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　　助教：

学院	计算机科学与技术	专业（方向）	计算机科学与技术
学号	191220029	**姓名**	傅小龙
Email	1830970417@qq.com	**开始/完成日期**	2021/5/14 - 2021/5/16

1.实验名称

Lab5：Respond to ICMP

2.实验目的

设计并实现路由器对ICMP包的回复，并在必要的时候生成ICMP错误信息的相关逻辑.

3. 实验内容

3.1 Responding to ICMP echo requests

3.1.1 Coding

这里要求实现路由器对收到的`ICMP echo request`作出回复。当然，对于不是发给自己的请求则转发之，对于收到的非ICMP请求则发出`ICMP error`信息.

执行逻辑如下：

```
Is this packet for me? ------------------------------+
    |yes                        no                   |
    ↓                                                |
Does this packet have ICMP header? ------------------+
    |yes                                no           |
    ↓                                                |
Is this packet ICMP echo request?                    |
    |yes            ↓no                              |
    ↓       create a ICMP error message--------------+
create a ICMP reply packet                           |
    |                                                |
    +------------------------------------------------+
    ↓
......
```

回复包的ICMP包头需要重新生成：序列号和请求包的相同，标识符和请求包的相同，数据和请求包的相同。回复包的IP包头中的目的ip为原来请求包IP包头的源ip,源ip为路由接口的ip.

代码实现如下：

```
for interface in interfaces:
    if ipv4.dst == interface.ipaddr :
        if icmp and icmp.icmptype == ICMPType.EchoRequest: # echo request
```

```
            print("This pkt makes an echoRequest for me.")
            echo_reply = ICMP()
            echo_reply.icmptype = ICMPType.EchoReply
            echo_reply.icmpdata.sequence = icmp.icmpdata.sequence
            echo_reply.icmpdata.identifier = icmp.icmpdata.identifier
            echo_reply.icmpdata.data = icmp.icmpdata.data
            packet[icmp_index] = echo_reply
            packet[ipv4_index].dst = packet[ipv4_index].src
            packet[ipv4_index].src = interface.ipaddr
            ether, ipv4, icmp = self.headers(packet)
            break
        else: # not echo request, send ICMP destination port unreachable error
pkt
            print("oh! this pkt is for me but not ICMP")
            '''Implemented in 3.2.1 Coding part'''
......
```

3.2 Generating ICMP error messages

3.2.1 Coding

ICMP错误信息包括原数据包ICMP包头的28字节，错误类型和错误码. ICMP错误信息的生成封装于`ctreate_icmp_err(self, packet, interface, err_type, err_code)`函数中，参考实验手册Task3 Coding环节，其实现如下：

```
def ctreate_icmp_err(self, packet, interface, err_type, err_code):
        i = packet.get_header_index(Ethernet)
        ether = packet[i]
        # remove Ethernet header --- the errored packet contents sent with the
ICMP error message should not have an Ethernet header
        del packet[i]
        ipv4_index = packet.get_header_index(IPv4)
        #icmp_index = packet.get_header_index(ICMP)

        icmp = ICMP()
        ip = IPv4()
        # protocol defaults to ICMP
        ip.protocol = IPProtocol.ICMP
        ip.ttl = default_ttl
        ip.dst = packet[ipv4_index].src
        ip.src = interface.ipaddr
        icmp.icmptype = err_type
        icmp.icmpcode = err_code
        icmp.icmpdata.data = packet.to_bytes()[:28]
        print(f"icmp_error pkt created:{ether + ip + icmp}")
        return ether + ip + icmp
```

本次实验需要路由器能够生成的ICMP错误信息的情况有以下四种：

① ICMP destination network unreachable

在转发包时，若最长匹配失败，那么需要向发送方发送这一错误信息. 相关逻辑如下：

```
if longest prefix match failed
|____then create ICMP error message packet accordingly
|____make a longest prefix match for error message packet
add packet to waiting queue
```

代码实现如下：

```
...(longest prefix match)...
if cur_prefixlen == 0:
    print("oh! prefix macth failed!!")
    for interface in interfaces:
        if interface.name == ifaceName:
            packet = self.ctreate_icmp_err(packet, interface,
ICMPType.DestinationUnreachable, 0)
            ether, ipv4, icmp = self.headers(packet)
            break
    cur_prefixlen, packet, nhopip, interface = self.longest_prefix_match(packet)
    print(f"packet from {interface.name} with nexthopip {nhopip} waiting to
forward")
    self.queue.append(WQentry(packet, interface, nhopip))
...(ttl check)...
```

② ICMP time exceeded

在IPv4包头的TTL项减为0时，路由器将抛弃该包，并向发送方发送这一错误信息. 对TTL项的检查应在最长匹配之前.

代码实现如下：

```
if packet[ipv4_index].ttl <= 0:
    print("oh! this packet has expired!(ttl <= 0)")
    for interface in interfaces:
        if interface.name == ifaceName:
            packet = self.ctreate_icmp_err(packet, interface,
ICMPType.TimeExceeded,     ICMPCodeTimeExceeded.TTLExpired)
            ether, ipv4, icmp = self.headers(packet)
            break
    cur_prefixlen, packet, nhopip, interface = self.longest_prefix_match(packet)
...(add packet to waiting queue)...
```

③ ICMP destination host unreachable

在路由器转发包时，若无法获取下一跳的mac信息，那么取消所有相同下一跳的包的转发操作，并向这些包的不同的发送方发送这一错误信息。

在具体实现中，在发现有包转发失败后，遍历队列中所有等待转发的包，若和转发失败的包由相同的下一跳ip，那么将该项添加到完成队列`(List) finish`等待删除，并采用`(List) source`来记录该包的发送方ip，若该ip是新加入的一项，那么向该ip发送对应的ICMP错误信息。

代码实现如下：

```
'''wqEntry failed to forward:'''
source = [] # senders who send pkts to same next hop
for tmp_entry in self.queue:
    if tmp_entry.nhopip == wqEntry.nhopip:
        finish.append(tmp_entry)
        ipv4_index = tmp_entry.packet.get_header_index(IPv4)
        if tmp_entry.packet[ipv4_index].src not in source:
            source.append(tmp_entry.packet[ipv4_index].src)
            packet = self.ctreate_icmp_err(wqEntry.packet, wqEntry.interface,
ICMPType.DestinationUnreachable, 1)
            interfaces = self.net.interfaces
            prefixlen, packet, nhopip, interface =
self.longest_prefix_match(packet)
            packet[packet.get_header_index(IPv4)].src = interface.ipaddr
            self.queue.append(WQentry(packet, interface, nhopip))
```

④ ***ICMP destination port unreachable***

当路由器收到发送给自己的包后，若不是`ICMP echo request`，那么需要向发送方发送这一错误信息。这一部分的具体位置在`3.1.1 Coding`环节的代码空缺部分.

代码实现如下：

```
for interface in interfaces:
    if interface.name == ifaceName:
        packet = self.ctreate_icmp_err(packet, interface,
ICMPType.DestinationUnreachable,  3)
        ether, ipv4, icmp = self.headers(packet)
        break
```

注：每个类型错误信息的错误码在API Reference上可查阅到：

```
>>> list(ICMPTypeCodeMap[ICMPType.DestinationUnreachable])
[ <DestinationUnreachable.HostUnreachable: 1>,
  <DestinationUnreachable.NetworkUnreachable: 0>,
  <DestinationUnreachable.PortUnreachable: 3>
  ...
]
>>> i = ICMP()
>>> i.icmpcode
<ICMPCodeTimeExceeded.TTLExpired: 0>
```

3.2.2 Testing

测试结果如下：

```
    eth1.  The destination address 1.2.3.4 should not match any
    entry in the forwarding table.
12  Router should send an ICMP destination network unreachable
    error back to 10.10.123.123 out router-eth1.
13  A UDP packet addressed to the router's IP address
    192.168.1.1 should arrive on router-eth1.  The router cannot
    handle this type of packet and should generate an ICMP
    destination port unreachable error.
14  The router should send an ICMP destination port unreachable
    error back to 172.16.111.222 out router-eth1.
15  An IP packet from 192.168.1.239 for 10.10.50.250 should
    arrive on router-eth0.  The host 10.10.50.250 is presumed
    not to exist, so any attempts to send ARP requests will
    eventually fail.
16  Router should send an ARP request for 10.10.50.250 on
    router-eth1.
17  Router should try to receive a packet (ARP response), but
    then timeout.
18  Router should send an ARP request for 10.10.50.250 on
    router-eth1.
19  Router should try to receive a packet (ARP response), but
    then timeout.
20  Router should send an ARP request for 10.10.50.250 on
    router-eth1.
21  Router should try to receive a packet (ARP response), but
    then timeout.
22  Router should send an ARP request for 10.10.50.250 on
    router-eth1.
23  Router should try to receive a packet (ARP response), but
    then timeout.
24  Router should send an ARP request for 10.10.50.250 on
    router-eth1.
25  Router should try to receive a packet (ARP response), but
    then timeout.  At this point, the router should give up and
    generate an ICMP host unreachable error.
26  Router should send an ARP request for 192.168.1.239.
27  Router should receive ARP reply for 192.168.1.239.
28  Router should send an ICMP host unreachable error to
    192.168.1.239.


All tests passed!


(syenv) njucs@njucs-VirtualBox:~/cnLab/cnLab05/lab-5-191220029$
```

3.2.3 Deploying

A. ICMP Echo Request

在`server1`端向`client`发送一个ICMP Echo Request:

```
(server1)# ping -c 1 10.1.1.1
```

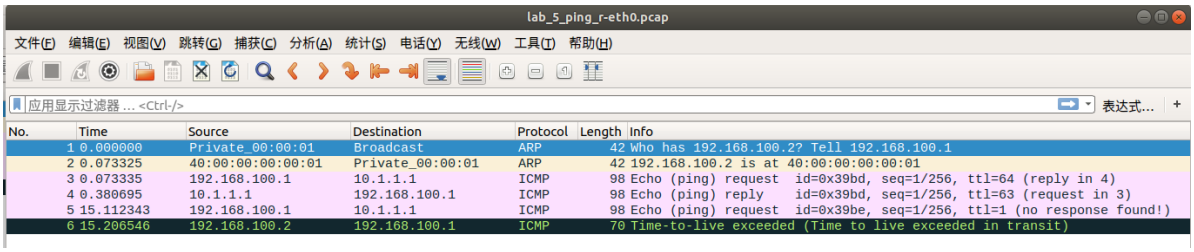
预期能够正确收到`client`发来的ICMP Echo Reply

然后再发送一个ttl为1的ICMP Echo Request:

```
(server1)# ping -c 1 -t 1 10.1.1.1
```

预期将收到`Router`发来的ICMP错误信息:TTL = 0

监听`router-eth0`接口，得到以下结果：



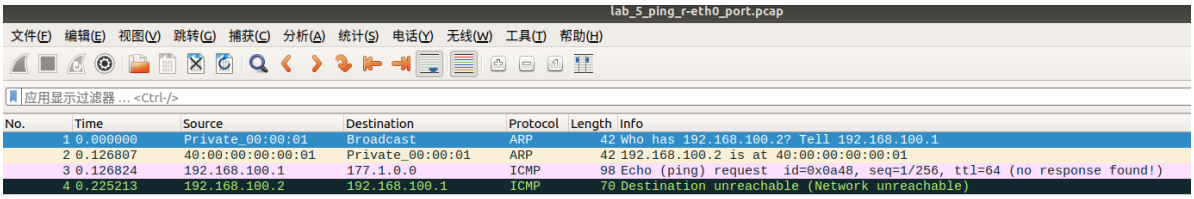
可以发现，第一次的ping操作收到了回复（对应第4个包），而第二次ping操作由于包的ttl减为0，router产生了`ttl exceeded`的ICMP错误信息。

修改`start_mininet.py`，添加一条路由`set_route(net, 'server1', '177.1.0.0/16', '192.168.100.2')`，然后启动mininet, 在在`server1`端向`177.1.0.0`发送一个ICMP Echo Request:

```
(server1)# ping -c 1 -t 1 177.1.0.0
```

预期将受到`Router`发送的ICMP错误信息：Destination Port Unreachable.

在`router-eth0`抓包结果如下：

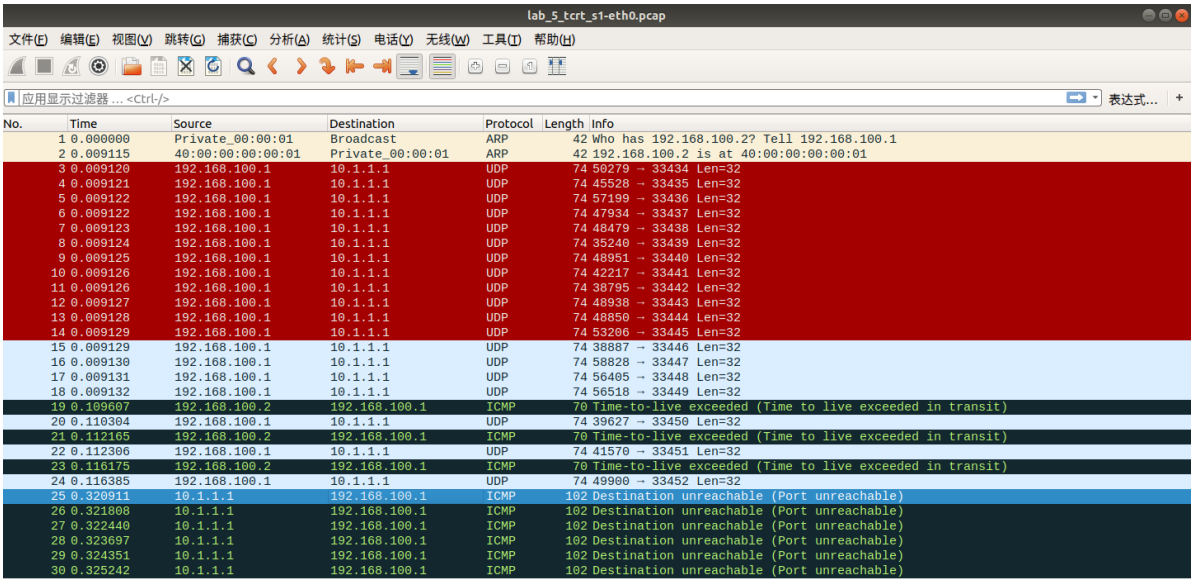


B. Traceroute

在`server1`端以`client`为目标执行traceroute指令：

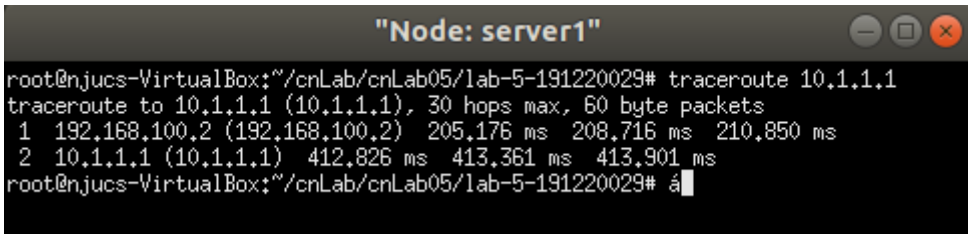
```
(server1)# traceroute 10.1.1.1
```

监听`server1-eth0`端口，得到以下结果：



`server1`在通过ARP知道下一跳(router-eth0)的mac后，连续发送了19UDP包，这些UDP包的TTL从1开始，每3个递增1直到7，直到收到`client`发来的包才停止. `client`最后发送了6个ICMP error(Port unreachable)，中间的3个(No.19, 21, 23)ICMP error包为router发送的，错误码为ttl exceeded.

traceroute结果如下：



4.实验总结与感想

本次实验完成了IPv4路由的最后一部分：响应ICMP。 通过本次实验进一步认识到了网络层路由的逻辑以及ICMP协议相关的数据结构及原理.

5.遇到的问题和思考

在对发送给路由器自己的非ICMP包作出ICMP error message响应时(对应3.2.1 ④ICMP destination port unreachable)，不能直接将该包的目的ip作为ICMP错误信息的源ip，否则将导致错误。

这是由于在判断包是否是发送给路由器的时候，条件是目的ip是否是路由器所有接口中的一个，这个接口可能并不是路由器收到包的那一个接口。ICMP error message包的转发接口应当是路由器收到包的接口才对。