.l2_pairs    ] >> FLOOD
[dump:00-00-00-00-00-01 ] [ethernet][arp]
[forwarding.l2_pairs    ] ----------------------------------------
[forwarding.l2_pairs    ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs    ] Packet dest    : 00:00:00:00:00:03 -- port: 3
[forwarding.l2_pairs    ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][arp]
[forwarding.l2_pairs    ] ----------------------------------------
[forwarding.l2_pairs    ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs    ] Packet dest    : 00:00:00:00:00:03 -- port: 1
[forwarding.l2_pairs    ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs    ] ----------------------------------------
[forwarding.l2_pairs    ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs    ] Packet dest    : 00:00:00:00:00:03 -- port: None
[forwarding.l2_pairs    ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][arp]
```

h2 ping h3

```
mininet> h2 ping h3 -c 1
PING 10.1.1.3 (10.1.1.3) 56(84) bytes of data.
From 10.1.1.2 icmp_seq=1 Destination Host Unreachable

--- 10.1.1.3 ping statistics ---
1 packets transmitted, 0 received, +1 errors, 100% packet loss, time 0ms

mininet> dpctl dump-flows
*** s1 ------------------------------------------------------------------------
*** s2 ------------------------------------------------------------------------
*** s3 ------------------------------------------------------------------------
*** s4 ------------------------------------------------------------------------
```

Log của controller

```
[forwarding.l2_pairs    ] ----------------------------------------
[forwarding.l2_pairs    ] Packet source: 00:00:00:00:00:02 -- port: 1
[forwarding.l2_pairs    ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs    ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][arp]
[forwarding.l2_pairs    ] ----------------------------------------
[forwarding.l2_pairs    ] Packet source: 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs    ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs    ] >> FLOOD
```

```
[dump:00-00-00-00-00-01 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:03 -- port: 1
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs      ] >> H2 - DROP
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:02 -- port: 1
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-01 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:03 -- port: 1
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs      ] >> H2 - DROP
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:02 -- port: 1
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-01 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs      ] ------------------------------------------
```

```
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][arp]
[forwarding.l2_pairs      ] -----------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:03 -- port: 1
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:02 -- port: 2
[forwarding.l2_pairs      ] >> H2 - DROP
[dump:00-00-00-00-00-03 ] [ethernet][arp]
```

h3 ping h4

```
mininet> h3 ping h4 -c 1
PING 10.1.1.4 (10.1.1.4) 56(84) bytes of data.
64 bytes from 10.1.1.4: icmp_seq=1 ttl=64 time=33.6 ms

--- 10.1.1.4 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 33.562/33.562/33.562/0.000 ms

mininet> dpctl dump-flows
*** s1 ------------------------------------------------------------------
*** s2 ------------------------------------------------------------------
*** s3 ------------------------------------------------------------------
 cookie=0x0,    duration=4.146s,    table=0,    n_packets=2,    n_bytes=140,    hard_timeout=20,
dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:03 actions=output:"s3-eth1"
 cookie=0x0,    duration=4.142s,    table=0,    n_packets=1,    n_bytes=98,    hard_timeout=20,
dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:04 actions=output:"s3-eth3"
*** s4 ------------------------------------------------------------------
 cookie=0x0,    duration=4.156s,    table=0,    n_packets=2,    n_bytes=140,    hard_timeout=20,
dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:03 actions=output:"s4-eth2"
 cookie=0x0,    duration=4.143s,    table=0,    n_packets=1,    n_bytes=98,    hard_timeout=20,
dl_src=00:00:00:00:00:03,dl_dst=00:00:00:00:00:04 actions=output:"s4-eth1"
```

Log của controller

```
[forwarding.l2_pairs      ] -----------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:03 -- port: 1
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs      ] -----------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:03 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][arp]
[forwarding.l2_pairs      ] -----------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:03 -- port: 3
[forwarding.l2_pairs      ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][arp]
[forwarding.l2_pairs      ] -----------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:04 -- port: 1
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:03 -- port: 2
[forwarding.l2_pairs      ] >> FLOW MOD
```

```
[forwarding.l2_pairs     ] Installing 00:00:00:00:00:04 -> 00:00:00:00:00:03
[dump:00-00-00-00-00-04 ] [ethernet][arp]
[forwarding.l2_pairs     ] -------------------------------------------
[forwarding.l2_pairs     ] Packet source: 00:00:00:00:00:03 -- port: 2
[forwarding.l2_pairs     ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs     ] >> FLOOD
[dump:00-00-00-00-00-01 ] [ethernet][arp]
[forwarding.l2_pairs     ] -------------------------------------------
[forwarding.l2_pairs     ] Packet source: 00:00:00:00:00:04 -- port: 3
[forwarding.l2_pairs     ] Packet dest    : 00:00:00:00:00:03 -- port: 1
[forwarding.l2_pairs     ] >> FLOW MOD
[forwarding.l2_pairs     ] Installing 00:00:00:00:00:04 -> 00:00:00:00:00:03
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs     ] -------------------------------------------
[forwarding.l2_pairs     ] Packet source: 00:00:00:00:00:03 -- port: 1
[forwarding.l2_pairs     ] Packet dest    : 00:00:00:00:00:04 -- port: 3
[forwarding.l2_pairs     ] >> FLOW MOD
[forwarding.l2_pairs     ] Installing 00:00:00:00:00:03 -> 00:00:00:00:00:04
[dump:00-00-00-00-00-03 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs     ] -------------------------------------------
[forwarding.l2_pairs     ] Packet source: 00:00:00:00:00:03 -- port: 2
[forwarding.l2_pairs     ] Packet dest    : 00:00:00:00:00:04 -- port: 1
[forwarding.l2_pairs     ] >> FLOW MOD
[forwarding.l2_pairs     ] Installing 00:00:00:00:00:03 -> 00:00:00:00:00:04
[dump:00-00-00-00-00-04 ] [ethernet][ipv4][icmp][echo][56 bytes]
```

h4 ping h1

```
mininet> h4 ping h1 -c 1
PING 10.1.1.1 (10.1.1.1) 56(84) bytes of data.
64 bytes from 10.1.1.1: icmp_seq=1 ttl=64 time=14.7 ms


--- 10.1.1.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 14.688/14.688/14.688/0.000 ms

mininet> dpctl dump-flows
*** s1 ------------------------------------------------------------------
 cookie=0x0,    duration=1.931s,    table=0,    n_packets=1,    n_bytes=98,    hard_timeout=20,
dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01 actions=output:"s1-eth1"
*** s2 ------------------------------------------------------------------
 cookie=0x0,    duration=1.935s,    table=0,    n_packets=1,    n_bytes=98,    hard_timeout=20,
dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01 actions=output:"s2-eth2"
*** s3 ------------------------------------------------------------------
 cookie=0x0,    duration=1.940s,    table=0,    n_packets=1,    n_bytes=98,    hard_timeout=20,
dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01 actions=output:"s3-eth2"
*** s4 ------------------------------------------------------------------
 cookie=0x0,    duration=1.945s,    table=0,    n_packets=1,    n_bytes=98,    hard_timeout=20,
dl_src=00:00:00:00:00:04,dl_dst=00:00:00:00:00:01 actions=output:"s4-eth2"
```

Log của controller

```
[forwarding.l2_pairs     ] -------------------------------------------
[forwarding.l2_pairs     ] Packet source: 00:00:00:00:00:04 -- port: 1
[forwarding.l2_pairs     ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
```

```
[forwarding.l2_pairs       ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][arp]
[forwarding.l2_pairs       ] -------------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:04 -- port: 3
[forwarding.l2_pairs       ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs       ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs       ] -------------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:04 -- port: 3
[forwarding.l2_pairs       ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs       ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][arp]
[forwarding.l2_pairs       ] -------------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:04 -- port: 2
[forwarding.l2_pairs       ] Packet dest    : ff:ff:ff:ff:ff:ff -- port: None
[forwarding.l2_pairs       ] >> FLOOD
[dump:00-00-00-00-00-01 ] [ethernet][arp]
[forwarding.l2_pairs       ] -------------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:01 -- port: 1
[forwarding.l2_pairs       ] Packet dest    : 00:00:00:00:00:04 -- port: 2
[forwarding.l2_pairs       ] >> FLOOD
[dump:00-00-00-00-00-01 ] [ethernet][arp]
[forwarding.l2_pairs       ] -------------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs       ] Packet dest    : 00:00:00:00:00:04 -- port: 3
[forwarding.l2_pairs       ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][arp]
[forwarding.l2_pairs       ] -------------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs       ] Packet dest    : 00:00:00:00:00:04 -- port: 3
[forwarding.l2_pairs       ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs       ] -------------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs       ] Packet dest    : 00:00:00:00:00:04 -- port: 1
[forwarding.l2_pairs       ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][arp]
[forwarding.l2_pairs       ] -------------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:04 -- port: 1
[forwarding.l2_pairs       ] Packet dest    : 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs       ] >> FLOW MOD
[forwarding.l2_pairs       ] Installing 00:00:00:00:00:04 -> 00:00:00:00:00:01
[dump:00-00-00-00-00-04 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs       ] -------------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:04 -- port: 3
[forwarding.l2_pairs       ] Packet dest    : 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs       ] >> FLOW MOD
[forwarding.l2_pairs       ] Installing 00:00:00:00:00:04 -> 00:00:00:00:00:01
[dump:00-00-00-00-00-03 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs       ] -------------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:04 -- port: 3
[forwarding.l2_pairs       ] Packet dest    : 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs       ] >> FLOW MOD
[forwarding.l2_pairs       ] Installing 00:00:00:00:00:04 -> 00:00:00:00:00:01
[dump:00-00-00-00-00-02 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs       ] -------------------------------------------
[forwarding.l2_pairs       ] Packet source: 00:00:00:00:00:04 -- port: 2
```

```
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:01 -- port: 1
[forwarding.l2_pairs      ] >> FLOW MOD
[forwarding.l2_pairs      ] Installing 00:00:00:00:00:04 -> 00:00:00:00:00:01
[dump:00-00-00-00-00-01 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs      ] -------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 1
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:04 -- port: 2
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-01 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs      ] -------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:04 -- port: 3
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs      ] -------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:04 -- port: 3
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs      ] -------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:04 -- port: 1
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][ipv4][icmp][echo][56 bytes]
[forwarding.l2_pairs      ] -------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 1
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:04 -- port: 2
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-01 ] [ethernet][arp]
[forwarding.l2_pairs      ] -------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:04 -- port: 3
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-02 ] [ethernet][arp]
[forwarding.l2_pairs      ] -------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:04 -- port: 3
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-03 ] [ethernet][arp]
[forwarding.l2_pairs      ] -------------------------------------------
[forwarding.l2_pairs      ] Packet source: 00:00:00:00:00:01 -- port: 2
[forwarding.l2_pairs      ] Packet dest    : 00:00:00:00:00:04 -- port: 1
[forwarding.l2_pairs      ] >> FLOOD
[dump:00-00-00-00-00-04 ] [ethernet][arp]
```