实验三 子网划分和 NAT 配置

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实验目的

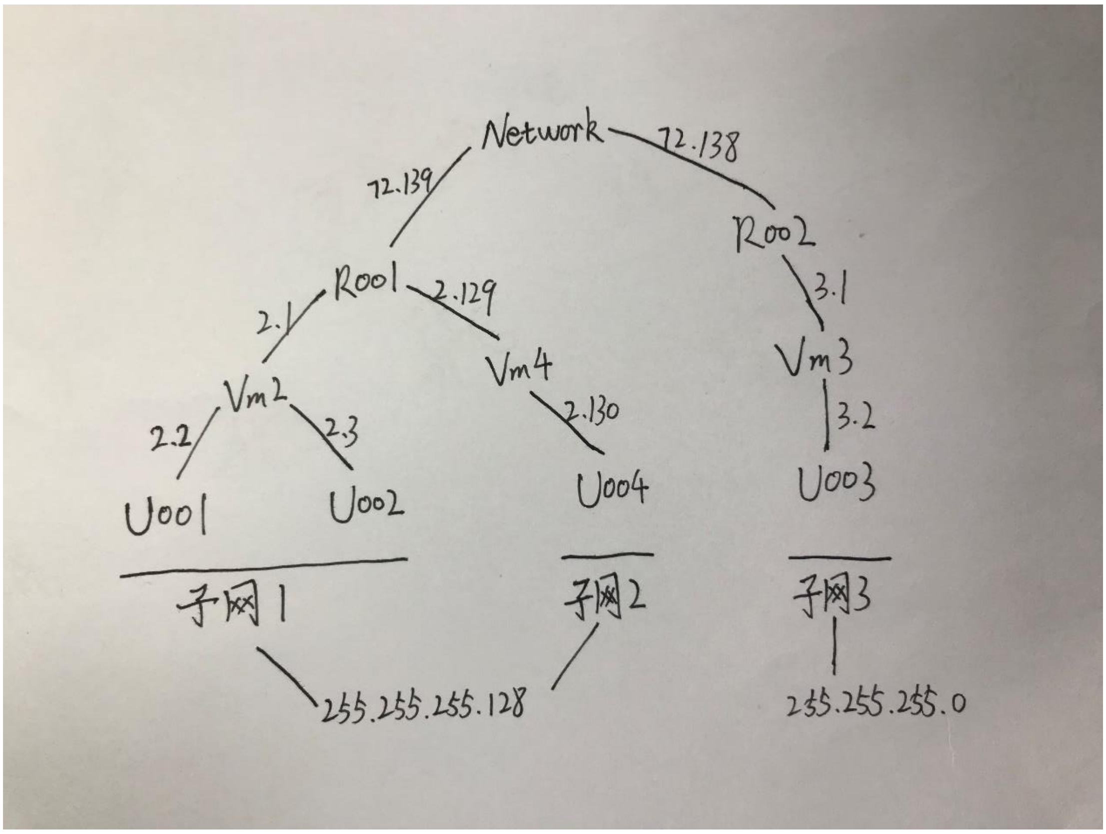
学会配置一个静态的包含多个子网的网络环境
学会使用 NAT 技术转换 IP 地址
能够熟练的设置路由规则使得网络连通

网络拓扑设置

附表 1 如下:

节点名	虚拟设备名	ip	netmask
Router0	R001	ens33: 192.168.72.139	255.255.255.128
		ens38: 192.168.2.1	
		ens39: 192.168.2.129	
Router1	R002	ens33: 192.168.72.138	255.255.255.0
		ens38: 192.168.3.1	
PC0	U001	ens33: 192.168.2.2	255.255.255.128
PC1	U002	ens33: 192.168.2.3	255.255.255.128
PC2	U003	ens33: 192.168.3.2	255.255.255.0
PC3	U004	ens33: 192.168.2.130	255.255.255.128

绘图说明如下(图中 ip 地址均省略前缀 192.168):



路由规则配置

在 R001 终端输入命令: sudo ip route add 192.168.3.0/24 via 192.168.72.138
在 R002 终端输入命令: sudo ip route add 192.168.2.0/24 via 192.168.72.139

NAT 设置命令

在 R001 终端输入命令:
sudo iptables -t nat -A POSTROUTING -o ens33 -s 192.168.2.0/24 -j SNAT --to 192.168.72.139

数据包截图

1. 配置好子网和路由规则后的 ping 截图

PC0pingPC2, PC3:

```
user1@ubuntu:~$ ping 192.168.3.2
PING 192.168.3.2 (192.168.3.2) 56(84) bytes of data.
^C
--- 192.168.3.2 ping statistics ---
2 packets transmitted, 0 received, 100% packet loss, time 1014ms

user1@ubuntu:~$ ping 192.168.2.130
PING 192.168.2.130 (192.168.2.130) 56(84) bytes of data.
64 bytes from 192.168.2.130: icmp_seq=1 ttl=63 time=0.699 ms
64 bytes from 192.168.2.130: icmp_seq=2 ttl=63 time=0.602 ms
^C
--- 192.168.2.130 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1011ms
rtt min/avg/max/mdev = 0.602/0.650/0.699/0.054 ms
```

PC2pingPC0, PC3:

```
user2@user2:~$ ping 192.168.2.2
PING 192.168.2.2 (192.168.2.2) 56(84) bytes of data.
^C
--- 192.168.2.2 ping statistics ---
3 packets transmitted, 0 received, 100% packet loss, time 2045ms

user2@user2:~$ ping 192.168.2.130
PING 192.168.2.130 (192.168.2.130) 56(84) bytes of data.
^C
--- 192.168.2.130 ping statistics ---
2 packets transmitted, 0 received, 100% packet loss, time 1006ms
```

PC3pingPC0, PC2:

```
user2@user2:~$ ping 192.168.2.2
PING 192.168.2.2 (192.168.2.2) 56(84) bytes of data.
64 bytes from 192.168.2.2: icmp_seq=1 ttl=63 time=0.921 ms
64 bytes from 192.168.2.2: icmp_seq=2 ttl=63 time=0.465 ms
^C
--- 192.168.2.2 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1001ms
rtt min/avg/max/mdev = 0.465/0.693/0.921/0.228 ms
user2@user2:~$ ping 192.168.3.2
PING 192.168.3.2 (192.168.3.2) 56(84) bytes of data.
^C
--- 192.168.3.2 ping statistics ---
2 packets transmitted, 0 received, 100% packet loss, time 1033ms
```

2. 进一步配置好 iptables 规则后的 ping 截图

PC0pingPC2, PC3:

```
user1@ubuntu:~$ ping 192.168.3.2
PING 192.168.3.2 (192.168.3.2) 56(84) bytes of data.
64 bytes from 192.168.3.2: icmp_seq=1 ttl=62 time=1.07 ms
64 bytes from 192.168.3.2: icmp_seq=2 ttl=62 time=0.851 ms
64 bytes from 192.168.3.2: icmp_seq=3 ttl=62 time=0.810 ms
^C
--- 192.168.3.2 ping statistics ---
3 packets transmitted, 3 received, 0% packet loss, time 2012ms
rtt min/avg/max/mdev = 0.810/0.912/1.077/0.122 ms
user1@ubuntu:~$ ping 192.168.2.130
PING 192.168.2.130 (192.168.2.130) 56(84) bytes of data.
64 bytes from 192.168.2.130: icmp_seq=1 ttl=63 time=0.698 ms
64 bytes from 192.168.2.130: icmp_seq=2 ttl=63 time=0.589 ms
^C
--- 192.168.2.130 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1012ms
rtt min/avg/max/mdev = 0.589/0.643/0.698/0.060 ms
```

PC2pingPC0, PC3:

```
user2@user2:~$ ping 192.168.2.2
PING 192.168.2.2 (192.168.2.2) 56(84) bytes of data.
64 bytes from 192.168.2.2: icmp_seq=1 ttl=62 time=0.810 ms
64 bytes from 192.168.2.2: icmp_seq=2 ttl=62 time=0.927 ms
^C
--- 192.168.2.2 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1001ms
rtt min/avg/max/mdev = 0.810/0.868/0.927/0.065 ms
user2@user2:~$ ping 192.168.2.130
PING 192.168.2.130 (192.168.2.130) 56(84) bytes of data.
64 bytes from 192.168.2.130: icmp_seq=1 ttl=62 time=0.783 ms
64 bytes from 192.168.2.130: icmp_seq=2 ttl=62 time=1.03 ms
^C
--- 192.168.2.130 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1001ms
rtt min/avg/max/mdev = 0.783/0.909/1.036/0.130 ms
user2@user2:~$
```

PC3pingPC0, PC2:

```
user2@user2:~$ ping 192.168.2.2
PING 192.168.2.2 (192.168.2.2) 56(84) bytes of data.
64 bytes from 192.168.2.2: icmp_seq=1 ttl=63 time=0.536 ms
64 bytes from 192.168.2.2: icmp_seq=2 ttl=63 time=0.517 ms
^C
--- 192.168.2.2 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1011ms
rtt min/avg/max/mdev = 0.517/0.526/0.536/0.024 ms
user2@user2:~$ ping 192.168.3.2
PING 192.168.3.2 (192.168.3.2) 56(84) bytes of data.
64 bytes from 192.168.3.2: icmp_seq=1 ttl=62 time=0.900 ms
64 bytes from 192.168.3.2: icmp_seq=2 ttl=62 time=0.787 ms
^C
--- 192.168.3.2 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1001ms
rtt min/avg/max/mdev = 0.787/0.843/0.900/0.063 ms
user2@user2:~$ _
```

3. 1, 2 结果对比及 NAT 作用解释

可以观察到，未配置 NAT 之前，左边的子网 1 和子网 2 及右边的子网 3 之间不能互相 ping 通，只有左边的子网 1 和子网 2 内部可以互相 ping 通。完成 NAT 配置后，整个网络都可以互相 ping 通。

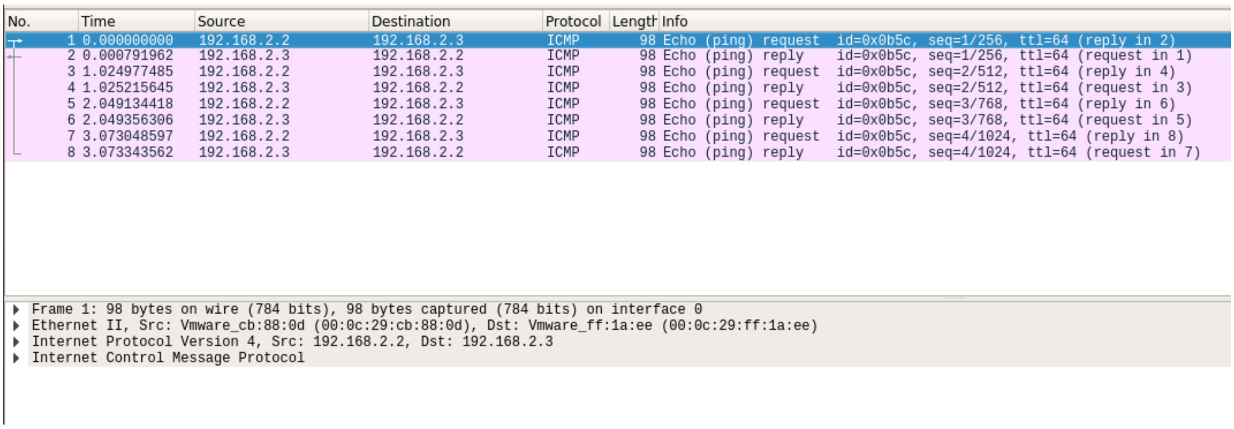
NAT 的运作机制是自动修改 IP 报文的源 IP 地址和目的 IP 地址，IP 地址校验则在 NAT 处理

过程中自动完成. NAT 的实现方式有三种, 即静态转换, 动态转换和端口多路复用.
实验中我们采用静态转换的方式, 完成了出网地址映射的功能, 使得我们的内部主机的 IP 能够映射为路由器的公网 IP, 从而使得我们搭建的网络的左右两边能够互通.

4. 完成配置后, PC0ping 其他主机时 wireshark 抓取的 PDU 截图.

以下数据包均在路由器 R001 上捕获.

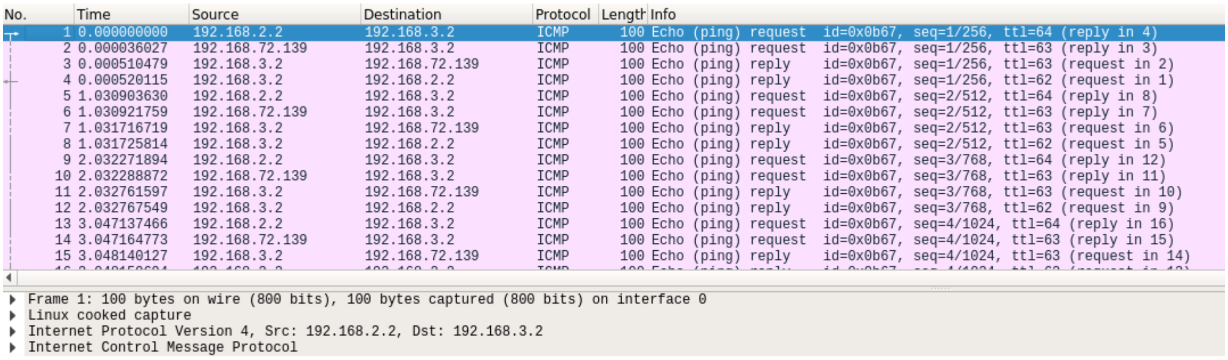
PC0pingPC1:



No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	192.168.2.2	192.168.2.3	ICMP	98	Echo (ping) request id=0x0b5c, seq=1/256, ttl=64 (reply in 2)
2	0.000791962	192.168.2.3	192.168.2.2	ICMP	98	Echo (ping) reply id=0x0b5c, seq=1/256, ttl=64 (request in 1)
3	1.024977485	192.168.2.2	192.168.2.3	ICMP	98	Echo (ping) request id=0x0b5c, seq=2/512, ttl=64 (reply in 4)
4	1.025215645	192.168.2.3	192.168.2.2	ICMP	98	Echo (ping) reply id=0x0b5c, seq=2/512, ttl=64 (request in 3)
5	2.049134418	192.168.2.2	192.168.2.3	ICMP	98	Echo (ping) request id=0x0b5c, seq=3/768, ttl=64 (reply in 6)
6	2.049356306	192.168.2.3	192.168.2.2	ICMP	98	Echo (ping) reply id=0x0b5c, seq=3/768, ttl=64 (request in 5)
7	3.073048597	192.168.2.2	192.168.2.3	ICMP	98	Echo (ping) request id=0x0b5c, seq=4/1024, ttl=64 (reply in 8)
8	3.073343562	192.168.2.3	192.168.2.2	ICMP	98	Echo (ping) reply id=0x0b5c, seq=4/1024, ttl=64 (request in 7)

```
Frame 1: 98 bytes on wire (784 bits), 98 bytes captured (784 bits) on interface 0
Ethernet II, Src: Vmware_cb:88:0d (00:0c:29:cb:88:0d), Dst: Vmware_ff:1a:ee (00:0c:29:ff:1a:ee)
Internet Protocol Version 4, Src: 192.168.2.2, Dst: 192.168.2.3
Internet Control Message Protocol
```

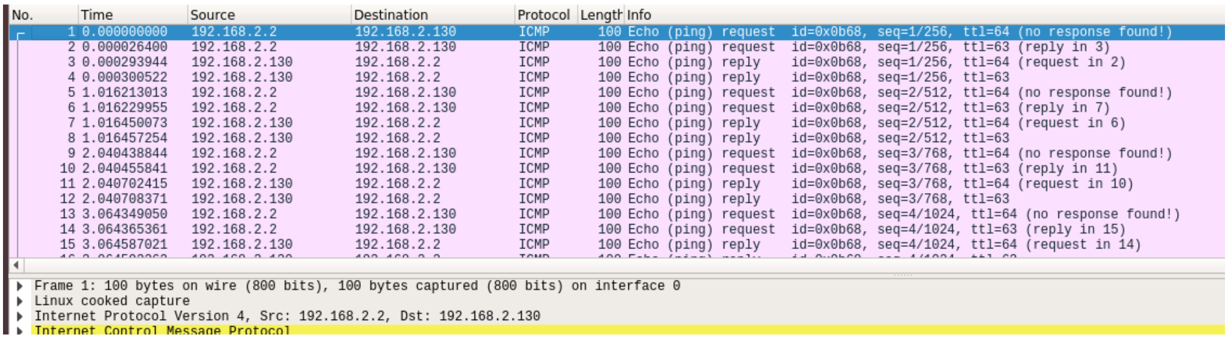
PC0pingPC2:



No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	192.168.2.2	192.168.3.2	ICMP	100	Echo (ping) request id=0x0b67, seq=1/256, ttl=64 (reply in 4)
2	0.000036027	192.168.72.139	192.168.3.2	ICMP	100	Echo (ping) request id=0x0b67, seq=1/256, ttl=63 (reply in 3)
3	0.000510479	192.168.3.2	192.168.72.139	ICMP	100	Echo (ping) reply id=0x0b67, seq=1/256, ttl=63 (request in 2)
4	0.000520115	192.168.3.2	192.168.2.2	ICMP	100	Echo (ping) reply id=0x0b67, seq=1/256, ttl=62 (request in 1)
5	1.030903630	192.168.2.2	192.168.3.2	ICMP	100	Echo (ping) request id=0x0b67, seq=2/512, ttl=64 (reply in 8)
6	1.030921759	192.168.72.139	192.168.3.2	ICMP	100	Echo (ping) request id=0x0b67, seq=2/512, ttl=63 (reply in 7)
7	1.031716719	192.168.3.2	192.168.72.139	ICMP	100	Echo (ping) reply id=0x0b67, seq=2/512, ttl=63 (request in 6)
8	1.031725814	192.168.3.2	192.168.2.2	ICMP	100	Echo (ping) reply id=0x0b67, seq=2/512, ttl=62 (request in 5)
9	2.032271894	192.168.2.2	192.168.3.2	ICMP	100	Echo (ping) request id=0x0b67, seq=3/768, ttl=64 (reply in 12)
10	2.032288872	192.168.72.139	192.168.3.2	ICMP	100	Echo (ping) request id=0x0b67, seq=3/768, ttl=63 (reply in 11)
11	2.032761597	192.168.3.2	192.168.72.139	ICMP	100	Echo (ping) reply id=0x0b67, seq=3/768, ttl=63 (request in 10)
12	2.032767549	192.168.3.2	192.168.2.2	ICMP	100	Echo (ping) reply id=0x0b67, seq=3/768, ttl=62 (request in 9)
13	3.047137466	192.168.2.2	192.168.3.2	ICMP	100	Echo (ping) request id=0x0b67, seq=4/1024, ttl=64 (reply in 16)
14	3.047164773	192.168.72.139	192.168.3.2	ICMP	100	Echo (ping) request id=0x0b67, seq=4/1024, ttl=63 (reply in 15)
15	3.048140127	192.168.3.2	192.168.72.139	ICMP	100	Echo (ping) reply id=0x0b67, seq=4/1024, ttl=63 (request in 14)

```
Frame 1: 100 bytes on wire (800 bits), 100 bytes captured (800 bits) on interface 0
Linux cooked capture
Internet Protocol Version 4, Src: 192.168.2.2, Dst: 192.168.3.2
Internet Control Message Protocol
```

PC0pingPC3:



No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	192.168.2.2	192.168.2.130	ICMP	100	Echo (ping) request id=0x0b68, seq=1/256, ttl=64 (no response found!)
2	0.000026400	192.168.2.2	192.168.2.130	ICMP	100	Echo (ping) request id=0x0b68, seq=1/256, ttl=63 (reply in 3)
3	0.000293944	192.168.2.130	192.168.2.2	ICMP	100	Echo (ping) reply id=0x0b68, seq=1/256, ttl=64 (request in 2)
4	0.000300522	192.168.2.130	192.168.2.2	ICMP	100	Echo (ping) reply id=0x0b68, seq=1/256, ttl=63
5	1.016213013	192.168.2.2	192.168.2.130	ICMP	100	Echo (ping) request id=0x0b68, seq=2/512, ttl=64 (no response found!)
6	1.016229955	192.168.2.2	192.168.2.130	ICMP	100	Echo (ping) request id=0x0b68, seq=2/512, ttl=63 (reply in 7)
7	1.016450073	192.168.2.130	192.168.2.2	ICMP	100	Echo (ping) reply id=0x0b68, seq=2/512, ttl=64 (request in 6)
8	1.016457254	192.168.2.130	192.168.2.2	ICMP	100	Echo (ping) reply id=0x0b68, seq=2/512, ttl=63
9	2.040438844	192.168.2.2	192.168.2.130	ICMP	100	Echo (ping) request id=0x0b68, seq=3/768, ttl=64 (no response found!)
10	2.040455841	192.168.2.2	192.168.2.130	ICMP	100	Echo (ping) request id=0x0b68, seq=3/768, ttl=63 (reply in 11)
11	2.040702415	192.168.2.130	192.168.2.2	ICMP	100	Echo (ping) reply id=0x0b68, seq=3/768, ttl=64 (request in 10)
12	2.040708371	192.168.2.130	192.168.2.2	ICMP	100	Echo (ping) reply id=0x0b68, seq=3/768, ttl=63
13	3.064349050	192.168.2.2	192.168.2.130	ICMP	100	Echo (ping) request id=0x0b68, seq=4/1024, ttl=64 (no response found!)
14	3.064365361	192.168.2.2	192.168.2.130	ICMP	100	Echo (ping) request id=0x0b68, seq=4/1024, ttl=63 (reply in 15)
15	3.064587021	192.168.2.130	192.168.2.2	ICMP	100	Echo (ping) reply id=0x0b68, seq=4/1024, ttl=64 (request in 14)

```
Frame 1: 100 bytes on wire (800 bits), 100 bytes captured (800 bits) on interface 0
Linux cooked capture
Internet Protocol Version 4, Src: 192.168.2.2, Dst: 192.168.2.130
Internet Control Message Protocol
```

协议报文分析

ICMP 报文的详细解析已在第一次实验中做过, 此处不再赘述. 这里分析 NAT 起到的作用. 可以观察到在子网 1 和子网 2 之间内部通信时, 源 IP 和目的 IP 地址均为发送方和接收方的 IP 地址, 没有发生改变. 但在左右两边互相通信时, 可以观察到 PC0 的 IP 地址 192.168.2.2 被换成了 Router1 与右边网络处于同一公网的 IP 地址 192.168.72.139, 从而 PC0 能够 ping

通右边的目的主机 PC2，其 IP 地址为 192.168.3.2.