

H2 南京大学本科生实验报告

课程名称：计算机网络 任课教师：李文中

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H3 1. 实验名称：Respond to ARP

H3 2. 实验目的

1. 理解路由器ARP协议机制
2. 掌握ARP应答表段的编写格式
3. 理解ARP缓存表的更新机制

H3 3. 实验过程

H4 Task 2 处理ARP请求数据包

H5 a. 实现原理

1. 判断是否为ARP请求包以及目的ip是否被该路由器子网覆盖；
2. 构造对应的ARP应答包发送至请求包的端口即可。

H5 b. 代码编写

```
def forward_packet(self, port, packet): #自定义转发数据报函数
    if packet[Ethernet].ethertype == EtherType.ARP:
        if packet[Arp].operation == ArpOperation.Request:
            self.arp_request(port, packet)#处理ARP请求包

def arp_request(self, port, packet):#ARP请求数据报处理函数
    ...#获得目的、源的ip和mac地址
    if dst_ip in self.mydic:
        ether = Ethernet(src=self.mydic[dst_ip],
                        dst=src_mac,
                        ethertype=EtherType.ARP)
        arp = Arp(operation=ArpOperation.Reply,
                senderhwaddr=self.mydic[dst_ip],
                senderprotoaddr=dst_ip,
                targethwaddr=src_mac,
                targetprotoaddr=src_ip)
        arppacket = ether + arp#构造ARP reply包
        self.net.send_packet(port, arppacket)

def router_main(self):
    while True:
        gotpkt = True
        try:
            timestamp, dev, pkt = self.net.recv_packet(timeout=1.0)
            self.forward_packet(dev, pkt)#收到包便进行转发处理
```

H5 c. 实现测试

H6 I. test scenario测试

给定测试文件测试结果

运行 `swyard -t lab_3/routertests1.srpy myrouter.py`, 结果如下:

```
Results for test scenario ARP request: 9 passed, 0 failed, 0 pending

Passed:
1  ARP request for 192.168.1.1 should arrive on router-eth0
2  Router should send ARP response for 192.168.1.1 on router-eth0
3  An ICMP echo request for 10.10.12.34 should arrive on router-eth0, but it should be dropped (router should only handle ARP requests at this point)
4  ARP request for 172.16.42.1 should arrive on router-eth2
5  Router should send ARP response for 172.16.42.1 on router-eth2
6  ARP request for 10.10.1.2 should arrive on router-eth1, but the router should not respond.
7  ARP request for 10.10.1.1 should arrive on on router-eth1
8  ARP request for 10.10.0.1 should arrive on on router-eth1
9  Router should send ARP response for 10.10.0.1 on router-eth1

All tests passed!
```

测试文档说明

```
s.add_interface('eth1', '10:00:00:00:00:00', '1.0.0.0')
s.add_interface('eth2', '20:00:00:00:00:00', '2.0.0.0')
s.add_interface('eth3', '30:00:00:00:00:00', '3.0.0.0')
#case1 ask 1.0.0.0's mac normal
request_pkt =
create_ip_arp_request('40:00:00:00:00:00', '4.0.0.0', '1.0.0.0')
s.expect(PacketInputEvent('eth1', request_pkt))
reply_pkt = create_ip_arp_reply('10:00:00:00:00:00',
'40:00:00:00:00:00', '1.0.0.0', '4.0.0.0')
s.expect(PacketOutputEvent('eth1', reply_pkt))
#case2 ask ip which not in router
request_pkt =
create_ip_arp_request('40:00:00:00:00:00', '4.0.0.0', '5.0.0.0')
s.expect(PacketInputEvent('eth1', request_pkt))
s.expect(PacketInputTimeoutEvent(0.4))
#case3 packet type not request can't process
p = Ethernet(src="00:11:22:33:44:55", dst="66:55:44:33:22:11") +
IPv4(src="1.1.1.1", dst="2.2.2.2", protocol=IPProtocol.UDP) +
UDP(src=5555, dst=8888)
s.expect(PacketInputEvent('eth1', p))
s.expect(PacketInputTimeoutEvent(0.4))
#case4 ask 3.0.0.0's mac normal
request_pkt =
create_ip_arp_request('60:00:00:00:00:00', '6.0.0.0', '3.0.0.0')
s.expect(PacketInputEvent('eth2', request_pkt))
reply_pkt = create_ip_arp_reply('30:00:00:00:00:00',
'60:00:00:00:00:00', '3.0.0.0', '6.0.0.0')
s.expect(PacketOutputEvent('eth2', reply_pkt))
```

1. 设置路由器的三个接口所含的ip地址和mac地址;
2. case1、4正常查询该路由网内ip地址对应的mac地址, 应从接收端口发出特定应答包;
3. case2中目的ip不在该子网内, case3数据包类型不为request, 路由器均不做处理。

测试结果

运行 `swyard -t mytests.py myrouter_to`, 结果如下:

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

Passed:
1 request packet Ethernet 40:00:00:00:00:00->ff:ff:ff:ff:ff:ff
  ARP | Arp 40:00:00:00:00:00:4.0.0.0
  ff:ff:ff:ff:ff:ff:1.0.0.0 arrive on eth1
2 reply packet Ethernet 10:00:00:00:00:00->40:00:00:00:00:00
  ARP | Arp 10:00:00:00:00:00:1.0.0.0
  40:00:00:00:00:00:4.0.0.0 forward to eth1
3 request packet Ethernet 40:00:00:00:00:00->ff:ff:ff:ff:ff:ff
  ARP | Arp 40:00:00:00:00:00:4.0.0.0
  ff:ff:ff:ff:ff:ff:5.0.0.0 arrive on eth1
4 the request dst ip 5.0.0.0 not in this router so nothing
  happen
5 A udp packet should arrive on eth1
6 the UDP packet current router can't process so nothing
  happen
7 request packet Ethernet 60:00:00:00:00:00->ff:ff:ff:ff:ff:ff
  ARP | Arp 60:00:00:00:00:00:6.0.0.0
  ff:ff:ff:ff:ff:ff:3.0.0.0 arrive on eth1
8 reply packet Ethernet 30:00:00:00:00:00->60:00:00:00:00:00
  ARP | Arp 30:00:00:00:00:00:3.0.0.0
  60:00:00:00:00:00:6.0.0.0 forward to eth1
```

H6 II. 抓包测试

在mininet中运行已有topo结构, 开启server2的wireshark抓包监听, 执行 `server2 ping -c1 10.1.1.2`得到抓包结果如图所示:

1	0.000000000	20:00:00:00:00:01	Broadcast	ARP	42 Who has 192.168.200.2? Tell 192.168.200.1
2	0.095440251	40:00:00:00:00:02	20:00:00:00:00:01	ARP	42 192.168.200.2 is at 40:00:00:00:00:02
3	0.095459634	192.168.200.1	10.1.1.2	ICMP	98 Echo (ping) request id=0x260e, seq=1/256, ttl=64 (no response found!)

▶ Frame 1: 42 bytes on wire (336 bits), 42 bytes captured (336 bits) on interface 0
▶ Ethernet II, Src: 20:00:00:00:00:01 (20:00:00:00:00:01), Dst: Broadcast (ff:ff:ff:ff:ff:ff)
▼ Address Resolution Protocol (request)
 Hardware type: Ethernet (1)
 Protocol type: IPv4 (0x0800)
 Hardware size: 6
 Protocol size: 4
 Opcode: request (1)
 Sender MAC address: 20:00:00:00:00:01 (20:00:00:00:00:01)
 Sender IP address: 192.168.200.1
 Target MAC address: 00:00:00:00:00:00 (00:00:00:00:00:00)
 Target IP address: 192.168.200.2

server2发起ARP request来获取client对应的mac地址, 目的mac段为全0, 即进行子网段广播。

1	0.000000000	20:00:00:00:00:01	Broadcast	ARP	42 Who has 192.168.200.2? Tell 192.168.200.1
2	0.095440251	40:00:00:00:00:02	20:00:00:00:00:01	ARP	42 192.168.200.2 is at 40:00:00:00:00:02
3	0.095459634	192.168.200.1	10.1.1.2	ICMP	98 Echo (ping) request id=0x260e, seq=1/256, ttl=64 (no response found!)

▶ Frame 2: 42 bytes on wire (336 bits), 42 bytes captured (336 bits) on interface 0
▶ Ethernet II, Src: 40:00:00:00:00:02 (40:00:00:00:00:02), Dst: 20:00:00:00:00:01 (20:00:00:00:00:01)
▼ Address Resolution Protocol (reply)
 Hardware type: Ethernet (1)
 Protocol type: IPv4 (0x0800)
 Hardware size: 6
 Protocol size: 4
 Opcode: reply (2)
 Sender MAC address: 40:00:00:00:00:02 (40:00:00:00:00:02)
 Sender IP address: 192.168.200.2
 Target MAC address: 20:00:00:00:00:01 (20:00:00:00:00:01)
 Target IP address: 192.168.200.1

client收到ARP request包后, 正确发送了ARP应答包; 但是由于路由器没有实现reply和ICMP包处理机制所以无法回应。

H4 Task3 ARP缓存表

H5 a. 实现原理

- 在路由表类中定义一个字典, 键值对为 $\langle ip: (mac, arp_time) \rangle$, 设置表项生存期;
- 当ARP请求包的目的ip在该路由子网中, 则将 $\langle src_ip, src_mac \rangle$, 加入ARP缓存表;
- 每当来一个包, 便刷新当前ARP表缓存, 将超时表项删除。

H5 b. 代码编写

```
def refresh_arp_table(self, time):#刷新ARP缓存
    for key, value in list(self.arp_table.items()):
        if time - value[1] >= self.max_arp_time:
            arp_table.pop(key)

def forward_packet(self, port, packet):
    now_time = time.time()
    self.refresh_arp_table(now_time)#每来一个包便进行刷新
def arp_request(self, port, packet):
    if dst_ip in self.mydic:
        self.arp_table[src_ip] = (src_mac, time.time())#加入ARP缓存
```

表

H5 c. 实现测试

在mininet中依次执行如下命令：

```
server2 ping -c1 server1
```

```
server1 ping -c1 server2
```

```
client ping -c1 server1
```

在每次更新ARP表项时，打印当前所有项，结果如下图所示：

```
20:38:37 2020/03/27 INFO Saving iptables state and installing switchyard rules
20:38:37 2020/03/27 INFO Using network devices: router-eth2 router-eth1 router-eth0
20:38:40 2020/03/27 INFO update {IPv4Address('192.168.200.1'): (EthAddr('20:00:00:00:00:01'), 1585312720.090401)}
20:38:40 2020/03/27 INFO Ethernet 40:00:00:00:00:02->20:00:00:00:00:01 ARP |
Arp 40:00:00:00:00:02:192.168.200.2 20:00:00:00:00:01:192.168.200.1
20:38:46 2020/03/27 INFO update {IPv4Address('192.168.200.1'): (EthAddr('20:00:00:00:00:01'), 1585312720.090401), IPv4Address('192.168.100.1'): (EthAddr('10:00:00:00:00:01'), 1585312726.8225892)}
20:38:46 2020/03/27 INFO Ethernet 40:00:00:00:00:01->10:00:00:00:00:01 ARP |
Arp 40:00:00:00:00:01:192.168.100.2 10:00:00:00:00:01:192.168.100.1
20:38:51 2020/03/27 INFO del {EthAddr('20:00:00:00:00:01'), 1585312720.090401)}
20:38:51 2020/03/27 INFO update {IPv4Address('192.168.100.1'): (EthAddr('10:00:00:00:00:01'), 1585312726.8225892), IPv4Address('10.1.1.1'): (EthAddr('30:00:00:00:00:01'), 1585312731.5415819)}
20:38:51 2020/03/27 INFO Ethernet 40:00:00:00:00:03->30:00:00:00:00:01 ARP |
Arp 40:00:00:00:00:03:10.1.1.2 30:00:00:00:00:01:10.1.1.1
```

可以看到每当来一个发自该子网内的包都会更新arp表，同时超时时也会删除arp表项。

H3 4. 总结与感想

本次实验难度相对较小，只实现了ARP的应答机制，但是仍需理清MAC表、ARP缓存表、路由表的区别和机制才能正确编写。下次实现需要更加完善的路由器难度可能会上升，理解机制尤为重要。

H3 5. 文档结构

```
njucs@njucs-VirtualBox:~/switchyard/lab_3$ tree
.
├── 181860109吴润泽_lab_3.pdf
├── lab_3_testcases
│   ├── routertests1full.srpy
│   └── routertests1.srpy
├── myrouter.py
├── mytests.py
└── start_mininet.py

1 directory, 6 files
```