

# NS Lab3 Report

## Part 1:

1.

Before:

```
[+] Run DHCP server
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
mininet>
```

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       255.255.0.0     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       255.255.0.0     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       255.255.0.0     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
mininet>
```

2. For Zebra: telnet 127.0.0.1 2601 / show ip route bgp  
For BGPD: telnet 127.0.0.1 2605 / show ip bgp summary

下列圖片在上方為 zebra，下方為 bgpd。

r1:

```
connection closed by foreign host.
root@ubuntu:/home/yucheng/Documents/ns_hw3/part1# telnet 127.0.0.1 2601
Trying 127.0.0.1...
Connected to 127.0.0.1.
Escape character is '^]'.

Hello, this is Quagga (version 1.2.4).
Copyright 1996-2005 Kunihiro Ishiguro, et al.

User Access Verification

Password:
zebra> show ip route bgp
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>* 140.114.0.0/16 [20/0] via 10.0.1.1, r1-eth0, 00:10:20
zebra>
```

```
root@ubuntu:/home/yucheng/Documents/ns_hw3/part1# telnet 127.0.0.1 2605
Trying 127.0.0.1...
Connected to 127.0.0.1.
Escape character is '^]'.

Hello, this is Quagga (version 1.2.4).
Copyright 1996-2005 Kunihiro Ishiguro, et al.

User Access Verification

Password:
r1> show ip bgp summary
BGP router identifier 10.0.1.2, local AS number 65001
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 65002    274    277      0    0    0 00:13:34      1

Total number of neighbors 1

Total num. Established sessions 1
Total num. of routes received    1
r1>
```

r2:

```

root@ubuntu:/home/yucheng/Documents/ns_hw3/part1# telnet 127.0.0.1 2601
Trying 127.0.0.1...
Connected to 127.0.0.1.
Escape character is '^]'.

Hello, this is Quagga (version 1.2.4).
Copyright 1996-2005 Kunihiro Ishiguro, et al.

User Access Verification

Password:
zebra> show ip route bgp
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, 00:21:44
B>* 140.114.0.0/16 [20/0] via 10.0.0.2, r2-eth0, 00:21:39
zebra>

```

```

root@ubuntu:/home/yucheng/Documents/ns_hw3/part1# telnet 127.0.0.1 2605
Trying 127.0.0.1...
Connected to 127.0.0.1.
Escape character is '^]'.

Hello, this is Quagga (version 1.2.4).
Copyright 1996-2005 Kunihiro Ishiguro, et al.

User Access Verification

Password:
r2> show ip route summary
% [BGP] Unknown command: show ip route summary
r2> show ip bgp summary
BGP router identifier 10.0.0.1, 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
10.0.0.2       4 65003    470    473      0   0   0 00:23:24      1
10.0.1.2       4 65001    471    472      0   0   0 00:23:24      1

Total number of neighbors 2

Total num. Established sessions 2
Total num. of routes received    2
r2>
et> r4 route

```

r3:

```

Connection closed by foreign host.
root@ubuntu:/home/yucheng/Documents/ns_hw3/part1# telnet 127.0.0.1 2601
Trying 127.0.0.1...
Connected to 127.0.0.1.
Escape character is '^]'.

Hello, this is Quagga (version 1.2.4).
Copyright 1996-2005 Kunihiro Ishiguro, et al.

User Access Verification

Password:
zebra> show ip route bgp
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, 00:25:07
B>* 140.114.0.0/16 [20/0] via 10.0.2.3, r3-eth1, 00:25:12
zebra>

```

```

root@ubuntu:/home/yucheng/Documents/ns_hw3/part1# telnet 127.0.0.1 2605
Trying 127.0.0.1...
Connected to 127.0.0.1.
Escape character is '^]'.

Hello, this is Quagga (version 1.2.4).
Copyright 1996-2005 Kunihiro Ishiguro, et al.

User Access Verification

Password:
r3> show ip bgp summary
BGP router identifier 10.0.0.2, local AS number 65003
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 65002    495    496      0   0   0 00:24:36      1
10.0.2.3       4 65004    494    497      0   0   0 00:24:36      1

Total number of neighbors 2

Total num. Established sessions 2
Total num. of routes received    2
r3>

```

r4:

```

root@ubuntu:/home/yucheng/Documents/ns_hw3/part1# telnet 127.0.0.1 2601
Trying 127.0.0.1...
Connected to 127.0.0.1.
Escape character is '^]'.

Hello, this is Quagga (version 1.2.4).
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User Access Verification

Password:
zebra> show ip route bgp
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, 00:26:22
zebra>

```

```

root@ubuntu:/home/yucheng/Documents/ns_hw3/part1# telnet 127.0.0.1 2605
Trying 127.0.0.1...
Connected to 127.0.0.1.
Escape character is '^]'.

Hello, this is Quagga (version 1.2.4).
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User Access Verification

Password:
r4> show ip bgp summary
BGP router identifier 10.0.2.3, local AS number 65004
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 65003    545    546      0   0   0 00:27:06      1

Total number of neighbors 1

Total num. Established sessions 1
Total num. of routes received    1
r4>

```

3.

### 3-1: BGP packets exchanged by r2 and r3:

r2-eth0:

No.	Time	Source	Destination	Protocol	Length	Info
2	0.776026298	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
3	0.776027063	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
7	3.776129260	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
9	3.776195078	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
11	6.777584553	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
13	6.777645329	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
15	9.778405799	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
17	9.778532719	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
19	12.779457866	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
20	12.779510695	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
22	15.780968577	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
23	15.780977631	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
28	18.781220954	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
30	18.781291194	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
32	21.783042962	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
34	21.783096810	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
36	24.783245152	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
38	24.783364542	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
40	27.784579137	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
41	27.784589130	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
44	30.786551905	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
46	30.786616496	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
48	33.787323667	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
50	33.787378930	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
52	36.789038085	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
54	36.789089297	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
56	39.789454890	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
58	39.789489538	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
60	42.791628054	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
62	42.791681006	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
64	45.792549345	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
65	45.792552299	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
69	48.793296468	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
71	48.793353583	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
74	51.794636837	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
76	51.794832406	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
78	54.795680783	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
80	54.795788353	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message

Frame 2: 85 bytes on wire (680 bits), 85 bytes captured (680 bits) on interface r2-eth0, id 0  
 Ethernet II, Src: e6:c6:fc:bc:2b:52 (e6:c6:fc:bc:2b:52), Dst: aa:41:6f:5b:f2:3a (aa:41:6f:5b:f2:3a)  
 Internet Protocol Version 4, Src: 10.0.0.1, Dst: 10.0.0.2  
 Transmission Control Protocol, Src Port: 41762, Dst Port: 179, Seq: 1, Ack: 1, Len: 19  
 Border Gateway Protocol - KEEPALIVE Message

r2-eth1:

No.	Time	Source	Destination	Protocol	Length	Info
436	336.162715664	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
438	339.163961652	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
440	339.164029288	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
442	342.166532530	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
444	342.166594400	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
446	345.168583168	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
448	345.168657752	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
450	348.169416489	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
452	348.169464556	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
454	351.171892660	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
456	351.171945944	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
458	354.172595563	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
459	354.172648749	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
461	357.173475165	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
462	357.173545452	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
464	360.173611178	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
465	360.173658057	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
467	363.174568990	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
468	363.174569554	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
471	366.176293852	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
473	366.176340903	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
475	369.176684681	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
477	369.176750883	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
479	372.178709083	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
481	372.178752162	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
483	375.179922089	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
485	375.179970292	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
487	378.180421574	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
488	378.180462270	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
490	381.182917454	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
491	381.182959425	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
493	384.183350428	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
495	384.183409098	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
497	387.185659421	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
499	387.185711746	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
501	390.186801508	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
503	390.186850096	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message

Frame 1: 85 bytes on wire (680 bits), 85 bytes captured (680 bits) on interface r2-eth1, id 0  
 Ethernet II, Src: 2e:d8:05:c8:78:e1 (2e:d8:05:c8:78:e1), Dst: be:e1:00:23:47:a8 (be:e1:00:23:47:a8)  
 Internet Protocol Version 4, Src: 10.0.1.2, Dst: 10.0.1.1  
 Transmission Control Protocol, Src Port: 179, Dst Port: 54282, Seq: 1, Ack: 1, Len: 19  
 Border Gateway Protocol - KEEPALIVE Message

be e1 00 23 47 a8 2e d8 05 c8 78 e1 08 00 45 c0 ...#G...x...E

Border Gateway Protocol: Protocol

Packets: 504 · Displayed: 262 (52.0%)

Profile: Default

## r3-eth0:

The screenshot shows a Wireshark capture on interface r3-eth0. The filter is set to 'bgp'. The packet list displays a series of BGP KEEPALIVE messages. The selected packet (No. 512) is a BGP KEEPALIVE Message from 10.0.0.2 to 10.0.0.1. The packet details pane shows the structure of the BGP message, including the BGP Version (4), Session ID (179), and Sequence Number (1). The packet bytes pane shows the raw data: 0000 e6 c6 fc bc 2b 52 aa 41 6f 5b f2 3a 08 00 45 c0 ... +R A o[... E.

No.	Time	Source	Destination	Protocol	Length	Info
451	354.143905353	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
453	357.145158966	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
454	357.145254908	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
456	360.146849938	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
457	360.146895251	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
459	363.147247646	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
460	363.147291396	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
462	366.149150469	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
463	366.149199084	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
465	369.150130197	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
467	369.150180525	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
469	372.151763146	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
471	372.152063971	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
473	375.153111987	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
475	375.153228022	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
477	378.153424584	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
479	378.153482192	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
481	381.154882253	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
482	381.154955371	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
484	384.155696183	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
485	384.155742322	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
487	387.157096145	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
488	387.157213715	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
490	390.158313432	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
491	390.158317165	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
494	393.159138507	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
496	393.159253036	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
498	396.161394187	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
500	396.161525572	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
502	399.162410062	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
504	399.162453922	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
506	402.163442880	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
508	402.163528271	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
510	405.165209154	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
512	405.165289961	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
514	408.165467440	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
516	408.165516544	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message

Frame 1: 85 bytes on wire (680 bits), 85 bytes captured (680 bits) on interface r3-eth0, id 0  
Ethernet II, Src: aa:41:6f:5b:f2:3a (aa:41:6f:5b:f2:3a), Dst: e6:c6:fc:bc:2b:52 (e6:c6:fc:bc:2b:52)  
Internet Protocol Version 4, Src: 10.0.0.2, Dst: 10.0.0.1  
Transmission Control Protocol, Src Port: 179, Dst Port: 41762, Seq: 1, Ack: 1, Len: 19  
Border Gateway Protocol - KEEPALIVE Message

0000 e6 c6 fc bc 2b 52 aa 41 6f 5b f2 3a 08 00 45 c0 ... +R A o[... E

Border Gateway Protocol: Protocol Packets: 517 · Displayed: 274 (53.0%) Profile: Default

## r3-eth1:

The screenshot shows a Wireshark capture on interface r3-eth1. The filter is set to 'bgp'. The packet list displays a series of BGP KEEPALIVE messages. The selected packet (No. 492) is a BGP KEEPALIVE Message from 10.0.2.3 to 10.0.2.1. The packet details pane shows the structure of the BGP message, including the BGP Version (4), Session ID (53838), and Sequence Number (1). The packet bytes pane shows the raw data: 0000 6a df c0 67 25 74 6a c2 f9 2f b5 c5 08 00 45 c0 j...g&tj.../... E.

No.	Time	Source	Destination	Protocol	Length	Info
430	372.149278351	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
432	375.150724605	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
434	375.150780165	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
436	378.151425876	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
438	378.151521187	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
440	381.152993295	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
442	381.153093961	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
444	384.154077396	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
445	384.154121347	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
447	387.154911999	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
448	387.154955113	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
450	390.157300959	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
451	390.157388302	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
453	393.158079545	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
455	393.158167452	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
457	396.159230839	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
459	396.159282383	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
461	399.160997313	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
462	399.161044197	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
464	402.161165595	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
465	402.161227648	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
467	405.163021837	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
468	405.163097475	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
470	408.164225228	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
472	408.164280459	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
474	411.165639365	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
476	411.165687498	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
478	414.167591411	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
480	414.167777824	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
482	417.168444496	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
483	417.168568846	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
485	420.169316500	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
486	420.169350759	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
488	423.169592065	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
489	423.169629307	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message
491	426.171128087	10.0.2.1	10.0.2.3	BGP	85	KEEPALIVE Message
492	426.171163062	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message

Frame 1: 85 bytes on wire (680 bits), 85 bytes captured (680 bits) on interface r3-eth1, id 0  
Ethernet II, Src: 6a:c2:f9:2f:b5:c5 (6a:c2:f9:2f:b5:c5), Dst: 6a:df:c0:67:25:74 (6a:df:c0:67:25:74)  
Internet Protocol Version 4, Src: 10.0.2.1, Dst: 10.0.2.3  
Transmission Control Protocol, Src Port: 53838, Dst Port: 179, Seq: 1, Ack: 1, Len: 19  
Border Gateway Protocol - KEEPALIVE Message

0000 6a df c0 67 25 74 6a c2 f9 2f b5 c5 08 00 45 c0 j...g&tj.../... E

Border Gateway Protocol: Protocol Packets: 493 · Displayed: 286 (58.0%) Profile: Default



### 3-2: Set r4-eth0 down:

```
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
QStandardPaths: XDG_RUNTIME_DIR not set, defaulting to '/tmp/runtime-root'
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
QStandardPaths: XDG_RUNTIME_DIR not set, defaulting to '/tmp/runtime-root'
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
mininet>
```

在輸入 r4 ip link set r4-eth0 down 之後，各路由器的 routing table

都有所改變，直接拿原本的 table 做比較:

<pre>mininet&gt; 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          255.255.0.0       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&gt; 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          255.255.0.0       UG       20     0      0 r2-eth0 mininet&gt; 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          255.255.0.0       UG       20     0      0 r3-eth1 mininet&gt; 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 mininet&gt;</pre>	<pre>mininet&gt; r4 ip link set r4-eth0 down mininet&gt; 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&gt; r2 route QStandardPaths: XDG_RUNTIME_DIR not set, defaulting to '/tmp/runtime-root' 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&gt; r3 route QStandardPaths: XDG_RUNTIME_DIR not set, defaulting to '/tmp/runtime-root' 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&gt; 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 mininet&gt;</pre>
---	--

左邊是原本都連得上的情況，右邊是將 r4-eth0 disable 掉的情

況。我們可以發現，r1、r2、r3 中，140.114.0.0 的這條路由全

都不見了；而對 r4 來說，則只剩下 140.114.0.0 這條路由。這代

表 r1、r2、r3 都可以正常傳送封包，就只傳不到 r4；而 r4 就只

能傳到 H4，剩下的 host、router 都無法傳到。

### 3-3: How does r3 know r4 is unreachable?

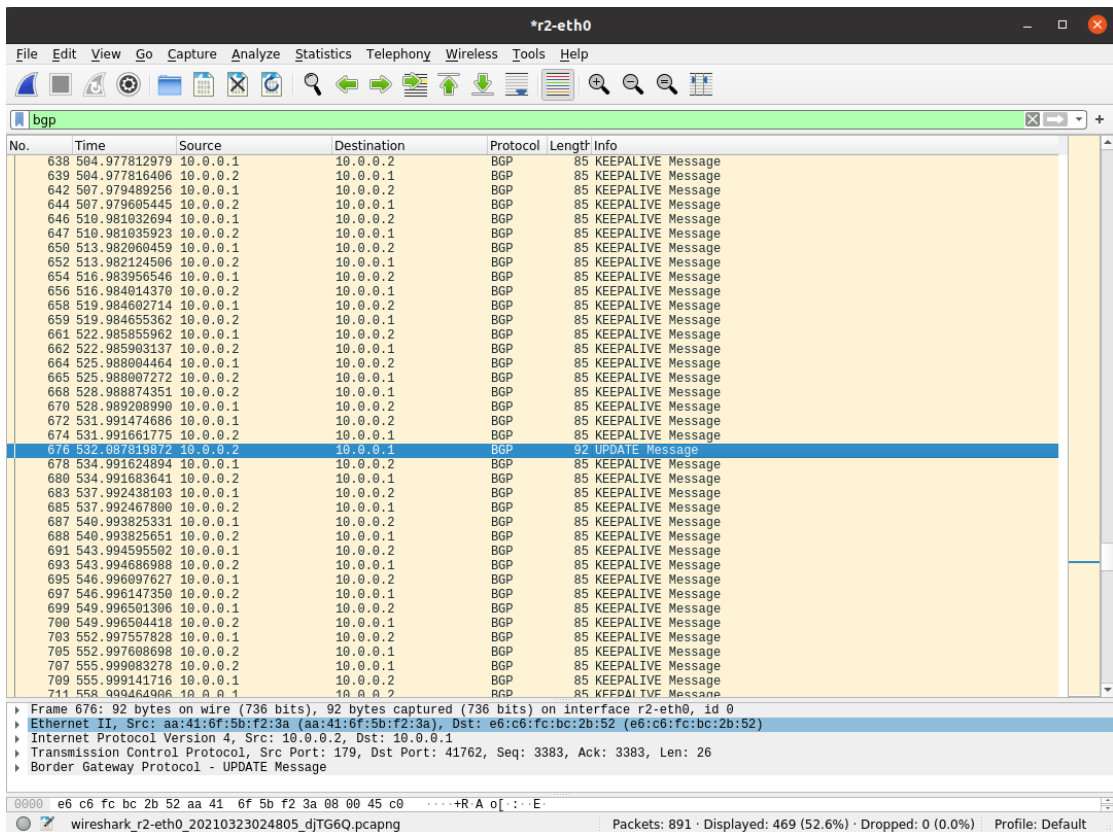
No.	Time	No.	Time	No.	Time	Source	Destination	Protocol	Length	Info
852	670.04	864	678.32	853	672.267439612	10.0.0.0	10.0.2.3	BGP	85	KEEPALIVE Message
854	673.04	866	681.32	855	675.269276947	10.0.0.0	10.0.2.1	BGP	85	KEEPALIVE Message
856	673.04	868	681.32	857	675.269333264	10.0.0.0	10.0.2.3	BGP	85	KEEPALIVE Message
858	676.04	870	684.32	859	678.269970622	10.0.0.0	10.0.2.1	BGP	85	KEEPALIVE Message
859	676.04	872	684.32	861	678.270014958	10.0.0.0	10.0.2.3	BGP	85	KEEPALIVE Message
861	679.04	874	687.33	863	681.270874624	10.0.0.0	10.0.2.1	BGP	85	KEEPALIVE Message
862	679.04	876	687.33	865	681.270920030	10.0.0.0	10.0.2.3	BGP	85	KEEPALIVE Message
864	682.04	878	690.33	867	684.271997036	10.0.0.0	10.0.2.1	BGP	85	KEEPALIVE Message
865	682.04	879	690.33	869	684.272050266	10.0.0.0	10.0.2.3	BGP	85	KEEPALIVE Message
868	685.04	881	693.33	871	687.272903003	10.0.0.0	10.0.2.1	BGP	85	KEEPALIVE Message
869	685.04	882	693.33	873	687.272961833	10.0.0.0	10.0.2.3	BGP	85	KEEPALIVE Message
872	688.04	884	696.33	875	690.273868135	10.0.0.0	10.0.2.1	BGP	85	KEEPALIVE Message
874	688.04	885	696.33	877	690.273920947	10.0.0.0	10.0.2.3	BGP	85	KEEPALIVE Message
876	691.05	887	699.33	879	693.274154394	10.0.0.0	10.0.2.1	BGP	85	KEEPALIVE Message
878	691.05	888	699.33	881	693.274202805	10.0.0.0	10.0.2.3	BGP	85	KEEPALIVE Message
880	694.05	890	702.33	883	696.275718305	10.0.0.0	10.0.2.1	BGP	85	KEEPALIVE Message
882	694.05	891	702.33	884	696.275776132	10.0.0.0	10.0.2.3	BGP	85	KEEPALIVE Message
884	697.05	893	705.34	886	699.275863970	10.0.0.0	10.0.2.1	BGP	85	KEEPALIVE Message
886	697.05	894	705.34	887	699.275908611	10.0.0.0	10.0.2.3	BGP	85	KEEPALIVE Message
888	700.05	896	708.34	889	702.276897373	10.0.0.0	10.0.2.1	BGP	85	KEEPALIVE Message
890	700.05	897	708.34	890	702.276944298	10.0.0.0	10.0.2.3	BGP	85	KEEPALIVE Message
				587	510.206602633	10.0.2.3	10.0.2.1	BGP	85	KEEPALIVE Message

上圖由左至右分別是 r2-eth0、r2-eth1、r3-eth0、r3-eth1 的 wireshark 截圖。這四個 interface 都由我大致在同一時間開始及停止 listen。可以發現，BGP 大概每隔 3 秒就會用一個 KEEPALIVE message 和自己的 neighbor 互傳。而 r3-eth1 在 disable r4-eth0 之後就沒有再傳送、接收到封包了，最後一個封包是在時間 510.2 秒收到來自 r4-eth0 的 KEEPALIVE。而其他 interface 的最後一個封包都在大約 700 秒左右。由此可以推斷，510 秒時大約就是下達 disable r4-eth0 指令的時候。而下達之後，r3 由於 r3-eth1 沒有收到該有的 KEEPALIVE message，而



知道 r4 變成 unreachable 了。

### 3-4: How does r2 know r4 is unreachable?



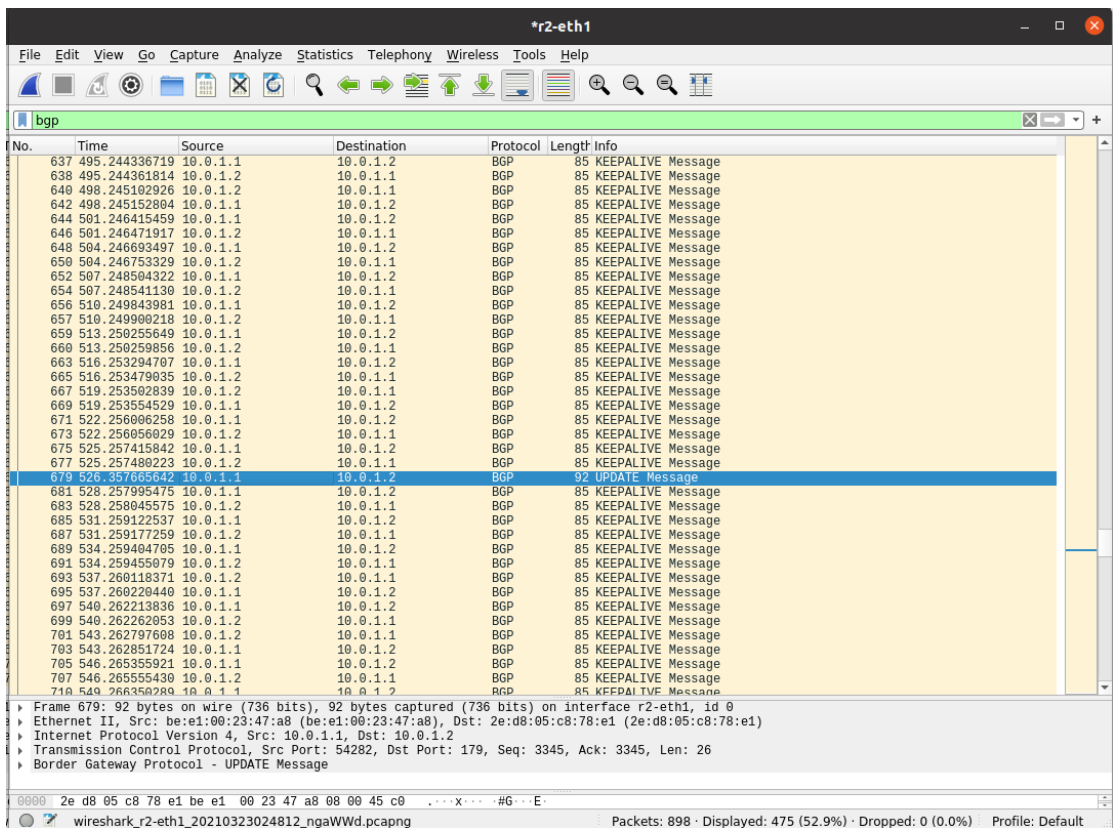
Wireshark capture of BGP messages on interface r2-eth0. The capture shows a series of BGP KEEPALIVE messages from 10.0.0.1 to 10.0.0.2, followed by a BGP UPDATE message. The packet list shows the details of the UPDATE message, including the Ethernet II, Internet Protocol Version 4, and Border Gateway Protocol (BGP) fields.

No.	Time	Source	Destination	Protocol	Length	Info
638	504.977812979	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
639	504.977816406	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
642	507.979489256	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
644	507.979605445	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
646	510.981032694	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
647	510.981035923	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
650	513.982060459	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
652	513.982124506	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
654	516.983956546	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
656	516.984014370	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
658	519.984602714	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
659	519.984655362	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
661	522.985855962	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
662	522.985903137	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
664	525.988004464	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
665	525.988007272	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
668	528.988074351	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
670	528.989208990	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
672	531.991474686	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
674	531.991661775	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
676	532.087819872	10.0.0.2	10.0.0.1	BGP	92	UPDATE Message
678	534.991624894	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
680	534.991683641	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
683	537.992438103	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
685	537.992467800	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
687	540.993825331	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
688	540.993825651	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
691	543.994595502	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
693	543.994686988	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
695	546.996097627	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
697	546.996147350	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
699	549.996501306	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
700	549.996504418	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
703	552.997557828	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
705	552.997608698	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
707	555.999033278	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message
709	555.999141716	10.0.0.2	10.0.0.1	BGP	85	KEEPALIVE Message
711	558.000464006	10.0.0.1	10.0.0.2	BGP	85	KEEPALIVE Message

Frame 676: 92 bytes on wire (736 bits), 92 bytes captured (736 bits) on interface r2-eth0, id 0  
Ethernet II, Src: aa:41:6f:5b:f2:3a (aa:41:6f:5b:f2:3a), Dst: e6:c6:fc:bc:2b:52 (e6:c6:fc:bc:2b:52)  
Internet Protocol Version 4, Src: 10.0.0.2, Dst: 10.0.0.1  
Transmission Control Protocol, Src Port: 179, Dst Port: 41762, Seq: 3383, Ack: 3383, Len: 26  
Border Gateway Protocol - UPDATE Message

0000 e6 c6 fc bc 2b 52 aa 41 6f 5b f2 3a 08 00 45 c0 .....R A o[...E

wireshark\_r2-eth0\_20210323024805\_djTG6Q.pcapng Packets: 891 · Displayed: 469 (52.6%) · Dropped: 0 (0.0%) Profile: Default



Wireshark capture of BGP messages on interface r2-eth1. The capture shows a series of BGP KEEPALIVE messages from 10.0.1.1 to 10.0.1.2, followed by a BGP UPDATE message. The packet list shows the details of the UPDATE message, including the Ethernet II, Internet Protocol Version 4, and Border Gateway Protocol (BGP) fields.

No.	Time	Source	Destination	Protocol	Length	Info
637	495.244336719	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
638	495.244361814	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
640	498.245102926	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
642	498.245152804	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
644	501.246415459	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
646	501.246471917	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
648	504.246693497	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
650	504.246753329	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
652	507.248504322	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
654	507.248541130	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
656	510.249843981	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
657	510.249900218	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
659	513.250255649	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
660	513.250259856	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
663	516.253294707	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
665	516.253479835	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
667	519.253502830	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
669	519.253545429	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
671	522.256006258	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
673	522.256056029	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
675	525.257415842	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
677	525.257480223	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
679	526.357665642	10.0.1.1	10.0.1.2	BGP	92	UPDATE Message
681	528.257995475	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
683	528.258045575	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
685	531.259122537	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
687	531.259177259	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
689	534.259404705	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
691	534.259455079	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
693	537.260118371	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
695	537.260220440	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
697	540.262213836	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
699	540.262262053	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
701	543.262797608	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
703	543.262851724	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
705	546.263555921	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
707	546.263555430	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
710	549.266350280	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message

Frame 679: 92 bytes on wire (736 bits), 92 bytes captured (736 bits) on interface r2-eth1, id 0  
Ethernet II, Src: be:e1:00:23:47:a8 (be:e1:00:23:47:a8), Dst: 2e:d8:05:c8:78:e1 (2e:d8:05:c8:78:e1)  
Internet Protocol Version 4, Src: 10.0.1.1, Dst: 10.0.1.2  
Transmission Control Protocol, Src Port: 54282, Dst Port: 179, Seq: 3345, Ack: 3345, Len: 26  
Border Gateway Protocol - UPDATE Message

0000 2e d8 05 c8 78 e1 be e1 00 23 47 a8 08 00 45 c0 ....X... #G...E

wireshark\_r2-eth1\_20210323024812\_ngaWWd.pcapng Packets: 898 · Displayed: 475 (52.9%) · Dropped: 0 (0.0%) Profile: Default

上兩圖分別是 r2-eth0、r2-eth1 的 wireshark 截圖。可以發現在 530 秒左右時，兩個 interface 都收到了一個 UPDATE message。而承上題，下達 disable 指令時大約是 510 秒。由此可以推斷，在 r3 得知 r4 unreachable 之後，便發送 UPDATE message 給其他的 router，告知他們更新 routing table，將 r4 移除。而 r2 收到了這個 message，因此得知了 r4 unreachable。

## Part 2:

### 1. Curl:

```
mininet> h3 python2 -m SimpleHTTPServer &
mininet> h4 curl 140.113.0.40:80
bash: curl: command not found
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="bgp_r1.conf">bgp_r1.conf</a>
<li><a href="bgp_r2.conf">bgp_r2.conf</a>
<li><a href="bgp_r3.conf">bgp_r3.conf</a>
<li><a href="bgp_r4.conf">bgp_r4.conf</a>
<li><a href="dhcpd.conf">dhcpd.conf</a>
<li><a href="topology.py">topology.py</a>
<li><a href="zebra.conf">zebra.conf</a>
</ul>
<hr>
</body>
</html>
mininet> █
```

## 2. Ping:

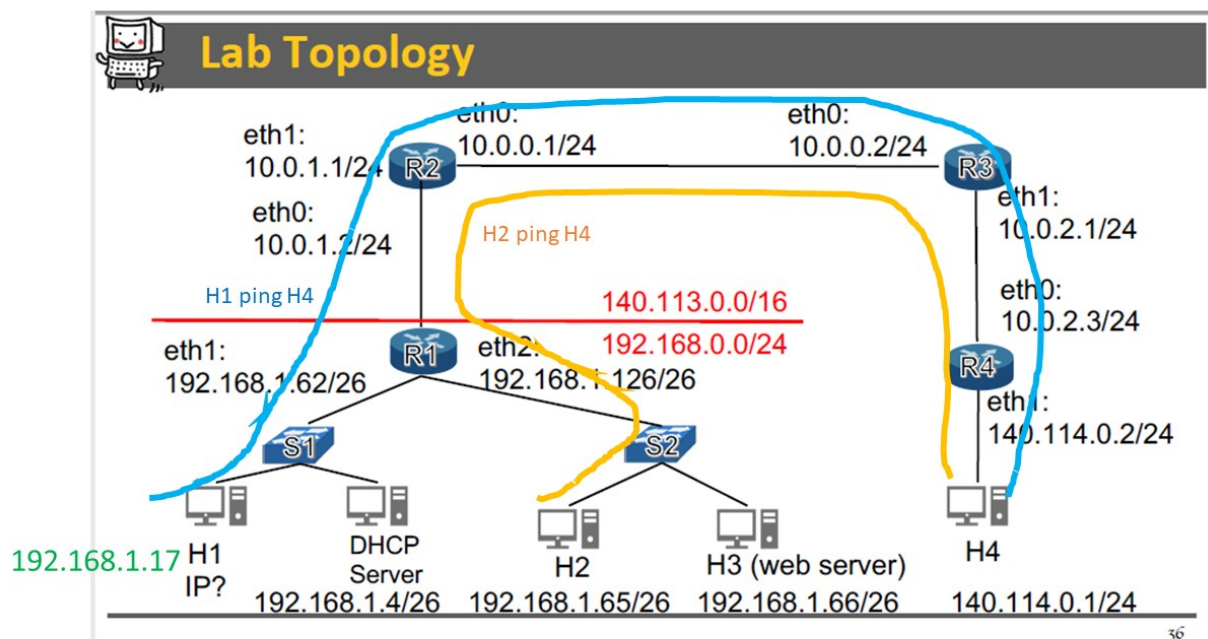
```
mininet> h1 ping h4 -c 1
PING 140.114.0.1 (140.114.0.1) 56(84) bytes of data.
64 bytes from 140.114.0.1: icmp_seq=1 ttl=60 time=0.322 ms

--- 140.114.0.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.322/0.322/0.322/0.000 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=0.305 ms

--- 140.114.0.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.305/0.305/0.305/0.000 ms
mininet> h3 ping h4 -c 1
Serving HTTP on 0.0.0.0 port 8000 ...
140.114.0.1 - - [23/Mar/2021 08:38:39] "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=0.261 ms

--- 140.114.0.1 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.261/0.261/0.261/0.000 ms
mininet>
```

## 3. r1 wireshark:



r1-eth0:

**\*r1-eth0**

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No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
2	0.000016395	10.0.1.1	10.0.1.2	TCP	66	59392 → 179 [ACK] Seq=1 Ack=20 Win=83 Len=0 TSval=1644974840 ...
3	0.000059801	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
4	0.000062646	10.0.1.2	10.0.1.1	TCP	66	179 → 59392 [ACK] Seq=20 Ack=39 Win=85 Len=0 TSval=1101791316...
5	0.786661469	140.113.0.30	140.114.0.1	ICMP	98	Echo (ping) request id=0x367c, seq=1/256, ttl=63 (reply in 0)
6	0.786686366	140.114.0.1	140.113.0.30	ICMP	98	Echo (ping) reply id=0x367c, seq=1/256, ttl=61 (request in 0)
7	0.001056240	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
8	3.001066834	10.0.1.2	10.0.1.1	TCP	66	179 → 59392 [ACK] Seq=20 Ack=39 Win=85 Len=0 TSval=1101794317...
9	3.001138724	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
10	3.001142119	10.0.1.1	10.0.1.2	TCP	66	59392 → 179 [ACK] Seq=39 Ack=39 Win=83 Len=0 TSval=1644977842...
11	6.005047457	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
12	6.005061820	10.0.1.2	10.0.1.1	TCP	66	179 → 59392 [ACK] Seq=39 Ack=58 Win=85 Len=0 TSval=1101797321...
13	6.005144040	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
14	6.005154511	10.0.1.1	10.0.1.2	TCP	66	59392 → 179 [ACK] Seq=58 Ack=58 Win=83 Len=0 TSval=1644980846...
15	6.451836501	140.113.0.40	140.114.0.1	ICMP	98	Echo (ping) request id=0x3680, seq=1/256, ttl=63 (reply in 1...
16	6.451860590	140.114.0.1	140.113.0.40	ICMP	98	Echo (ping) reply id=0x3680, seq=1/256, ttl=61 (request in 1...
17	9.007089556	10.0.1.1	10.0.1.2	BGP	85	KEEPALIVE Message
18	9.007077710	10.0.1.2	10.0.1.1	TCP	66	179 → 59392 [ACK] Seq=58 Ack=77 Win=85 Len=0 TSval=1101800323...
19	9.007137348	10.0.1.2	10.0.1.1	BGP	85	KEEPALIVE Message
20	9.007139885	10.0.1.1	10.0.1.2	TCP	66	59392 → 179 [ACK] Seq=77 Ack=77 Win=83 Len=0 TSval=1644983848...

r1-eth1: ( h1 ping h4 )

**\*r1-eth1**

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No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	192.168.1.17	140.114.0.1	ICMP	98	Echo (ping) request id=0x367c, seq=1/256, ttl=64 (reply in 2)
2	0.000040625	140.114.0.1	192.168.1.17	ICMP	98	Echo (ping) reply id=0x367c, seq=1/256, ttl=60 (request in 2)
3	5.161934016	62:2d:04:67:fc:18	aa:bb:45:8e:a4:ae	ARP	42	Who has 192.168.1.17? Tell 192.168.1.62
4	5.162116391	aa:bb:45:8e:a4:ae	62:2d:04:67:fc:18	ARP	42	Who has 192.168.1.62? Tell 192.168.1.17
5	5.162119081	62:2d:04:67:fc:18	aa:bb:45:8e:a4:ae	ARP	42	192.168.1.62 is at 62:2d:04:67:fc:18
6	5.162146509	aa:bb:45:8e:a4:ae	62:2d:04:67:fc:18	ARP	42	192.168.1.17 is at aa:bb:45:8e:a4:ae

r1-eth2: ( h2 ping h4 )

**\*r1-eth2**

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No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000000	192.168.1.65	140.114.0.1	ICMP	98	Echo (ping) request id=0x3680, seq=1/256, ttl=64 (reply in 2)
2	0.000041411	140.114.0.1	192.168.1.65	ICMP	98	Echo (ping) reply id=0x3680, seq=1/256, ttl=60 (request in 2)
3	5.128175273	1e:1c:dc:4e:b6:96	56:63:38:44:e7:cb	ARP	42	Who has 192.168.1.65? Tell 192.168.1.126
4	5.128288039	56:63:38:44:e7:cb	1e:1c:dc:4e:b6:96	ARP	42	Who has 192.168.1.126? Tell 192.168.1.65
5	5.128292936	1e:1c:dc:4e:b6:96	56:63:38:44:e7:cb	ARP	42	192.168.1.126 is at 1e:1c:dc:4e:b6:96
6	5.128320931	56:63:38:44:e7:cb	1e:1c:dc:4e:b6:96	ARP	42	192.168.1.65 is at 56:63:38:44:e7:cb

結合以上拓撲結構和 wireshark 截圖，我們可以得出以下結論：

- I. h1 ( 192.168.1.17 ) 發出 ping request，首先到 r1-eth1，經由 r1 轉傳，從 r1-eth0 出來。由於經過 NAT，source ip 變為 140.113.0.30。到 h4 ( 140.114.0.1 ) 後，h4 收到並送出 ping reply，經由原路徑返回。相反的，過 r1 一樣會將 destination ip 從 140.113.0.30 轉成 192.168.1.17，並由 h1 接收。
- II. h2 ( 192.168.1.65 ) 同理，經過設有 NAT 的 r1 會將 source ip 從原本的 192.168.1.65 轉成 140.113.0.40；回來時也將 destination ip 從 140.113.0.40 轉成 192.168.1.65。