Part1

1. Take routing tables screenshot before/after on [r1-r4] (10%)

before

```
mininet> r1 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
10.0.1.0        0.0.0.0         255.255.255.0   U     0      0        0 r1-eth0
192.168.1.0     0.0.0.0         255.255.255.192 U     0      0        0 r1-eth1
192.168.1.64    0.0.0.0         255.255.255.192 U     0      0        0 r1-eth2
mininet> r2 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
10.0.0.0        0.0.0.0         255.255.255.0   U     0      0        0 r2-eth0
10.0.1.0        0.0.0.0         255.255.255.0   U     0      0        0 r2-eth1
mininet> r3 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
10.0.0.0        0.0.0.0         255.255.255.0   U     0      0        0 r3-eth0
10.0.2.0        0.0.0.0         255.255.255.0   U     0      0        0 r3-eth1
mininet> r4 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
10.0.2.0        0.0.0.0         255.255.255.0   U     0      0        0 r4-eth0
140.114.0.0     0.0.0.0         255.255.255.0   U     0      0        0 r4-eth1
```

after

```
mininet> r1 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
10.0.1.0        0.0.0.0         255.255.255.0   U     0      0        0 r1-eth0
140.114.0.0     10.0.1.1        255.255.255.0   UG    20     0        0 r1-eth0
192.168.1.0     0.0.0.0         255.255.255.192 U     0      0        0 r1-eth1
192.168.1.64    0.0.0.0         255.255.255.192 U     0      0        0 r1-eth2
mininet> r2 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
10.0.0.0        0.0.0.0         255.255.255.0   U     0      0        0 r2-eth0
10.0.1.0        0.0.0.0         255.255.255.0   U     0      0        0 r2-eth1
140.113.0.0     10.0.1.2        255.255.0.0     UG    20     0        0 r2-eth1
140.114.0.0     10.0.0.2        255.255.255.0   UG    20     0        0 r2-eth0
mininet> r3 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
10.0.0.0        0.0.0.0         255.255.255.0   U     0      0        0 r3-eth0
10.0.2.0        0.0.0.0         255.255.255.0   U     0      0        0 r3-eth1
140.113.0.0     10.0.0.1        255.255.0.0     UG    20     0        0 r3-eth0
140.114.0.0     10.0.2.3        255.255.255.0   UG    20     0        0 r3-eth1
mininet> r4 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
10.0.2.0        0.0.0.0         255.255.255.0   U     0      0        0 r4-eth0
140.113.0.0     10.0.2.1        255.255.0.0     UG    20     0        0 r4-eth0
140.114.0.0     0.0.0.0         255.255.255.0   U     0      0        0 r4-eth1
```

2. Telnet zebra and bgpd daemons of [r1-r4] and take screenshots of routes in zebra and bgpd daemons.

```
r1> sshhooww  iipp  bbggpp  ssuummmmaarryy

BGP router identifier 10.0.1.2, local AS number 65000
RIB entries 3, using 336 bytes of memory
Peers 1, using 9088 bytes of memory

Neighbor        V         AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
10.0.1.1        4 65001     204     207        0    0    0 00:10:06        1

Total number of neighbors 1

Total num. Established sessions 1
Total num. of routes received     1
```

```
zebra> sshhooww  iipp  rroouuttee  bbggpp

Codes: K - kernel route, C - connected, S - static, R - RIP,
       O - OSPF, I - IS-IS, B - BGP, P - PIM, A - Babel, N - NHRP,
       > - selected route, * - FIB route

B>* 140.114.0.0/24 [20/0] via 10.0.1.1, r1-eth0, 00:04:31
```

```
r2> sshhooww  iipp  bbggpp  ssuummmmaarryy

BGP router identifier 10.0.1.1, local AS number 65001
RIB entries 3, using 336 bytes of memory
Peers 2, using 18 KiB of memory

Neighbor        V         AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
10.0.0.2        4 65002     239     242        0    0    0 00:11:49        1
10.0.1.2        4 65000     240     241        0    0    0 00:11:49        1

Total number of neighbors 2

Total num. Established sessions 2
Total num. of routes received     2
```

```
zebra> sshhooww  iipp  rroouuttee  bbggpp

Codes: K - kernel route, C - connected, S - static, R - RIP,
       O - OSPF, I - IS-IS, B - BGP, P - PIM, A - Babel, N - NHRP,
       > - selected route, * - FIB route

B>* 140.113.0.0/16 [20/0] via 10.0.1.2, r2-eth1, 00:06:49
B>* 140.114.0.0/24 [20/0] via 10.0.0.2, r2-eth0, 00:06:44
```

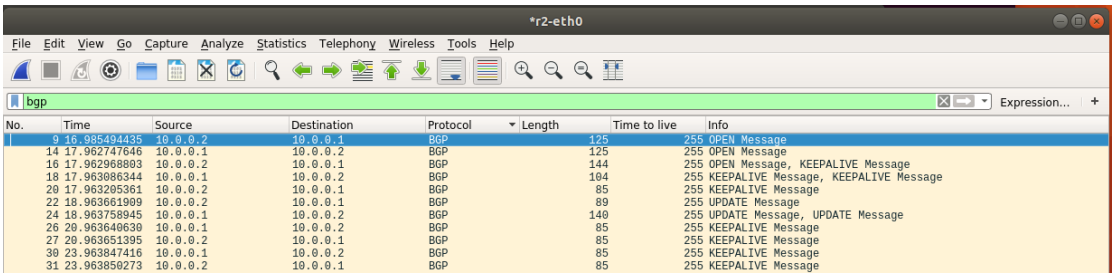
```
r3> sshhooww  iipp  bbggpp  ssuummmmaarryy

BGP router identifier 10.0.0.2, local AS number 65002
RIB entries 3, using 336 bytes of memory
Peers 2, using 18 KiB of memory

Neighbor        V         AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
10.0.0.1        4 65001     253     254        0    0    0 00:12:31        1
10.0.2.3        4 65003     252     255        0    0    0 00:12:31        1

Total number of neighbors 2

Total num. Established sessions 2
Total num. of routes received     2
```

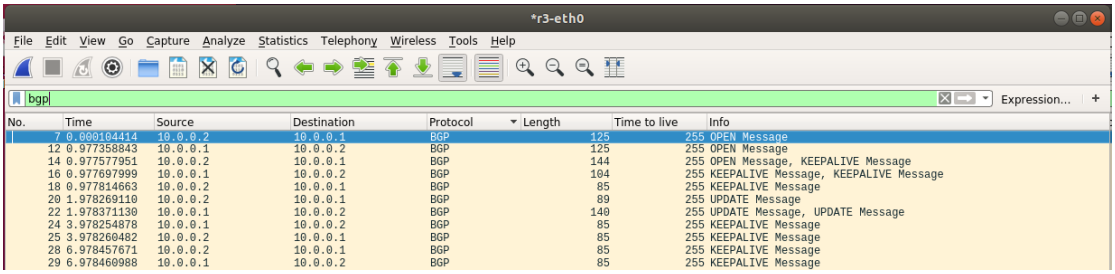
```
 zebra> sshhooww  iipp  rroouuttee  bbggpp

 Codes: K - kernel route, C - connected, S - static, R - RIP,
        O - OSPF, I - IS-IS, B - BGP, P - PIM, A - Babel, N - NHRP,
        > - selected route, * - FIB route

 B>* 140.113.0.0/16 [20/0] via 10.0.0.1, r3-eth0, 00:08:06
 B>* 140.114.0.0/24 [20/0] via 10.0.2.3, r3-eth1, 00:08:11
```

```
r4> sshhooww  iipp  bbggpp  ssuummmmaarryy

BGP router identifier 10.0.2.3, local AS number 65003
RIB entries 3, using 336 bytes of memory
Peers 1, using 9088 bytes of memory

Neighbor        V         AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
10.0.2.1        4 65002     280     281        0    0    0 00:13:50        1

Total number of neighbors 1

Total num. Established sessions 1
Total num. of routes received     1
```

```
 zebra> sshhooww  iipp  rroouuttee  bbggpp

 Codes: K - kernel route, C - connected, S - static, R - RIP,
        O - OSPF, I - IS-IS, B - BGP, P - PIM, A - Babel, N - NHRP,
        > - selected route, * - FIB route

 B>* 140.113.0.0/16 [20/0] via 10.0.2.1, r4-eth0, 00:08:58
```

3. Capture BGP packets from wireshark and take screenshot to verify your answer for the following questions (20%)
    1. Show BGP packets (OPEN, UPDATE, KEEP ALIVE) exchanged by r2 and r3





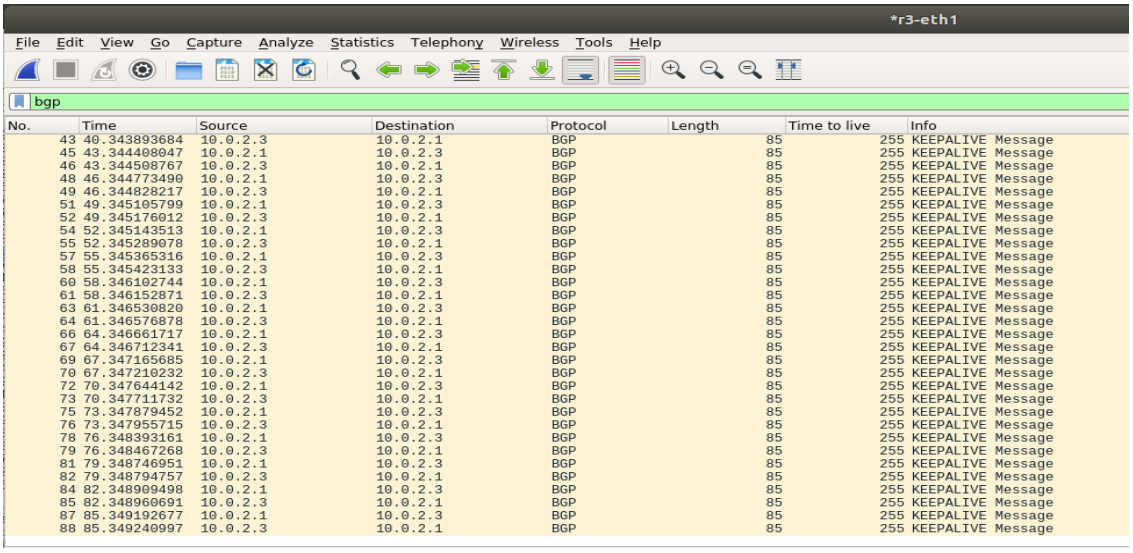
2. What will happen to the routing table if you set r4-eth0 down

   關掉 r4-eth0 後 r1, r2, r3 會無法連接到 140.114.0.0/24 的網段和 r4 所以 routing table 會沒有他們的 entry，而 r4 的 routing table 會只有 140.114.0.0/24 的網段。

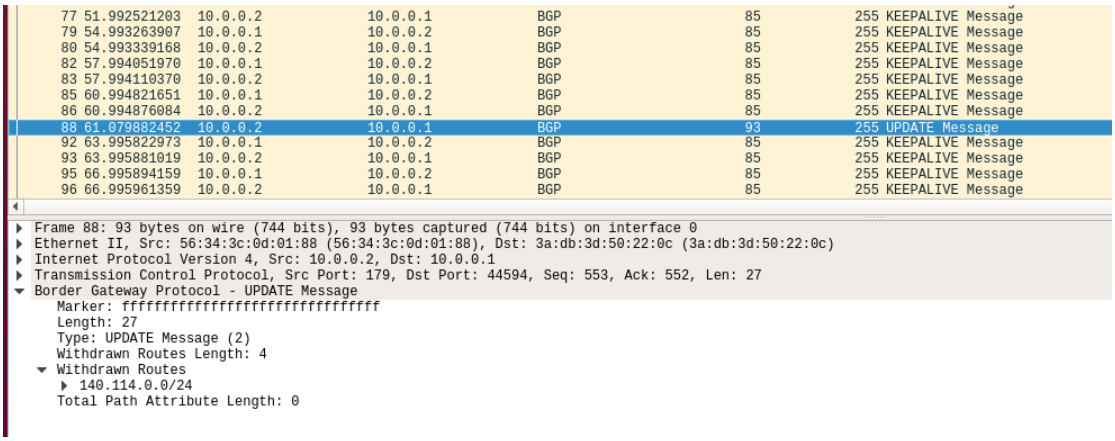
```
mininet> r4 ip link set r4-eth0 down
mininet> r1 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
10.0.1.0        0.0.0.0         255.255.255.0   U     0      0        0 r1-eth0
192.168.1.0     0.0.0.0         255.255.255.192 U     0      0        0 r1-eth1
192.168.1.64    0.0.0.0         255.255.255.192 U     0      0        0 r1-eth2
mininet> r2 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
10.0.0.0        0.0.0.0         255.255.255.0   U     0      0        0 r2-eth0
10.0.1.0        0.0.0.0         255.255.255.0   U     0      0        0 r2-eth1
140.113.0.0     10.0.1.2        255.255.0.0     UG    20     0        0 r2-eth1
mininet> r3 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
10.0.0.0        0.0.0.0         255.255.255.0   U     0      0        0 r3-eth0
10.0.2.0        0.0.0.0         255.255.255.0   U     0      0        0 r3-eth1
140.113.0.0     10.0.0.1        255.255.0.0     UG    20     0        0 r3-eth0
mininet> r4 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
140.114.0.0     0.0.0.0         255.255.255.0   U     0      0        0 r4-eth1
```

3. How does r3 know r4 is unreachable? Explain how

   在 r4 關掉 r4-eth 後，r3 會因為收不到 r4 的 KEEPALIVE 訊息，所以知道 r4 已經 unreachable。



4. How does r2 know r4 is unreachable? Explain how
   r3 會傳 BGP 的 UPDATE Message 告訴 r2，140.114.0.0/24 已經 unreachable。



Part2

1. Take screenshot of curl result

```
mininet> h4 curl 140.113.0.40:80
<!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="configs/">configs/</a>
<li><a href="dhcpd.conf">dhcpd.conf</a>
<li><a href="topology.py">topology.py</a>
</ul>
<hr>
</body>
</html>
```

2. Check reachability and take screenshot

```
mininet> h1 ping h4 -c 1
PING 140.114.0.1 (140.114.0.1) 56(84) bytes of data.
64 bytes from 140.114.0.1: icmp_seq=1 ttl=60 time=0.274 ms

--- 140.114.0.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.274/0.274/0.274/0.000 ms
mininet> h2 ping h4 -c 1
PING 140.114.0.1 (140.114.0.1) 56(84) bytes of data.
64 bytes from 140.114.0.1: icmp_seq=1 ttl=60 time=0.264 ms

--- 140.114.0.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.264/0.264/0.264/0.000 ms
mininet> h3 ping h4 -c 1
QStandardPaths: XDG_RUNTIME_DIR not set, defaulting to '/tmp/runtime-root'
192.168.1.3 - - [26/Mar/2021 11:49:19] "GET / HTTP/1.1" 200 -
140.114.0.1 - - [26/Mar/2021 12:19:58] "GET / HTTP/1.1" 200 -
PING 140.114.0.1 (140.114.0.1) 56(84) bytes of data.
64 bytes from 140.114.0.1: icmp_seq=1 ttl=60 time=0.260 ms

--- 140.114.0.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.260/0.260/0.260/0.000 ms
```

3. Run wireshark on r1 to take screenshot of input/output packet (10%)

   從 r1-eth0 的前兩個 packet 是 h1 ping h4 的 icmp packet，從 r1-eth1 進來的 192.168.1.3 因為 source nat 的關係，所以出去的時候變成 140.113.0.30，從 r1-eth0 進來的要傳給 140.113.0.30 的 packet 因為 destination nat 的關係變成傳給 192.168.1.3。

   從 r1-eth0 的後兩個 packet 是 h1 ping h4 的 icmp packet，從 r1-eth2 進來的 192.168.1.65 因為 source nat 的關係，所以出去的時候變成 140.113.0.40，從 r1-eth0 進來的要傳給 140.113.0.40 的 packet 因為 destination nat 的關係變成傳給 192.168.1.65。