# 南京大学计算机网络实验报告

**任课教师:田臣**

# 实验二 Learning Switch

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**计算机科学与技术系**

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# 实验目的

- 学习Switch的工作原理
- 实现Switch的三种机制Timeout/LRU/LFU

# 实验内容

**Task1: Preparation**

按手册将准备工作完成即可，此处略

**Task2: Basic Switch**

实现方式：

- 使用一个字典存储MAC地址到端口的映射规则
- 在每次接受到一个packet后，将src和input port加入字典中
- 从字典中查找dst对应的output port，若存在，则直接从output port发送packet

代码示意如下：

```
mac2port_table = {}
while True:
    #recv a packet

    mac2port_table[packet[0].src] = input_port
    output_port = mac2port_table.get(packet[0].dst,False)

    #send packet
    if packet[0].dst in mymacs:
        #intend for me
    elif output_port:
        #send directly
        net.send_packet(output_port, packet)
    else:
        #flood packet
```

### Task3: Timeouts

实现方式:

- 延续**Task2**中用字典存储映射的方式，对value的数据结构修改为 `mac2port_table_item` 的结构，包含了两个成员变量端口名称 `port` 和时间戳 `timestamp`
- 在每次收到一个packet时，以当前时间和输入端口创建一个 `mac2port_table_item` 并存入字典 `mac2port_table` 中
- 从字典中查找是否存在目的地址的映射规则，并与当前时间比较，检查该规则是否**TimeOut**

代码示意如下:

首先是 `mac2port_table_item` 的定义

```
class mac2port_table_item:
    timestamp = 0
    port = ""
    def __init__(self,timestamp,port):
        self.timestamp = timestamp
        self.port = port
    def __repr__(self):
        return "<mac2port table item>time=%d,port=%s"%(self.timestamp,self.port)

```

然后是主要逻辑:

```
mac2port_table = {}
while True:
    #recv packet

    nowTime = int(time.time())
    #learning
    mac2port_table[packet[0].src] = mac2port_table_item(nowTime,input_port)

```

```
    #get output port and judge port timeout

    output_port_item=mac2port_table.get(packet[0].dst,mac2port_table_item(0,""))

    # 10s timeout
    if output_port_item.timestamp and nowTime-output_port_item.timestamp>10:
        del mac2port_table[packet[0].dst]
        output_port_item = mac2port_table_item(0,"")

    #send packet
```

#### Task4: Least Recently Used

LRU替换规则适合使用OrderedDict实现

实现方式：

- 使用一个OrderedDict存储MAC地址到端口的映射规则
- 当接受到一个包时，将src对应的端口从 `mac2port_table_lru` 弹出，然后重新插入，使得该规则成为**最近使用**
- 根据包的dst在 `mac2port_table_lru` 中查找对应的端口，如果存在则将其更新为**最近使用**，否则判断表是否已满，然后插入到 `mac2port_table_lru` 中，并把表中最后一个元素弹出

代码示意如下：

先实现一个 `mac2port_table_lru` 类

```
class mac2port_table_lru(OrderedDict):
    def __init__(self,capacity):
        self.capacity = capacity
        self.table = OrderedDict()

    def get(self,key):
        if key in self.table: #get and update
            value = self.table.pop(key)
            self.table[key] = value
```

```python
        else:
            value = None
        return value

    def set(self,key,value):
        if key in self.table:
            value = self.table.pop(key)
            self.table[key] = value
        else:
            if len(self.table) == self.capacity:
                self.table.popitem(last = False)
                self.table[key] = value
            else:
                self.table[key] = value

```

然后在循环中实现主要逻辑：

```python
#recv packet

mac2port_table.set(packet[0].src,input_port)

output_port = mac2port_table.get(packet[0].dst)

#send packet

```

**Task5: Least Traffic Volume**

本质就是实现一个LFU替换，利用字典结合列表可实现LFU算法

实现方式：

- 使用一个字典map存储MAC地址(key)到端口(value)的映射，然后另外用一个字典freq_map存储访问频率(key)到字典map的结点(value) `node:{key:MAC,value:port}` 的映射
- 在每次调用get方法时更新结点的访问次数，并更新其在freq_map中的位置
- 在调用set方法时，如果表已满，则删除freq_map中访问次数最少的链表中的一个结点，并插入新的结点

代码示意如下：

首先实现 `LFUNode` 和 `mac2port_table_traffic` 类

```
class LFUNode():
    def __init__(self, key, value):
        self.freq = 0
        self.key = key
        self.value = value

class mac2port_table_traffic():
    def __init__(self,capacity):
        self.capacity = capacity
        self.map = {}
        self.freq_map = {}

    def get(self,key):
        if key in self.map: #get and update
            node = self.map.get(key)
            freq = node.freq
            self.freq_map[freq].remove(node)
            if len(self.freq_map[freq]) == 0:
                del self.freq_map[freq]

            freq += 1
            print(node)
            node.freq = freq
            if freq not in self.freq_map:
                self.freq_map[freq] = []
            self.freq_map[freq].append(node)

        else:
            return None
        return node.value

    def set(self,key,value):

        if key in self.map:
            node = self.map.get(key)
            node.value = value

        else:
```

```
            if len(self.map) == self.capacity:
                min_freq = min(self.freq_map)
                node = self.freq_map[min_freq].pop()
                del self.map[node.key]
            node = LFUNode(key,value)
            node.freq = 0
            self.map[key] = node
            if node.freq not in self.freq_map:
                self.freq_map[node.freq] = []
            self.freq_map[node.freq].append(node)

    def print(self):
        print("\nmy table({}) is :".format(len(self.map)))
        for key,value in self.freq_map.items():
            for v in value:
                print("MAC:{} port:{} freq:{}".format(v.key,v.value,v.freq))
        print("")

```

循环中的主要逻辑：

```
#recv packet

mac2port_table.set(packet[0].src,input_port)

output_port = mac2port_table.get(packet[0].dst)

#send packet

```

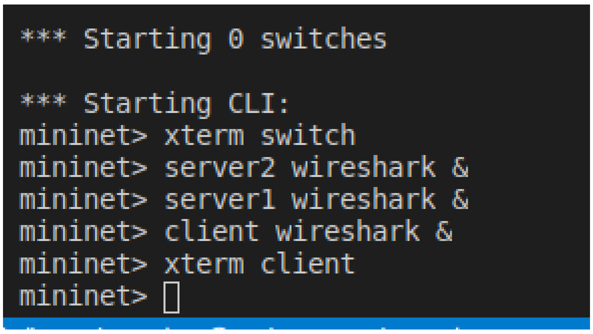
# 实验结果

## Task 2

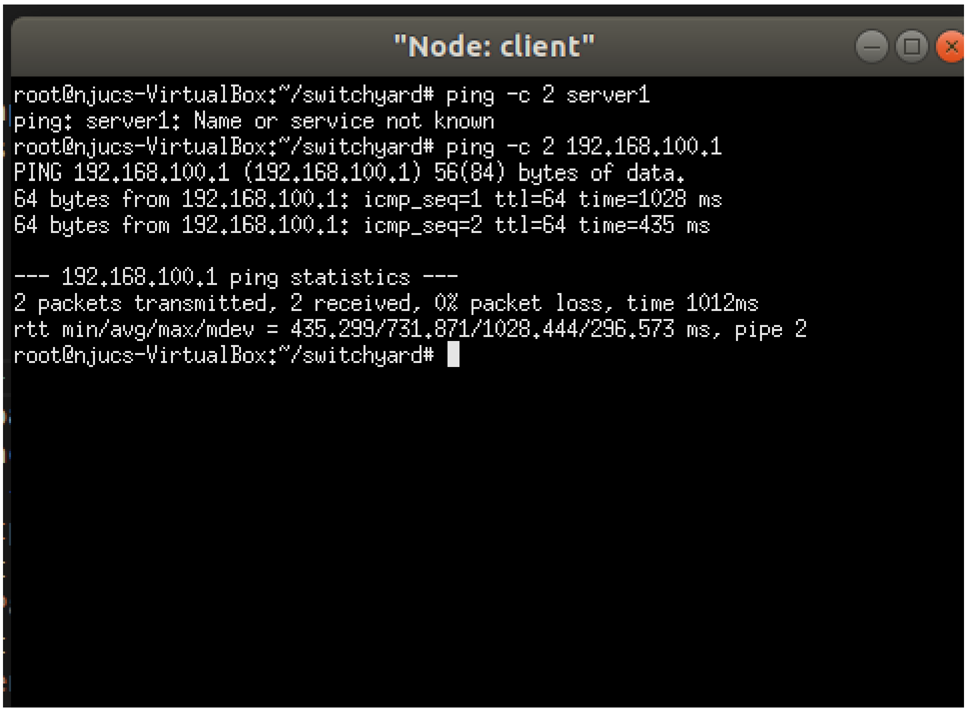
**Testing:** 无要求

### Deploying:

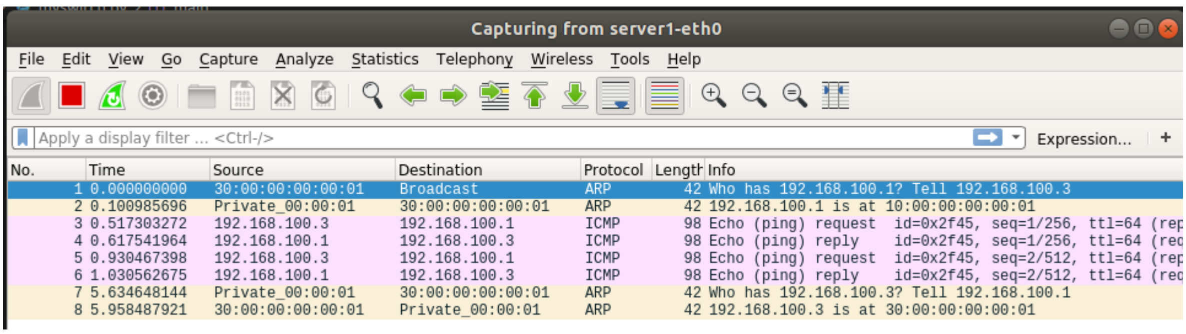
1、打开xterm和wireshark

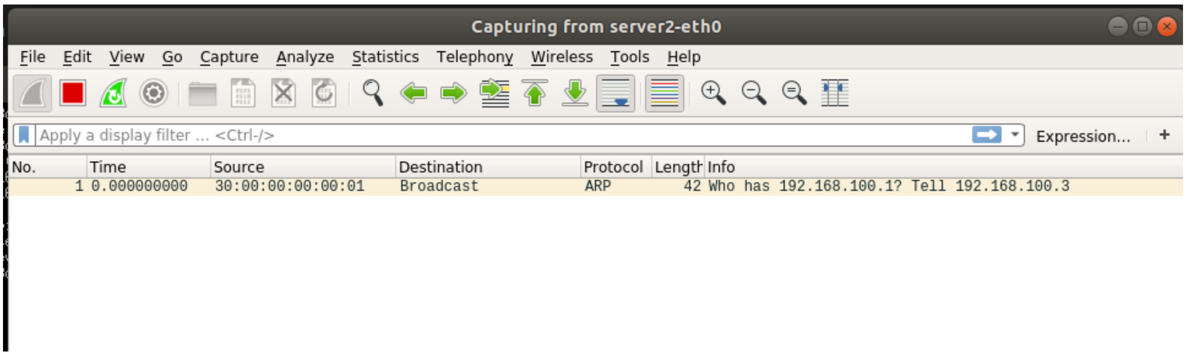



2、client ping server1




3、然后查看server1和server2的wireshark





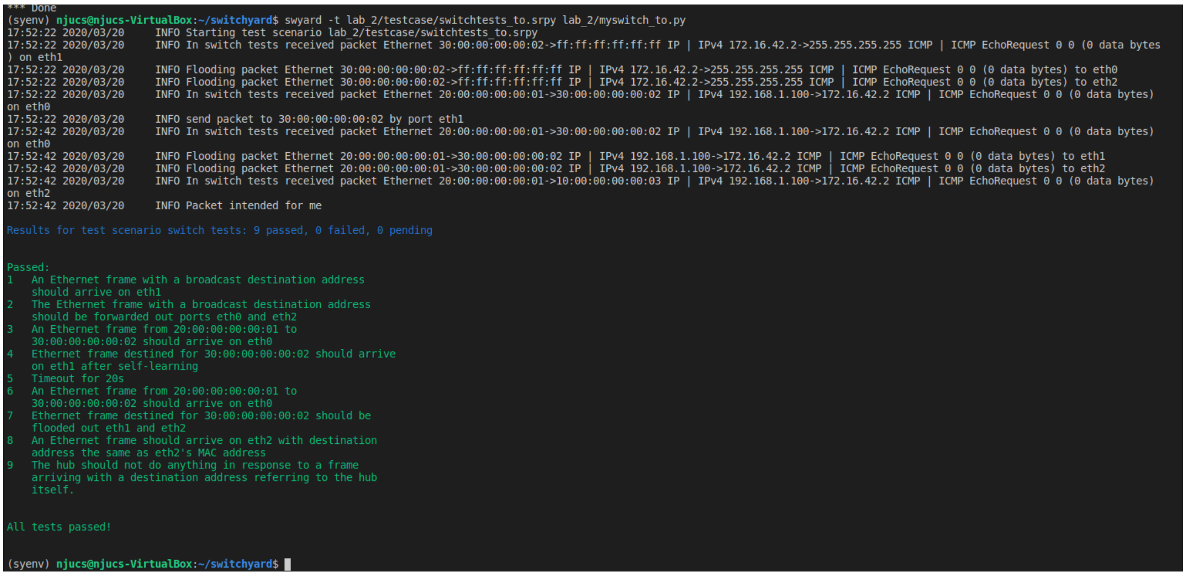

**实验现象：server1收到了client发送的包，而server2只收到了一个ARP包**

**解释：**

1. 在client向server1发包前，先发送了ARP广播询问server1的MAC地址，此时switch学习了client与对应端口的规则
2. server1通过广播回复client的询问，此使switch学习了server1与对应端口的规则，并且在switch转发时，直接根据第一步学习的规则向client对应的端口发送该回复，因此server2不会收到这个包
3. 后续的由于ping发送和回复的包也都因为switch中存在client和server1的MAC地址和对应端口，所以server2收不到这些包

# Task 3

## Testing:



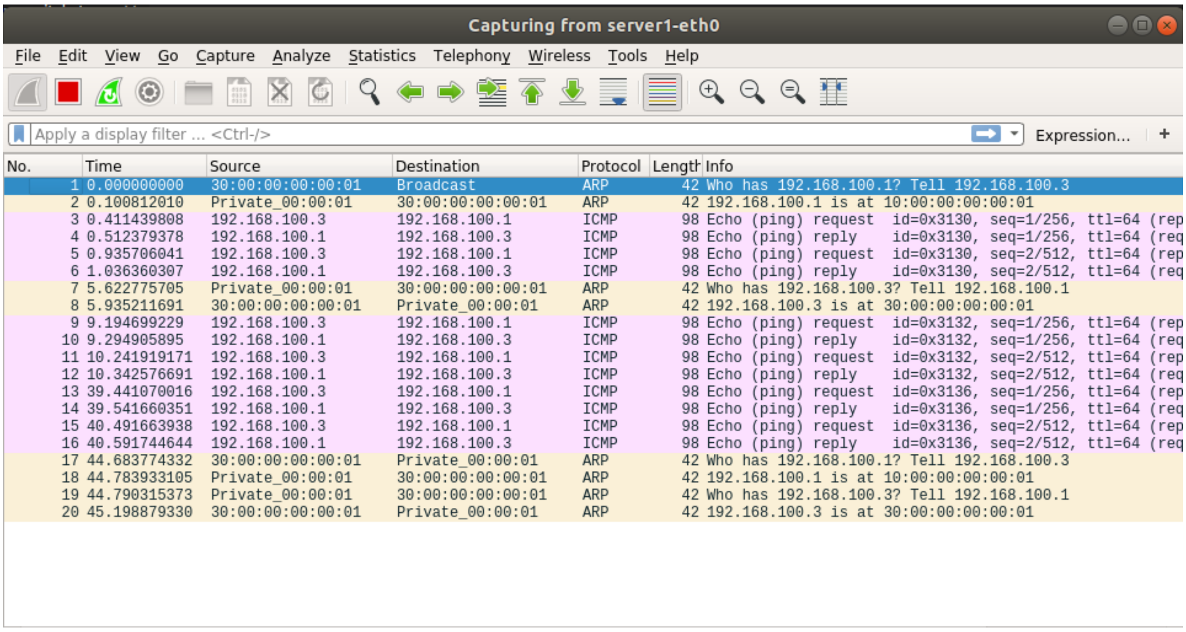

## Deploying:

1、打开xterm和wireshark

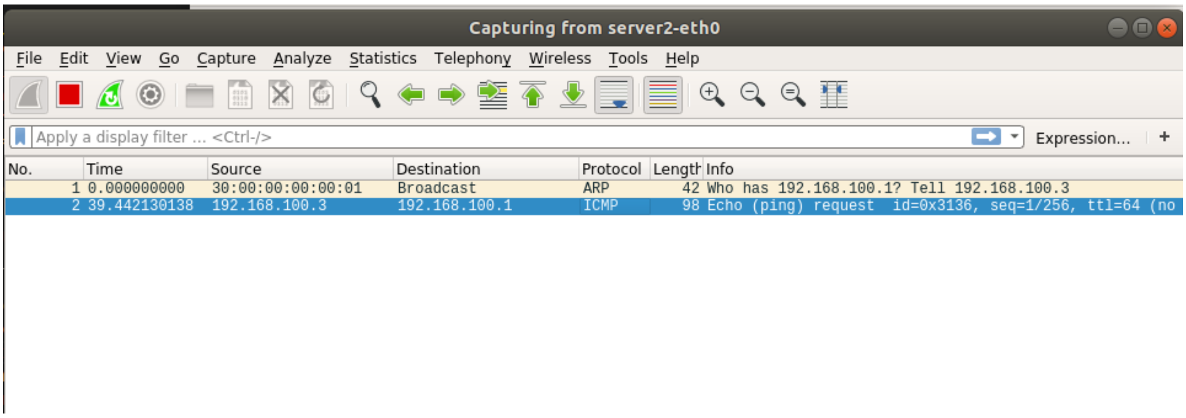
```
*** Starting CLI:
mininet> xterm switch
mininet> server1 wireshark &
mininet> server2 wireshark &
mininet> client ping -c 2 server1
PING 192.168.100.1 (192.168.100.1) 56(84) bytes of data.
64 bytes from 192.168.100.1: icmp_seq=1 ttl=64 time=911 ms
64 bytes from 192.168.100.1: icmp_seq=2 ttl=64 time=432 ms

--- 192.168.100.1 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1000ms
rtt min/avg/max/mdev = 432.724/672.247/911.771/239.524 ms
mininet> client ping -c 2 server1
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=438 ms
64 bytes from 192.168.100.1: icmp_seq=2 ttl=64 time=497 ms

--- 192.168.100.1 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1000ms
rtt min/avg/max/mdev = 438.254/467.766/497.278/29.512 ms
mininet> client ping -c 2 server1
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=431 ms
64 bytes from 192.168.100.1: icmp_seq=2 ttl=64 time=489 ms

--- 192.168.100.1 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1001ms
rtt min/avg/max/mdev = 431.509/460.603/489.697/29.094 ms
mininet>
```

2、令client ping server1，五秒后再次执行client ping server1，等待超过十秒后再一次令client ping server1

3、观察server1 server2 的wireshark




| 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 | 0.100812010 | 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 | 0.411439808 | 192.168.100.3 | 192.168.100.1 | ICMP | 98 | Echo (ping) request id=0x3130, seq=1/256, ttl=64 (rep |
| 4 | 0.512379378 | 192.168.100.1 | 192.168.100.3 | ICMP | 98 | Echo (ping) reply id=0x3130, seq=1/256, ttl=64 (req |
| 5 | 0.935706041 | 192.168.100.3 | 192.168.100.1 | ICMP | 98 | Echo (ping) request id=0x3130, seq=2/512, ttl=64 (rep |
| 6 | 1.036360307 | 192.168.100.1 | 192.168.100.3 | ICMP | 98 | Echo (ping) reply id=0x3130, seq=2/512, ttl=64 (req |
| 7 | 5.622775705 | Private_00:00:01 | 30:00:00:00:00:01 | ARP | 42 | Who has 192.168.100.3? Tell 192.168.100.1 |
| 8 | 5.935211691 | 30:00:00:00:00:01 | Private_00:00:01 | ARP | 42 | 192.168.100.3 is at 30:00:00:00:00:01 |
| 9 | 9.194699229 | 192.168.100.3 | 192.168.100.1 | ICMP | 98 | Echo (ping) request id=0x3132, seq=1/256, ttl=64 (rep |
| 10 | 9.294905895 | 192.168.100.1 | 192.168.100.3 | ICMP | 98 | Echo (ping) reply id=0x3132, seq=1/256, ttl=64 (req |
| 11 | 10.241919171 | 192.168.100.3 | 192.168.100.1 | ICMP | 98 | Echo (ping) request id=0x3132, seq=2/512, ttl=64 (rep |
| 12 | 10.342576691 | 192.168.100.1 | 192.168.100.3 | ICMP | 98 | Echo (ping) reply id=0x3132, seq=2/512, ttl=64 (req |
| 13 | 39.441070016 | 192.168.100.3 | 192.168.100.1 | ICMP | 98 | Echo (ping) request id=0x3136, seq=1/256, ttl=64 (rep |
| 14 | 39.541660351 | 192.168.100.1 | 192.168.100.3 | ICMP | 98 | Echo (ping) reply id=0x3136, seq=1/256, ttl=64 (req |
| 15 | 40.491663938 | 192.168.100.3 | 192.168.100.1 | ICMP | 98 | Echo (ping) request id=0x3136, seq=2/512, ttl=64 (rep |
| 16 | 40.591744644 | 192.168.100.1 | 192.168.100.3 | ICMP | 98 | Echo (ping) reply id=0x3136, seq=2/512, ttl=64 (req |
| 17 | 44.683774332 | 30:00:00:00:00:01 | Private_00:00:01 | ARP | 42 | Who has 192.168.100.1? Tell 192.168.100.3 |
| 18 | 44.783933105 | Private_00:00:01 | 30:00:00:00:00:01 | ARP | 42 | 192.168.100.1 is at 10:00:00:00:00:01 |
| 19 | 44.790315373 | Private_00:00:01 | 30:00:00:00:00:01 | ARP | 42 | Who has 192.168.100.3? Tell 192.168.100.1 |
| 20 | 45.198879330 | 30:00:00:00:00:01 | Private_00:00:01 | ARP | 42 | 192.168.100.3 is at 30:00:00:00:00:01 |




**实验现象：在mininet中一共构造了三次流量，都是由client向server1 ping，从wireshark显示的时间上可以看到，server2为收到前两次ping产生的包（除ARP外），而收到了第三次产生的包**

**解释：**

1. 在第一次广播时，switch就学习了client和server1的MAC和端口对应规则，因此在前十秒产生的client和server1之间的流量都是直接发送，不会被server2接收
2. 在十秒过后，也就是第三次ping的时候，switch接受到了一个由client发来的包，发现学习到的规则已经**TimeOut**了，所以进行泛洪，server2也接受到了这个包
3. 之后的包又由于规则进行了更新，所以server2接受不到这些包

# Task 4

**Testing:**

```
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, eth2, eth3 and eth4
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
     30:00:00:00:00:02 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.
```

**Deploying:**

1、首先在 `start_mininet.py` 中更改拓扑结构，本次测试需要6个点

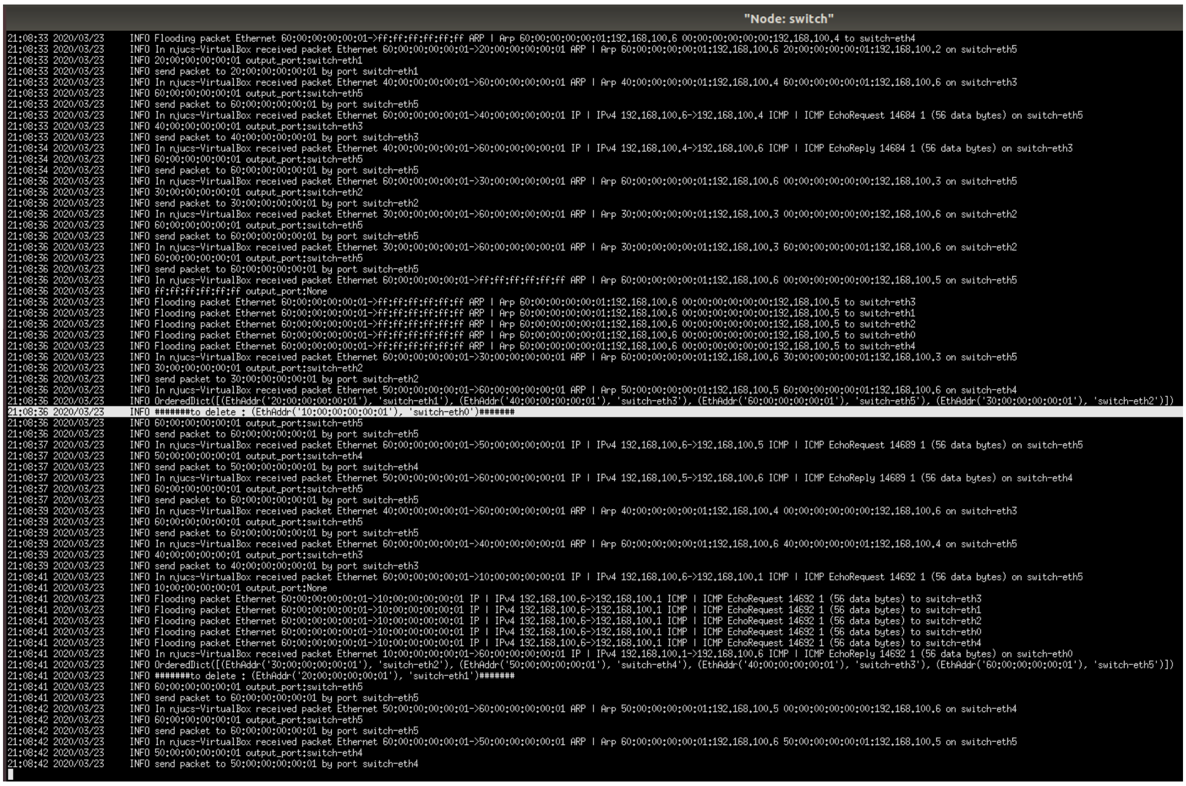
```
# Host and link configuration
#
#
#   server1       server3
#          \       /
#           switch ----client
#          /   |   \
#   server2 server4 server5
#
```

2、打开wireshark，并构建流量：client依次对server1,server2,server3,server4,server5,server1 ping

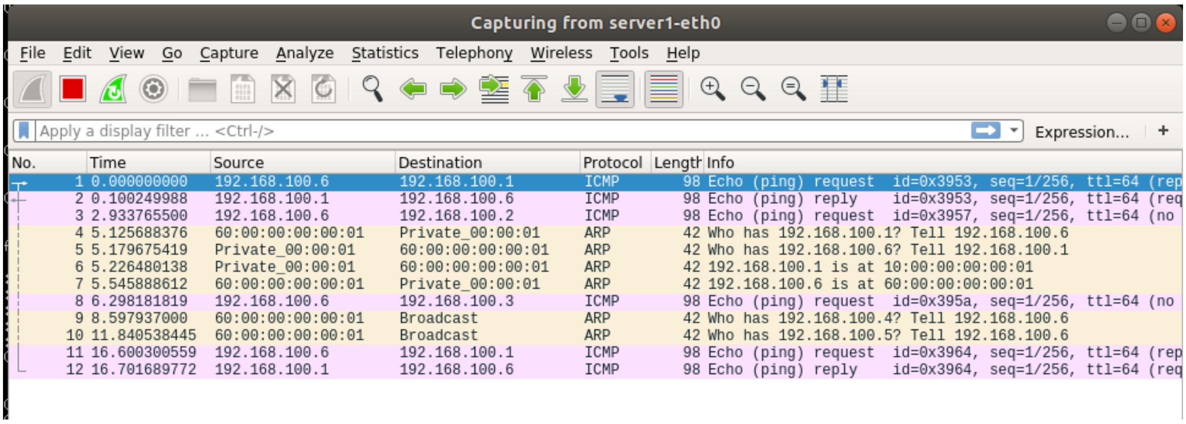
```
mininet> server1 wireshark &
mininet> server2 wireshark &
mininet> client ping -c 1 server1
PING 192.168.100.1 (192.168.100.1) 56(84) bytes of data.
64 bytes from 192.168.100.1: icmp_seq=1 ttl=64 time=612 ms

--- 192.168.100.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 612.349/612.349/612.349/0.000 ms
mininet> client ping -c 1 server2
PING 192.168.100.2 (192.168.100.2) 56(84) bytes of data.
64 bytes from 192.168.100.2: icmp_seq=1 ttl=64 time=590 ms

--- 192.168.100.2 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 590.144/590.144/590.144/0.000 ms
mininet> client ping -c 1 server3
PING 192.168.100.3 (192.168.100.3) 56(84) bytes of data.
64 bytes from 192.168.100.3: icmp_seq=1 ttl=64 time=490 ms

--- 192.168.100.3 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 490.194/490.194/490.194/0.000 ms
mininet> client ping -c 1 server4
PING 192.168.100.4 (192.168.100.4) 56(84) bytes of data.
64 bytes from 192.168.100.4: icmp_seq=1 ttl=64 time=863 ms

--- 192.168.100.4 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 863.138/863.138/863.138/0.000 ms
mininet> client ping -c 1 server5
PING 192.168.100.5 (192.168.100.5) 56(84) bytes of data.
64 bytes from 192.168.100.5: icmp_seq=1 ttl=64 time=938 ms

--- 192.168.100.5 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 938.887/938.887/938.887/0.000 ms
mininet> client ping -c 1 server1
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=576 ms

--- 192.168.100.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 576.497/576.497/576.497/0.000 ms
mininet>
```

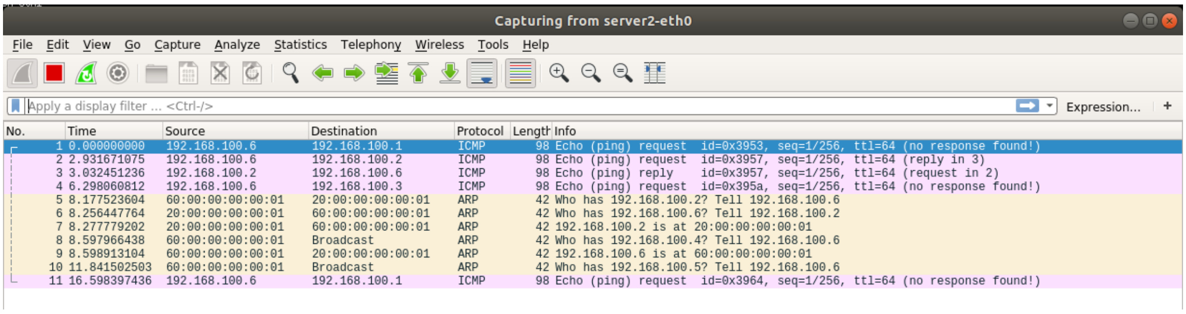
3、查看switch日志，在高亮一行（ping server5以后）显示了即将被替换掉的表项

`{EthAddr('10:00:00:00:00:01'),'switch-eth0'}`



4、查看server1 server2的wireshark




**实验现象：在最开始泛洪时server2接收到了client发给server1的包，而结束时，server2再次接收到了client发给server1的包**

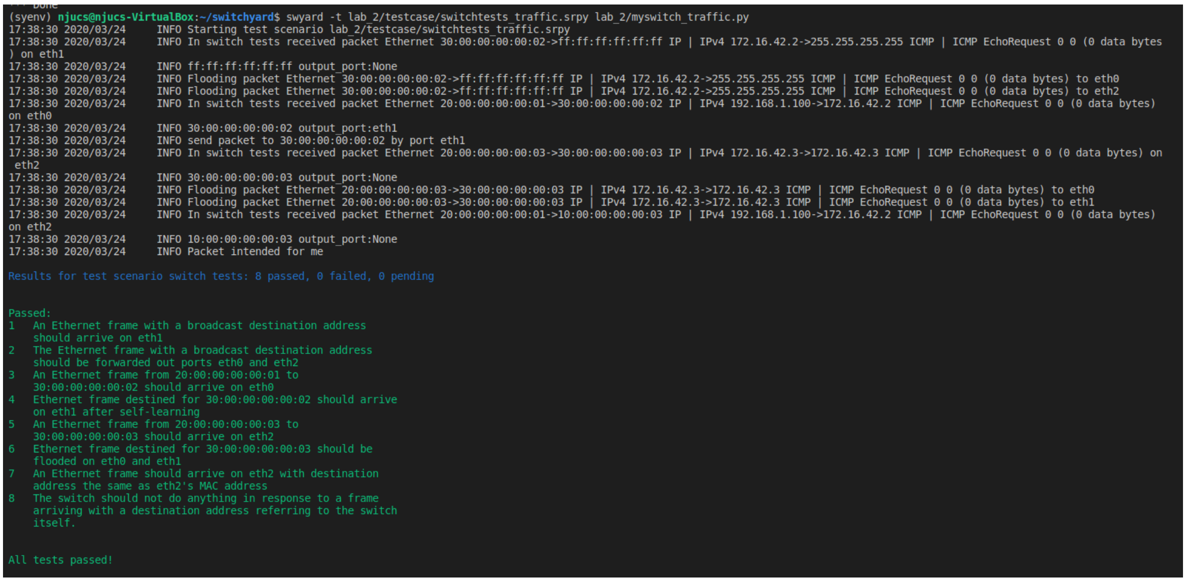
**解释：**

1. 在最开始时，switch的表里为空，学习client的规则后，对接收到的包进行泛洪

2. 之后client依次向server2,3,4发包，switch共学习到了server1,2,3,4,client的规则，此时表已满
3. 在client向server5 ping的时候，根据LRU，server1的规则被替换
4. 最后client向server1 ping的时候，表里无对应的规则，因此switch将包进行泛洪，server2也就再次收到了这个包

## Task 5

### Testing:



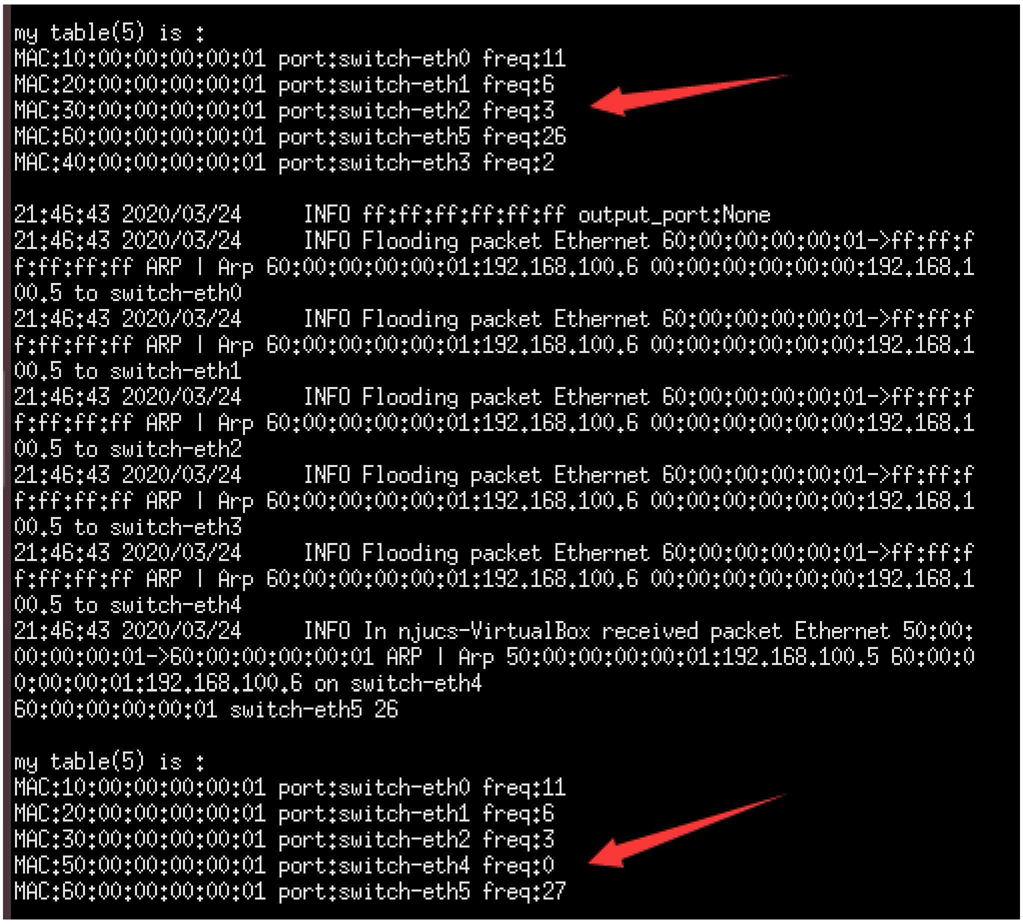
```
(syenv) njucs@njucs-VirtualBox:~/switchyard$ swyard -t lab_2/testcase/switchtests_traffic.srpy lab_2/myswitch_traffic.py
17:38:30 2020/03/24     INFO Starting test scenario lab_2/testcase/switchtests_traffic.srpy
17:38:30 2020/03/24     INFO In switch tests received packet Ethernet 30:00:00:00:00:02->ff:ff:ff:ff:ff:ff IP | IPv4 172.16.42.2->255.255.255.255 ICMP | ICMP EchoRequest 0 0 (0 data bytes
) on eth1
17:38:30 2020/03/24     INFO ff:ff:ff:ff:ff:ff output_port:None
17:38:30 2020/03/24     INFO Flooding packet Ethernet 30:00:00:00:00:02->ff:ff:ff:ff:ff:ff IP | IPv4 172.16.42.2->255.255.255.255 ICMP | ICMP EchoRequest 0 0 (0 data bytes) to eth0
17:38:30 2020/03/24     INFO Flooding packet Ethernet 30:00:00:00:00:02->ff:ff:ff:ff:ff:ff IP | IPv4 172.16.42.2->255.255.255.255 ICMP | ICMP EchoRequest 0 0 (0 data bytes) to eth2
17:38:30 2020/03/24     INFO In switch tests received packet Ethernet 20:00:00:00:00:01->30:00:00:00:00:02 IP | IPv4 192.168.1.100->172.16.42.2 ICMP | ICMP EchoRequest 0 0 (0 data bytes)
on eth0
17:38:30 2020/03/24     INFO 30:00:00:00:00:02 output_port:eth1
17:38:30 2020/03/24     INFO send packet to 30:00:00:00:00:02 by port eth1
17:38:30 2020/03/24     INFO In switch tests received 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) on
 eth2
17:38:30 2020/03/24     INFO 30:00:00:00:00:03 output_port:None
17:38:30 2020/03/24     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 eth0
17:38:30 2020/03/24     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
17:38:30 2020/03/24     INFO In switch tests received packet Ethernet 20:00:00:00:00:01->10:00:00:00:00:03 IP | IPv4 192.168.1.100->172.16.42.2 ICMP | ICMP EchoRequest 0 0 (0 data bytes)
on eth2
17:38:30 2020/03/24     INFO 10:00:00:00:00:03 output_port:None
17:38:30 2020/03/24     INFO 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!
```

### Deploying:

1、首先构造一些流量：

```
client ping -c 10 server1
client ping -c 5 server2
client ping -c 2 server3
client ping -c 1 server4
```

此时switch的表如下图中第一个箭头，此时表已满，表中server4即将被替换



```
my table(5) is :
MAC:10:00:00:00:00:01 port:switch-eth0 freq:11
MAC:20:00:00:00:00:01 port:switch-eth1 freq:6
MAC:30:00:00:00:00:01 port:switch-eth2 freq:3
MAC:60:00:00:00:00:01 port:switch-eth5 freq:26
MAC:40:00:00:00:00:01 port:switch-eth3 freq:2

21:46:43 2020/03/24     INFO ff:ff:ff:ff:ff:ff output_port:None
21:46:43 2020/03/24     INFO Flooding packet Ethernet 60:00:00:00:00:01->ff:ff:f
f:ff:ff:ff ARP | Arp 60:00:00:00:00:01:192.168.100.6 00:00:00:00:00:00:192.168.1
00.5 to switch-eth0
21:46:43 2020/03/24     INFO Flooding packet Ethernet 60:00:00:00:00:01->ff:ff:f
f:ff:ff:ff ARP | Arp 60:00:00:00:00:01:192.168.100.6 00:00:00:00:00:00:192.168.1
00.5 to switch-eth1
21:46:43 2020/03/24     INFO Flooding packet Ethernet 60:00:00:00:00:01->ff:ff:f
f:ff:ff:ff ARP | Arp 60:00:00:00:00:01:192.168.100.6 00:00:00:00:00:00:192.168.1
00.5 to switch-eth2
21:46:43 2020/03/24     INFO Flooding packet Ethernet 60:00:00:00:00:01->ff:ff:f
f:ff:ff:ff ARP | Arp 60:00:00:00:00:01:192.168.100.6 00:00:00:00:00:00:192.168.1
00.5 to switch-eth3
21:46:43 2020/03/24     INFO Flooding packet Ethernet 60:00:00:00:00:01->ff:ff:f
f:ff:ff:ff ARP | Arp 60:00:00:00:00:01:192.168.100.6 00:00:00:00:00:00:192.168.1
00.5 to switch-eth4
21:46:43 2020/03/24     INFO In njucs-VirtualBox received packet Ethernet 50:00:
00:00:00:01->60:00:00:00:00:01 ARP | Arp 50:00:00:00:00:01:192.168.100.5 60:00:0
0:00:00:01:192.168.100.6 on switch-eth4
60:00:00:00:00:01 switch-eth5 26

my table(5) is :
MAC:10:00:00:00:00:01 port:switch-eth0 freq:11
MAC:20:00:00:00:00:01 port:switch-eth1 freq:6
MAC:30:00:00:00:00:01 port:switch-eth2 freq:3
MAC:50:00:00:00:00:01 port:switch-eth4 freq:0
MAC:60:00:00:00:00:01 port:switch-eth5 freq:27
```

2、再构造一个流量

```
client ping -c 1 server5
```

此时如上图所示，由于表中无server5，所以client发送的ARP包被泛洪。接着server5的应答被直接发送到client，而server5被加入到switch的表中，如上图的第二个箭头，server4被替换

# 总结与感想

本次实验学习了switch的原理，进一步了解了链路层中的优化