Part1

h1's interface:

```
eric070021@ubuntu:~/Desktop$ docker exec -it h1 bash
root@18ce7cdcb2ed:/# ifconfig
eth0      Link encap:Ethernet  HWaddr 02:42:ac:11:00:02
          inet addr:172.17.0.2  Bcast:172.17.255.255  Mask:255.255.0.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:8554 errors:0 dropped:0 overruns:0 frame:0
          TX packets:6273 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:20582577 (20.5 MB)  TX bytes:343826 (343.8 KB)

h1R1veth  Link encap:Ethernet  HWaddr ce:46:85:88:c0:7b
          inet addr:192.168.1.2  Bcast:0.0.0.0  Mask:255.255.255.255
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:5 errors:0 dropped:0 overruns:0 frame:0
          TX packets:53 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:210 (210.0 B)  TX bytes:4236 (4.2 KB)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

root@18ce7cdcb2ed:/# ip r
default via 192.168.1.1 dev h1R1veth
172.17.0.0/16 dev eth0  proto kernel  scope link  src 172.17.0.2
192.168.1.0/24 dev h1R1veth  proto kernel  scope link  src 192.168.1.2
```

h2's interface:

```
eric070021@ubuntu:~/Desktop$ docker exec -it h2 bash
root@a21c72bfcf76:/# ifconfig
eth0      Link encap:Ethernet  HWaddr 02:42:ac:11:00:03
          inet addr:172.17.0.3  Bcast:172.17.255.255  Mask:255.255.0.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:8708 errors:0 dropped:0 overruns:0 frame:0
          TX packets:6679 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:20589727 (20.5 MB)  TX bytes:365834 (365.8 KB)

h2R1veth  Link encap:Ethernet  HWaddr ee:ce:c3:4c:5b:fd
          inet addr:192.168.2.2  Bcast:0.0.0.0  Mask:255.255.255.255
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

root@a21c72bfcf76:/# ip r
default via 192.168.2.1 dev h2R1veth
172.17.0.0/16 dev eth0  proto kernel  scope link  src 172.17.0.3
192.168.2.0/24 dev h2R1veth  proto kernel  scope link  src 192.168.2.2
```

R1's interface:

```
root@d141e430a3a0:/# ifconfig
R1R2veth  Link encap:Ethernet  HWaddr 22:93:7a:73:2e:7a
          inet addr:140.113.2.1  Bcast:0.0.0.0  Mask:255.255.255.255
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:1184 errors:0 dropped:0 overruns:0 frame:0
          TX packets:1167 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:95957 (95.9 KB)  TX bytes:85620 (85.6 KB)

R1h1veth  Link encap:Ethernet  HWaddr 9e:9a:ee:c5:3e:11
          inet addr:192.168.1.1  Bcast:0.0.0.0  Mask:255.255.255.255
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:53 errors:0 dropped:0 overruns:0 frame:0
          TX packets:5 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:4236 (4.2 KB)  TX bytes:210 (210.0 B)

R1h2veth  Link encap:Ethernet  HWaddr 16:94:f9:48:28:f7
          inet addr:192.168.2.1  Bcast:0.0.0.0  Mask:255.255.255.255
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

eth0      Link encap:Ethernet  HWaddr 02:42:ac:11:00:04
          inet addr:172.17.0.4  Bcast:172.17.255.255  Mask:255.255.0.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:9758 errors:0 dropped:0 overruns:0 frame:0
          TX packets:8013 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:23564810 (23.5 MB)  TX bytes:441090 (441.0 KB)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:303 errors:0 dropped:0 overruns:0 frame:0
          TX packets:303 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:17098 (17.0 KB)  TX bytes:17098 (17.0 KB)

root@d141e430a3a0:/# ip r
default via 172.17.0.1 dev eth0
140.113.1.0/24 via 140.113.2.2 dev R1R2veth  proto zebra
140.113.2.0/24 dev R1R2veth  proto kernel  scope link  src 140.113.2.1
172.17.0.0/16 dev eth0  proto kernel  scope link  src 172.17.0.4
192.168.1.0/24 dev R1h1veth  proto kernel  scope link  src 192.168.1.1
192.168.2.0/24 dev R1h2veth  proto kernel  scope link  src 192.168.2.1
```

R2's interface:

```
eric070021@ubuntu:~/Desktop$ docker exec -it R2 bash
root@5fe41b4c7ff0:/# ifconfig
R2R1veth  Link encap:Ethernet  HWaddr 4a:d3:21:25:97:f5
          inet addr:140.113.2.2  Bcast:0.0.0.0  Mask:255.255.255.255
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:48530 errors:0 dropped:0 overruns:0 frame:0
          TX packets:49435 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:3716617 (3.7 MB)  TX bytes:3785562 (3.7 MB)

R2hRveth  Link encap:Ethernet  HWaddr ee:04:58:d6:7f:27
          inet addr:140.113.1.1  Bcast:0.0.0.0  Mask:255.255.255.255
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

eth0      Link encap:Ethernet  HWaddr 02:42:ac:11:00:05
          inet addr:172.17.0.5  Bcast:172.17.255.255  Mask:255.255.0.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:9984 errors:0 dropped:0 overruns:0 frame:0
          TX packets:7683 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:23580525 (23.5 MB)  TX bytes:421884 (421.8 KB)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:231 errors:0 dropped:0 overruns:0 frame:0
          TX packets:231 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:13189 (13.1 KB)  TX bytes:13189 (13.1 KB)

root@5fe41b4c7ff0:/# ip r
default via 172.17.0.1 dev eth0
140.113.1.0/24 dev R2hRveth  proto kernel  scope link  src 140.113.1.1
140.113.2.0/24 dev R2R1veth  proto kernel  scope link  src 140.113.2.2
172.17.0.0/16 dev eth0  proto kernel  scope link  src 172.17.0.5
192.168.1.0/24 via 140.113.2.1 dev R2R1veth  proto zebra
192.168.2.0/24 via 140.113.2.1 dev R2R1veth  proto zebra
```

hR's interface:

```
eric070021@ubuntu:~/Desktop$ docker exec -it hR bash
root@a24810be5242:/# ifconfig
eth0      Link encap:Ethernet  HWaddr 02:42:ac:11:00:06
          inet addr:172.17.0.6  Bcast:172.17.255.255  Mask:255.255.0.0
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:8897 errors:0 dropped:0 overruns:0 frame:0
          TX packets:6655 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:20601932 (20.6 MB)  TX bytes:364474 (364.4 KB)

hRR2veth  Link encap:Ethernet  HWaddr d6:9b:a8:c8:30:53
          inet addr:140.113.1.2  Bcast:0.0.0.0  Mask:255.255.255.255
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:0 (0.0 B)  TX bytes:0 (0.0 B)

root@a24810be5242:/# ip r
default via 140.113.1.1 dev hRR2veth
140.113.1.0/24 dev hRR2veth  proto kernel  scope link  src 140.113.1.2
172.17.0.0/16 dev eth0  proto kernel  scope link  src 172.17.0.6
```

R1's bgp summary:

```
R1bgp> show ip bgp summary
BGP router identifier 140.113.2.1, local AS number 65000
RIB entries 5, using 560 bytes of memory
Peers 1, using 4568 bytes of memory

Neighbor        V         AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down   State/PfxRcd
140.113.2.2     4 65001   26971    26972       0    0    0 22:29:03        1

Total number of neighbors 1
```

R2's bgp summary:

```
R2bgp> show ip bgp summary
BGP router identifier 140.113.2.2, local AS number 65001
RIB entries 5, using 560 bytes of memory
Peers 1, using 4568 bytes of memory

Neighbor        V         AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down   State/PfxRcd
140.113.2.1     4 65000   26990    26993       0    0    0 22:30:06        2

Total number of neighbors 1
```

R1's bgpd.conf:

```
! BGP configuration for R1
!
hostname R1bgp
password vRouter
!
router bgp 65000
        bgp router-id 140.113.2.1
        timers bgp 3 9
        neighbor 140.113.2.2 remote-as 65001
        neighbor 140.113.2.2 ebgp-multihop
        neighbor 140.113.2.2 timers connect 5
        neighbor 140.113.2.2 advertisement-interval 5
        network 192.168.1.0/24
        network 192.168.2.0/24
!
log stdout
```

R2's bgpd.conf:

```
! BGP configuration for R2
!
hostname R2bgp
password vRouter
!
router bgp 65001
        bgp router-id 140.113.2.2
        timers bgp 3 9
        neighbor 140.113.2.1 remote-as 65000
        neighbor 140.113.2.1 ebgp-multihop
        neighbor 140.113.2.1 timers connect 5
        neighbor 140.113.2.1 advertisement-interval 5
        network 140.113.1.0/24
!
log stdout
```

Part 2

h1 and h2 both can't ping hR.

Since the packet send from h1 or h2 will be converted to another ip rather than router's ip by snat, hR will send the icmp ack packet back to the modified ip but there is this ip is not in this network, thus h1 and h2 can't ping hR.

```
eric070021@ubuntu:~/Desktop$ docker exec -it h1 bash
root@18ce7cdcb2ed:/# ping 140.113.1.2 -c 3
PING 140.113.1.2 (140.113.1.2) 56(84) bytes of data.

--- 140.113.1.2 ping statistics ---
3 packets transmitted, 0 received, 100% packet loss, time 2056ms
```

```
eric070021@ubuntu:~/Desktop$ docker exec -it h2 bash
root@a21c72bfcf76:/# ping 140.113.1.2 -c 3
PING 140.113.1.2 (140.113.1.2) 56(84) bytes of data.

--- 140.113.1.2 ping statistics ---
3 packets transmitted, 0 received, 100% packet loss, time 2053ms
```

This is the rule of snat.

```
root@d141e430a3a0:/# iptables -t nat -nv -L POSTROUTING
Chain POSTROUTING (policy ACCEPT 0 packets, 0 bytes)
 pkts bytes target     prot opt in     out       source               destination
    8   672 SNAT       all  --  *      R1R2veth  192.168.1.0/24       0.0.0.0/0            to:140.113.2.30
    1    84 SNAT       all  --  *      R1R2veth  192.168.2.0/24       0.0.0.0/0            to:140.113.2.40
```

In the tcpdump, we can see the ip change from 192.168.1.2 to 140.113.2.30 (take h1 ping hR for example)

Part 3

hR curl h1:

```
eric070021@ubuntu:~/Desktop$ docker exec -it hR bash
root@a24810be5242:/# curl 140.113.2.1:8080
<!DOCTYPE html PUBLIC "-//W3C//DTD HTML 3.2 Final//EN"><html>
<title>Directory listing for /</title>
<body>
<h2>Directory listing for /</h2>
<hr>
<ul>
<li><a href=".dockerenv">.dockerenv</a>
<li><a href="bin/">bin/</a>
<li><a href="boot/">boot/</a>
<li><a href="dev/">dev/</a>
<li><a href="etc/">etc/</a>
<li><a href="home/">home/</a>
<li><a href="lib/">lib/</a>
<li><a href="lib64/">lib64/</a>
<li><a href="media/">media/</a>
<li><a href="mnt/">mnt/</a>
<li><a href="opt/">opt/</a>
<li><a href="proc/">proc/</a>
<li><a href="root/">root/</a>
<li><a href="run/">run/</a>
<li><a href="sbin/">sbin/</a>
<li><a href="srv/">srv/</a>
<li><a href="sys/">sys/</a>
<li><a href="tmp/">tmp/</a>
<li><a href="usr/">usr/</a>
<li><a href="var/">var/</a>
</ul>
<hr>
</body>
</html>
root@a24810be5242:/#
```

```
                                        root@18ce7cdcb2ed: /
File  Edit  View  Search  Terminal  Help
eric070021@ubuntu:~$ docker exec -it h1 bash
root@18ce7cdcb2ed:/# python -m SimpleHTTPServer 8080
Serving HTTP on 0.0.0.0 port 8080 ...
140.113.1.2 - - [26/Mar/2022 08:17:28] "GET / HTTP/1.1" 200 -
```

hR curl h2:

```
root@a24810be5242:/# curl 140.113.2.1:9090
<!DOCTYPE html PUBLIC "-//W3C//DTD HTML 3.2 Final//EN"><html>
<title>Directory listing for /</title>
<body>
<h2>Directory listing for /</h2>
<hr>
<ul>
<li><a href=".dockerenv">.dockerenv</a>
<li><a href="bin/">bin/</a>
<li><a href="boot/">boot/</a>
<li><a href="dev/">dev/</a>
<li><a href="etc/">etc/</a>
<li><a href="home/">home/</a>
<li><a href="lib/">lib/</a>
<li><a href="lib64/">lib64/</a>
<li><a href="media/">media/</a>
<li><a href="mnt/">mnt/</a>
<li><a href="opt/">opt/</a>
<li><a href="proc/">proc/</a>
<li><a href="root/">root/</a>
<li><a href="run/">run/</a>
<li><a href="sbin/">sbin/</a>
<li><a href="srv/">srv/</a>
<li><a href="sys/">sys/</a>
<li><a href="tmp/">tmp/</a>
<li><a href="usr/">usr/</a>
<li><a href="var/">var/</a>
</ul>
<hr>
</body>
</html>
root@a24810be5242:/#
```

```
                                        root@a21c72bfcf76: /
File  Edit  View  Search  Terminal  Help
eric070021@ubuntu:~$ docker exec -it h2 bash
root@a21c72bfcf76:/#  python -m SimpleHTTPServer 9090
Serving HTTP on 0.0.0.0 port 9090 ...
140.113.1.2 - - [26/Mar/2022 08:18:42] "GET / HTTP/1.1" 200 -
```

This is the rule of dnat.

```
root@d141e430a3a0:/# iptables -t nat -nv -L PREROUTING
Chain PREROUTING (policy ACCEPT 0 packets, 0 bytes)
 pkts bytes target     prot opt in     out     source               destination
    0     0 DNAT       tcp  --  *      *       0.0.0.0/0            0.0.0.0/0            tcp dpt:8080 to:192.168.1.2:8080
    0     0 DNAT       tcp  --  *      *       0.0.0.0/0            0.0.0.0/0            tcp dpt:9090 to:192.168.2.2:9090
```

In the picture, we can see the http request to 140.113.2.1:8080 be converted to 192.168.1.2:8080 (h1's ip).