Part A

A1. Topology

(a) The code for creating the topology is in the attached files start.py and topo.py

(b)

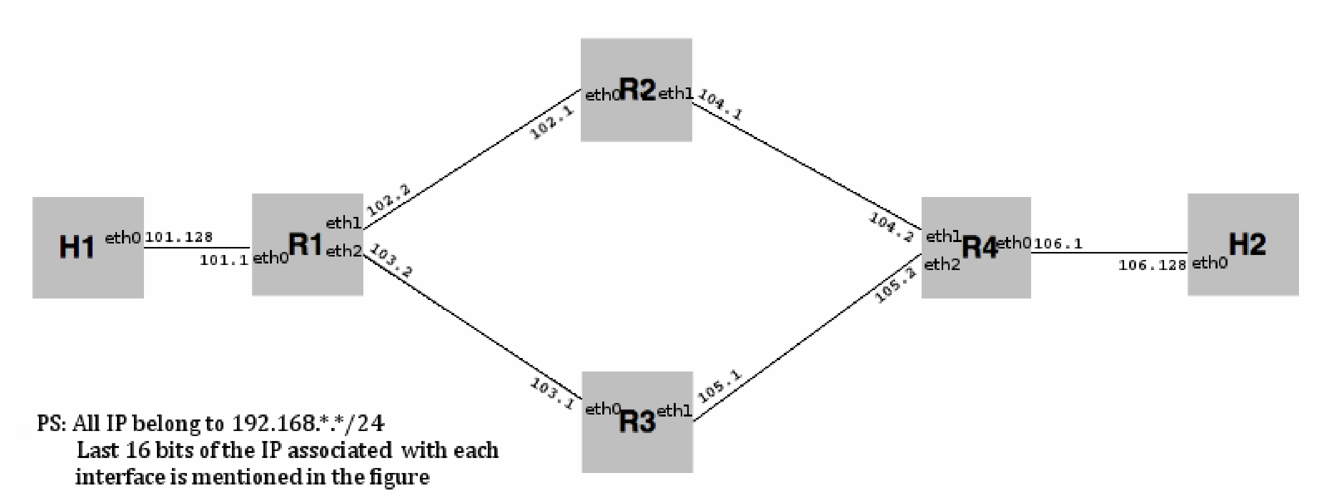


Figure 1. Network Topology

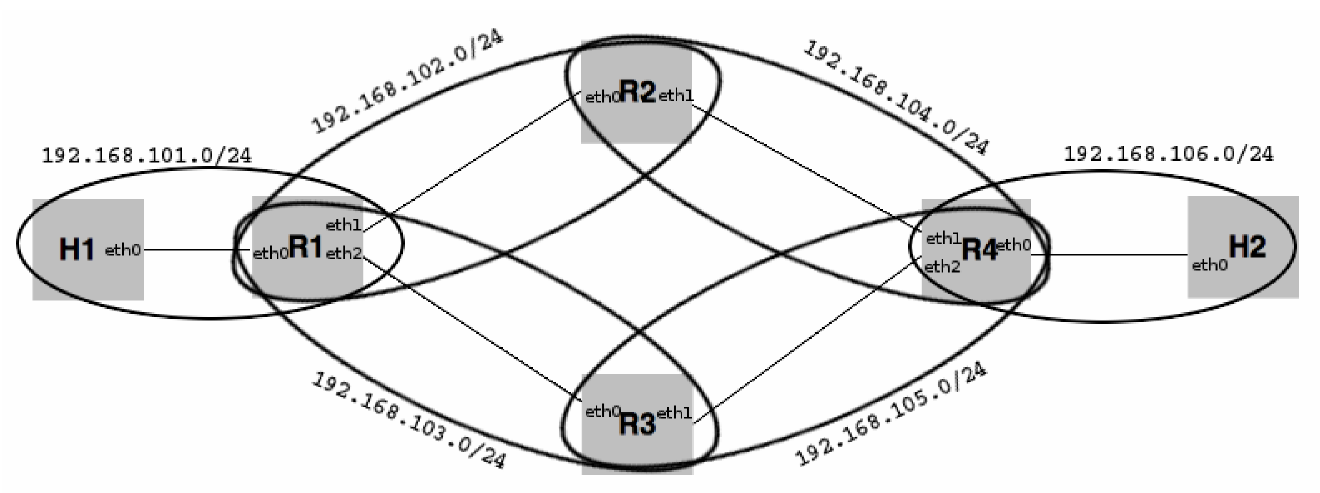


Figure 2. Subnet Figure

A2. Static Route

(a) Routing Table at all Nodes

root@mininet-vm: /home/mininet/Neha/PartA/A2

File Edit View Search Terminal Help

```
mininext> H1 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.101.0   *               255.255.255.0   U     0      0        0 H1-eth0
192.168.102.0   192.168.101.1   255.255.255.0   UG    0      0        0 H1-eth0
192.168.103.0   192.168.101.1   255.255.255.0   UG    0      0        0 H1-eth0
192.168.104.0   192.168.101.1   255.255.255.0   UG    0      0        0 H1-eth0
192.168.105.0   192.168.101.1   255.255.255.0   UG    0      0        0 H1-eth0
192.168.106.0   192.168.101.1   255.255.255.0   UG    0      0        0 H1-eth0
mininext> H2 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.101.0   192.168.106.1   255.255.255.0   UG    0      0        0 H2-eth0
192.168.102.0   192.168.106.1   255.255.255.0   UG    0      0        0 H2-eth0
192.168.103.0   192.168.106.1   255.255.255.0   UG    0      0        0 H2-eth0
192.168.104.0   192.168.106.1   255.255.255.0   UG    0      0        0 H2-eth0
192.168.105.0   192.168.106.1   255.255.255.0   UG    0      0        0 H2-eth0
192.168.106.0   *               255.255.255.0   U     0      0        0 H2-eth0
mininext>
```

```
root@mininet-vm: /home/mininet/Neha/PartA/A2
File  Edit  View  Search  Terminal  Help
mininext> R1 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.101.0   *               255.255.255.0   U     0      0        0 R1-eth0
192.168.102.0   *               255.255.255.0   U     0      0        0 R1-eth1
192.168.103.0   *               255.255.255.0   U     0      0        0 R1-eth2
192.168.104.0   192.168.102.1   255.255.255.0   UG    0      0        0 R1-eth1
192.168.105.0   192.168.103.1   255.255.255.0   UG    0      0        0 R1-eth2
192.168.106.0   192.168.102.1   255.255.255.0   UG    0      0        0 R1-eth1
mininext> R2 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.101.0   192.168.102.2   255.255.255.0   UG    0      0        0 R2-eth0
192.168.102.0   *               255.255.255.0   U     0      0        0 R2-eth0
192.168.103.0   192.168.102.2   255.255.255.0   UG    0      0        0 R2-eth0
192.168.104.0   *               255.255.255.0   U     0      0        0 R2-eth1
192.168.105.0   192.168.104.2   255.255.255.0   UG    0      0        0 R2-eth1
192.168.106.0   192.168.104.2   255.255.255.0   UG    0      0        0 R2-eth1
mininext> R3 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.101.0   192.168.103.2   255.255.255.0   UG    0      0        0 R3-eth0
192.168.102.0   192.168.103.2   255.255.255.0   UG    0      0        0 R3-eth0
192.168.103.0   *               255.255.255.0   U     0      0        0 R3-eth0
192.168.104.0   192.168.105.2   255.255.255.0   UG    0      0        0 R3-eth1
192.168.105.0   *               255.255.255.0   U     0      0        0 R3-eth1
192.168.106.0   192.168.105.2   255.255.255.0   UG    0      0        0 R3-eth1
mininext> R4 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.101.0   192.168.104.1   255.255.255.0   UG    0      0        0 R4-eth1
192.168.102.0   192.168.104.1   255.255.255.0   UG    0      0        0 R4-eth1
192.168.103.0   192.168.105.1   255.255.255.0   UG    0      0        0 R4-eth2
192.168.104.0   *               255.255.255.0   U     0      0        0 R4-eth1
192.168.105.0   *               255.255.255.0   U     0      0        0 R4-eth2
192.168.106.0   *               255.255.255.0   U     0      0        0 R4-eth0
mininext>
```

The link between H1-R1, R1-R2, R1-R3, R2-R4, R3-R4 and R4-H2 is already created in the topology.

To configure the Routing table correctly I created six subnets:
The subnet between H1 and R1 is in subnet 192.168.101.0/24
The subnet between R1 and R2 is in subnet 192.168.102.0/24
The subnet between R1 and R3 is in subnet 192.168.103.0/24
The subnet between R2 and R4 is in subnet 192.168.104.0/24
The subnet between R3 and R4 is in subnet 192.168.105.0/24
The subnet between R4 and H2 is in subnet 192.168.106.0/24

H1 routes all its packets to R1.
R1 route packet to subnet 192.168.104.0/24 and subnet 192.168.106.0/24 via 192.168.102.2/24, which is the interface of R2.
R1 route packet to subnet 192.168.105.0/24 via 192.168.103.1/24, which is the interface of R3

R2 route packet to subnet 192.168.101.0/24 and subnet 192.168.103.0/24 via 192.168.102.2/24, which is the interface of R1
R2 route packet to subnet 192.168.105.0/24 and subnet 192.168.106.0/24 via 192.168.104.2/24, which is the interface of R4

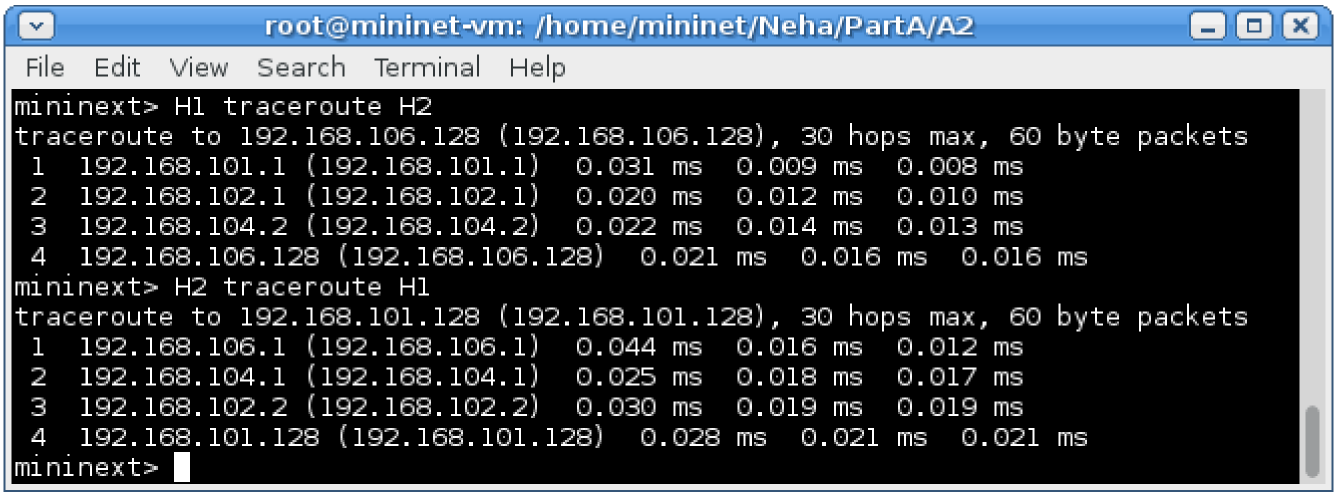
R3 route packet to subnet 192.168.101.0/24 and subnet 192.168.102.0/24 via 192.168.103.2/24,

which is the interface of R1
R3 route packet to subnet 192.168.104.0/24 and subnet 192.168.106.0/24 via 192.168.105.2/24, which is the interface of R4

R4 route packet to subnet 192.168.101.0/24 and subnet 192.168.102.0/24 via 192.168.104.1/24, which is the interface of R2.
R4 route packet to subnet 192.168.103.0/24 via 192.168.105.1/24, which is the interface of R3

H2 routes all its packets to R4.

(b) Traceroute




```
mininext> H1 traceroute H2
traceroute to 192.168.106.128 (192.168.106.128), 30 hops max, 60 byte packets
 1  192.168.101.1 (192.168.101.1)  0.031 ms  0.009 ms  0.008 ms
 2  192.168.102.1 (192.168.102.1)  0.020 ms  0.012 ms  0.010 ms
 3  192.168.104.2 (192.168.104.2)  0.022 ms  0.014 ms  0.013 ms
 4  192.168.106.128 (192.168.106.128)  0.021 ms  0.016 ms  0.016 ms
mininext> H2 traceroute H1
traceroute to 192.168.101.128 (192.168.101.128), 30 hops max, 60 byte packets
 1  192.168.106.1 (192.168.106.1)  0.044 ms  0.016 ms  0.012 ms
 2  192.168.104.1 (192.168.104.1)  0.025 ms  0.018 ms  0.017 ms
 3  192.168.102.2 (192.168.102.2)  0.030 ms  0.019 ms  0.019 ms
 4  192.168.101.128 (192.168.101.128)  0.028 ms  0.021 ms  0.021 ms
mininext>
```

Figure. TraceRoute between H1 and H2

Part B

B1. RIP Configuration

I have set the default gateway of H1(192.168.101.128/24) as R1(192.168.101.1) and H2(192.168.106.128/24) as R4(192.168.106.1). This I did in topo.py file itself.

I configured Quagga ripd daemon to set R1, R2, R3 and R4 as RIP router.

Step 1:
I enable zebra and ripd in the file /etc/quagga/daemons
zebra=yes
ripd=yes

Step 2:
Next I created two blank files - zebra.conf and ripd.conf in the config directory of all the routers - /config/XX, where XX is R1, R2, R3, R4
To set password for zebra I updated the zebra.conf file for every router and included the following line:
password a

Step 3:
Then I copied /etc/quagga/debian.conf to all the routers as above

Step 4:
Then I restart the quagga service:
$ /etc/init.d/quagga restart

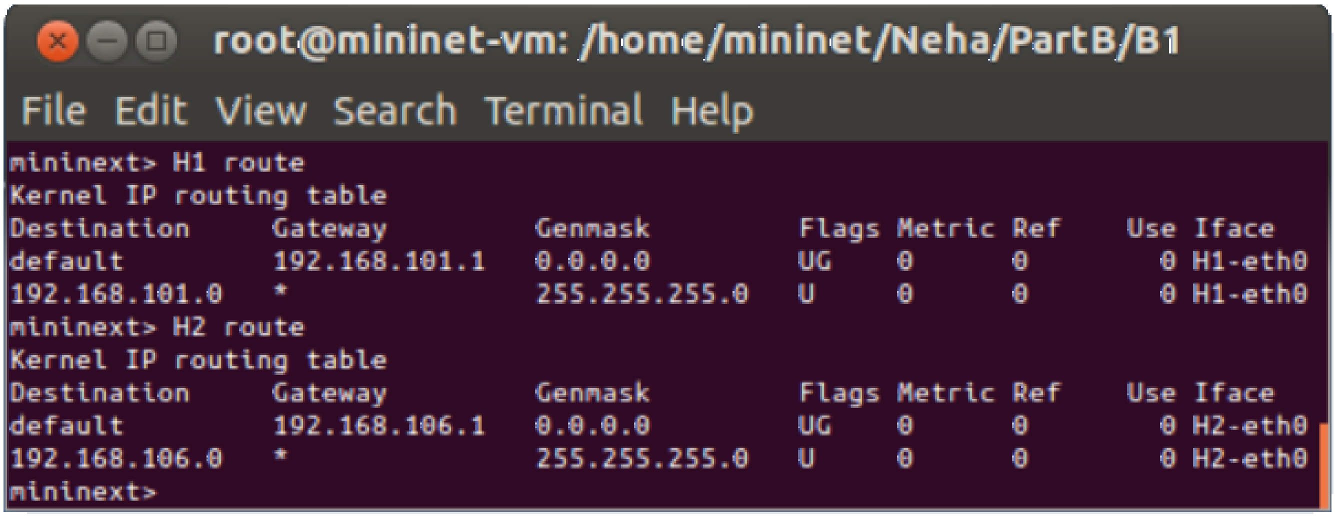
Step 5:
Lastly I configured every router with Quagga ripd daemons

a. Run start.py
```
$ python start.py
```
b. Login to any router/host
```
mininet> xterm R1
```
c. Launch mx on any host/router
```
$ cd /home/mininet/miniNExT/util
$ ./mx R1
```
d. Find the port of running ripd
```
$ netstat -na
```
e. Remote access for localhost/ripd process
```
$ telnet localhost zebra
User Access Verification
Password:                          -> login with password
 ripd> enable
ripd# config term                  -> to configure the ripd terminal
ripd(config)# router rip           -> Enables RIP as a routing protocol
ripd(config-router)# network X.X.X.X/24   -> configure the subnet where the
                                   router is connected to
```

```
ripd(config-router)# exit      -> come out of the terminal
ripd(config)# write            -> save the config
                                  configuration saved to /configs/R1/ripd.conf
```

Finally all ripd configuration are saved in /configs/XX/ripd.conf, where XX is R1, R2, R3, R4
Once done I run the start.py file again to check. All screen shots are after this step.
B2. Run RIP Daemon

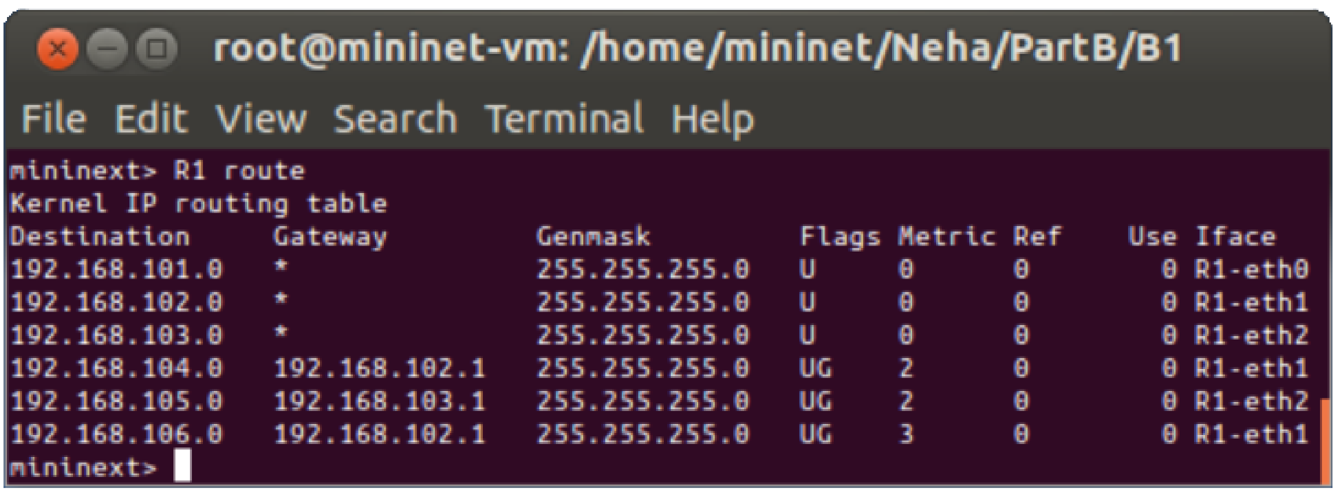
(a) Routing Table at Each Node (both the kernel and the Quagga routing table)



root@mininet-vm: /home/mininet/Neha/PartB/B1

File Edit View Search Terminal Help

```
mininext> H1 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
default         192.168.101.1   0.0.0.0         UG    0      0        0 H1-eth0
192.168.101.0   *               255.255.255.0   U     0      0        0 H1-eth0
mininext> H2 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
default         192.168.106.1   0.0.0.0         UG    0      0        0 H2-eth0
192.168.106.0   *               255.255.255.0   U     0      0        0 H2-eth0
mininext>
```



root@mininet-vm: /home/mininet/Neha/PartB/B1

File Edit View Search Terminal Help

```
mininext> R1 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.101.0   *               255.255.255.0   U     0      0        0 R1-eth0
192.168.102.0   *               255.255.255.0   U     0      0        0 R1-eth1
192.168.103.0   *               255.255.255.0   U     0      0        0 R1-eth2
192.168.104.0   192.168.102.1   255.255.255.0   UG    2      0        0 R1-eth1
192.168.105.0   192.168.103.1   255.255.255.0   UG    2      0        0 R1-eth2
192.168.106.0   192.168.102.1   255.255.255.0   UG    3      0        0 R1-eth1
mininext>
```

root@mininet-vm: /home/mininet/Neha/PartB/B1

File Edit View Search Terminal Help

```
mininext> R1 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.101.0   *               255.255.255.0   U     0      0        0 R1-eth0
192.168.102.0   *               255.255.255.0   U     0      0        0 R1-eth1
192.168.103.0   *               255.255.255.0   U     0      0        0 R1-eth2
192.168.104.0   192.168.102.1   255.255.255.0   UG    2      0        0 R1-eth1
192.168.105.0   192.168.103.1   255.255.255.0   UG    2      0        0 R1-eth2
192.168.106.0   192.168.102.1   255.255.255.0   UG    3      0        0 R1-eth1
mininext>
```

root@mininet-vm: /home/mininet/Neha/PartB/B1

File Edit View Search Terminal Help

```
mininext> R1 ip route show
192.168.101.0/24 dev R1-eth0  proto kernel  scope link  src 192.168.101.1
192.168.102.0/24 dev R1-eth1  proto kernel  scope link  src 192.168.102.2
192.168.103.0/24 dev R1-eth2  proto kernel  scope link  src 192.168.103.2
192.168.104.0/24 via 192.168.102.1 dev R1-eth1  proto zebra  metric 2
192.168.105.0/24 via 192.168.103.1 dev R1-eth2  proto zebra  metric 2
192.168.106.0/24 via 192.168.102.1 dev R1-eth1  proto zebra  metric 3
mininext>
```

root@mininet-vm: /home/mininet/Neha/PartB/B1

File Edit View Search Terminal Help

```
mininext> R2 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.101.0   192.168.102.2   255.255.255.0   UG    2      0        0 R2-eth0
192.168.102.0   *               255.255.255.0   U     0      0        0 R2-eth0
192.168.103.0   192.168.102.2   255.255.255.0   UG    2      0        0 R2-eth0
192.168.104.0   *               255.255.255.0   U     0      0        0 R2-eth1
192.168.105.0   192.168.104.2   255.255.255.0   UG    2      0        0 R2-eth1
192.168.106.0   192.168.104.2   255.255.255.0   UG    2      0        0 R2-eth1
mininext>
```

root@mininet-vm: /home/mininet/Neha/PartB/B1

File Edit View Search Terminal Help

```
mininext> R2 ip route show
```

root@mininet-vm: /home/mininet/Neha/PartB/B1

File Edit View Search Terminal Help

```
mininext> R3 route
Kernel IP routing table
```

root@mininet-vm: /home/mininet/Neha/PartB/B1

File Edit View Search Terminal Help

```
mininext> R3 ip route show
```

root@mininet-vm: /home/mininet/Neha/PartB/B1

File Edit View Search Terminal Help

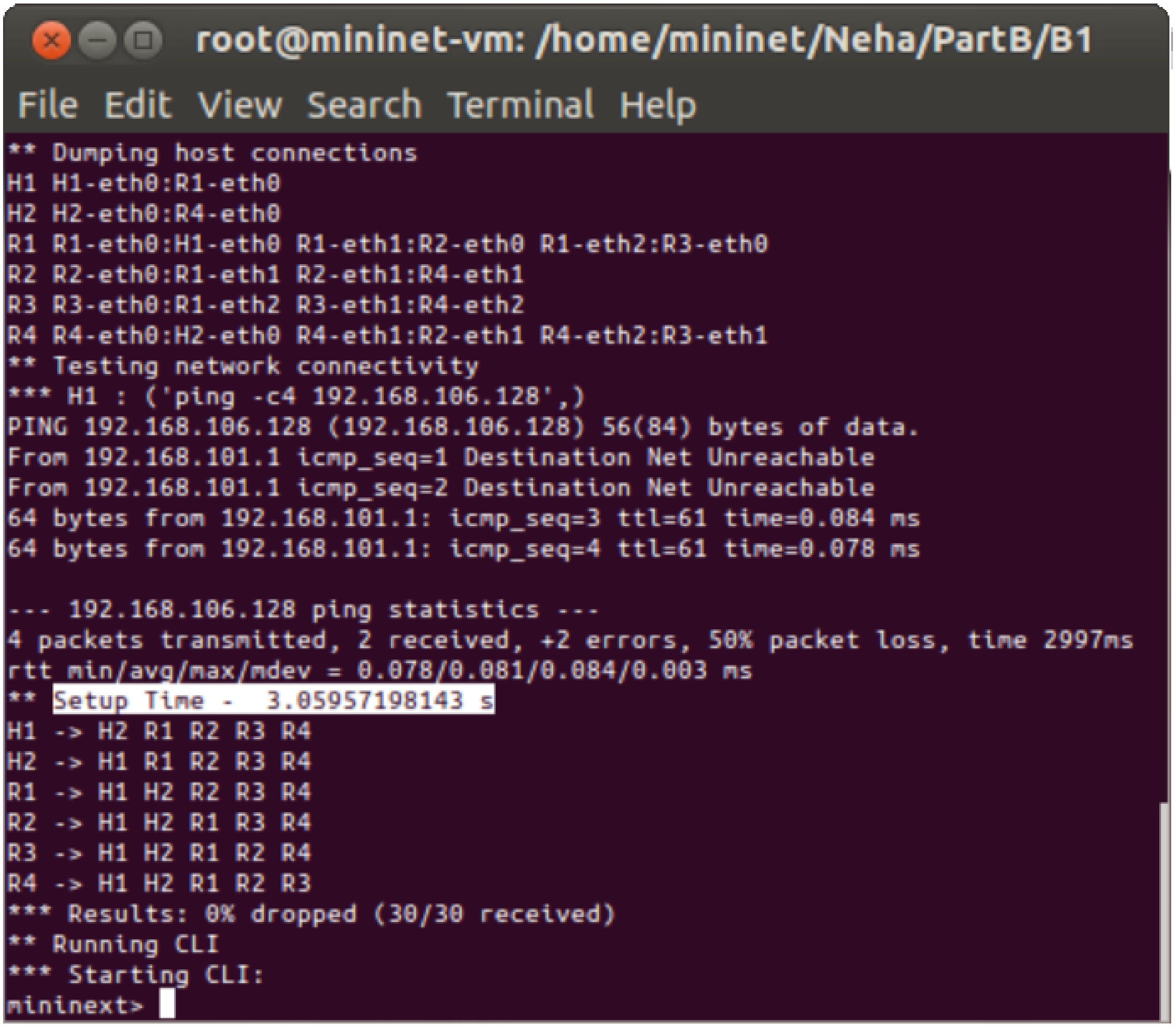
```
mininext> R4 route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.101.0   192.168.104.1   255.255.255.0   UG    3      0        0 R4-eth1
192.168.102.0   192.168.104.1   255.255.255.0   UG    2      0        0 R4-eth1
192.168.103.0   192.168.105.1   255.255.255.0   UG    2      0        0 R4-eth2
192.168.104.0   *               255.255.255.0   U     0      0        0 R4-eth1
192.168.105.0   *               255.255.255.0   U     0      0        0 R4-eth2
192.168.106.0   *               255.255.255.0   U     0      0        0 R4-eth0
mininext>
```

root@mininet-vm: /home/mininet/Neha/PartB/B1

File Edit View Search Terminal Help

```
mininext> R4 ip route show
192.168.101.0/24 via 192.168.104.1 dev R4-eth1  proto zebra  metric 3
192.168.102.0/24 via 192.168.104.1 dev R4-eth1  proto zebra  metric 2
192.168.103.0/24 via 192.168.105.1 dev R4-eth2  proto zebra  metric 2
192.168.104.0/24 dev R4-eth1  proto kernel  scope link  src 192.168.104.2
192.168.105.0/24 dev R4-eth2  proto kernel  scope link  src 192.168.105.2
192.168.106.0/24 dev R4-eth0  proto kernel  scope link  src 192.168.106.1
mininext>
```

(b) Traceroute between H1 and H2



```
root@mininet-vm: /home/mininet/Neha/PartB/B1
File Edit View Search Terminal Help
** Dumping host connections
H1 H1-eth0:R1-eth0
H2 H2-eth0:R4-eth0
R1 R1-eth0:H1-eth0 R1-eth1:R2-eth0 R1-eth2:R3-eth0
R2 R2-eth0:R1-eth1 R2-eth1:R4-eth1
R3 R3-eth0:R1-eth2 R3-eth1:R4-eth2
R4 R4-eth0:H2-eth0 R4-eth1:R2-eth1 R4-eth2:R3-eth1
** Testing network connectivity
*** H1 : ('ping -c4 192.168.106.128',)
PING 192.168.106.128 (192.168.106.128) 56(84) bytes of data.
From 192.168.101.1 icmp_seq=1 Destination Net Unreachable
From 192.168.101.1 icmp_seq=2 Destination Net Unreachable
64 bytes from 192.168.101.1: icmp_seq=3 ttl=61 time=0.084 ms
64 bytes from 192.168.101.1: icmp_seq=4 ttl=61 time=0.078 ms

--- 192.168.106.128 ping statistics ---
4 packets transmitted, 2 received, +2 errors, 50% packet loss, time 2997ms
rtt min/avg/max/mdev = 0.078/0.081/0.084/0.003 ms
** Setup Time -  3.05957198143 s
H1 -> H2 R1 R2 R3 R4
H2 -> H1 R1 R2 R3 R4
R1 -> H1 H2 R2 R3 R4
R2 -> H1 H2 R1 R3 R4
R3 -> H1 H2 R1 R2 R4
R4 -> H1 H2 R1 R2 R3
*** Results: 0% dropped (30/30 received)
** Running CLI
*** Starting CLI:
mininext>
```

(c) Time taken for ping = 3.06s

(d) Convergence Time.

As it can be seen from the output, initially it takes around 3 secs to converge.
To determine convergence time I'm using the ping command. By implementation ping sends packets every 1 sec on unsuccessful ping. So as soon as the setup is done I'm sending some ping command from H1 to H2. This gives the number of seconds it takes for the algorithm to converge.

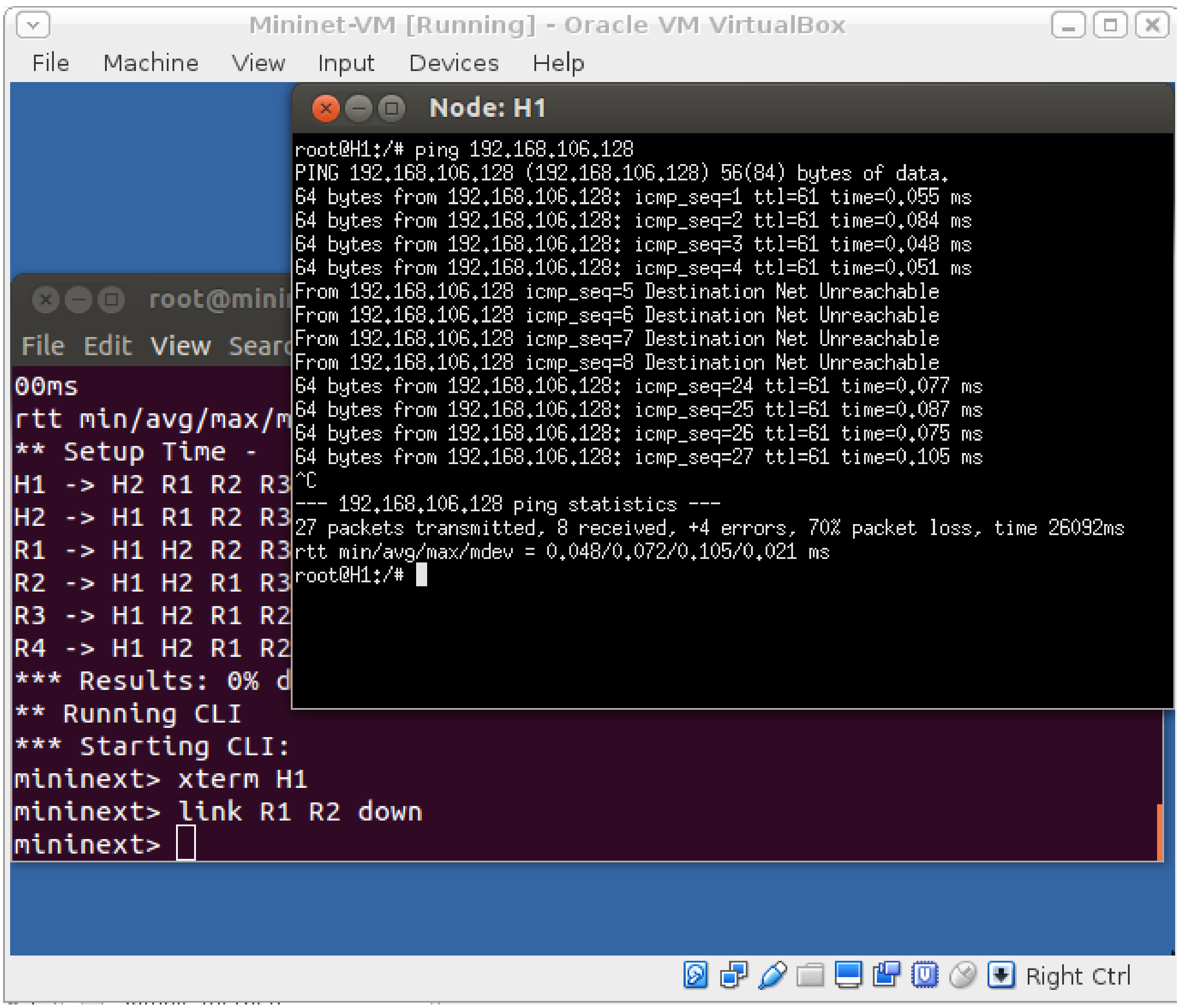
These 3.05957198143s includes initial setup and convergence time.

B3. Connectivity Re-establish

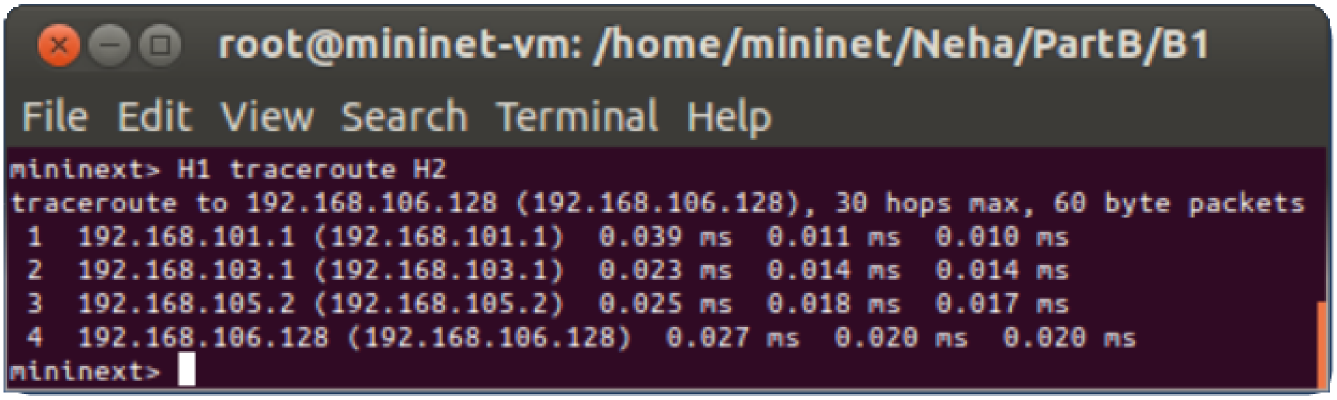
(a) To bring a link down I am using the command:
$ link R1 R2 down

(b) Time for connectivity to be established: 10s (approx).

First I log into H1 (xterm H1) and start pinging to H2. Then I break down the link from R1 and R2. This results in the ping to fail, since the route between H1 and H2 is broken. After 10 consecutive destination host unreachable H1 connects to H2 again. Since ping waits for 1 sec by default before sending another packet, we can assume that it took 10 secs to establish connection.



(c) Provide the Traceroute Output



root@mininet-vm: /home/mininet/Neha/PartB/B1

File Edit View Search Terminal Help

```
mininext> H1 traceroute H2
traceroute to 192.168.106.128 (192.168.106.128), 30 hops max, 60 byte packets
 1  192.168.101.1 (192.168.101.1)  0.039 ms  0.011 ms  0.010 ms
 2  192.168.103.1 (192.168.103.1)  0.023 ms  0.014 ms  0.014 ms
 3  192.168.105.2 (192.168.105.2)  0.025 ms  0.018 ms  0.017 ms
 4  192.168.106.128 (192.168.106.128)  0.027 ms  0.020 ms  0.020 ms
mininext> 
```

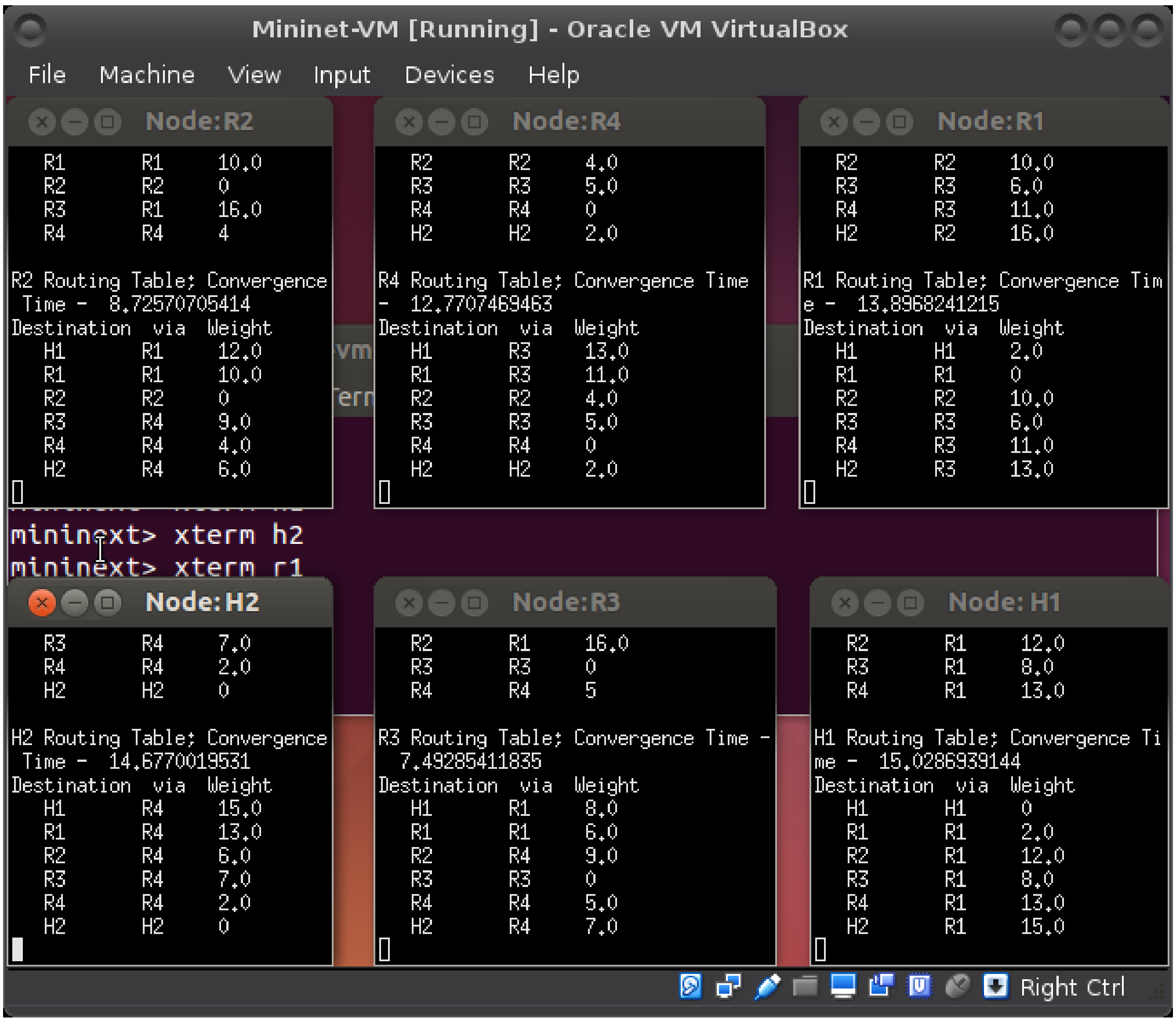
Part C

C1. Running Custom RIP Protocol

(a) Code – the following code are submitted:

- start.py – Staring and creating the topology
- topo.py – Topology description
- server.py – The server code to run on each node
- weight.txt – The weight of each edge in the topology

For negative cycle Bellman Ford algorithm does not converge, rather it exits. In distributed case, there are many ways of handling a negative weight edge. What I am doing is convert the negative weight to 0. This might not always give the optimal path, but does gives a proper path and the algorithm converges.



My solution works fine for positive weights. The output is for the following case:

R1—R2 10 R1—R3 6 R2—R4 4

R3—R4 5 H1—R1 2 R4—H2 2

(b) Time taken to find shortest Path – 15.028 sec

(c)Application Layer Routing Table at each node

C2. Weight Change

(a) Time Taken to Converge – 28.030 sec

(b) Application Layer Routing Table at each node