

CS3543 Lab Assignment for Jan 24th

Member 1: Vijay Tadikamalla (CS17BTECH11040)

Member 2: Dhananjay Raut (CS17BTECH11014)

General Information

1. This assignment is a pair assignment. The same mark will be offered to the pair of students regardless of individual contributions.
2. The assignment is customized for Ubuntu + KVM environment. It is highly recommended for non-Ubuntu users to enable dual boot on your laptop computer and install Ubuntu. If you would like to work on another operating system and virtualization platform, you need to interpret the Ubuntu/KVM terminology to another environment's terminology.
3. Each pair can create a locally copy of this question file, give the answer to the local copy, and submit in a form of PDF file.
4. Only one submission is good enough as far as the student name and ID are properly mentioned.
5. Do not send any private comments to separately mention the buddy.

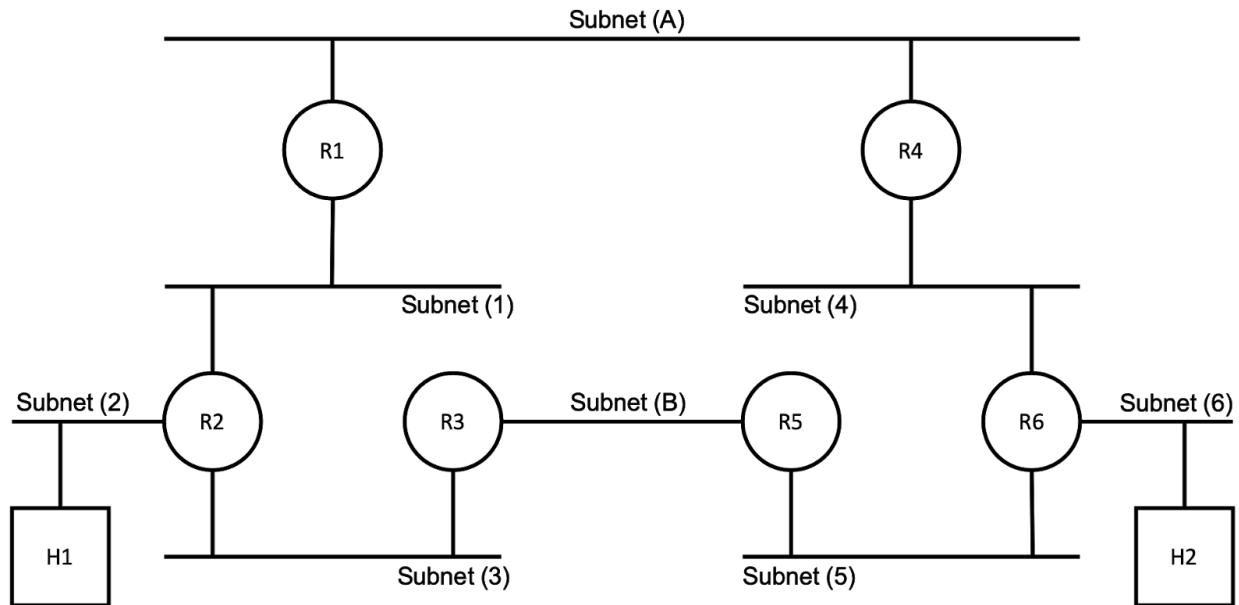


Fig.1. Blank Network Diagram

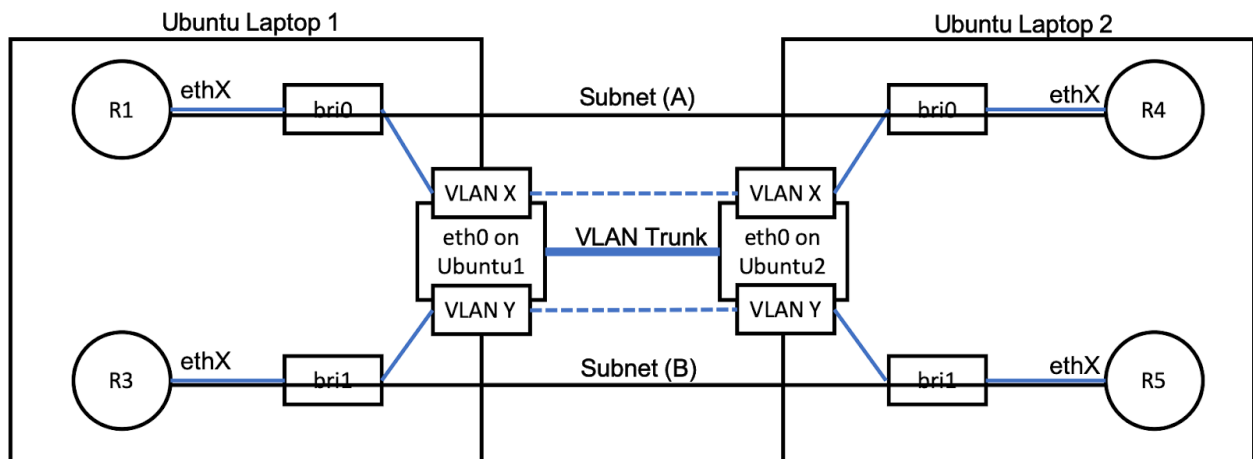


Fig.2. Conceptual Illustration of VLAN Configuration on Ubuntu Laptops 1 and 2

(Instruction)

This assignment requires to directly connect two Ubuntu laptops using a LAN cable to form a slightly bigger network than the previous assignment as shown in Fig. 1. In order to enable inter-router connections via Subnets (A) and (B) between the Ubuntu laptops, VLAN I/F (for VLAN Trunk) needs to be created on the physical LAN port of both Ubuntu laptops, and VLAN I/F needs to be attached to the corresponding bridge I/F as illustrated in Fig.2. Explore the ubuntu configuration 1) to create VLANs on Ubuntu, 2) to configure VLAN I/F (Trunking), and 3) attach VLAN I/F to a bridge I/F, 4) to let the traffic go through a separate VLAN/Bridge between respective pairs of VMs {R1 and R4} and {R3 and R5}.

Question 0.

Complete the following table about the VLAN and Bridge configurations for Subnets (A) and (B). It is strongly recommended to unify the bridge name between Laptops 1 and 2 for each subnet to avoid confusion.

	For Subnet (A)	For Subnet (B)
VLAN ID	10	20
Name of VLAN I/F on Laptop 1	enp4s0f1.10	enp4s0f1.20
Name of VLAN I/F on Laptop 2	enp2s0.10	enp2s0.20
Name of Bridge I/F on Laptop 1	bri0	bri4
Name of Bridge I/F on Laptop 2		

Question 1.

Assign the necessary configuration (NIC and IPv4/v6 addresses) to implement the network illustrated in Fig. 1, note down the configuration in the network diagram, and insert the update network diagram as an image as the answer to the question.

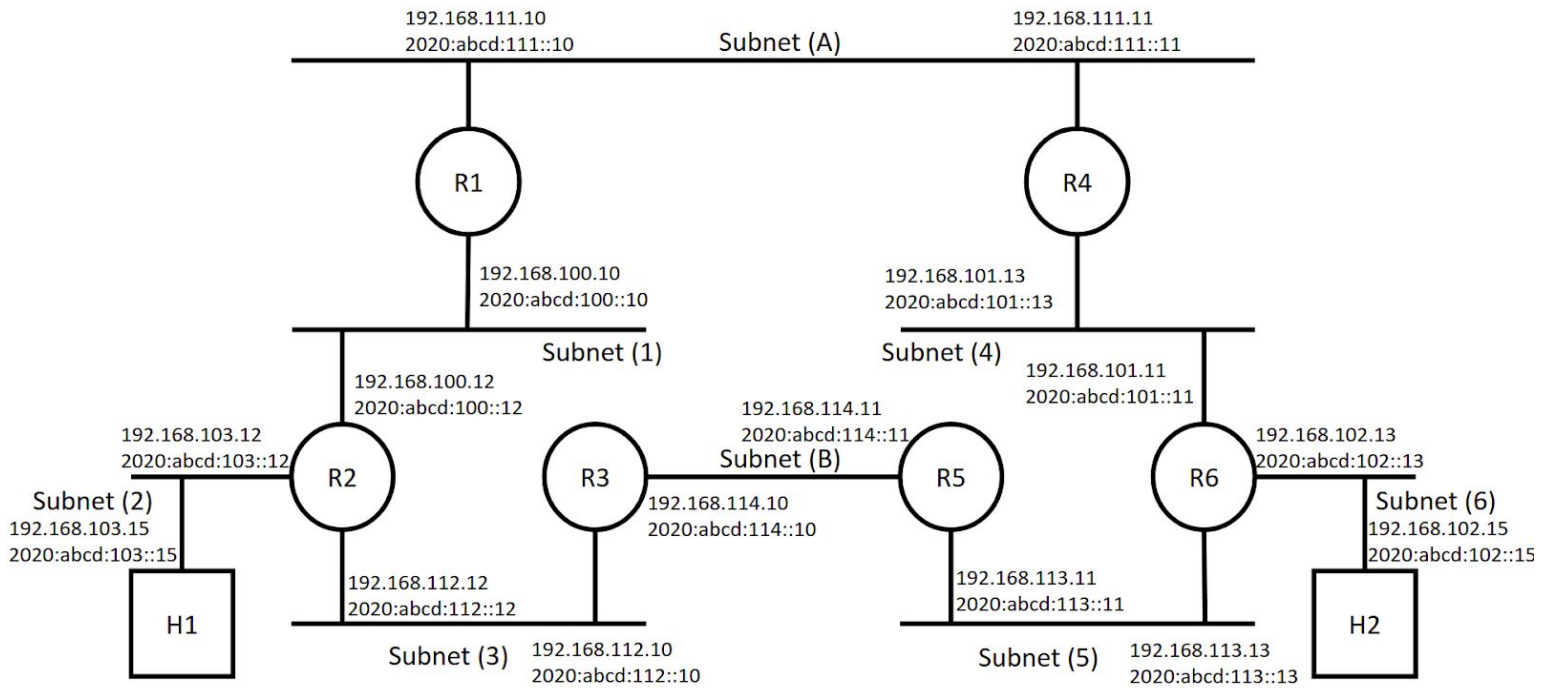
Supplemental Instructions for Question 1.

- This assignment does not provide any addressing information. It must be determined and noted down in the network diagram by yourself. Make sure that the following minimum information are clearly visible.
 - To each subnet: Bridge Name, IPv4 Prefix, IPv6 Prefix
 - To each NIC: I/F Name, MAC Address, IPv4 Address, IPv6 Address
- You may use the base network diagram given in the supplemental power-point file or your hand illustration. The example of subnet and NIC information is also available in the same power-point file. If you don't have a better idea, follow the example.

Subnet Name	IPv4 prefix	IPv6 prefix	bridge
A	192.168.111.0	2020:abcd:111::0	bri0 in both
B	192.168.114.0	2020:abcd:114::0	bri4 in both
1	192.168.100.0	2020:abcd:100::0	bri1
2	192.168.103.0	2020:abcd:103::0	bri2
3	192.168.112.0	2020:abcd:112::0	bri3
4	192.168.101.0	2020:abcd:101::0	bri1
5	192.168.113.0	2020:abcd:113::0	bri2
6	192.168.102.0	2020:abcd:102::0	bri3

NIC	Mac address	bridge	I/F name
R1.1	52:54:00:f7:14:c4	bri0	eth0
R2.1	52:54:00:12:83:f2	bri1	eth0
R3.1	52:54:00:fa:fd:15	bri3	eth0
R1.2	52:54:00:9c:3b:14	bri1	eth1
R2.2	52:54:00:d2:ae:c6	bri3	eth1
R3.2	52:54:00:02:77:31	bri4	eth1
R2.3	52:54:00:48:cd:5c	bri2	eth2
H1.1	52:54:00:9a:bc:0d	bri2	eth0

NIC	Mac address	bridge	I/F name
R4.1	80:00:27:CE:93:6D	bri0	eth0
R5.1	08:00:27:31:46:03	bri3	eth0
R6.1	08:00:27:E1:97:67	bri1	eth0
R4.2	08:00:27:B9:49:72	bri1	eth1
R5.2	08:00:27:32:49:AD	bri4	eth1
R6.2	08:00:27:76:0B:1F	bri2	eth1
R6.3	08:00:27:09:4A:C3	bri3	eth2
H2.1	08:00:27:4D:DB:5E	bri2	eth0



Some screenshots

vm1 on QEMU/KVM (R1):

```

vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface IP Address S/L Description
-----
eth0 192.168.111.10/24 u/u
eth1 2020:abcd:111::10/64 u/u
eth2 192.168.100.10/24 u/u
lo 127.0.0.1/8 u/u
::1/128

vyos@vyos:~$ show ip route
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
I - ISIS, B - BGP, > - selected route, * - FIB route

C>* 127.0.0.0/8 is directly connected, lo
C>* 192.168.100.0/24 is directly connected, eth1
S>* 192.168.102.0/24 [1/0] via 192.168.102.15, eth2
S>* 192.168.103.0/24 [1/0] via 192.168.103.12, eth1
C>* 192.168.111.0/24 is directly connected, eth0
vyos@vyos:~$

```

vm2 on QEMU/KVM (R4):

```

vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface IP Address S/L Description
-----
eth0 192.168.101.13/24 u/u
eth1 2020:abcd:101::13/64 u/u
eth2 192.168.101.11/24 u/u
lo 127.0.0.1/8 u/u
::1/128

vyos@vyos:~$ show ip route
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
I - ISIS, B - BGP, > - selected route, * - FIB route

C>* 127.0.0.0/8 is directly connected, lo
C>* 192.168.100.0/24 is directly connected, eth0
S>* 192.168.102.0/24 [1/0] via 192.168.102.10, eth0
S>* 192.168.103.0/24 [1/0] via 192.168.103.15, eth2
C>* 192.168.101.0/24 is directly connected, eth1
vyos@vyos:~$

```

vm3 on QEMU/KVM (R2):

```

vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface IP Address S/L Description
-----
eth0 192.168.112.12/24 u/u
eth1 2020:abcd:112::12/64 u/u
eth2 192.168.114.10/24 u/u
lo 2020:abcd:102::12/64 u/u
::1/128

vyos@vyos:~$ show ip route
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
I - ISIS, B - BGP, > - selected route, * - FIB route

C>* 127.0.0.0/8 is directly connected, lo
S>* 192.168.102.0/24 [1/0] via 192.168.102.10, eth0
C>* 192.168.114.0/24 is directly connected, eth1
vyos@vyos:~$

```

vm4 on QEMU/KVM (R5):

```

vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface IP Address S/L Description
-----
eth0 192.168.113.11/24 u/u
eth1 2020:abcd:113::11/64 u/u
lo 127.0.0.1/8 u/u
::1/128

vyos@vyos:~$ show ip route
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
I - ISIS, B - BGP, > - selected route, * - FIB route

C>* 127.0.0.0/8 is directly connected, lo
S>* 192.168.102.0/24 [1/0] via 192.168.102.12, eth0
C>* 192.168.103.0/24 is directly connected, eth2
vyos@vyos:~$

```

```
vm6 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface      IP Address      S/L  Description
-----
eth0           192.168.101.13/24  u/u
              2020:abcd:101::13/64
eth1           192.168.102.13/24  u/u
              2020:abcd:102::13/64
eth2           192.168.113.13/24  u/u
              2020:abcd:113::13/64
lo             127.0.0.1/8        u/u
              ::1/128
vyos@vyos:~$ _
```

```
vm5 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface      IP Address      S/L  Description
-----
eth0           192.168.113.11/24  u/u
              2020:abcd:113::11/64
eth1           192.168.114.11/24  u/u
              2020:abcd:114::11/64
lo             127.0.0.1/8        u/u
              ::1/128
vyos@vyos:~$
```

```
vm4 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface      IP Address      S/L  Description
-----
eth0            192.168.111.11/24  u/u
                2020:abcd:111::11/64
eth1            192.168.101.11/24  u/u
                2020:abcd:101::11/64
lo              127.0.0.1/8       u/u
                ::1/128
vyos@vyos:~$
```

```
vm7 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface      IP Address      S/L  Description
-----
eth0            192.168.102.15/24  u/u
                2020:abcd:102::15/64
lo              127.0.0.1/8       u/u
                ::1/128
INIT: Id "T0" respawning too fast: disabled for 5 minutes
INIT: Id "T0" respawning too fast: disabled for 5 minutes
```

Question 2.

Configure static routes so that the traffic between H1 and H2 goes through Subnet (A) for both directions. Answer by inserting the screen captures of routing table of R2 and R6, and traceroute results between H1 and H2.

R6 route table

```
vyos@vyos:~$ show ip route
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
       I - ISIS, B - BGP, > - selected route, * - FIB route

C>* 127.0.0.0/8 is directly connected, lo
C>* 192.168.101.0/24 is directly connected, eth0
S   192.168.102.0/24 [1/0] via 192.168.102.0 inactive
C>* 192.168.102.0/24 is directly connected, eth1
S>* 192.168.103.0/24 [1/0] via 192.168.101.11, eth0
C>* 192.168.113.0/24 is directly connected, eth2
vyos@vyos:~$
```

R2 route table

```
vyos@vyos:~$ show ip route
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
       I - ISIS, B - BGP, > - selected route, * - FIB route

C>* 127.0.0.0/8 is directly connected, lo
C>* 192.168.100.0/24 is directly connected, eth0
S>* 192.168.102.0/24 [1/0] via 192.168.100.10, eth0
S   192.168.103.0/24 [1/0] via 192.168.103.15 inactive
C>* 192.168.103.0/24 is directly connected, eth2
C>* 192.168.112.0/24 is directly connected, eth1
vyos@vyos:~$ █
```


From H2 to H1

```
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface      IP Address      S/L  Description
-----
eth0           192.168.102.15/24  u/u
               2020:abcd:102::15/64
lo             127.0.0.1/8      u/u
               ::1/128
INIT: Id "T0" respawning too fast: disabled for 5 minutes
^C
vyos@vyos:~$ traceroute 192.168.103.15
traceroute to 192.168.103.15 (192.168.103.15), 30 hops max, 60 byte packets
 1  192.168.102.13 (192.168.102.13)  0.235 ms  0.122 ms  0.120 ms
 2  192.168.101.11 (192.168.101.11)  0.831 ms  1.021 ms  0.969 ms
 3  192.168.111.10 (192.168.111.10)  1.426 ms  1.383 ms  1.786 ms
 4  192.168.100.12 (192.168.100.12)  2.141 ms  2.099 ms  2.646 ms
 5  192.168.103.15 (192.168.103.15)  2.604 ms  2.557 ms  2.508 ms
vyos@vyos:~$ _
```

Ping H2 to H1

```
vyos@vyos:~$ ping 192.168.103.15
PING 192.168.103.15 (192.168.103.15) 56(84) bytes of data.
64 bytes from 192.168.103.15: icmp_req=1 ttl=60 time=2.19 ms
64 bytes from 192.168.103.15: icmp_req=2 ttl=60 time=2.24 ms
64 bytes from 192.168.103.15: icmp_req=3 ttl=60 time=2.60 ms
64 bytes from 192.168.103.15: icmp_req=4 ttl=60 time=1.74 ms
64 bytes from 192.168.103.15: icmp_req=5 ttl=60 time=1.95 ms
```

From H1 to H2:

```
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface      IP Address      S/L  Description
-----
eth0            192.168.103.15/24  u/u
                2020:abcd:103::15/64
lo              127.0.0.1/8      u/u
                ::1/128
vyos@vyos:~$ traceroute 192.168.102.15
traceroute to 192.168.102.15 (192.168.102.15), 30 hops max, 60 byte packets
 1  192.168.103.12 (192.168.103.12)  0.465 ms  0.432 ms  0.422 ms
 2  192.168.100.10 (192.168.100.10)  0.565 ms  0.569 ms  0.566 ms
 3  192.168.111.11 (192.168.111.11)  1.942 ms  1.945 ms  1.943 ms
 4  192.168.101.13 (192.168.101.13)  2.973 ms  2.976 ms  4.083 ms
 5  192.168.102.15 (192.168.102.15)  4.556 ms  4.612 ms  4.625 ms
vyos@vyos:~$
```

Ping H1 to H2:

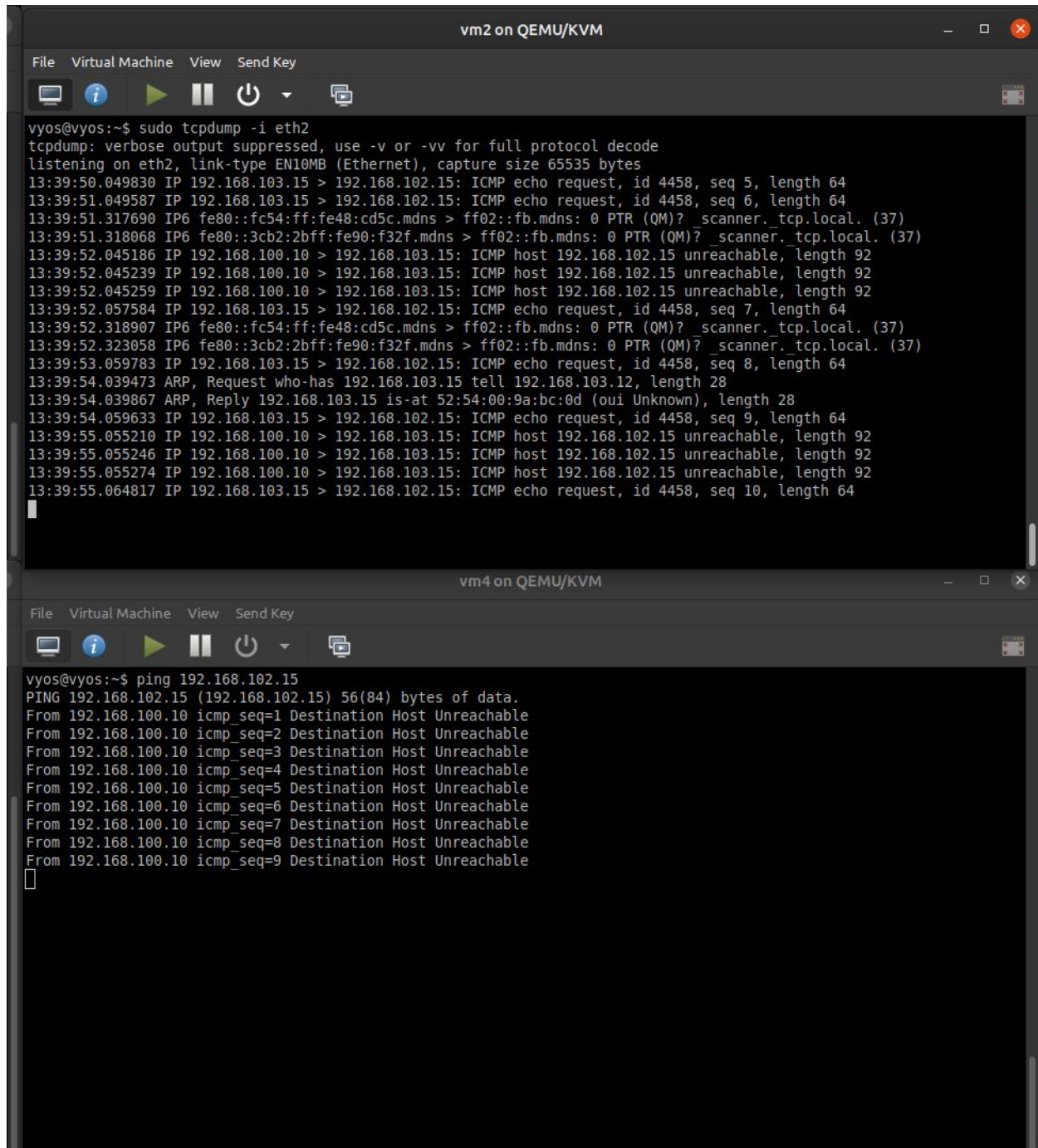
```
vyos@vyos:~$ ping 192.168.102.15
PING 192.168.102.15 (192.168.102.15) 56(84) bytes of data.
64 bytes from 192.168.102.15: icmp_req=1 ttl=60 time=2.86 ms
64 bytes from 192.168.102.15: icmp_req=2 ttl=60 time=2.31 ms
64 bytes from 192.168.102.15: icmp_req=3 ttl=60 time=3.75 ms
64 bytes from 192.168.102.15: icmp_req=4 ttl=60 time=3.40 ms
64 bytes from 192.168.102.15: icmp_req=5 ttl=60 time=3.38 ms
64 bytes from 192.168.102.15: icmp_req=6 ttl=60 time=2.90 ms
64 bytes from 192.168.102.15: icmp_req=7 ttl=60 time=3.10 ms
64 bytes from 192.168.102.15: icmp_req=8 ttl=60 time=3.42 ms
```

Question 3. (For Static Routing)

Execute ping (only IPv4 is OK) from H1 to H2, and disconnect Subnet (A) by unplugging the LAN cable between the laptops, and explain what happens in the network and how a router react when the next hop router becomes unreachable. Insert the screen captures of tcpdump on both NICs of R1, and provide additional explanation of what you observe as part of the answer.

```
vm2 on QEMU/KVM
File Virtual Machine View Send Key
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on eth0, link-type EN10MB (Ethernet), capture size 65535 bytes
13:38:29.065157 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
13:38:29.065218 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
13:38:29.065224 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
13:38:29.074836 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 4423, seq 4, length 64
13:38:30.079825 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 4423, seq 5, length 64
13:38:31.079779 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 4423, seq 6, length 64
13:38:32.075231 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
13:38:32.075291 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
13:38:32.075297 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
13:38:32.086320 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 4423, seq 7, length 64
13:38:33.089869 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 4423, seq 8, length 64
13:38:34.089688 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 4423, seq 9, length 64
13:38:35.085132 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
13:38:35.085191 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
13:38:35.085197 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
13:38:35.097060 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 4423, seq 10, length 64

vm4 on QEMU/KVM
File Virtual Machine View Send Key
vyos@vyos:~$ ping 192.168.102.15
PING 192.168.102.15 (192.168.102.15) 56(84) bytes of data.
From 192.168.100.10 icmp_seq=1 Destination Host Unreachable
From 192.168.100.10 icmp_seq=2 Destination Host Unreachable
From 192.168.100.10 icmp_seq=3 Destination Host Unreachable
From 192.168.100.10 icmp_seq=4 Destination Host Unreachable
From 192.168.100.10 icmp_seq=5 Destination Host Unreachable
From 192.168.100.10 icmp_seq=6 Destination Host Unreachable
From 192.168.100.10 icmp_seq=7 Destination Host Unreachable
From 192.168.100.10 icmp_seq=8 Destination Host Unreachable
From 192.168.100.10 icmp_seq=9 Destination Host Unreachable
```



The image displays two screenshots of a virtual machine window titled "vm2 on QEMU/KVM" and "vm4 on QEMU/KVM".

The top screenshot (vm2) shows the output of the command `sudo tcpdump -i eth2`. The output indicates that verbose output is suppressed and lists several network events, including ICMP echo requests and host unreachable messages. The events are as follows:

- 13:39:50.049830 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 4458, seq 5, length 64
- 13:39:51.049587 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 4458, seq 6, length 64
- 13:39:51.317690 IP6 fe80::fc54:ff:fe48:cd5c.mdns > ff02::fb.mdns: 0 PTR (QM)? _scanner._tcp.local. (37)
- 13:39:51.318068 IP6 fe80::3cb2:2bff:fe90:f32f.mdns > ff02::fb.mdns: 0 PTR (QM)? _scanner._tcp.local. (37)
- 13:39:52.045186 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
- 13:39:52.045239 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
- 13:39:52.045259 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
- 13:39:52.057584 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 4458, seq 7, length 64
- 13:39:52.318907 IP6 fe80::fc54:ff:fe48:cd5c.mdns > ff02::fb.mdns: 0 PTR (QM)? _scanner._tcp.local. (37)
- 13:39:52.323058 IP6 fe80::3cb2:2bff:fe90:f32f.mdns > ff02::fb.mdns: 0 PTR (QM)? _scanner._tcp.local. (37)
- 13:39:53.059783 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 4458, seq 8, length 64
- 13:39:54.039473 ARP, Request who-has 192.168.103.15 tell 192.168.103.12, length 28
- 13:39:54.039867 ARP, Reply 192.168.103.15 is-at 52:54:00:9a:bc:0d (oui Unknown), length 28
- 13:39:54.059633 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 4458, seq 9, length 64
- 13:39:55.055210 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
- 13:39:55.055246 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
- 13:39:55.055274 IP 192.168.100.10 > 192.168.103.15: ICMP host 192.168.102.15 unreachable, length 92
- 13:39:55.064817 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 4458, seq 10, length 64

The bottom screenshot (vm4) shows the output of the command `ping 192.168.102.15`. The output indicates that the destination host is unreachable for all nine attempts:

```
PING 192.168.102.15 (192.168.102.15) 56(84) bytes of data.  
From 192.168.100.10 icmp_seq=1 Destination Host Unreachable  
From 192.168.100.10 icmp_seq=2 Destination Host Unreachable  
From 192.168.100.10 icmp_seq=3 Destination Host Unreachable  
From 192.168.100.10 icmp_seq=4 Destination Host Unreachable  
From 192.168.100.10 icmp_seq=5 Destination Host Unreachable  
From 192.168.100.10 icmp_seq=6 Destination Host Unreachable  
From 192.168.100.10 icmp_seq=7 Destination Host Unreachable  
From 192.168.100.10 icmp_seq=8 Destination Host Unreachable  
From 192.168.100.10 icmp_seq=9 Destination Host Unreachable
```

Ping shows destination host Unreachable as it clearly cannot contact the destination. We can observe ICMP destination unreachable messages in the tcpdump.

Question 4. (For Static Routing)

Configure static routes on the routers so that 1) ping traffic from H1 to H2 goes through Subnet (A), and 2) that from H2 to H1 goes through Subnet (B) using both IPv4 and IPv6. Answer by inserting the screen captures of the routing table on R2 and R6, and the tcpdump result on R1 and R5 on those you should observe the traffic is one way.

IPv6:

The image displays four screenshots of QEMU/KVM virtual machines, each showing the configuration of a router (vm1, vm2, vm3, and vm4). Each screenshot includes the output of the 'show interfaces' and 'show ipv6 route' commands.

vm1 on QEMU/KVM:

```
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface IP Address S/L Description
-----
eth0 192.168.111.10/24 u/u
eth1 2020:abcd:111::10/64 u/u
eth2 192.168.100.10/24 u/u
lo 2020:abcd:100::10/64 u/u
::1/128

vyos@vyos:~$ show ipv6 route
Codes: K - kernel route, C - connected, S - static, R - RIPng, O - OSPFv3,
I - ISIS, B - BGP, * - FIB route.

C* ::1/128 is directly connected, lo
C* 2020:abcd:100::/64 is directly connected, eth1
S* 2020:abcd:102::/64 [1/0] via 2020:abcd:111::11, eth0
C* 2020:abcd:111::/64 is directly connected, eth0
C* fe80::/64 is directly connected, eth1
C* fe80::/64 is directly connected, eth0
vyos@vyos:~$
```

vm2 on QEMU/KVM:

```
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface IP Address S/L Description
-----
eth0 192.168.100.12/24 u/u
eth1 2020:abcd:100::12/64 u/u
eth2 192.168.112.12/24 u/u
lo 2020:abcd:103::12/64 u/u
::1/128

vyos@vyos:~$ show ipv6 route
Codes: K - kernel route, C - connected, S - static, R - RIPng, O - OSPFv3,
I - ISIS, B - BGP, * - FIB route.

C* ::1/128 is directly connected, lo
C* 2020:abcd:100::/64 is directly connected, eth0
S* 2020:abcd:102::/64 [1/0] via 2020:abcd:100::10, eth0
S 2020:abcd:103::/64 [1/0] via 2020:abcd:103::15 inactive
C* 2020:abcd:103::/64 is directly connected, eth2
C* 2020:abcd:112::/64 is directly connected, eth1
C* fe80::/64 is directly connected, eth0
C* fe80::/64 is directly connected, eth1
C* fe80::/64 is directly connected, eth2
vyos@vyos:~$
```

vm3 on QEMU/KVM:

```
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface IP Address S/L Description
-----
eth0 192.168.112.10/24 u/u
eth1 2020:abcd:112::10/64 u/u
eth2 192.168.114.10/24 u/u
lo 2020:abcd:114::10/64 u/u
::1/128

vyos@vyos:~$ show ipv6 route
Codes: K - kernel route, C - connected, S - static, R - RIPng, O - OSPFv3,
I - ISIS, B - BGP, * - FIB route.

C* ::1/128 is directly connected, lo
S* 2020:abcd:103::/64 [1/0] via 2020:abcd:112::12, eth0
C* 2020:abcd:112::/64 is directly connected, eth0
C* 2020:abcd:114::/64 is directly connected, eth1
C* fe80::/64 is directly connected, eth1
C* fe80::/64 is directly connected, eth0
vyos@vyos:~$
```

vm4 on QEMU/KVM:

```
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface IP Address S/L Description
-----
eth0 192.168.103.15/24 u/u
lo 2020:abcd:103::15/64 u/u
::1/128

vyos@vyos:~$ show ipv6 route
Codes: K - kernel route, C - connected, S - static, R - RIPng, O - OSPFv3,
I - ISIS, B - BGP, * - FIB route.

C* ::1/128 is directly connected, lo
S* 2020:abcd:102::/64 [1/0] via 2020:abcd:103::12, eth0
C* 2020:abcd:103::/64 is directly connected, eth0
C* fe80::/64 is directly connected, eth0
vyos@vyos:~$
```

```
vyos@vyos:~$ ping6 2020:abcd:102::15
PING 2020:abcd:102::15(2020:abcd:102::15) 56 data bytes
64 bytes from 2020:abcd:102::15: icmp_seq=1 ttl=60 time=2.63 ms
64 bytes from 2020:abcd:102::15: icmp_seq=2 ttl=60 time=3.70 ms
64 bytes from 2020:abcd:102::15: icmp_seq=3 ttl=60 time=3.94 ms
64 bytes from 2020:abcd:102::15: icmp_seq=4 ttl=60 time=4.49 ms
64 bytes from 2020:abcd:102::15: icmp_seq=5 ttl=60 time=3.96 ms
64 bytes from 2020:abcd:102::15: icmp_seq=6 ttl=60 time=1.65 ms
64 bytes from 2020:abcd:102::15: icmp_seq=7 ttl=60 time=3.45 ms
64 bytes from 2020:abcd:102::15: icmp_seq=8 ttl=60 time=4.30 ms
64 bytes from 2020:abcd:102::15: icmp_seq=9 ttl=60 time=3.50 ms
64 bytes from 2020:abcd:102::15: icmp_seq=10 ttl=60 time=3.58 ms
64 bytes from 2020:abcd:102::15: icmp_seq=11 ttl=60 time=2.64 ms
```

IPv4

```
vm1 on QEMU/KVM
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface IP Address S/L Description
-----
eth0 192.168.111.10/24 u/u
eth1 2020:abcd:111::10/64 u/u
lo 192.168.100.10/24 u/u
lo 127.0.0.1/8 u/u
::1/128
vyos@vyos:~$ show ip route
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
I - ISIS, B - BGP, > - selected route, * - FIB route
C* 127.0.0.0/8 is directly connected, lo
C* 192.168.100.0/24 is directly connected, eth1
S* 192.168.102.0/24 [1/0] via 192.168.111.11, eth0
C* 192.168.111.0/24 is directly connected, eth0
vyos@vyos:~$

vm2 on QEMU/KVM
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface IP Address S/L Description
-----
eth0 192.168.100.12/24 u/u
eth1 2020:abcd:100::12/64 u/u
eth2 2020:abcd:112::12/64 u/u
lo 192.168.103.12/24 u/u
lo 127.0.0.1/8 u/u
::1/128
vyos@vyos:~$ show ip route
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
I - ISIS, B - BGP, > - selected route, * - FIB route
C* 127.0.0.0/8 is directly connected, lo
C* 192.168.100.0/24 is directly connected, eth0
S* 192.168.102.0/24 [1/0] via 192.168.100.10, eth0
C* 192.168.103.0/24 is directly connected, eth2
C* 192.168.112.0/24 is directly connected, eth1
vyos@vyos:~$

vm3 on QEMU/KVM
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface IP Address S/L Description
-----
eth0 192.168.112.10/24 u/u
eth1 2020:abcd:112::10/64 u/u
eth2 192.168.114.10/24 u/u
lo 2020:abcd:114::10/64 u/u
lo 127.0.0.1/8 u/u
::1/128
vyos@vyos:~$ show ip route
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
I - ISIS, B - BGP, > - selected route, * - FIB route
C* 127.0.0.0/8 is directly connected, lo
S* 192.168.103.0/24 [1/0] via 192.168.112.12, eth0
S* 192.168.112.0/24 is directly connected, eth0
C* 192.168.114.0/24 is directly connected, eth1
vyos@vyos:~$

vm4 on QEMU/KVM
vyos@vyos:~$ show interfaces
Codes: S - State, L - Link, u - Up, D - Down, A - Admin Down
Interface IP Address S/L Description
-----
eth0 192.168.103.15/24 u/u
lo 2020:abcd:103::15/64 u/u
lo 127.0.0.1/8 u/u
::1/128
vyos@vyos:~$ show ip route
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
I - ISIS, B - BGP, > - selected route, * - FIB route
C* 127.0.0.0/8 is directly connected, lo
S* 192.168.102.0/24 [1/0] via 192.168.103.12, eth0
C* 192.168.103.0/24 is directly connected, eth0
vyos@vyos:~$
```

```
vyos@vyos:~$ ping 192.168.102.15
PING 192.168.102.15 (192.168.102.15) 56(84) bytes of data.
64 bytes from 192.168.102.15: icmp_req=1 ttl=60 time=3.37 ms
64 bytes from 192.168.102.15: icmp_req=2 ttl=60 time=3.96 ms
64 bytes from 192.168.102.15: icmp_req=3 ttl=60 time=3.99 ms
64 bytes from 192.168.102.15: icmp_req=4 ttl=60 time=3.56 ms
64 bytes from 192.168.102.15: icmp_req=5 ttl=60 time=3.75 ms
64 bytes from 192.168.102.15: icmp_req=6 ttl=60 time=2.81 ms
64 bytes from 192.168.102.15: icmp_req=7 ttl=60 time=3.89 ms
64 bytes from 192.168.102.15: icmp_req=8 ttl=60 time=3.41 ms
64 bytes from 192.168.102.15: icmp_req=9 ttl=60 time=4.56 ms
64 bytes from 192.168.102.15: icmp_req=10 ttl=60 time=3.58 ms

```

Traceroutes from both sides:

```
vm4 on QEMU/KVM
File Virtual Machine View Send Key
[Icons: Monitor, Info, Play, Pause, Power, Dropdown, Copy]

vyos@vyos:~$ traceroute 192.168.102.15
traceroute to 192.168.102.15 (192.168.102.15), 30 hops max, 60 byte packets
 1  192.168.103.12 (192.168.103.12)  0.250 ms  0.252 ms  0.251 ms
 2  * * *
 3  * * *
 4  192.168.101.13 (192.168.101.13)  2.287 ms  2.508 ms  2.511 ms
 5  192.168.102.15 (192.168.102.15)  3.924 ms  4.377 ms  4.469 ms
vyos@vyos:~$
```

```
vm4 on QEMU/KVM
File Virtual Machine View Send Key
[Icons: Monitor, Info, Play, Pause, Power, Dropdown, Copy]

vyos@vyos:~$ traceroute6 2020:abcd:102::15
traceroute to 2020:abcd:102::15 (2020:abcd:102::15), 30 hops max, 80 byte packets
 1  2020:abcd:103::12 (2020:abcd:103::12)  0.398 ms  0.501 ms  0.775 ms
 2  * * *
 3  * * *
 4  2020:abcd:113::13 (2020:abcd:113::13)  3.462 ms  3.469 ms  3.388 ms
 5  2020:abcd:102::15 (2020:abcd:102::15)  3.940 ms  3.921 ms  3.914 ms
vyos@vyos:~$
```

```
vm7 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help

vyos@vyos:~$ traceroute 192.168.103.15
traceroute to 192.168.103.15 (192.168.103.15), 30 hops max, 60 byte packets
 1  192.168.102.13 (192.168.102.13)  0.356 ms  0.246 ms  0.184 ms
 2  * * *
 3  * * *
 4  192.168.112.12 (192.168.112.12)  1.775 ms  1.716 ms  1.655 ms
 5  192.168.103.15 (192.168.103.15)  1.610 ms  1.625 ms  1.559 ms
vyos@vyos:~$
```

```
vm7 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help

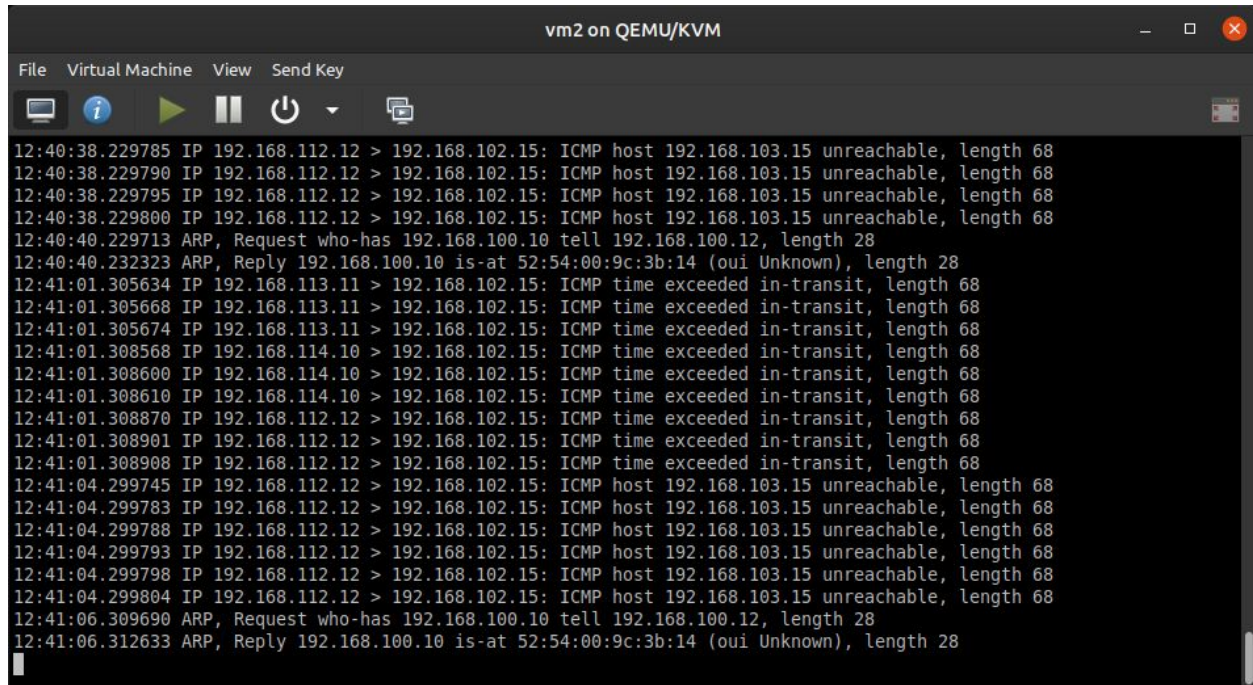
vyos@vyos:~$ traceroute6 2020:abcd:103::15
traceroute to 2020:abcd:103::15 (2020:abcd:103::15), 30 hops max, 80 byte packets
 1  2020:abcd:102::13 (2020:abcd:102::13)  0.744 ms  0.516 ms  0.384 ms
 2  * * *
 3  * * *
 4  2020:abcd:100::12 (2020:abcd:100::12)  3.535 ms  4.072 ms  3.886 ms
 5  2020:abcd:103::15 (2020:abcd:103::15)  3.699 ms  3.499 ms  3.312 ms
vyos@vyos:~$
```


Question 5.

Create a routing loop among R1, R2, ... R6, and explain what happens in the network. Insert the screen captures of tcpdump on H1 and IPv4/v6 traceroute performed from H1 to H2. And explain 1) the traceroute results, and 2) what kind of message H1 receives when the routing loop happens.

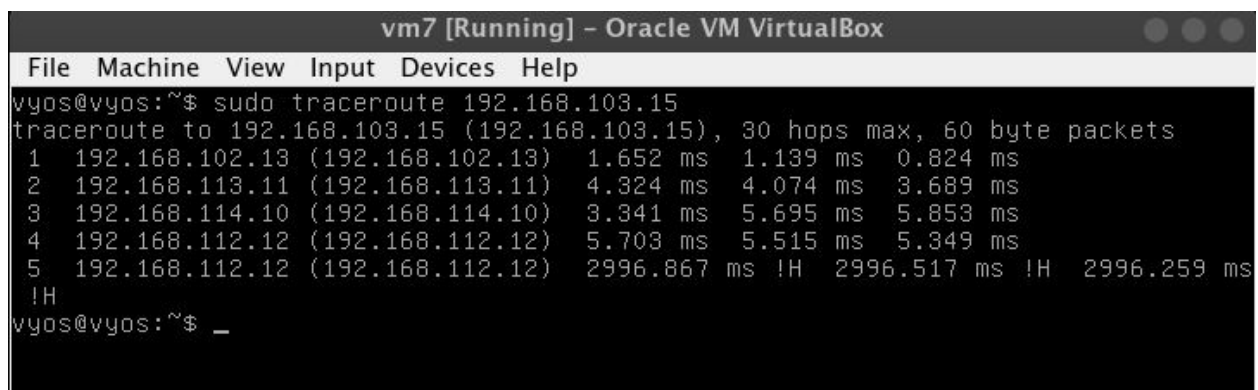
We created a clockwise loop such that messages from H2 to H1 will loop infinitely.

Tcpdump at R2 showing ICMP time exceeded message.



```
vm2 on QEMU/KVM
File Virtual Machine View Send Key
12:40:38.229785 IP 192.168.112.12 > 192.168.102.15: ICMP host 192.168.103.15 unreachable, length 68
12:40:38.229790 IP 192.168.112.12 > 192.168.102.15: ICMP host 192.168.103.15 unreachable, length 68
12:40:38.229795 IP 192.168.112.12 > 192.168.102.15: ICMP host 192.168.103.15 unreachable, length 68
12:40:38.229800 IP 192.168.112.12 > 192.168.102.15: ICMP host 192.168.103.15 unreachable, length 68
12:40:40.229713 ARP, Request who-has 192.168.100.10 tell 192.168.100.12, length 28
12:40:40.232323 ARP, Reply 192.168.100.10 is-at 52:54:00:9c:3b:14 (oui Unknown), length 28
12:41:01.305634 IP 192.168.113.11 > 192.168.102.15: ICMP time exceeded in-transit, length 68
12:41:01.305668 IP 192.168.113.11 > 192.168.102.15: ICMP time exceeded in-transit, length 68
12:41:01.305674 IP 192.168.113.11 > 192.168.102.15: ICMP time exceeded in-transit, length 68
12:41:01.308568 IP 192.168.114.10 > 192.168.102.15: ICMP time exceeded in-transit, length 68
12:41:01.308600 IP 192.168.114.10 > 192.168.102.15: ICMP time exceeded in-transit, length 68
12:41:01.308610 IP 192.168.114.10 > 192.168.102.15: ICMP time exceeded in-transit, length 68
12:41:01.308870 IP 192.168.112.12 > 192.168.102.15: ICMP time exceeded in-transit, length 68
12:41:01.308901 IP 192.168.112.12 > 192.168.102.15: ICMP time exceeded in-transit, length 68
12:41:01.308908 IP 192.168.112.12 > 192.168.102.15: ICMP time exceeded in-transit, length 68
12:41:04.299745 IP 192.168.112.12 > 192.168.102.15: ICMP host 192.168.103.15 unreachable, length 68
12:41:04.299783 IP 192.168.112.12 > 192.168.102.15: ICMP host 192.168.103.15 unreachable, length 68
12:41:04.299788 IP 192.168.112.12 > 192.168.102.15: ICMP host 192.168.103.15 unreachable, length 68
12:41:04.299793 IP 192.168.112.12 > 192.168.102.15: ICMP host 192.168.103.15 unreachable, length 68
12:41:04.299798 IP 192.168.112.12 > 192.168.102.15: ICMP host 192.168.103.15 unreachable, length 68
12:41:04.299804 IP 192.168.112.12 > 192.168.102.15: ICMP host 192.168.103.15 unreachable, length 68
12:41:06.309690 ARP, Request who-has 192.168.100.10 tell 192.168.100.12, length 28
12:41:06.312633 ARP, Reply 192.168.100.10 is-at 52:54:00:9c:3b:14 (oui Unknown), length 28
```

Traceroute from H2 to H1



```
vm7 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
vyos@vyos:~$ sudo traceroute 192.168.103.15
traceroute to 192.168.103.15 (192.168.103.15), 30 hops max, 60 byte packets
 1  192.168.102.13 (192.168.102.13)  1.652 ms  1.139 ms  0.824 ms
 2  192.168.113.11 (192.168.113.11)  4.324 ms  4.074 ms  3.689 ms
 3  192.168.114.10 (192.168.114.10)  3.341 ms  5.695 ms  5.853 ms
 4  192.168.112.12 (192.168.112.12)  5.703 ms  5.515 ms  5.349 ms
 5  192.168.112.12 (192.168.112.12)  2996.867 ms  !H  2996.517 ms  !H  2996.259 ms
!H
vyos@vyos:~$ _
```


IPv6

Tcpdump on R2 showing time limit exceeded

```
vm2 on QEMU/KVM
File Virtual Machine View Send Key
mp6 sum ok] ICMP6, time exceeded in-transit, length 88 for 2020:abcd:103::15
12:49:57.944889 IP6 (hlim 64, next-header ICMPv6 (58) payload length: 88) 2020:abcd:100::12 > 2020:abcd:102::15: [ic
mp6 sum ok] ICMP6, time exceeded in-transit, length 88 for 2020:abcd:103::15
12:49:57.945144 IP6 (hlim 64, next-header ICMPv6 (58) payload length: 88) 2020:abcd:100::12 > 2020:abcd:102::15: [ic
mp6 sum ok] ICMP6, time exceeded in-transit, length 88 for 2020:abcd:103::15
12:50:00.939791 IP6 (hlim 64, next-header ICMPv6 (58) payload length: 88) 2020:abcd:100::12 > 2020:abcd:102::15: [ic
mp6 sum ok] ICMP6, destination unreachable, length 88, unreachable address 2020:abcd:103::15
12:50:00.939837 IP6 (hlim 64, next-header ICMPv6 (58) payload length: 88) 2020:abcd:100::12 > 2020:abcd:102::15: [ic
mp6 sum ok] ICMP6, destination unreachable, length 88, unreachable address 2020:abcd:103::15
12:50:00.939844 IP6 (hlim 64, next-header ICMPv6 (58) payload length: 88) 2020:abcd:100::12 > 2020:abcd:102::15: [ic
mp6 sum ok] ICMP6, destination unreachable, length 88, unreachable address 2020:abcd:103::15
12:50:00.939849 IP6 (hlim 64, next-header ICMPv6 (58) payload length: 88) 2020:abcd:100::12 > 2020:abcd:102::15: [ic
mp6 sum ok] ICMP6, destination unreachable, length 88, unreachable address 2020:abcd:103::15
12:50:00.939855 IP6 (hlim 64, next-header ICMPv6 (58) payload length: 88) 2020:abcd:100::12 > 2020:abcd:102::15: [ic
mp6 sum ok] ICMP6, destination unreachable, length 88, unreachable address 2020:abcd:103::15
12:50:00.939861 IP6 (hlim 64, next-header ICMPv6 (58) payload length: 88) 2020:abcd:100::12 > 2020:abcd:102::15: [ic
mp6 sum ok] ICMP6, destination unreachable, length 88, unreachable address 2020:abcd:103::15
12:50:02.949798 IP6 (hlim 255, next-header ICMPv6 (58) payload length: 32) fe80::5054:ff:fe12:83f2 > 2020:abcd:100::
10: [icmp6 sum ok] ICMP6, neighbor solicitation, length 32, who has 2020:abcd:100::10
source link-address option (1), length 8 (1): 52:54:00:12:83:f2
0x0000: 5254 0012 83f2
12:50:02.950146 IP6 (hlim 255, next-header ICMPv6 (58) payload length: 24) 2020:abcd:100::10 > fe80::5054:ff:fe12:83
f2: [icmp6 sum ok] ICMP6, neighbor advertisement, length 24, tgt is 2020:abcd:100::10, Flags [router, solicited]
```

Traceroute6 from H2 to H1

```
vm7 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
vyos@vyos:~$ sudo traceroute6 2020:abcd:103::15
traceroute to 2020:abcd:103::15 (2020:abcd:103::15), 30 hops max, 80 byte packet
s
 1  2020:abcd:102::13 (2020:abcd:102::13)  0.430 ms  0.382 ms  0.183 ms
 2  * * *
 3  2020:abcd:112::10 (2020:abcd:112::10)  2.852 ms  2.736 ms  2.655 ms
 4  2020:abcd:100::12 (2020:abcd:100::12)  2.586 ms  2.517 ms  2.440 ms
 5  2020:abcd:100::12 (2020:abcd:100::12) 2997.506 ms !H 2997.465 ms !H 2997.
389 ms !H
vyos@vyos:~$ _
```

The traceroute detects loop and shows high timings with 3 tries (around 2997 ms) and the !H shows traceroute is unable to reach host i.e. the destination. Message from H2 to R2 goes as expected but then the loop is detected and traceroute shows high timings.

Question 6.1.

Delete the static routes from all the routers, and enable OSPF for IPv4 and OSPFv3 for IPv6 on them so that ping and ping6 are successful between H1 and H2. Insert screen captures of the OSPF/OSPFv3 neighbor tables, IPv4/v6 routing tables on R2 and R6, successful ping/ping6 results on H1 or H2.

The image displays four terminal windows, each representing a different router (vm1, vm2, vm3, vm4) running on QEMU/KVM. Each window shows the output of the 'show ip ospf neighbor' command, which lists the OSPFv3 neighbor relationships. The output includes columns for Neighbor ID, Pri, State, Dead Time, Address, Interface, RxmtL, RqstL, and DBsmL. The routers are configured with various interfaces and addresses, and the neighbor tables show the state of the OSPFv3 adjacency between them.

```
vm1 on QEMU/KVM
File Virtual Machine View Send Key
vyos@vyos:~$ show ip ospf neighbor
Neighbor ID Pri State Dead Time Address Interface RxmtL RqstL DBsmL
10.1.1.4 1 Full/DR 38.720s 192.168.111.11 eth0:192.168.111.10 0 0 0
10.1.1.2 1 Full/Backup 33.540s 192.168.108.12 eth1:192.168.108.10 0 0 0
vyos@vyos:~$ show ipv6 ospfv3 neighbor
Neighbor ID Pri DeadTime State/IfState Duration I/F[State]
10.2.1.2 1 00:00:37 Full/DR 01:58:24 eth1[BDR]
10.2.1.4 1 00:00:36 Full/DR 00:03:54 eth0[BDR]
vyos@vyos:~$
```

```
vm2 on QEMU/KVM
File Virtual Machine View Send Key
vyos@vyos:~$ show ip ospf neighbor
Neighbor ID Pri State Dead Time Address Interface RxmtL RqstL DBsmL
10.1.1.1 1 Full/DR 39.633s 192.168.108.10 eth0:192.168.108.12 0 0 0
10.1.1.3 1 Full/DR 36.974s 192.168.112.10 eth1:192.168.112.12 0 0 0
10.1.1.0 1 Full/Backup 37.959s 192.168.103.15 eth2:192.168.103.12 0 0 0
vyos@vyos:~$ show ipv6 ospfv3 neighbor
Neighbor ID Pri DeadTime State/IfState Duration I/F[State]
10.2.1.3 1 00:00:34 Full/DR 01:58:58 eth1[BDR]
10.2.1.1 1 00:00:34 Full/BDR 01:59:47 eth0[BDR]
10.2.1.0 1 00:00:34 Full/BDR 01:58:47 eth2[BDR]
vyos@vyos:~$
```

```
vm3 on QEMU/KVM
File Virtual Machine View Send Key
vyos@vyos:~$ show ip ospf neighbor
Neighbor ID Pri State Dead Time Address Interface RxmtL RqstL DBsmL
10.1.1.5 1 Full/DR 34.197s 192.168.114.11 eth1:192.168.114.10 0 0 0
10.1.1.2 1 Full/Backup 38.851s 192.168.112.12 eth0:192.168.112.10 0 0 0
vyos@vyos:~$ show ipv6 ospfv3 neighbor
Neighbor ID Pri DeadTime State/IfState Duration I/F[State]
10.2.1.5 1 00:00:00 Full/DR 00:04:40 eth1[BDR]
10.2.1.2 1 00:00:35 Full/BDR 01:58:56 eth0[BDR]
vyos@vyos:~$
```

```
vm4 on QEMU/KVM
File Virtual Machine View Send Key
vyos@vyos:~$ show ip ospf neighbor
Neighbor ID Pri State Dead Time Address Interface RxmtL RqstL DBsmL
10.1.1.2 1 Full/DR 38.796s 192.168.103.12 eth0:192.168.103.15 0 0 0
vyos@vyos:~$ show ipv6 ospfv3 neighbor
Neighbor ID Pri DeadTime State/IfState Duration I/F[State]
10.2.1.2 1 00:00:32 Full/DR 01:58:49 eth0[BDR]
vyos@vyos:~$
```

IPV4

1) Tcpcdump showing ospf working with different messages.

```
vm1 on QEMU/KVM
vyos@vyos:~$ sudo tcpdump
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on eth0, link-type EN10MB (Ethernet), capture size 65535 bytes
13:21:14.184893 IP 192.168.111.11 > 224.0.0.5: OSPFv2, Hello, length 48
13:21:14.778752 IP 192.168.111.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:21:24.185291 IP 192.168.111.11 > 224.0.0.5: OSPFv2, Hello, length 48
13:21:24.778549 IP 192.168.111.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:21:34.185711 IP 192.168.111.11 > 224.0.0.5: OSPFv2, Hello, length 48
13:21:34.788260 IP 192.168.111.10 > 224.0.0.5: OSPFv2, Hello, length 48

vm2 on QEMU/KVM
vyos@vyos:~$ sudo tcpdump
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on eth0, link-type EN10MB (Ethernet), capture size 65535 bytes
13:21:24.238265 IP 192.168.100.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:21:27.762881 IP 192.168.100.12 > 224.0.0.5: OSPFv2, Hello, length 48
13:21:34.238988 IP 192.168.100.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:21:37.763937 IP 192.168.100.12 > 224.0.0.5: OSPFv2, Hello, length 48

vm3 on QEMU/KVM
vyos@vyos:~$ sudo tcpdump
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on eth0, link-type EN10MB (Ethernet), capture size 65535 bytes
13:21:22.249520 IP 192.168.112.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:21:28.395893 IP 192.168.112.12 > 224.0.0.5: OSPFv2, Hello, length 48
13:21:32.250310 IP 192.168.112.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:21:38.395967 IP 192.168.112.12 > 224.0.0.5: OSPFv2, Hello, length 48

vm4 on QEMU/KVM
vyos@vyos:~$ sudo tcpdump
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on eth0, link-type EN10MB (Ethernet), capture size 65535 bytes
13:21:38.714926 IP 192.168.103.12 > 224.0.0.5: OSPFv2, Hello, length 48
```

2) Ping from H1 to H2 with tcpcdumps on other routers

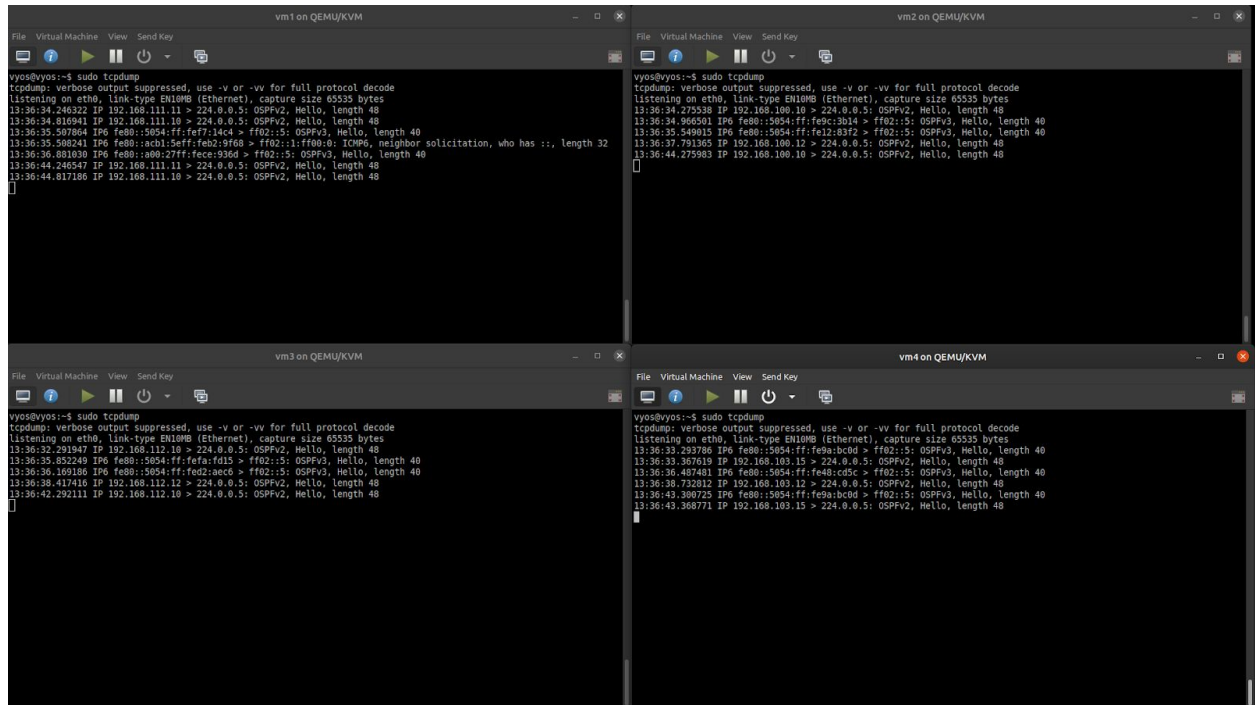
```
vm1 on QEMU/KVM
vyos@vyos:~$ sudo tcpdump
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on eth0, link-type EN10MB (Ethernet), capture size 65535 bytes
13:22:24.188150 IP 192.168.111.11 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:24.782838 IP 192.168.111.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:34.188944 IP 192.168.111.11 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:34.783491 IP 192.168.111.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:44.188852 IP 192.168.111.11 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:44.785071 IP 192.168.111.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:53.799519 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 2, length 64
13:22:53.802791 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 2, length 64
13:22:54.180272 IP 192.168.111.11 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:54.784390 IP 192.168.111.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:55.802774 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 4, length 64
13:22:55.806082 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 4, length 64
13:22:57.807951 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 6, length 64
13:22:57.811946 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 6, length 64
13:22:58.806485 ARP, Request who-has 192.168.111.10 tell 192.168.111.11, length 40
13:22:58.806485 ARP, Reply 192.168.111.10 is-at 52:54:00:17:14:c4 (oui Unknown), length 28
13:22:59.809012 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 8, length 64
13:22:59.815440 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 8, length 64
13:23:01.811086 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 10, length 64
13:23:01.815436 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 10, length 64

vm2 on QEMU/KVM
vyos@vyos:~$ sudo tcpdump
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on eth0, link-type EN10MB (Ethernet), capture size 65535 bytes
13:22:24.241571 IP 192.168.100.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:27.763949 IP 192.168.100.12 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:34.242118 IP 192.168.100.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:37.764145 IP 192.168.100.12 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:44.242418 IP 192.168.100.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:47.764358 IP 192.168.100.12 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:53.257787 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 2, length 64
13:22:53.261426 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 2, length 64
13:22:54.243039 IP 192.168.100.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:55.261036 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 4, length 64
13:22:55.265447 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 4, length 64
13:22:57.265083 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 6, length 64
13:22:57.270598 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 6, length 64
13:22:57.764519 IP 192.168.100.12 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:58.259755 ARP, Request who-has 192.168.100.10 tell 192.168.100.12, length 28
13:22:58.262138 ARP, Reply 192.168.100.10 is-at 52:54:00:9c:3b:14 (oui Unknown), length 28
13:22:59.267159 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 8, length 64
13:22:59.274176 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 8, length 64
13:23:01.270045 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 10, length 64
13:23:01.274550 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 10, length 64

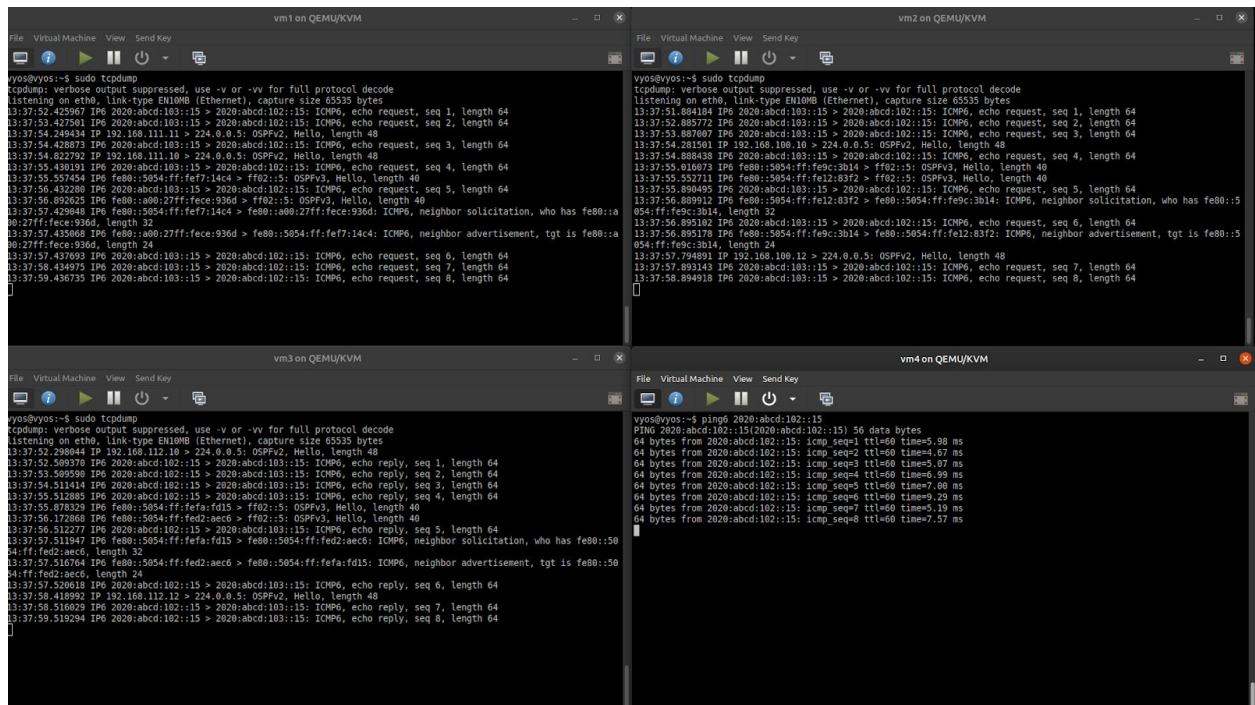
vm3 on QEMU/KVM
vyos@vyos:~$ sudo tcpdump
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on eth0, link-type EN10MB (Ethernet), capture size 65535 bytes
13:22:28.397146 IP 192.168.112.12 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:32.254071 IP 192.168.112.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:38.397280 IP 192.168.112.12 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:42.254222 IP 192.168.112.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:48.397577 IP 192.168.112.12 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:52.255064 IP 192.168.112.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:52.875874 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 1, length 64
13:22:52.877996 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 1, length 64
13:22:54.880231 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 3, length 64
13:22:54.883026 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 3, length 64
13:22:56.882578 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 5, length 64
13:22:56.885554 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 5, length 64
13:22:57.888021 ARP, Request who-has 192.168.112.10 tell 192.168.112.12, length 28
13:22:57.888071 ARP, Reply 192.168.112.10 is-at 52:54:00:fa:fd:15 (oui Unknown), length 28
13:22:58.397784 IP 192.168.112.12 > 224.0.0.5: OSPFv2, Hello, length 48
13:22:58.885970 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 7, length 64
13:22:58.888440 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 7, length 64
13:23:00.888694 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 9, length 64
13:23:00.891584 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 9, length 64
13:23:02.255975 IP 192.168.112.10 > 224.0.0.5: OSPFv2, Hello, length 48
13:23:02.891051 IP 192.168.103.15 > 192.168.102.15: ICMP echo request, id 3527, seq 11, length 64
13:23:02.895580 IP 192.168.102.15 > 192.168.103.15: ICMP echo reply, id 3527, seq 11, length 64

vm4 on QEMU/KVM
vyos@vyos:~$ ping 192.168.102.15
PING 192.168.102.15 (192.168.102.15) 56(84) bytes of data:
64 bytes from 192.168.102.15: icmp_seq=1 ttl=60 time=3.76 ms
64 bytes from 192.168.102.15: icmp_seq=2 ttl=60 time=7.58 ms
64 bytes from 192.168.102.15: icmp_seq=3 ttl=60 time=7.49 ms
64 bytes from 192.168.102.15: icmp_seq=4 ttl=60 time=6.68 ms
64 bytes from 192.168.102.15: icmp_seq=5 ttl=60 time=3.67 ms
64 bytes from 192.168.102.15: icmp_seq=6 ttl=60 time=7.88 ms
64 bytes from 192.168.102.15: icmp_seq=7 ttl=60 time=3.82 ms
64 bytes from 192.168.102.15: icmp_seq=8 ttl=60 time=9.26 ms
64 bytes from 192.168.102.15: icmp_seq=9 ttl=60 time=3.57 ms
64 bytes from 192.168.102.15: icmp_seq=10 ttl=60 time=7.48 ms
64 bytes from 192.168.102.15: icmp_seq=11 ttl=60 time=4.95 ms
```


1) ospfv3 working with different messages seen in tcpdump



2) Ping6 from H1 to H2 and tcpdumps on other routers



Question 6.2.

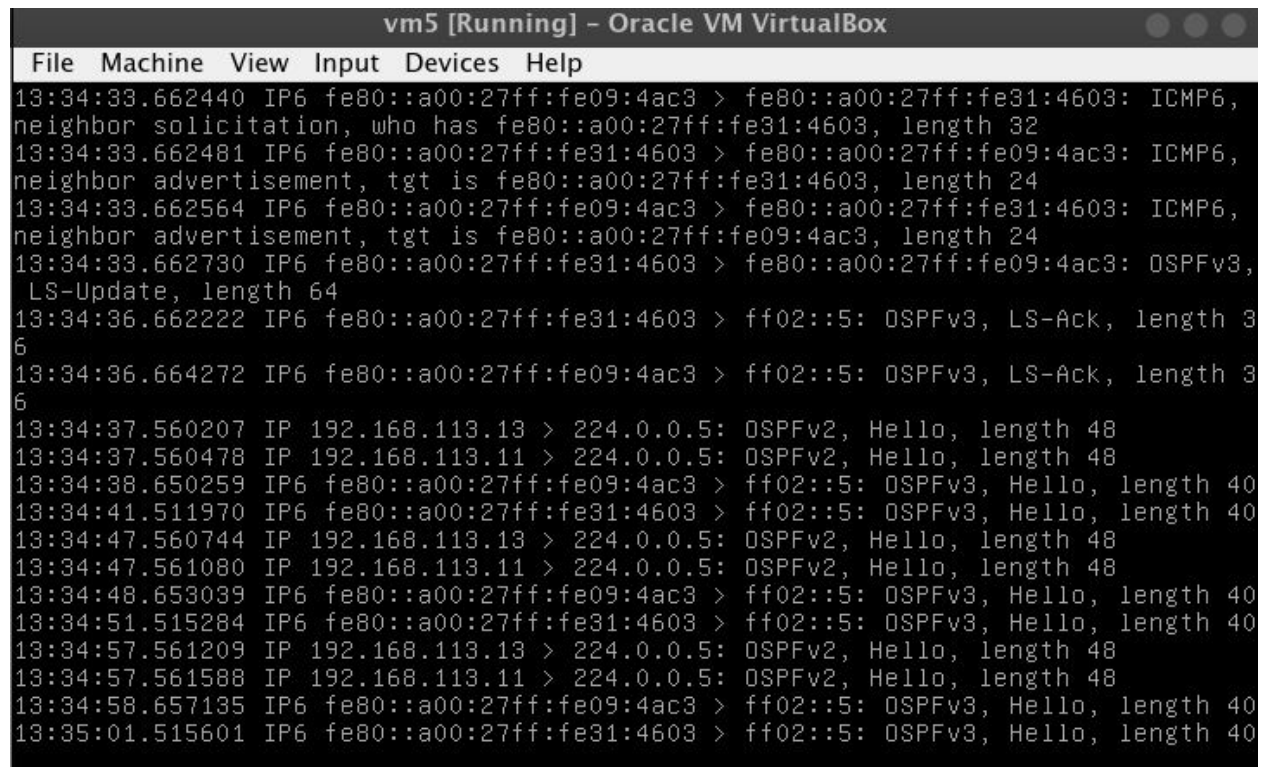
Select two different types that you observe in the experiment, and explain what kind of information they carry and what their role is respectively.

There are many different types of OSPF-related messages.

In the screenshot below we can observe the following OSPF messages:

1. **Hello:** These messages discover neighbors and build adjacencies between them. It also performs some other functions like Adjacency negotiation and Adjacency keepalive. It contains the following information in the packets.
 - a. Designated Router IP (DR)
 - b. Backup Designated Router IP (BDR)
2. **Link State Update:** It sends specifically requested link-state records. Its function is Database synchronization and flooding. When a router receives Link state request, responds with an LSU that contains the details information for the requested Link State Acknowledgement.

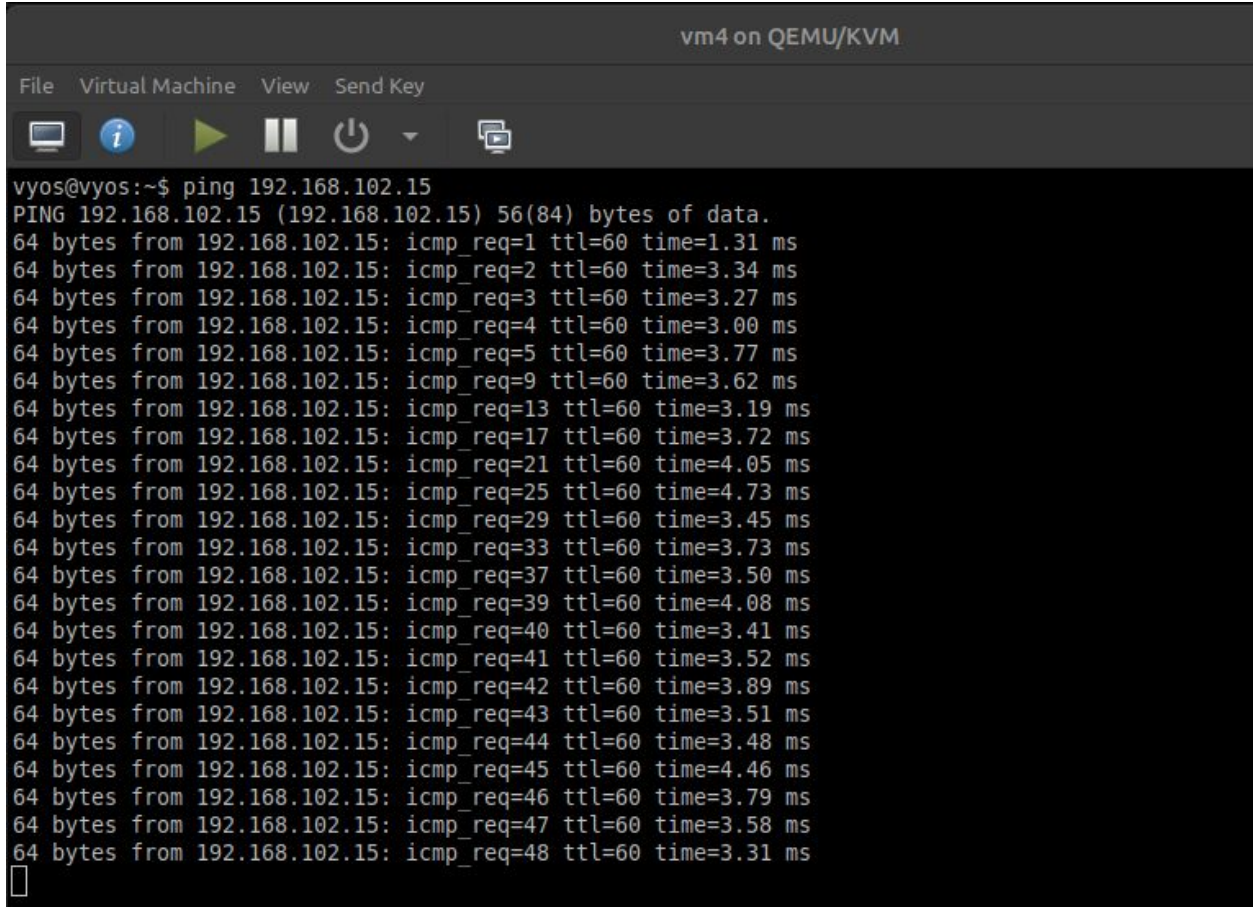
Sample screenshot showing some messages



```
vm5 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
13:34:33.662440 IP6 fe80::a00:27ff:fe09:4ac3 > fe80::a00:27ff:fe31:4603: ICMP6,
neighbor solicitation, who has fe80::a00:27ff:fe31:4603, length 32
13:34:33.662481 IP6 fe80::a00:27ff:fe31:4603 > fe80::a00:27ff:fe09:4ac3: ICMP6,
neighbor advertisement, tgt is fe80::a00:27ff:fe31:4603, length 24
13:34:33.662564 IP6 fe80::a00:27ff:fe09:4ac3 > fe80::a00:27ff:fe31:4603: ICMP6,
neighbor advertisement, tgt is fe80::a00:27ff:fe09:4ac3, length 24
13:34:33.662730 IP6 fe80::a00:27ff:fe31:4603 > fe80::a00:27ff:fe09:4ac3: OSPFv3,
LS-Update, length 64
13:34:36.662222 IP6 fe80::a00:27ff:fe31:4603 > ff02::5: OSPFv3, LS-Ack, length 3
6
13:34:36.664272 IP6 fe80::a00:27ff:fe09:4ac3 > ff02::5: OSPFv3, LS-Ack, length 3
6
13:34:37.560207 IP 192.168.113.13 > 224.0.0.5: OSPFv2, Hello, length 48
13:34:37.560478 IP 192.168.113.11 > 224.0.0.5: OSPFv2, Hello, length 48
13:34:38.650259 IP6 fe80::a00:27ff:fe09:4ac3 > ff02::5: OSPFv3, Hello, length 40
13:34:41.511970 IP6 fe80::a00:27ff:fe31:4603 > ff02::5: OSPFv3, Hello, length 40
13:34:47.560744 IP 192.168.113.13 > 224.0.0.5: OSPFv2, Hello, length 48
13:34:47.561080 IP 192.168.113.11 > 224.0.0.5: OSPFv2, Hello, length 48
13:34:48.653039 IP6 fe80::a00:27ff:fe09:4ac3 > ff02::5: OSPFv3, Hello, length 40
13:34:51.515284 IP6 fe80::a00:27ff:fe31:4603 > ff02::5: OSPFv3, Hello, length 40
13:34:57.561209 IP 192.168.113.13 > 224.0.0.5: OSPFv2, Hello, length 48
13:34:57.561588 IP 192.168.113.11 > 224.0.0.5: OSPFv2, Hello, length 48
13:34:58.657135 IP6 fe80::a00:27ff:fe09:4ac3 > ff02::5: OSPFv3, Hello, length 40
13:35:01.515601 IP6 fe80::a00:27ff:fe31:4603 > ff02::5: OSPFv3, Hello, length 40
```

Question 7.1. (For OSPF)

Execute ping (only IPv4 is OK) from H1 to H2, and disconnect Subnet (A) by unplugging the LAN cable between the laptops. Keep pinging even after you disconnect the LAN cable (up to 1 minute should be enough), and observe what happens to the ping result.



```
vm4 on QEMU/KVM
File Virtual Machine View Send Key
vyos@vyos:~$ ping 192.168.102.15
PING 192.168.102.15 (192.168.102.15) 56(84) bytes of data.
64 bytes from 192.168.102.15: icmp_req=1 ttl=60 time=1.31 ms
64 bytes from 192.168.102.15: icmp_req=2 ttl=60 time=3.34 ms
64 bytes from 192.168.102.15: icmp_req=3 ttl=60 time=3.27 ms
64 bytes from 192.168.102.15: icmp_req=4 ttl=60 time=3.00 ms
64 bytes from 192.168.102.15: icmp_req=5 ttl=60 time=3.77 ms
64 bytes from 192.168.102.15: icmp_req=9 ttl=60 time=3.62 ms
64 bytes from 192.168.102.15: icmp_req=13 ttl=60 time=3.19 ms
64 bytes from 192.168.102.15: icmp_req=17 ttl=60 time=3.72 ms
64 bytes from 192.168.102.15: icmp_req=21 ttl=60 time=4.05 ms
64 bytes from 192.168.102.15: icmp_req=25 ttl=60 time=4.73 ms
64 bytes from 192.168.102.15: icmp_req=29 ttl=60 time=3.45 ms
64 bytes from 192.168.102.15: icmp_req=33 ttl=60 time=3.73 ms
64 bytes from 192.168.102.15: icmp_req=37 ttl=60 time=3.50 ms
64 bytes from 192.168.102.15: icmp_req=39 ttl=60 time=4.08 ms
64 bytes from 192.168.102.15: icmp_req=40 ttl=60 time=3.41 ms
64 bytes from 192.168.102.15: icmp_req=41 ttl=60 time=3.52 ms
64 bytes from 192.168.102.15: icmp_req=42 ttl=60 time=3.89 ms
64 bytes from 192.168.102.15: icmp_req=43 ttl=60 time=3.51 ms
64 bytes from 192.168.102.15: icmp_req=44 ttl=60 time=3.48 ms
64 bytes from 192.168.102.15: icmp_req=45 ttl=60 time=4.46 ms
64 bytes from 192.168.102.15: icmp_req=46 ttl=60 time=3.79 ms
64 bytes from 192.168.102.15: icmp_req=47 ttl=60 time=3.58 ms
64 bytes from 192.168.102.15: icmp_req=48 ttl=60 time=3.31 ms

```

First few icmp requests succeed as expected before taking the bridge down. Some requests start failing after 5th after we take the bridge down. Success rate is low for some time as only fraction of packages goes from subnet B. then ospf detects the situation and configures routing. And after this every requests succeed as we can see after 39th requests.

Question 7.2.

Insert the screen captures of the routing table on R2 to compare those before and after unplugging the LAN cable. And explain which change in the routing table is the cause of observation that you gave in the previous answer in 7.1.

Before:

```
vyos@vyos:~$ show ip ospf route
===== OSPF network routing table =====
N   192.168.100.0/24      [10] area: 0.0.0.0
                        directly attached to eth0
N   192.168.101.0/24      [30] area: 0.0.0.0
                        via 192.168.100.10, eth0
N   192.168.102.0/24      [40] area: 0.0.0.0
                        via 192.168.100.10, eth0
                        via 192.168.112.10, eth1
N   192.168.103.0/24      [10] area: 0.0.0.0
                        directly attached to eth2
N   192.168.111.0/24      [20] area: 0.0.0.0
                        via 192.168.100.10, eth0
N   192.168.112.0/24      [10] area: 0.0.0.0
                        directly attached to eth1
N   192.168.113.0/24      [30] area: 0.0.0.0
                        via 192.168.112.10, eth1
N   192.168.114.0/24      [20] area: 0.0.0.0
                        via 192.168.112.10, eth1

===== OSPF router routing table =====

===== OSPF external routing table =====

vyos@vyos:~$ show ipv6 ospfv3 route
*N IA 2020:abcd:100::/64      ::              eth0 00:27:28
*N IA 2020:abcd:101::/64      fe80::5054:ff:fe9c:3b14 eth0 00:25:04
*N IA 2020:abcd:102::/64      fe80::5054:ff:fe9c:3b14 eth0 00:25:04
  N IA 2020:abcd:102::/64      fe80::5054:ff:fe9c:3b14 eth0 00:25:04
*N IA 2020:abcd:103::/64      ::              eth2 00:27:08
  N IA 2020:abcd:103::/64      fe80::5054:ff:fe9a:bc0d eth2 00:27:08
*N IA 2020:abcd:111::/64      fe80::5054:ff:fe9c:3b14 eth0 00:25:09
  N IA 2020:abcd:111::/64      fe80::5054:ff:fe9c:3b14 eth0 00:25:04
*N IA 2020:abcd:112::/64      ::              eth1 00:27:19
*N IA 2020:abcd:113::/64      fe80::5054:ff:fefa:fd15 eth1 00:24:25
  N IA 2020:abcd:113::/64      fe80::5054:ff:fefa:fd15 eth1 00:24:25
*N IA 2020:abcd:114::/64      fe80::5054:ff:fefa:fd15 eth1 00:24:29
vyos@vyos:~$
```


After :

```
vyos@vyos:~$ show ip ospf route
===== OSPF network routing table =====
N   192.168.100.0/24      [10] area: 0.0.0.0
                                directly attached to eth0
N   192.168.101.0/24      [40] area: 0.0.0.0
                                via 192.168.112.10, eth1
N   192.168.102.0/24      [40] area: 0.0.0.0
                                via 192.168.112.10, eth1
N   192.168.103.0/24      [10] area: 0.0.0.0
                                directly attached to eth2
N   192.168.111.0/24      [20] area: 0.0.0.0
                                via 192.168.100.10, eth0
N   192.168.112.0/24      [10] area: 0.0.0.0
                                directly attached to eth1
N   192.168.113.0/24      [30] area: 0.0.0.0
                                via 192.168.112.10, eth1
N   192.168.114.0/24      [20] area: 0.0.0.0
                                via 192.168.112.10, eth1

===== OSPF router routing table =====

===== OSPF external routing table =====

vyos@vyos:~$ show ipv6 ospfv3 route
*N IA 2020:abcd:100::/64      ::                                eth0 00:31:50
*N IA 2020:abcd:101::/64      fe80::5054:ff:fefa:fd15          eth1 00:01:10
*N IA 2020:abcd:102::/64      fe80::5054:ff:fefa:fd15          eth1 00:01:10
N   IA 2020:abcd:102::/64      fe80::5054:ff:fefa:fd15          eth1 00:01:10
*N IA 2020:abcd:103::/64      ::                                eth2 00:31:30
N   IA 2020:abcd:103::/64      fe80::5054:ff:fe9a:bc0d          eth2 00:31:30
*N IA 2020:abcd:111::/64      fe80::5054:ff:fe9c:3b14          eth0 00:00:59
N   IA 2020:abcd:111::/64      fe80::5054:ff:fefa:fd15          eth1 00:01:10
*N IA 2020:abcd:112::/64      ::                                eth1 00:31:40
*N IA 2020:abcd:113::/64      fe80::5054:ff:fefa:fd15          eth1 00:28:46
N   IA 2020:abcd:113::/64      fe80::5054:ff:fefa:fd15          eth1 00:28:46
*N IA 2020:abcd:114::/64      fe80::5054:ff:fefa:fd15          eth1 00:28:50
vyos@vyos:~$
```

We can see some changes in the table for example the entry for 192.168.101.0/24(R4). Before taking the bridge down the target was 192.168.100.10(R1) after taking it down it was changed to 192.168.112.10(R3) as the link from R1 to R4 was taken down.

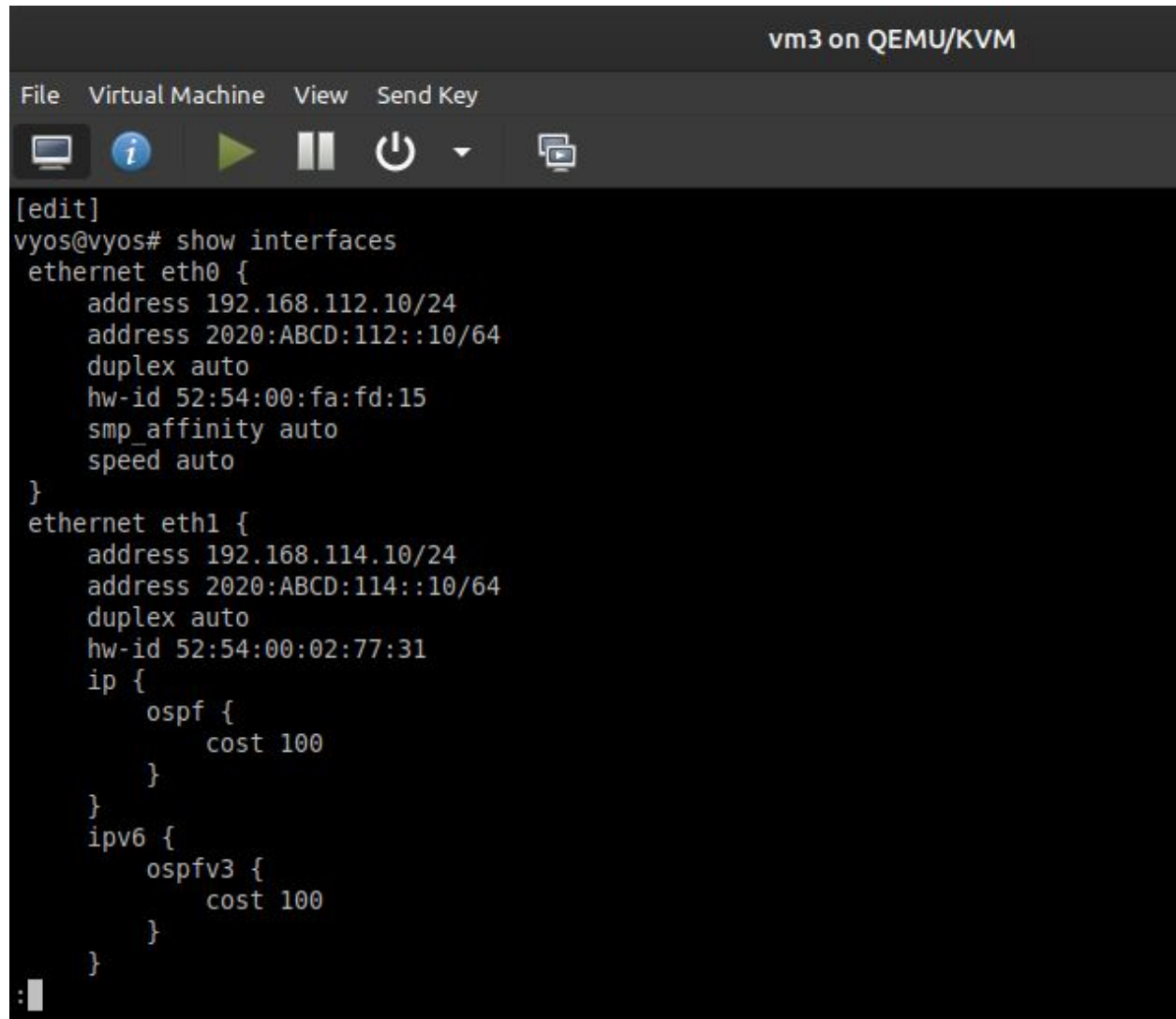
Question 8.

Configure OSPF Link Costs on the routers so that 1) ping traffic from H1 to H2 goes through Subnet (A), and 2) that from H2 to H1 goes through Subnet (B) using both IPv4 and IPv6.

Answer by inserting the screen captures of the routing table on R2 and R6, and the tcpdump result on R1 and R5 on those you should observe the traffic is one way.

We updated link costs at R3 and R5 to a high value (100)

We can see the updated cost at R3 in the following screenshot.



```
vm3 on QEMU/KVM
File Virtual Machine View Send Key
[edit]
vyos@vyos# show interfaces
  ethernet eth0 {
    address 192.168.112.10/24
    address 2020:ABCD:112::10/64
    duplex auto
    hw-id 52:54:00:fa:fd:15
    smp_affinity auto
    speed auto
  }
  ethernet eth1 {
    address 192.168.114.10/24
    address 2020:ABCD:114::10/64
    duplex auto
    hw-id 52:54:00:02:77:31
    ip {
      ospf {
        cost 100
      }
    }
    ipv6 {
      ospfv3 {
        cost 100
      }
    }
  }
}
```

ospf routing tables at R2

```
vm2 on QEMU/KVM
File Virtual Machine View Send Key
[Icons: Monitor, Info, Play, Pause, Power, Dropdown, Copy]

vyos@vyos:~$ show ip ospf route
===== OSPF network routing table =====
N   192.168.100.0/24    [10] area: 0.0.0.0
                        directly attached to eth0
N   192.168.101.0/24    [30] area: 0.0.0.0
                        via 192.168.100.10, eth0
N   192.168.102.0/24    [40] area: 0.0.0.0
                        via 192.168.100.10, eth0
N   192.168.103.0/24    [10] area: 0.0.0.0
                        directly attached to eth2
N   192.168.111.0/24    [20] area: 0.0.0.0
                        via 192.168.100.10, eth0
N   192.168.112.0/24    [10] area: 0.0.0.0
                        directly attached to eth1
N   192.168.113.0/24    [40] area: 0.0.0.0
                        via 192.168.100.10, eth0
N   192.168.114.0/24    [50] area: 0.0.0.0
                        via 192.168.100.10, eth0

===== OSPF router routing table =====

===== OSPF external routing table =====

vyos@vyos:~$ show ipv6 ospfv3 route
*N IA 2020:abcd:100::/64      ::                                eth0 01:02:55
*N IA 2020:abcd:101::/64      fe80::5054:ff:fe9c:3b14          eth0 00:28:04
*N IA 2020:abcd:102::/64      fe80::5054:ff:fe9c:3b14          eth0 00:28:04
*N IA 2020:abcd:103::/64      ::                                eth2 01:02:35
*N IA 2020:abcd:111::/64      fe80::5054:ff:fe9c:3b14          eth0 00:28:04
*N IA 2020:abcd:112::/64      ::                                eth1 01:02:45
*N IA 2020:abcd:113::/64      fe80::5054:ff:fe9c:3b14          eth0 00:03:53
*N IA 2020:abcd:114::/64      fe80::5054:ff:fe9c:3b14          eth0 00:03:53
vyos@vyos:~$ █
```

ospf routing table at R6

```
vm6 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
vyos@vyos:~$ show ip ospf route
===== OSPF network routing table =====
N    192.168.100.0/24      [40] area: 0.0.0.0
      via 192.168.113.11, eth2
N    192.168.101.0/24      [10] area: 0.0.0.0
      directly attached to eth0
N    192.168.102.0/24      [10] area: 0.0.0.0
      directly attached to eth1
N    192.168.103.0/24      [40] area: 0.0.0.0
      via 192.168.113.11, eth2
N    192.168.111.0/24      [50] area: 0.0.0.0
      via 192.168.113.11, eth2
N    192.168.112.0/24      [30] area: 0.0.0.0
      via 192.168.113.11, eth2
N    192.168.113.0/24      [10] area: 0.0.0.0
      directly attached to eth2
N    192.168.114.0/24      [20] area: 0.0.0.0
      via 192.168.113.11, eth2

===== OSPF router routing table =====
===== OSPF external routing table =====
vyos@vyos:~$ _
```

```
vm6 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
vyos@vyos:~$ show ipv6 ospfv3 route
*N IA 2020:abcd:100::/64      fe80::a00:27ff:fe31:4603      eth2 00:06:23
*N IA 2020:abcd:101::/64      ::                             eth0 01:02:39
*N IA 2020:abcd:102::/64      ::                             eth1 01:03:19
*N IA 2020:abcd:103::/64      fe80::a00:27ff:fe31:4603      eth2 00:06:23
*N IA 2020:abcd:111::/64      fe80::a00:27ff:fe31:4603      eth2 00:06:23
*N IA 2020:abcd:112::/64      fe80::a00:27ff:fe31:4603      eth2 01:01:49
*N IA 2020:abcd:113::/64      ::                             eth2 01:01:49
*N IA 2020:abcd:114::/64      fe80::a00:27ff:fe31:4603      eth2 01:01:49
vyos@vyos:~$
```

We can see that at R2 the entry for H2(192.168.102.15) goes to R1 (subnet A) and the entry for H1(192.168.103.15) at R6 goes to R5(192.168.113.11)

Done!!

Some notes:

1. OSPF ECMP was omitted because it makes less sense in this scenario.
2. If you're stuck in VLAN configuration, ping TAs or come to the lab session.