Lab2:Learning Switch

一、实验目标

1. 实现基于MAC地址学习的二层自学习交换机
2. 处理环路广播

二、实验环境

实验在VMware运行的Arch Linux虚拟机上进行

组件	版本/配置
控制器	OSKen
虚拟化平台	Mininet
抓包工具	Wireshark

三、任务描述及方案设计

a.实验任务一

在简单交换机的基础上实现二层自学习交换机，避免数据包的洪泛。

方案设计

SDN 自学习交换机的工作流程可以参考：

1. 控制器为每个交换机维护一个 mac-port 映射表。
2. 控制器收到 packet_in 消息后，解析其中携带的数据包。
3. 控制器学习 src_mac - in_port 映射。
4. 控制器查询 dst_mac ， 如果未学习，则洪泛数据包；如果已学习，则向指定端口转发数据包(packet_out)，并向交换机下发流表项(flow_mod)，指导交换机转发同类型的数据包。

核心代码展示：(完整代码见报告最后)

```
self.mac_to_port.setdefault(dpid,{})
self.mac_to_port[dpid][src] = in_port

if dst in self.mac_to_port[dpid]:
    actions = [parser.OFPActionOutput(self.mac_to_port[dpid][dst])]
    match = parser.OFPMatch(eth_dst = dst)
    self.add_flow(dp,1,match,actions,idle_timeout=20)
else:
    actions = [parser.OFPActionOutput(ofp.OFPP_FLOOD)]

# h1 ping h3后，交换机的表学习到了h1的端口
# 因此h3 -> h1的响应部分，仍然会上传packetIn,学习h3，同时，交换机学习到了h3的端口，并下放h1
# 按此逻辑，只有request会泄洪，因为reply虽然会上传packetIn,但控制器已经记录了out_port。

data = None
if msg.buffer_id == ofp.OFP_NO_BUFFER:
    data = msg.data

out = parser.OFPPacketOut(
    datapath = dp,
    buffer_id = msg.buffer_id,
    in_port = in_port,
    actions = actions,
    data=data
)
dp.send_msg(out)
```

代码简述:

b.实验任务二

请在自学习交换机的基础上完善代码，处理环路广播。

方案设计

当序号为 dpid 的交换机从 in_port 第一次收到某个 src_mac 主机发出，询问 dst_ip 的广播 ARP Request 数据包时，控制器记录一个映射 (dpid, src_mac, dst_ip)->in_port 。下一次该交换机收到同一 (src_mac, dst_ip) 但 in_port 不同的 ARP Request 数据包时直接丢弃，否则洪泛。

核心代码展示:(完整代码见报告最后)

```
dropp = False

header_list = dict((p.protocol_name, p) for p in pkt.protocols if type(p) != str)
if dst == ETHERNET_MULTICAST and ARP in header_list:
    arp_pkt = pkt.get_protocol(arp.arp)
    dst_ip = arp_pkt.dst_ip
    arp_key = (dpid,src,dst_ip)
    if arp_key in self.arp_map:
        if self.arp_map[arp_key] != in_port:
            dropp = True
    self.arp_map[arp_key] = in_port

if not dropp:
    self.mac_to_port.setdefault(dpid,{})
    self.mac_to_port[dpid][src] = in_port

    if dst in self.mac_to_port[dpid]:
        actions = [parser.OFPActionOutput(self.mac_to_port[dpid][dst])]
        match = parser.OFPMatch(eth_dst = dst)
        self.add_flow(dp,1,match,actions,idle_timeout=10)
    else:
        actions = [parser.OFPActionOutput(ofp.OFPP_FLOOD)]

    data = None
    if msg.buffer_id == ofp.OFP_NO_BUFFER:
        data = msg.data

    out = parser.OFPPacketOut(
        datapath = dp,
        buffer_id = msg.buffer_id,
        in_port = in_port,
        actions = actions,
        data=data
    )
    dp.send_msg(out)
else:
    out = parser.OFPPacketOut(
        datapath=dp,
        buffer_id=msg.buffer_id,
        in_port=in_port,
        actions=[],
        data=None
    )
```

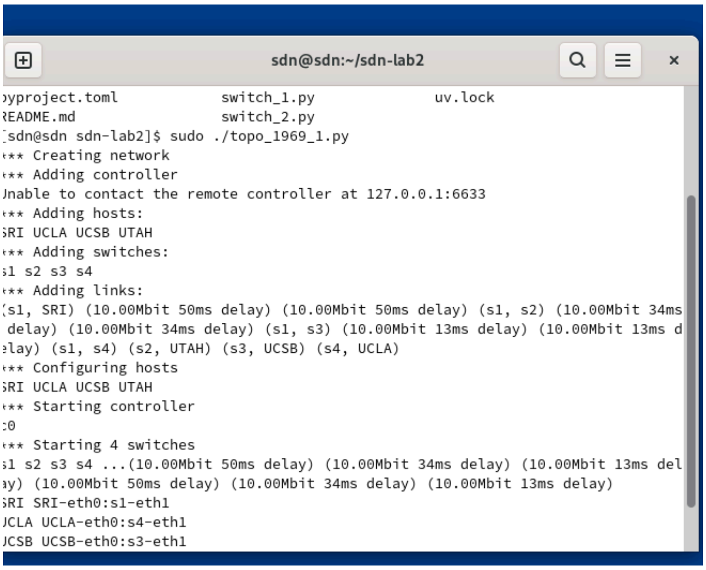
```
            dp.send_msg(out)
```

代码简述:
交换机发给控制器packet-In消息，控制器若发现是广播ARP request包，就记录dpid(唯一标识某个交换机),源mac,目的IP -> in_port的映射,若发现已记录过了,就标记dropp为真准备丢弃。
若dropp为true,构造一条actions为空的OFPPacketOut发给dp即丢弃该包。
若dropp为false,就进行二层自学习交换机的流程。

四、实验过程

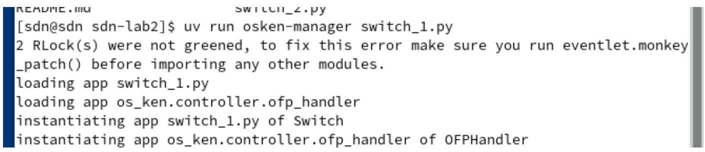
启动1969_1拓扑

```
sudo ./topo_1969_1.py
```



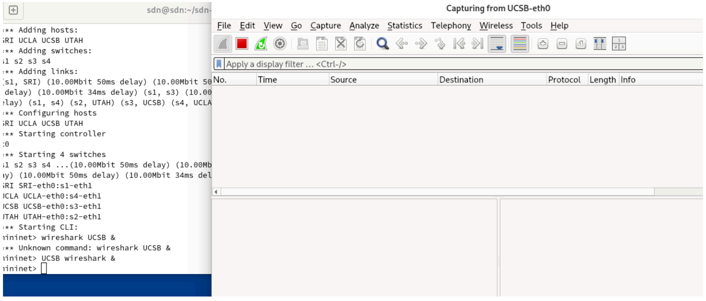
启动编写好的控制器

```
uv run osken-manager switch_1.py
```

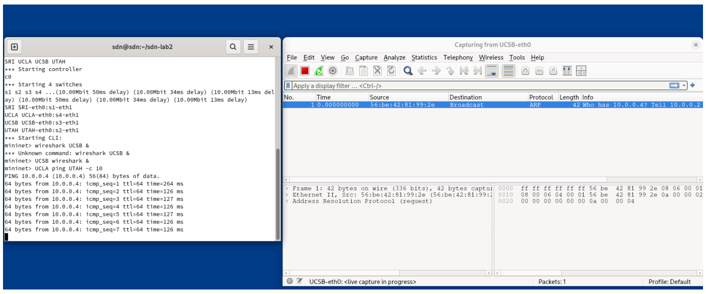


抓包UCSB

```
UCSB wireshark &
```




```
UCLA ping UTAH -c 10
```

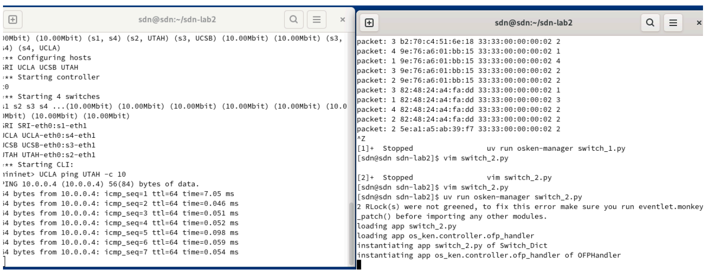


发现UCSB只收到了第一次的广播包,说明实现成功。

类似地，启动拓扑2,和编写好的控制器，尝试ping

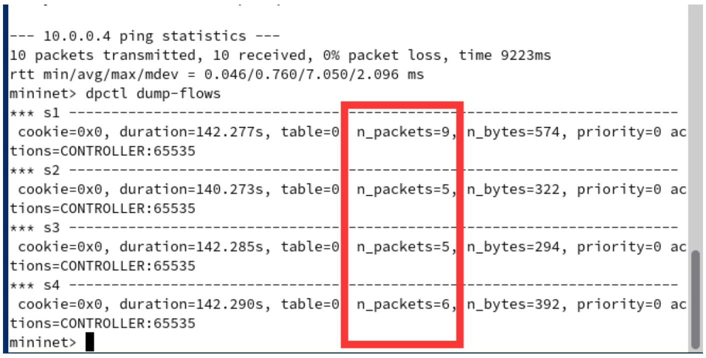
```
sudo ./topo_1969_2.py
uv run osken-manager switch_2.py
UCLA ping UTAH -c 10
```

发现ping通

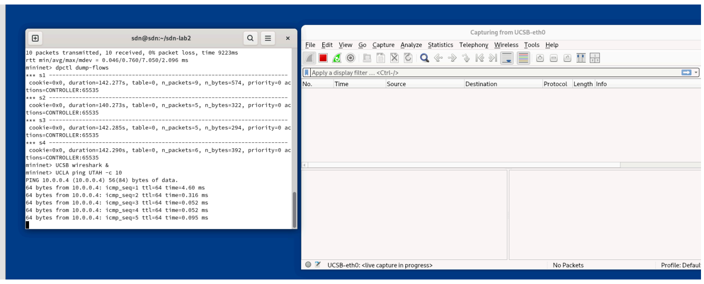


查看流表项，发现匹配次数大大减少

```
dpctl dump-flows
```



并且抓一下UTAH的包，发现没有收到任何包。（因为在测试能否ping通时，已经记录了流表项和mac地址,所以连第一次的广播包也没有收到）



五、遇到的问题及解决方案

1.缓存问题混淆

起初误以为"不考虑缓存"及发data=None,结果发现搞反，data=None是告知控制器使用缓存的data。修正后保留了缓存处理部分，使得代码更完整。

2.arp ip的获取

起初直接调用arp_pkt = pkt.get_protocol(arp.arp)
dst_ip = arp_pkt.dst_ip
发现报错。
错误原因:代码并不知道包是否为arp包，若不是，则出错。因此，将代码移入到检测arp包的条件后即可。

六、结论

成功设计了二层自学习交换机，避免了数据包的泛洪，成功实现给出的策略解决了环路广播。

附录：

switch_1.py

```python
from os_ken.base import app_manager
from os_ken.controller import ofp_event
from os_ken.controller.handler import MAIN_DISPATCHER, CONFIG_DISPATCHER
from os_ken.controller.handler import set_ev_cls
from os_ken.ofproto import ofproto_v1_3
from os_ken.lib.packet import packet
from os_ken.lib.packet import ethernet

class Switch(app_manager.OSKenApp):
    OFP_VERSIONS = [ofproto_v1_3.OFP_VERSION]

    def __init__(self, *args, **kwargs):
        super(Switch, self).__init__(*args, **kwargs)
        # maybe you need a global data structure to save the mapping
        self.mac_to_port = {}

    def add_flow(self, datapath, priority, match, actions, idle_timeout=0, hard_timeout=0):
        dp = datapath
        ofp = dp.ofproto
        parser = dp.ofproto_parser
        inst = [parser.OFPInstructionActions(ofp.OFPIT_APPLY_ACTIONS, actions)]
        mod = parser.OFPFlowMod(
            datapath=dp,
            priority=priority,
            idle_timeout=idle_timeout,
            hard_timeout=hard_timeout,
            match=match,
            instructions=inst
        )
        dp.send_msg(mod)

    @set_ev_cls(ofp_event.EventOFPSwitchFeatures, CONFIG_DISPATCHER)
    def switch_features_handler(self, ev):
        msg = ev.msg
        dp = msg.datapath
        ofp = dp.ofproto
        parser = dp.ofproto_parser
        match = parser.OFPMatch()
        actions = [parser.OFPActionOutput(ofp.OFPP_CONTROLLER, ofp.OFPCML_NO_BUFFER)]
        self.add_flow(dp, 0, match, actions)

    @set_ev_cls(ofp_event.EventOFPPacketIn, MAIN_DISPATCHER)
    def packet_in_handler(self, ev):
        msg = ev.msg
        dp = msg.datapath
        ofp = dp.ofproto
```

```
parser = dp.ofproto_parser
dpid = dp.id
in_port = msg.match['in_port']
pkt = packet.Packet(msg.data)
eth_pkt = pkt.get_protocol(ethernet.ethernet)
dst = eth_pkt.dst
src = eth_pkt.src
self.logger.info('packet: %s %s %s %s', dpid, src, dst, in_port)
# You need to code here to avoid the direct flooding

# dpid1 mac1:port1 mac2:port2
self.mac_to_port.setdefault(dpid,{})
self.mac_to_port[dpid][src] = in_port

if dst in self.mac_to_port[dpid]:
    actions = [parser.OFPActionOutput(self.mac_to_port[dpid][dst])]
    match = parser.OFPMatch(eth_dst = dst)
    self.add_flow(dp,1,match,actions,idle_timeout=20)
else:
    actions = [parser.OFPActionOutput(ofp.OFPP_FLOOD)]

# h1 ping h3后，交换机的表学习到了h1的端口
# 因此h3 -> h1的响应部分，仍然会上传packetIn,学习h3，同时，交换机学习到了h3的端口，并下放h1
# 按此逻辑，只有request会泄洪，因为reply虽然会上传packetIn,但控制器已经记录了out_port。

data = None
if msg.buffer_id == ofp.OFP_NO_BUFFER:
    data = msg.data

out = parser.OFPPacketOut(
    datapath = dp,
    buffer_id = msg.buffer_id,
    in_port = in_port,
    actions = actions,
    data=data
)
dp.send_msg(out)
```

switch_2.py

```python
from os_ken.base import app_manager
from os_ken.controller import ofp_event
from os_ken.controller.handler import MAIN_DISPATCHER, CONFIG_DISPATCHER
from os_ken.controller.handler import set_ev_cls
from os_ken.ofproto import ofproto_v1_3
from os_ken.lib.packet import packet
from os_ken.lib.packet import ethernet
from os_ken.lib.packet import arp
from os_ken.lib.packet import ether_types

# 定义常量
ETHERNET = ethernet.ethernet.__name__
ETHERNET_MULTICAST = "ff:ff:ff:ff:ff:ff"
ARP = arp.arp.__name__

class Switch_Dict(app_manager.OSKenApp):
    """支持环路防护的自学习交换机"""
    OFP_VERSIONS = [ofproto_v1_3.OFP_VERSION]

    def __init__(self, *args, **kwargs):
        super(Switch_Dict, self).__init__(*args, **kwargs)
        self.mac_to_port = {}  # MAC地址学习表: dpid -> {mac: port}
        self.arp_map = {}  # ARP请求记录表: (dpid, src_mac, dst_ip) -> in_port

    def add_flow(self, datapath, priority, match, actions, idle_timeout=0, hard_timeout=0):
        """下发流表项到交换机"""
        dp = datapath
        ofp = dp.ofproto
        parser = dp.ofproto_parser

        # 构造流表项指令
        inst = [parser.OFPInstructionActions(ofp.OFPIT_APPLY_ACTIONS, actions)]

        # 创建FlowMod消息
        mod = parser.OFPFlowMod(
            datapath=dp,
            priority=priority,
            idle_timeout=idle_timeout,
            hard_timeout=hard_timeout,
            match=match,
            instructions=inst
        )

        # 发送流表项
        dp.send_msg(mod)
```

```python
@set_ev_cls(ofp_event.EventOFPSwitchFeatures, CONFIG_DISPATCHER)
def switch_features_handler(self, ev):
    """处理交换机连接事件"""
    msg = ev.msg
    dp = msg.datapath
    ofp = dp.ofproto
    parser = dp.ofproto_parser

    # 添加默认流表项（table-miss）
    match = parser.OFPMatch()
    actions = [parser.OFPActionOutput(ofp.OFPP_CONTROLLER, ofp.OFPCML_NO_BUFFER)]
    self.add_flow(dp, 0, match, actions)

@set_ev_cls(ofp_event.EventOFPPacketIn, MAIN_DISPATCHER)
def packet_in_handler(self, ev):
    """处理Packet-In消息"""
    msg = ev.msg
    dp = msg.datapath
    ofp = dp.ofproto
    parser = dp.ofproto_parser

    # 获取交换机ID和入端口
    dpid = dp.id
    in_port = msg.match['in_port']

    # 解析数据包
    pkt = packet.Packet(msg.data)
    eth_pkt = pkt.get_protocol(ethernet.ethernet)

    # 过滤LLDP和IPv6数据包
    if eth_pkt.ethertype == ether_types.ETH_TYPE_LLDP:
        return
    if eth_pkt.ethertype == ether_types.ETH_TYPE_IPV6:
        return

    # 获取源/目的MAC地址
    dst = eth_pkt.dst
    src = eth_pkt.src

    dropp = False

    header_list = dict((p.protocol_name, p) for p in pkt.protocols if type(p) != str)
    if dst == ETHERNET_MULTICAST and ARP in header_list:
        arp_pkt = pkt.get_protocol(arp.arp)
        dst_ip = arp_pkt.dst_ip
        arp_key = (dpid,src,dst_ip)
```

```
        if arp_key in self.arp_map:
            if self.arp_map[arp_key] != in_port:
                dropp = True
        self.arp_map[arp_key] = in_port

    if not dropp:
        self.mac_to_port.setdefault(dpid,{})
        self.mac_to_port[dpid][src] = in_port

        if dst in self.mac_to_port[dpid]:
            actions = [parser.OFPActionOutput(self.mac_to_port[dpid][dst])]
            match = parser.OFPMatch(eth_dst = dst)
            self.add_flow(dp,1,match,actions,idle_timeout=10)
        else:
            actions = [parser.OFPActionOutput(ofp.OFPP_FLOOD)]

        data = None
        if msg.buffer_id == ofp.OFP_NO_BUFFER:
            data = msg.data

        out = parser.OFPPacketOut(
            datapath = dp,
            buffer_id = msg.buffer_id,
            in_port = in_port,
            actions = actions,
            data=data
        )
        dp.send_msg(out)
    else:
        out = parser.OFPPacketOut(
            datapath=dp,
            buffer_id=msg.buffer_id,
            in_port=in_port,
            actions=[],
            data=None
        )
        dp.send_msg(out)
```