

南京大学本科生实验报告

课程名称：计算机网络 任课教师：田臣/李文中 助教：

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实验名称

Lab2

实验目的

对交换机的机制进行熟悉

实验内容

对交换机节点进行配置

实验结果

Task2

本实验是对集线器代码的修改，完成交换机功能的配置。交换机的主要工作逻辑是区分是否是广播地址，区分源地址和目的地址是否在交换机表中，若源地址不在交换机表中则添加，若目的地址不在交换机表中，则向除源节点外的节点广播。

根据以上逻辑编写代码（源码见 `myswitch.py`）

在client节点中 `ping -c 2 192.168.100.1`

```
root@njucs-VirtualBox:~/switchyard/lab-02-wjrzm# ping -c 2 192.168.100.1
PING 192.168.100.1 (192.168.100.1) 56(84) bytes of data.
64 bytes from 192.168.100.1: icmp_seq=1 ttl=64 time=836 ms
64 bytes from 192.168.100.1: icmp_seq=2 ttl=64 time=462 ms

--- 192.168.100.1 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1000ms
rtt min/avg/max/mdev = 462.629/649.438/836.247/186.809 ms
root@njucs-VirtualBox:~/switchyard/lab-02-wjrzm# SSS
```

可以观察到如下INFO，和交换机的逻辑一致

```
(syenv) root@njucs-VirtualBox:~/switchyard/lab-02-wjrz# swyard myswitch.py
14:39:30 2022/03/21      INFO Saving iptables state and installing switchyard rules
14:39:30 2022/03/21      INFO Using network devices: switch-eth1 switch-eth2 switch-eth0
14:41:23 2022/03/21      INFO Received a boardcast which src is not saved
14:41:23 2022/03/21      INFO Broadcasting packet Ethernet 30:00:00:00:00:01->ff:ff:ff:ff:ff:ff ARP | Arp 30:00:00:00:00:01:192.168.100.3 00:00:00:00:00:00:192.168.100.1 to switch-eth1
14:41:23 2022/03/21      INFO Broadcasting packet Ethernet 30:00:00:00:00:01->ff:ff:ff:ff:ff:ff ARP | Arp 30:00:00:00:00:01:192.168.100.3 00:00:00:00:00:00:192.168.100.1 to switch-eth0
14:41:23 2022/03/21      INFO Received a packet which src is not saved
14:41:23 2022/03/21      INFO Flooding packet Ethernet 10:00:00:00:00:01->30:00:00:00:00:01 ARP | Arp 10:00:00:00:00:01:192.168.100.1 30:00:00:00:00:01:192.168.100.3 to switch-eth2
```

```
14:41:23 2022/03/21      INFO Received a packet which src already is saved
14:41:23 2022/03/21      INFO Flooding packet Ethernet 30:00:00:00:00:01->10:00:00:00:00:01 IP | IPv4 192.168.100.3->192.168.100.1 ICMP | ICMP EchoRequest 4540 1 (56 data bytes) to switch-eth0
14:41:24 2022/03/21      INFO Received a packet which src already is saved
14:41:24 2022/03/21      INFO Flooding packet Ethernet 10:00:00:00:00:01->30:00:00:00:00:01 IP | IPv4 192.168.100.1->192.168.100.3 ICMP | ICMP EchoReply 4540 1 (56 data bytes) to switch-eth2
14:41:24 2022/03/21      INFO Received a packet which src already is saved
14:41:24 2022/03/21      INFO Flooding packet Ethernet 30:00:00:00:00:01->10:00:00:00:00:01 IP | IPv4 192.168.100.3->192.168.100.1 ICMP | ICMP EchoRequest 4540 2 (56 data bytes) to switch-eth0
14:41:24 2022/03/21      INFO Received a packet which src already is saved
14:41:24 2022/03/21      INFO Flooding packet Ethernet 10:00:00:00:00:01->30:00:00:00:00:01 IP | IPv4 192.168.100.1->192.168.100.3 ICMP | ICMP EchoReply 4540 2 (56 data bytes) to switch-eth2
14:41:29 2022/03/21      INFO Received a packet which src already is saved
14:41:29 2022/03/21      INFO Flooding packet Ethernet 10:00:00:00:00:01->30:00:00:00:00:01 ARP | Arp 10:00:00:00:00:01:192.168.100.1 00:00:00:00:00:00:192.168.100.3 to switch-eth2
14:41:29 2022/03/21      INFO Received a packet which src already is saved
14:41:29 2022/03/21      INFO Flooding packet Ethernet 30:00:00:00:00:01->10:00:00:00:00:01 ARP | Arp 30:00:00:00:00:01:192.168.100.3 10:00:00:00:00:01:192.168.100.1 to switch-eth0
```

server1中有如下信息：

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	30:00:00:00:00:01	Broadcast	ARP	42	Who has 192.168.100.1? Tell 192.168.100.3
2	0.100225825	Private_00:00:01	30:00:00:00:00:01	ARP	42	192.168.100.1 is at 10:00:00:00:00:01
3	0.411621916	192.168.100.3	192.168.100.1	ICMP	98	Echo (ping) request id=0x0ee4, seq=1/256, ttl=64 (req
4	0.511882853	192.168.100.1	192.168.100.3	ICMP	98	Echo (ping) reply id=0x0ee4, seq=1/256, ttl=64 (req
5	1.036766086	192.168.100.3	192.168.100.1	ICMP	98	Echo (ping) request id=0x0ee4, seq=2/512, ttl=64 (req
6	1.137590732	192.168.100.1	192.168.100.3	ICMP	98	Echo (ping) reply id=0x0ee4, seq=2/512, ttl=64 (req
7	5.739432429	Private_00:00:01	30:00:00:00:00:01	ARP	42	Who has 192.168.100.3? Tell 192.168.100.1
8	6.062372296	30:00:00:00:00:01	Private_00:00:01	ARP	42	192.168.100.3 is at 30:00:00:00:00:01

server2有如下信息：

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	30:00:00:00:00:01	Broadcast	ARP	42	Who has 192.168.100.1? Tell 192.168.100.3

可见，client首先向交换机发送广播，交换机表记录client的MAC和PORT，并向server1,server2广播，server1向交换机发送送给client的信息，交换机表记录server1的MAC和PORT，并在表中查询到client的mac，发向其对应的端口。随后client和server1进行ICMP协议的消息传输，一共有两个来回。最后server1发送给交换机发向client的信息，交换机查表将消息发送个client对应端口，server1通过arp协议完成了ip地址转换成mac地址的任务，最后client发向server1，交换机将信息转发给对应的端口。而server2中仅收到了广播信息，并未做出回应。

Task3

按照手册里面的流程图进行代码编写，在原本的交换机代码中加入计时功能。

引入类：

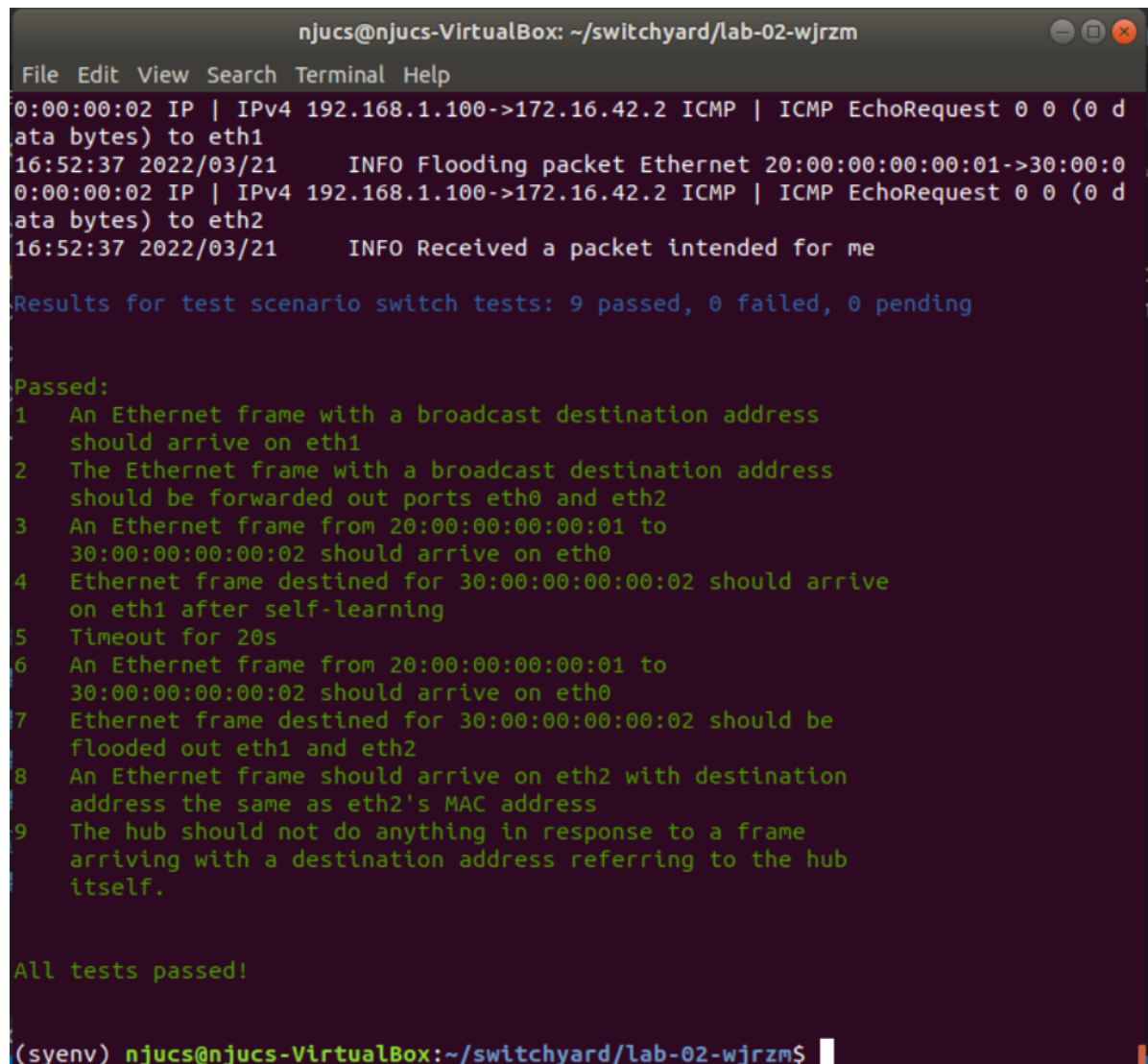
```
class table:
    def __init__(self, macs, ports, timestamps):
        self.mac = macs
        self.port = ports
        self.timestamp = timestamps
```

加入对时间的判断：

```
index = 0
while index < len(list_table):
    temp_time = time.time()
    if temp_time - list_table[index].timestamp >= 10:
        del(list_table[index])
    else:
        index += 1
```

程序源码见 `myswitch_to.py`

运行手册提供的测试代码，结果如下：



```
njucs@njucs-VirtualBox: ~/switchyard/lab-02-wjrz
File Edit View Search Terminal Help
0:00:00:02 IP | IPv4 192.168.1.100->172.16.42.2 ICMP | ICMP EchoRequest 0 0 (0 d
ata bytes) to eth1
16:52:37 2022/03/21      INFO Flooding packet Ethernet 20:00:00:00:00:01->30:00:0
0:00:00:02 IP | IPv4 192.168.1.100->172.16.42.2 ICMP | ICMP EchoRequest 0 0 (0 d
ata bytes) to eth2
16:52:37 2022/03/21      INFO Received a packet intended for me
Results for test scenario switch tests: 9 passed, 0 failed, 0 pending

Passed:
1  An Ethernet frame with a broadcast destination address
   should arrive on eth1
2  The Ethernet frame with a broadcast destination address
   should be forwarded out ports eth0 and eth2
3  An Ethernet frame from 20:00:00:00:00:01 to
   30:00:00:00:00:02 should arrive on eth0
4  Ethernet frame destined for 30:00:00:00:00:02 should arrive
   on eth1 after self-learning
5  Timeout for 20s
6  An Ethernet frame from 20:00:00:00:00:01 to
   30:00:00:00:00:02 should arrive on eth0
7  Ethernet frame destined for 30:00:00:00:00:02 should be
   flooded out eth1 and eth2
8  An Ethernet frame should arrive on eth2 with destination
   address the same as eth2's MAC address
9  The hub should not do anything in response to a frame
   arriving with a destination address referring to the hub
   itself.

All tests passed!

(syenv) njucs@njucs-VirtualBox:~/switchyard/lab-02-wjrz$
```

在mininet中试验得：

第一次在client中 `ping -c 1 192.168.100.1`，可以看到switch中收到了一个没有收到过的src，并且在最后得到了交换机表项。隔一段时间后再 `ping -c 1 192.168.100.1`

```
09:36:14 2022/03/22      INFO Received a packet which src already is saved
09:36:14 2022/03/22      INFO Flooding packet Ethernet 10:00:00:00:00:01->30:00:00:00:00:01 ARP | Arp 10:00:00:00:00:01:192.168.100.1 00:00:00:00:00:00:192.168.100.3 to switch-eth2
09:36:14 2022/03/22      INFO 30:00:00:00:00:01 switch-eth2 1647912968.6992354
09:36:14 2022/03/22      INFO 10:00:00:00:00:01 switch-eth0 1647912974.1959352
09:36:14 2022/03/22      INFO Received a packet which src already is saved
09:36:14 2022/03/22      INFO Flooding packet Ethernet 30:00:00:00:00:01->10:00:00:00:00:01 ARP | Arp 30:00:00:00:00:01:192.168.100.3 10:00:00:00:00:01:192.168.100.1 to switch-eth0
09:36:14 2022/03/22      INFO 30:00:00:00:00:01 switch-eth2 1647912974.4039004
09:36:14 2022/03/22      INFO 10:00:00:00:00:01 switch-eth0 1647912974.1959352
09:37:50 2022/03/22      INFO Received a packet which src is not saved
09:37:50 2022/03/22      INFO The dst port is not saved
```

在9.37分时，又进行的一次ping中可见，src和dst都没有储存在交换机表中，可知switch表已经被清空。

Task4

在这任务中，我们仍然依赖时间戳，在每一次交换机表项数超过5的时候，我们将其中时间戳最小的那一项清楚，这意味着这个被清除的项就是满足lru算法的项，因为它是最近最少被使用的数据。

加入对时间戳最小表项的判断：

```
if len(list_table) == max_len:
    index = 0
    timestamp_min = list_table[index].timestamp
    for i in range(0, len(list_table)):
        if list_table[i].timestamp < timestamp_min:
            index = i
            timestamp_min = list_table[i].timestamp
    del(list_table[index])
list_table.append(table(eth.src, fromIface, time.time()))
```

程序源码见 `myswitch_lru.py`

运行手册的测试代码，结果如下：


```
njucs@njucs-VirtualBox: ~/switchyard/lab-02-wjrzmm
File Edit View Search Terminal Help
5 An Ethernet frame from 20:00:00:00:00:03 to
  30:00:00:00:00:02 should arrive on eth2
6 Ethernet frame destined for 30:00:00:00:00:02 should arrive
  on eth1 after self-learning
7 An Ethernet frame from 30:00:00:00:00:04 to
  20:00:00:00:00:01 should arrive on eth3
8 Ethernet frame destined to 20:00:00:00:00:01 should arrive
  on eth0 after self-learning
9 An Ethernet frame from 20:00:00:00:00:01 to
  30:00:00:00:00:04 should arrive on eth0
10 Ethernet frame destined to 20:00:00:00:00:01 should arrive
  on eth3 after self-learning
11 An Ethernet frame from 40:00:00:00:00:05 to
  20:00:00:00:00:01 should arrive on eth4
12 Ethernet frame destined to 20:00:00:00:00:01 should arrive
  on eth0 after self-learning
13 An Ethernet frame from 30:00:00:00:00:05 to
  20:00:00:00:00:01 should arrive on eth4
14 Ethernet frame destined to 20:00:00:00:00:01 should arrive
  on eth0 after self-learning
15 An Ethernet frame from 20:00:00:00:00:05 to
  30:00:00:00:00:02 should arrive on eth4
16 Ethernet frame destined to 30:00:00:00:00:02 should be
  flooded to eth0, eth1, eth2 and eth3
17 An Ethernet frame should arrive on eth2 with destination
  address the same as eth2's MAC address
18 The hub should not do anything in response to a frame
  arriving with a destination address referring to the hub
  itself.

All tests passed!

(syenv) njucs@njucs-VirtualBox:~/switchyard/lab-02-wjrzmm$
```

在mininet中试验得：

添加测试代码

```
for i in range(len(list_table)):
    log_info(f"{list_table[i].mac} {list_table[i].port}
{list_table[i].timestamp}")
```

并且修改 `max_len=2` 以便于测试，我们首先在client中 `ping -c 1 192.168.100.1` 可以看到交换机表中如下显示：

```
09:26:29 2022/03/22      INFO Received a packet which src already is saved
09:26:29 2022/03/22      INFO Flooding packet Ethernet 30:00:00:00:00:01->10:00:00:00:00:01 ARP | Arp 30:00:00:00:00:01:192.168.100.3 10:00:00:00:00:01:192.168.100.1 to switch-eth0
09:26:29 2022/03/22      INFO 30:00:00:00:00:01 switch-eth2 1647912389.1875746
09:26:29 2022/03/22      INFO 10:00:00:00:00:01 switch-eth0 1647912388.9769588
```

然后在client中 `ping -c 1 192.168.100.2` 可以看到交换机表中如下显示：

```
09:26:39 2022/03/22      INFO Received a packet which src already is saved
09:26:39 2022/03/22      INFO Flooding packet Ethernet 30:00:00:00:00:01->20:00:00:00:00:01 ARP | Arp 30:00:00:00:00:01:192.168.100.3 20:00:00:00:00:01:192.168.100.2 to switch-eth1
09:26:39 2022/03/22      INFO 30:00:00:00:00:01 switch-eth2 1647912399.7960076
09:26:39 2022/03/22      INFO 20:00:00:00:00:01 switch-eth1 1647912399.4726014
```

由此可见eth2端口的时间戳被更新，且由于lru原则，eth0端口对应的表项已经被删除。

Task5

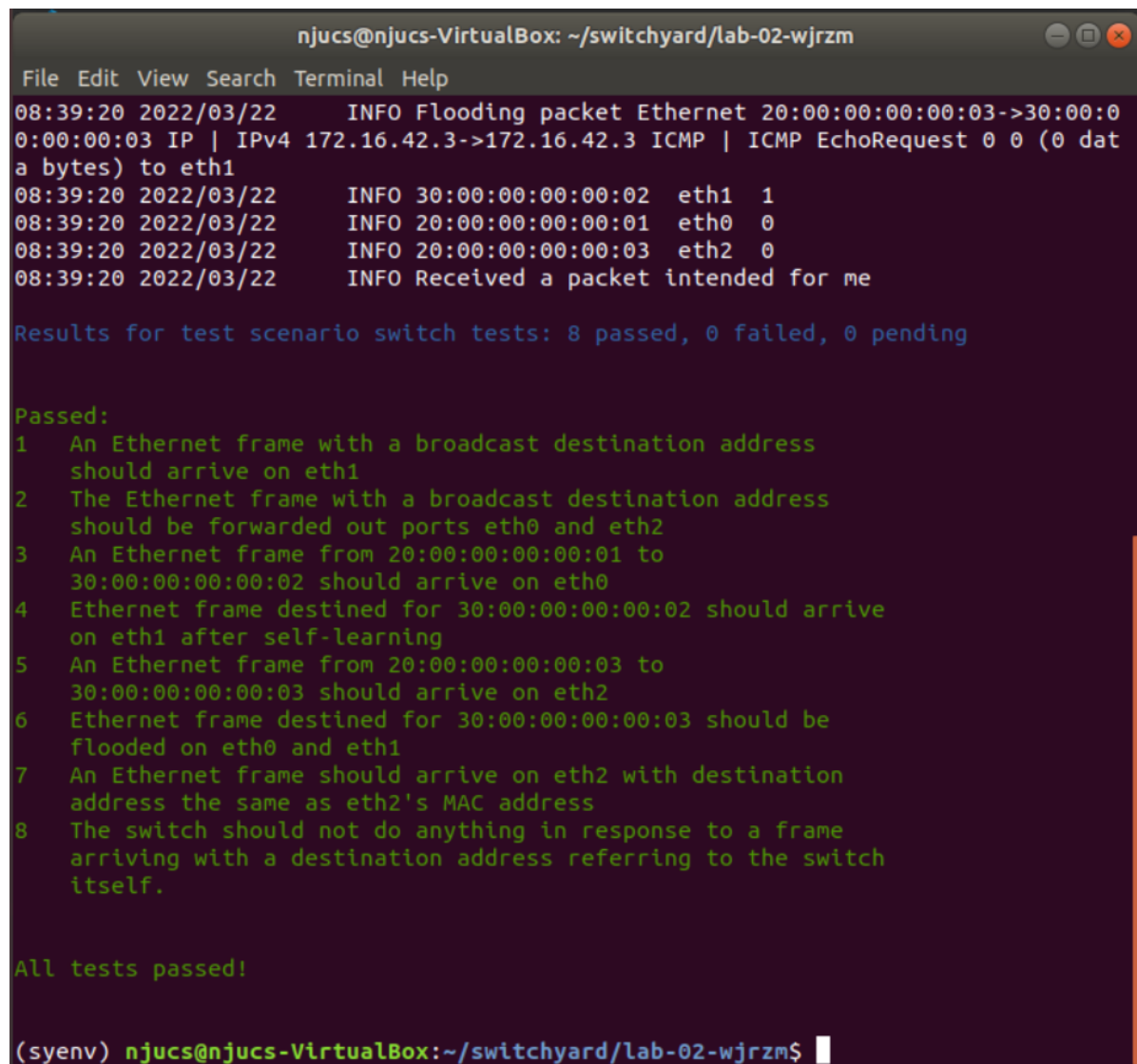
在这个任务中，我们将交换机表项中记录的时间戳替换为 `traffic volume`，按照手册中流程图中的规则，如果 `Destination MAC address == MAC address of entry`，则对改端口vol值加一。

加入对vol值的判断：

```
if len(list_table) == max_len:
    index = 0
    vol_min = list_table[index].vol
    for i in range(0, len(list_table)):
        if list_table[i].vol < vol_min:
            index = i
            vol_min = list_table[i].vol
    del(list_table[index])
list_table.append(table(eth.src, fromIface, 0))
```

具体代码见 `myswitch_traffic.py` 文件。

运行手册的测试代码，结果如下：



```
njucs@njucs-VirtualBox: ~/switchyard/lab-02-wjrzrm
File Edit View Search Terminal Help
08:39:20 2022/03/22      INFO Flooding packet Ethernet 20:00:00:00:00:03->30:00:00:00:00:03 IP | IPv4 172.16.42.3->172.16.42.3 ICMP | ICMP EchoRequest 0 0 (0 data bytes) to eth1
08:39:20 2022/03/22      INFO 30:00:00:00:00:02 eth1 1
08:39:20 2022/03/22      INFO 20:00:00:00:00:01 eth0 0
08:39:20 2022/03/22      INFO 20:00:00:00:00:03 eth2 0
08:39:20 2022/03/22      INFO Received a packet intended for me

Results for test scenario switch tests: 8 passed, 0 failed, 0 pending

Passed:
1  An Ethernet frame with a broadcast destination address should arrive on eth1
2  The Ethernet frame with a broadcast destination address should be forwarded out ports eth0 and eth2
3  An Ethernet frame from 20:00:00:00:00:01 to 30:00:00:00:00:02 should arrive on eth0
4  Ethernet frame destined for 30:00:00:00:00:02 should arrive on eth1 after self-learning
5  An Ethernet frame from 20:00:00:00:00:03 to 30:00:00:00:00:03 should arrive on eth2
6  Ethernet frame destined for 30:00:00:00:00:03 should be flooded on eth0 and eth1
7  An Ethernet frame should arrive on eth2 with destination address the same as eth2's MAC address
8  The switch should not do anything in response to a frame arriving with a destination address referring to the switch itself.

All tests passed!

(syenv) njucs@njucs-VirtualBox:~/switchyard/lab-02-wjrzrm$
```

在mininet中运行得：（修改 `max_len=2` 以便于测试）

首先在client中 `ping -c 1 192.168.100.1`

得到最终结果如下：

```
09:13:32 2022/03/22      INFO Received a packet which src already is saved
09:13:32 2022/03/22      INFO Flooding packet Ethernet 30:00:00:00:00:01->10:00:00:00:00:01 ARP | Arp 30:00:00:00:00:01:192.168.100.3 10:00:00:00:00:01:192.168.100.1 to switch-eth0
09:13:32 2022/03/22      INFO 30:00:00:00:00:01  switch-eth2  3
09:13:32 2022/03/22      INFO 10:00:00:00:00:01  switch-eth0  2
```

再在client中 `ping -c 1 192.168.100.2`

得到最终结果如下：

```
09:13:45 2022/03/22      INFO Received a packet which src already is saved
09:13:45 2022/03/22      INFO Flooding packet Ethernet 30:00:00:00:00:01->20:00:00:00:00:01 ARP | Arp 30:00:00:00:00:01:192.168.100.3 20:00:00:00:00:01:192.168.100.2 to switch-eth1
09:13:45 2022/03/22      INFO 30:00:00:00:00:01  switch-eth2  6
09:13:45 2022/03/22      INFO 20:00:00:00:00:01  switch-eth1  2
```

可见，在traffic volume中删去了最小的那个端口表项。

实验总结

在实验中，要注意关注实验手册中的流程图，一些细节性的要求，例如在哪些情况下更改拓扑结构不改变对应的信息，例如在哪些情况下会进行表项的排序等。本实验基本上是按照对于交换机的理解，在基础代码上进行一点修改即可。