实验一指导书

实验目的

通过本次实验，希望大家掌握以下内容：

- 了解**自学习交换机**的工作原理，学习用`Ryu app`编程实现自学习交换机。
- 思考环状拓扑中出现**广播风暴**的原因，复习传统网络怎样处理这一问题——生成树协议。
- `SDN`控制器掌握网络全局信息，思考`SDN`如何借助这一优势，以多种新策略解决环路广播问题。
- 理解数控平面之间利用`Packet In`、`Packet Out`、`Flow Mod`等`OpenFlow Message`进行交互的过程。
- 学习`Flow Table`的使用，理解默认流表项的作用。

问题背景

你是一名网络工程师，擅长利用`SDN`技术解决网络设计中的难题。而你的许多同事是传统网络技术的支持者，对于`SDN`技术，他们经常发出质疑：“传统网络工作地蛮好的，为什么要把它替换掉？”

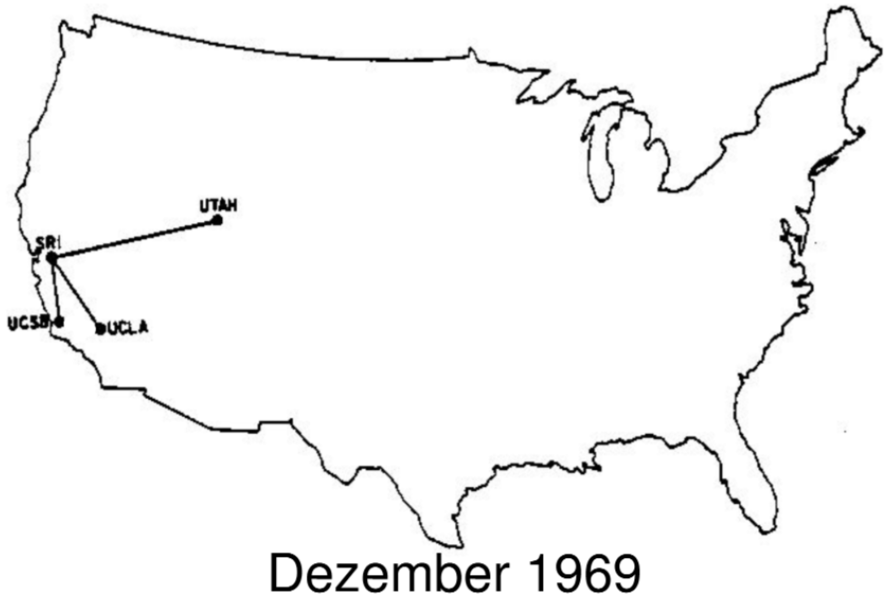
一次意外中你穿越到了1969年，正值互联网的前身`ARPANET`的初创时期。与历史不同的是，你将以`SDN`提供的全新方案，设计、建立、维护`ARPANET`。

接下来的四次实验分别涉及**二层交换机**、**网络状态感知**、**路由策略**、**网络验证**四个主题，请跟随`APRANET`的发展历程，用你的智慧解决纷至沓来的一个个问题，通过一次次实验逐步丰富、完善你所设计的`ARPANET`。

在实验中，注意对比`SDN`和传统网络在解决同一问题时各自采用的策略，客观分析`SDN`的得与失。

最后，祝你最终收获一个令自己满意的作品！

实验任务一：自学习交换机



1969年的`ARPANET`非常简单，仅由四个结点组成。假设每个结点都对应一个交换机，每个交换机都具有一个直连主机，你的任务是实现不同主机之间的正常通信。

预备实验中的简单交换机洪泛数据包，虽然能初步实现主机间的通信，但会带来不必要的带宽消耗；并且会使通信内容泄露给第三者。因此，请你**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。**

问题说明

- `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。

- 网络拓扑为`topo_1969_1.py`，启动方式：

```
sudo python topo_1969_1.py
```

- 可以不考虑交换机对数据包的缓存(`no_buffer`)。

代码框架

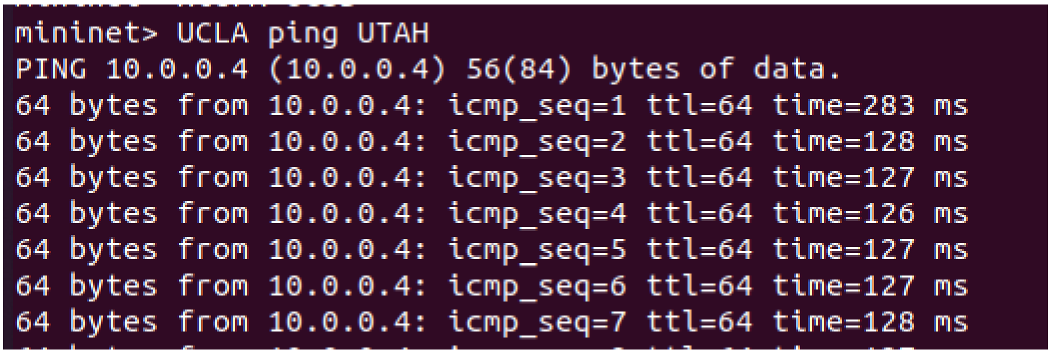
以下给出代码框架，只需补充关键的若干行实现即可：

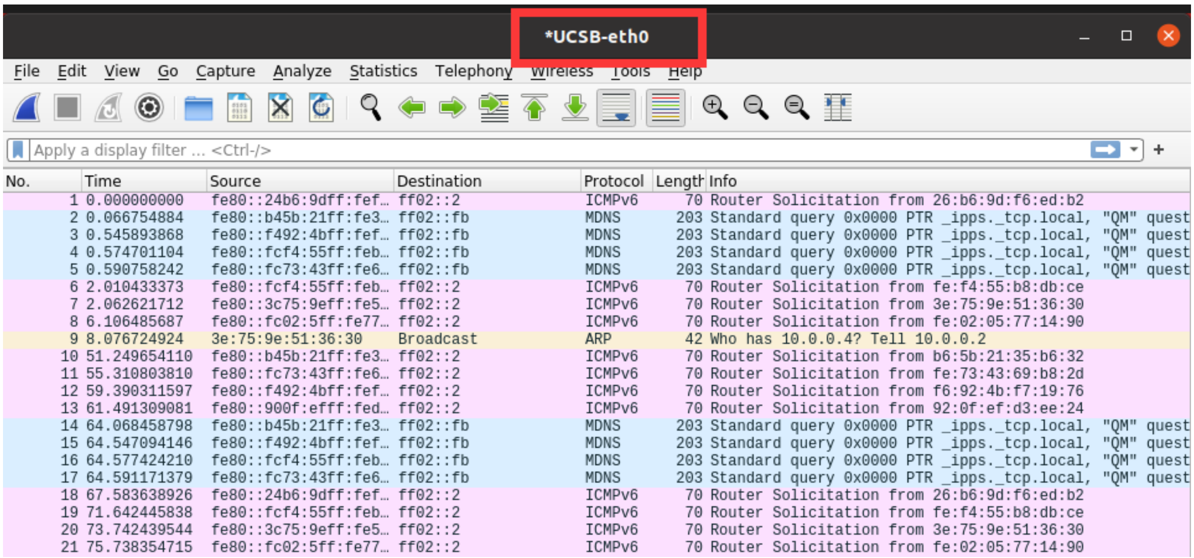
```
from ryu.base import app_manager
from ryu.controller import ofp_event
from ryu.controller.handler import MAIN_DISPATCHER, CONFIG_DISPATCHER
from ryu.controller.handler import set_ev_cls
from ryu.ofproto import ofproto_v1_3
from ryu.lib.packet import packet
from ryu.lib.packet import ethernet
class Switch(app_manager.RyuApp):
    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

    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

        # the identity of switch
        dpid = dp.id
        self.mac_to_port.setdefault(dpid,{})
        # the port that receive the packet
        in_port = msg.match['in_port']
        pkt = packet.Packet(msg.data)
        eth_pkt = pkt.get_protocol(ethernet.ethernet)
        # get the mac
        dst = eth_pkt.dst
        src = eth_pkt.src
        # we can use the logger to print some useful information
        self.logger.info('packet: %s %s %s %s', dpid, src, dst, in_port)

        # you need to code here to avoid the direct flooding
        # having fun
        # :)
```

结果示例

`UCLA ping UTAH`，`UCSB`不再收到相关数据包：



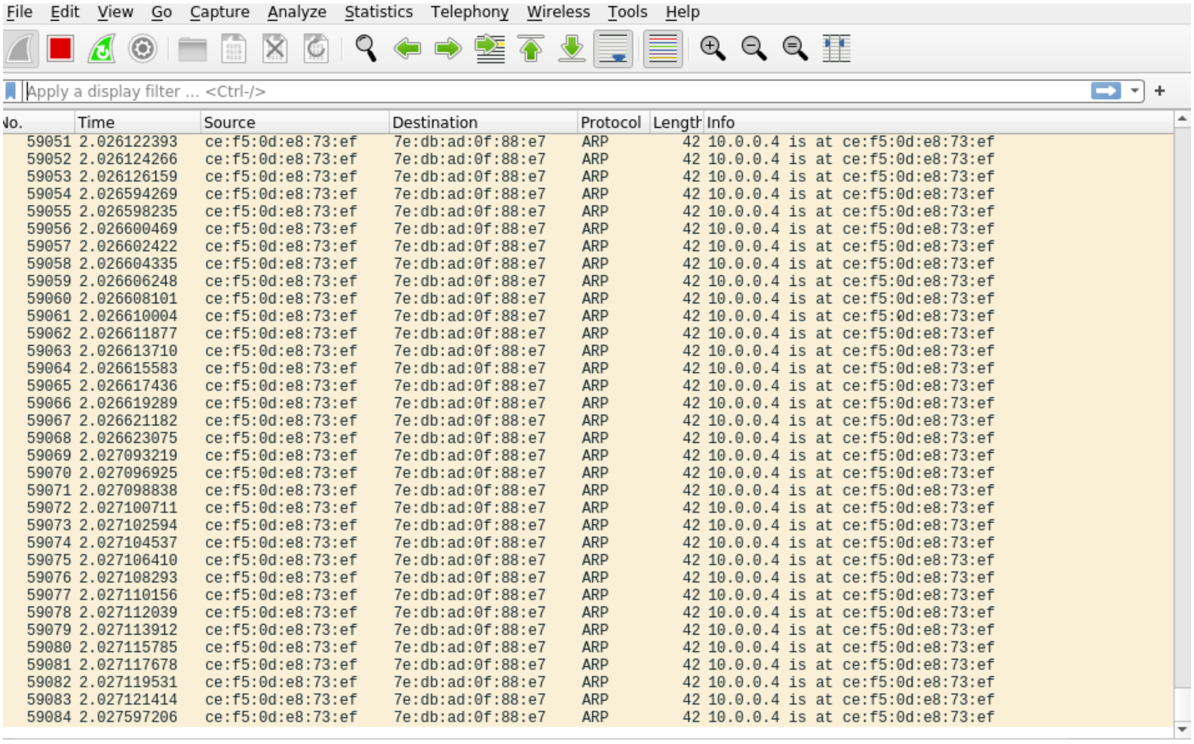


No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	fe80::24b6:9dff:fef…	ff02::2	ICMPv6	70	Router Solicitation from 26:b6:9d:f6:ed:b2
2	0.066754884	fe80::b45b:21ff:fe3…	ff02::fb	MDNS	203	Standard query 0x0000 PTR _ipps._tcp.local, "QM" quest
3	0.545893868	fe80::f492:4bff:fef…	ff02::fb	MDNS	203	Standard query 0x0000 PTR _ipps._tcp.local, "QM" quest
4	0.574701104	fe80::fcf4:55ff:feb…	ff02::fb	MDNS	203	Standard query 0x0000 PTR _ipps._tcp.local, "QM" quest
5	0.590758242	fe80::fc73:43ff:fe6…	ff02::fb	MDNS	203	Standard query 0x0000 PTR _ipps._tcp.local, "QM" quest
6	2.010433373	fe80::fcf4:55ff:feb…	ff02::2	ICMPv6	70	Router Solicitation from fe:f4:55:b8:db:ce
7	2.062621712	fe80::3c75:9eff:fe5…	ff02::2	ICMPv6	70	Router Solicitation from 3e:75:9e:51:36:30
8	6.106485687	fe80::fc02:5ff:fe77…	ff02::2	ICMPv6	70	Router Solicitation from fe:02:05:77:14:90
9	8.076724924	3e:75:9e:51:36:30	Broadcast	ARP	42	Who has 10.0.0.4? Tell 10.0.0.2
10	51.249654110	fe80::b45b:21ff:fe3…	ff02::2	ICMPv6	70	Router Solicitation from b6:5b:21:35:b6:32
11	55.310803810	fe80::fc73:43ff:fe6…	ff02::2	ICMPv6	70	Router Solicitation from fe:73:43:69:b8:2d
12	59.390311597	fe80::f492:4bff:fef…	ff02::2	ICMPv6	70	Router Solicitation from f6:92:4b:f7:19:76
13	61.491309081	fe80::900f:efff:fed…	ff02::2	ICMPv6	70	Router Solicitation from 92:0f:ef:d3:ee:24
14	64.068458798	fe80::b45b:21ff:fe3…	ff02::fb	MDNS	203	Standard query 0x0000 PTR _ipps._tcp.local, "QM" quest
15	64.547094146	fe80::f492:4bff:fef…	ff02::fb	MDNS	203	Standard query 0x0000 PTR _ipps._tcp.local, "QM" quest
16	64.577424210	fe80::fcf4:55ff:feb…	ff02::fb	MDNS	203	Standard query 0x0000 PTR _ipps._tcp.local, "QM" quest
17	64.591171379	fe80::fc73:43ff:fe6…	ff02::fb	MDNS	203	Standard query 0x0000 PTR _ipps._tcp.local, "QM" quest
18	67.583638926	fe80::24b6:9dff:fef…	ff02::2	ICMPv6	70	Router Solicitation from 26:b6:9d:f6:ed:b2
19	71.642445838	fe80::fcf4:55ff:feb…	ff02::2	ICMPv6	70	Router Solicitation from fe:f4:55:b8:db:ce
20	73.742439544	fe80::3c75:9eff:fe5…	ff02::2	ICMPv6	70	Router Solicitation from 3e:75:9e:51:36:30
21	75.738354715	fe80::fc02:5ff:fe77…	ff02::2	ICMPv6	70	Router Solicitation from fe:02:05:77:14:90

实验任务二：环路广播

Dezember 1969

`UCLA`和`UCSB`通信频繁，两者间建立了一条直连链路。在新的拓扑`topo_1969_2.py`中运行自学习交换机，`UCLA`和`UTAH`之间无法正常通信。分析流表发现，源主机虽然只发了很少的几个数据包，但流表项却匹配了上千次；`wireShark`也截取到了数目异常大的相同报文。



这实际上是 `ARP` 广播数据包在环状拓扑中洪泛导致的，传统网络利用**生成树协议**解决这一问题。在 `SDN` 中，不必局限于生成树协议，可以通过多种新的策略解决这一问题。以下给出一种解决思路，请在自学习交换机的基础上完善代码，解决问题：

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。

代码框架

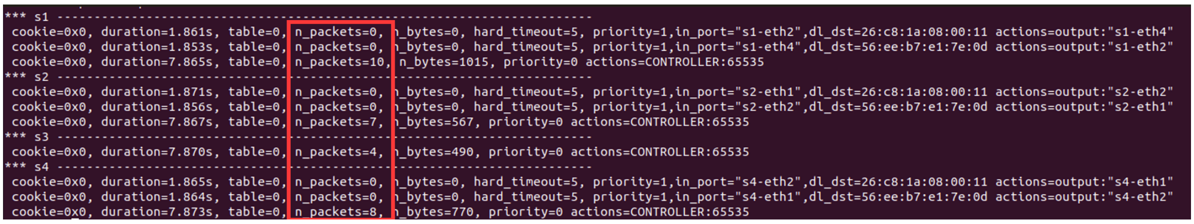
```
from ryu.base import app_manager
from ryu.controller import ofp_event
from ryu.controller.handler import MAIN_DISPATCHER, CONFIG_DISPATCHER
from ryu.controller.handler import set_ev_cls
from ryu.ofproto import ofproto_v1_3
from ryu.lib.packet import packet
from ryu.lib.packet import ethernet
from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

ETHERNET = ethernet.ethernet.__name__
ETHERNET_MULTICAST = "ff:ff:ff:ff:ff:ff"
ARP = arp.arp.__name__


class Switch_Dict(app_manager.RyuApp):
    OFP_VERSIONS = [ofproto_v1_3.OFP_VERSION]
```

```python
    def __init__(self, *args, **kwargs):
        super(Switch_Dict, self).__init__(*args, **kwargs)
        self.sw = {} #(dpid, src_mac, dst_ip)=>in_port, you may use it in
mission 2
        # maybe you need a global data structure to save the mapping
        # just data structure in mission 1


    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

        # the identity of switch
        dpid = dp.id
        self.mac_to_port.setdefault(dpid, {})
        # the port that receive the packet
        in_port = msg.match['in_port']
        pkt = packet.Packet(msg.data)
        eth_pkt = pkt.get_protocol(ethernet.ethernet)
        if eth_pkt.ethertype == ether_types.ETH_TYPE_LLDP:
            return
        if eth_pkt.ethertype == ether_types.ETH_TYPE_IPV6:
            return
        # get the mac
        dst = eth_pkt.dst
        src = eth_pkt.src
        # get protocols
        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:
        # you need to code here to avoid broadcast loop to finish mission 2
```

```
        # self-learning
        # you need to code here to avoid the direct flooding
        # having fun
        # :)
        # just code in mission 1
```

结果示例

解决`ARP`数据包在环状拓扑中的洪泛问题后，`UCLA`和`UTAH`之间可以`ping`通，并且流表项的匹配次数明显减少：



附加题

实验任务二只给出了一种参考方案，`SDN`中还有多种方案可供选择，请尝试设计实现一种新的策略解决环路广播问题。

附加题主要面向学有余力的同学，请结合自身实际决定是否选做。

扩展资料

- `SDN`论坛：sdnlab
- 关于`Mininet`的更多资料：Mininet Doc，Mininet API
- 关于`Ryu APP`开发的更多资料：Ryu Book