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# Computer Network lab2 实验报告

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## 1 实验名称

Lab 2: Learning Switch

## 2 实验目的

1. 理解并实现以太网交换机的基本功能。
2. 学习如何通过交换机的端口接收和转发以太网帧。
3. 掌握交换机的 MAC 地址学习机制和表项管理策略。
4. 熟悉 Switchyard 框架的使用方法。

## 3 实验进行

### 3.1 Preparation

下载实验模板代码，初始化项目。

使用 Switchyard 框架搭建基本的路由器框架。

### 3.2 Basic Switch

实现基本交换机功能，接收时学习 MAC 地址，发送时根据 MAC 地址表进行转发或泛洪。

```
import switchyard
from switchyard.lib.userlib import *

def main(net: switchyard.llnetbase.LLNetBase):
    my_interfaces = net.interfaces()
    mymacs = [intf.ethaddr for intf in my_interfaces]
    eth_dict = {}

    while True:
        try:
            _, fromIface, packet = net.recv_packet()
        except NoPackets:
            continue
        except Shutdown:
            break

        log_debug (f"In {net.name} received packet {packet} on {fromIface}")
        eth = packet.get_header(Ethernet)
        if eth is None:
            log_info("Received a non-Ethernet packet?!")
            return
        if eth.dst in mymacs:
            eth_dict [eth.src] = fromIface
            log_info("Received a packet intended for me")
        else:
            eth_dict [eth.src] = fromIface
            if eth.dst not in eth_dict:
                for intf in my_interfaces:
                    if fromIface!= intf.name:
                        log_info (f"Flooding packet {packet} to {intf.name}")
                        net.send_packet(intf, packet)
            else:
                log_info (f"Sending packet {packet} to {eth_dict[eth.dst]}")
                net.send_packet(eth_dict[eth.dst], packet)

    net.shutdown()
```

### 3.3 Timeouts

在基本交换机的基础上，为 MAC 地址表项增加超时机制，使表项在一定时间后自动失效。

```
import switchyard
```

```

import time
from switchyard.lib.userlib import *

def main(net: switchyard.llnetbase.LLNetBase):
    my_interfaces = net.interfaces()
    mymacs = [intf.ethaddr for intf in my_interfaces]
    eth_dict = {}

    while True:
        try:
            _, fromIface, packet = net.recv_packet()
        except NoPackets:
            continue
        except Shutdown:
            break

        log_debug (f"In {net.name} received packet {packet} on {fromIface}")
        eth = packet.get_header(Ethernet)
        if eth is None:
            log_info("Received a non-Ethernet packet?!")
            return
        if eth.dst in mymacs:
            eth_dict [eth.src] = (fromIface, time.time())
            log_info("Received a packet intended for me")
        else:
            eth_dict [eth.src] = (fromIface, time.time())
            if eth.dst not in eth_dict:
                for intf in my_interfaces:
                    if fromIface!= intf.name:
                        log_info (f"Flooding packet {packet} to {intf.name}")
                        net.send_packet(intf, packet)
            else:
                if time.time() - eth_dict[eth.dst][1] < 10:
                    log_info (f"Sending packet {packet} to
{eth_dict[eth.dst][0]}")
                    net.send_packet(eth_dict[eth.dst][0], packet)
                else:
                    log_info (f"Removing forwarding table entry
{eth_dict[eth.dst][0]}")
                    del eth_dict[eth.dst]
                    for intf in my_interfaces:
                        if fromIface!= intf.name:

```

```

log_info (f"Flooding packet {packet} to
{intf.name}")

net.send_packet(intf, packet)

net.shutdown()

```

### 3.4 Least Recently Used

当 MAC 地址表满时，根据最近最少使用（LRU）规则删除表项。

```

import switchyard
import collections
from switchyard.lib.userlib import *

def main(net: switchyard.llnetbase.LLNetBase):
    my_interfaces = net.interfaces()
    mymacs = [intf.ethaddr for intf in my_interfaces]
    eth_dict = collections.OrderedDict()

    while True:
        try:
            _, fromIface, packet = net.recv_packet()
        except NoPackets:
            continue
        except Shutdown:
            break

        log_debug (f"In {net.name} received packet {packet} on {fromIface}")
        eth = packet.get_header(Ethernet)
        if eth is None:
            log_info("Received a non-Ethernet packet?!")
            return
        if eth.dst in mymacs:
            if len(eth_dict) == 5 and eth.src not in eth_dict:
                eth_dict.popitem(last=False)
            if eth.src not in eth_dict:
                eth_dict[eth.src] = fromIface
            log_info("Received a packet intended for me")
        else:
            if len(eth_dict) == 5 and eth.src not in eth_dict:
                eth_dict.popitem(last=False)
            if eth.src not in eth_dict:
                eth_dict[eth.src] = fromIface
            if eth.dst not in eth_dict:

```

```

        for intf in my_interfaces:
            if fromIface != intf.name:
                log_info (f"Flooding packet {packet} to {intf.name}")
                net.send_packet(intf, packet)
            else:
                log_info (f"Sending packet {packet} to {eth_dict[eth.dst]}")
                net.send_packet(eth_dict[eth.dst], packet)

net.shutdown()

```

### 3.5 Least Traffic Volume

当 MAC 地址表满时，根据流量最少的规则删除表项。

```

import switchyard
import random
from switchyard.lib.userlib import *

def main(net: switchyard.llnetbase.LLNetBase):
    my_interfaces = net.interfaces()
    mymacs = [intf.ethaddr for intf in my_interfaces]
    eth_dict = {}

    while True:
        try:
            _, fromIface, packet = net.recv_packet()
        except NoPackets:
            continue
        except Shutdown:
            break

        log_debug (f"In {net.name} received packet {packet} on {fromIface}")
        eth = packet.get_header(Ethernet)
        if eth is None:
            log_info("Received a non-Ethernet packet?!")
            return
        if eth.dst in mymacs:
            if eth.src not in eth_dict:
                if len(eth_dict) == 5:
                    tmpk = random.choice(list(eth_dict.keys()))
                    for k, v in eth_dict.items():
                        if v[1] < eth_dict[tmpk][1]:
                            tmpk = k
                    del eth_dict[tmpk]

```

```

        eth_dict[eth.src] = [fromIface, 0]
        log_info("Received a packet intended for me")
    else:
        if eth.src not in eth_dict:
            if len(eth_dict) == 5:
                tmpk = random.choice(list(eth_dict.keys()))
                for k, v in eth_dict.items():
                    if v[1] < eth_dict[tmpk][1]:
                        tmpk = k
                del eth_dict[tmpk]
            eth_dict[eth.src] = [fromIface, 0]
        if eth.dst not in eth_dict:
            for intf in my_interfaces:
                if fromIface != intf.name:
                    log_info(f"Flooding packet {packet} to {intf.name}")
                    net.send_packet(intf, packet)
        else:
            log_info(f"Sending packet {packet} to
{eth_dict[eth.dst][0]}")
            eth_dict[eth.dst][1] += 1
            net.send_packet(eth_dict[eth.dst][0], packet)

net.shutdown()

```

### 3.6 测试与部署

使用 Switchyard 提供的测试用例进行功能测试。

```
swyard -t testcases/myswitch_to_testscenario.srpy myswitch_to.py
```

```
lungsion@lungsion-VMware: ~  
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 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 60s  
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!  
  
lungsion@lungsion-VMware:~$
```

在 Mininet 环境中部署交换机，验证其在实际网络环境中的运行情况。

```
sudo python start_mininet.py  
mininet> xterm switch  
/home/syenv/bin/swyard myswitch_to.py  
mininet> xterm client  
mininet> xterm server1  
mininet> xterm server2  
client> ping -c 2 192.168.100.1
```

```
lungsion@lungsion-VMware: ~  
server2 server2-eth0 20:00:00:00:00:01  
client client-eth0 30:00:00:00:00:01  
switch switch-eth0 40:00:00:00:00:01  
switch switch-eth1 40:00:00:00:00:02  
switch switch-eth2 40:00:00:00:00:03  
*** client : ('sysctl -w net.ipv6.conf.all.disable_ipv6=1',)  
net.ipv6.conf.all.disable_ipv6 = 1  
*** client : ('sysctl -w net.ipv6.conf.default.disable_ipv6=1',)  
net.ipv6.conf.default.disable_ipv6 = 1  
*** server1 : ('sysctl -w net.ipv6.conf.all.disable_ipv6=1',)  
net.ipv6.conf.all.disable_ipv6 = 1  
*** server1 : ('sysctl -w net.ipv6.conf.default.disable_ipv6=1',)  
net.ipv6.conf.default.disable_ipv6 = 1  
*** server2 : ('sysctl -w net.ipv6.conf.all.disable_ipv6=1',)  
net.ipv6.conf.all.disable_ipv6 = 1  
*** server2 : ('sysctl -w net.ipv6.conf.default.disable_ipv6=1',)  
net.ipv6.conf.default.disable_ipv6 = 1  
*** switch : ('sysctl -w net.ipv6.conf.all.disable_ipv6=1',)  
net.ipv6.conf.all.disable_ipv6 = 1  
*** switch : ('sysctl -w net.ipv6.conf.default.disable_ipv6=1',)  
net.ipv6.conf.default.disable_ipv6 = 1  
*** Starting controller  
  
*** Starting 0 switches  
  
*** Starting CLI:  
mininet> xterm switch  
mininet> xterm client  
mininet> xterm server1  
mininet> xterm server2  
mininet>   
  
"Node: switch"  
root@lungsion-VMware:/home/lungsion# ./syenv/bin/swyard ./lab2/myswitch_to.py  
16:17:25 2025/06/03 INFO Saving iptables state and installing switchyard rul  
es  
16:17:25 2025/06/03 INFO Using network devices: switch-eth1 switch-eth2 swit  
ch-eth0
```



```

"Node: switch"
16:19:06 2025/06/03      INFO Flooding packet Ethernet 30:00:00:00:00:01->ff:
f:ff:ff:ff ARP | Arp 30:00:00:00:00:01:192.168.100.3 00:00:00:00:00:00:192.1
00.1 to switch-eth0
16:19:06 2025/06/03      INFO Sending packet Ethernet 10:00:00:00:00:
:00:00:01 ARP | Arp 10:00:00:00:00:01:192.168.100.1 30:00:00:00:00:0
0.3 to switch-eth2
16:19:07 2025/06/03      INFO Sending packet Ethernet 30:00:0
:00:00:01 IP | IPv4 192.168.100.3->192.168.100.1 ICMP | ICMP
(56 data bytes) to switch-eth0
16:19:07 2025/06/03      INFO Sending packet Ethernet
:00:00:01 IP | IPv4 192.168.100.1->192.168.100.3 ICM
6 data bytes) to switch-eth2
16:19:07 2025/06/03      INFO Sending pac
:00:00:01 IP | IPv4 192.168.100.3->192.1
(56 data bytes) to switch-eth0
16:19:07 2025/06/03      INFO Sending
:00:00:01 IP | IPv4 192.168.100.1->1
6 data bytes) to switch-eth2
16:19:12 2025/06/03      INFO Sending
:00:00:01 ARP | Arp 10:00:00:00:00:0
0.3 to switch-eth2
16:19:12 2025/06/03      INFO Sending
:00:00:01 ARP | Arp 30:00:00:00:00:0
0.1 to switch-eth0

```

#### 4 实验总结

通过本次实验，我深入理解了以太网交换机的工作原理，掌握了如何通过交换机的端口接收和转发以太网帧，以及如何实现 MAC 地址的学习和表项管理。实验过程中，我学习了以下内容：

以太网交换机的基本功能：了解了交换机如何通过 MAC 地址表进行帧的转发和泛洪。

表项管理策略：学会了如何实现超时机制、最近最少使用（LRU）规则和流量最少的删除规则。

Switchyard 框架的使用：熟悉了 Switchyard 框架的编程方法，包括如何接收和发送数据包。

Mininet 与网络测试：掌握了 Mininet 网络仿真环境的使用方法，能够通过 Wireshark 捕获并分析网络数据包。

本次实验为后续学习更复杂的网络设备和协议奠定了基础，使我更加深入地理解了计算机网络中交换机的工作机制。

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