Part-B

B1).

a)

Set of Commands used for the configuration:

After logging in to Mininext, followed steps were used:

1. sudo vi /etc/quagga/daemons
   And then changed the zebra and ripd variables to yes to enable those services.

   zebra=yes
   bgpd=no
   ospfd=no
   ospf6d=no
   ripd=yes
   ripngd=no
   isisd=no
   babeld=no
2. Copy the sample configuration files into **/etc/quagga** for zebra and ripd services.
3. Then, start the quagga daemon, using following command:
   sudo /etc/init.d/quagga start

I have setup the following configuration files for every host and saved them in "configs" directory in hw3.

b)

Configuration Files:

Configuration File for: Router 1

```
mininet@mininet-vm:~/hw3/configs$ more quagga1.conf
hostname r1
password zebra

router rip
network 192.168.1.0/24
network 192.168.2.0/24
network 192.168.4.0/24

log file /var/log/quagga/ripd.log
```

Configuration File for: Router 2

```
mininet@mininet-vm:~/hw3/configs$ more quagga2.conf
hostname r2
password zebra

router rip
network 192.168.2.0/24
network 192.168.3.0/24

log file /var/log/quagga/ripd.log
```

Configuration File for: Router 3

```
mininet@mininet-vm:~/hw3/configs$ more quagga3.conf
hostname r3
password zebra

router rip
network 192.168.4.0/24
network 192.168.5.0/24

log file /var/log/quagga/ripd.log
```

Configuration File for: Router 4

```
mininet@mininet-vm:~/hw3/configs$ more quagga4.conf
hostname r4
password zebra

router rip
network 192.168.3.0/24
network 192.168.5.0/24
network 192.168.6.0/24

log file /var/log/quagga/ripd.log
```

Configuration File for: Host 1

```
mininet@mininet-vm:~/hw3/configs$ more quagga-host1.conf
hostname h1
password zebra

router rip
network 192.168.1.0/24

log file /var/log/quagga/ripd.log
```

Configuration File for: Host 2

```
mininet@mininet-vm:~/hw3/configs$ more quagga-host2.conf
hostname h2
password zebra

router rip
network 192.168.6.0/24

log file /var/log/quagga/ripd.log
```

Configuration File for: Zebra

```
mininet@mininet-vm:~/hw3/configs$ more zebra.conf
! -*- zebra -*-
!
! zebra sample configuration file
!
! $Id: zebra.conf.sample,v 1.1 2002/12/13 20:15:30 paul Exp $
!
hostname zebra
password zebra
log stdout
!enable password zebra
!
! Interface's description.
!
!interface lo
! description test of desc.
!
!interface sit0
! multicast

!
! Static default route sample.
!
!ip route 0.0.0.0/0 203.181.89.241
!

!log file /var/log/quagga/zebra.log
```

B2).

a) Kernel & Quagga Routing Tables:

Host 1:

Kernel Routing Table

mininet@mininet-vm: ~/hw3

```
mininext> h1 route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         192.168.1.12    0.0.0.0         UG    0      0        0 h1-eth0
192.168.1.0     0.0.0.0         255.255.255.0   U     0      0        0 h1-eth0
192.168.2.0     192.168.1.12    255.255.255.0   UG    2      0        0 h1-eth0
192.168.3.0     192.168.1.12    255.255.255.0   UG    3      0        0 h1-eth0
192.168.4.0     192.168.1.12    255.255.255.0   UG    2      0        0 h1-eth0
192.168.5.0     192.168.1.12    255.255.255.0   UG    3      0        0 h1-eth0
192.168.6.0     192.168.1.12    255.255.255.0   UG    4      0        0 h1-eth0
mininext>
```

Quagga Routing Table:

Node: h1

```
Escape character is '^]'.

Hello, this is Quagga (version 0.99.22.4).
Copyright 1996-2005 Kunihiro Ishiguro, et al.


User Access Verification

Password:
Password:
h1> show ip rip
Codes: R - RIP, C - connected, S - Static, O - OSPF, B - BGP
Sub-codes:
      (n) - normal, (s) - static, (d) - default, (r) - redistribute,
      (i) - interface

     Network         Next Hop         Metric From            Tag Time
C(i) 192.168.1.0/24  0.0.0.0               1 self              0
R(n) 192.168.2.0/24  192.168.1.12          2 192.168.1.12      0 02:41
R(n) 192.168.3.0/24  192.168.1.12          3 192.168.1.12      0 02:41
R(n) 192.168.4.0/24  192.168.1.12          2 192.168.1.12      0 02:41
R(n) 192.168.5.0/24  192.168.1.12          3 192.168.1.12      0 02:41
R(n) 192.168.6.0/24  192.168.1.12          4 192.168.1.12      0 02:41
h1>
```

Router 1:

Kernel Routing Table

mininet@mininet-vm: ~/hw3

```
mininext> r1 route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.1.0     0.0.0.0         255.255.255.0   U     0      0        0 r1-eth0
192.168.2.0     0.0.0.0         255.255.255.0   U     0      0        0 r1-eth1
192.168.3.0     192.168.2.12    255.255.255.0   UG    2      0        0 r1-eth1
192.168.4.0     0.0.0.0         255.255.255.0   U     0      0        0 r1-eth2
192.168.5.0     192.168.4.12    255.255.255.0   UG    2      0        0 r1-eth2
192.168.6.0     192.168.2.12    255.255.255.0   UG    3      0        0 r1-eth1
mininext>
```

Quagga Routing Table:

Node: r1

```
Connected to localhost.
Escape character is '^]'.

Hello, this is Quagga (version 0.99.22.4).
Copyright 1996-2005 Kunihiro Ishiguro, et al.


User Access Verification

Password:
r1> show ip rip
Codes: R - RIP, C - connected, S - Static, O - OSPF, B - BGP
Sub-codes:
      (n) - normal, (s) - static, (d) - default, (r) - redistribute,
      (i) - interface

     Network         Next Hop         Metric From            Tag Time
C(i) 192.168.1.0/24  0.0.0.0               1 self              0
C(i) 192.168.2.0/24  0.0.0.0               1 self              0
R(n) 192.168.3.0/24  192.168.2.12          2 192.168.2.12      0 02:50
C(i) 192.168.4.0/24  0.0.0.0               1 self              0
R(n) 192.168.5.0/24  192.168.4.12          2 192.168.4.12      0 02:50
R(n) 192.168.6.0/24  192.168.2.12          3 192.168.2.12      0 02:50
r1>
```

Router 2:

Kernel Routing Table

mininet@mininet-vm: ~/hw3

```
mininext> r2 route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.1.0     192.168.2.1     255.255.255.0   UG    2      0        0 r2-eth0
192.168.2.0     0.0.0.0         255.255.255.0   U     0      0        0 r2-eth0
192.168.3.0     0.0.0.0         255.255.255.0   U     0      0        0 r2-eth1
192.168.4.0     192.168.2.1     255.255.255.0   UG    2      0        0 r2-eth0
192.168.5.0     192.168.3.12    255.255.255.0   UG    2      0        0 r2-eth1
192.168.6.0     192.168.3.12    255.255.255.0   UG    2      0        0 r2-eth1
mininext>
```

Quagga Routing Table:

Node: r2

```
Connected to localhost.
Escape character is '^]'.

Hello, this is Quagga (version 0.99.22.4).
Copyright 1996-2005 Kunihiro Ishiguro, et al.


User Access Verification

Password:
r2> show ip rip
Codes: R - RIP, C - connected, S - Static, O - OSPF, B - BGP
Sub-codes:
      (n) - normal, (s) - static, (d) - default, (r) - redistribute,
      (i) - interface

     Network         Next Hop         Metric From            Tag Time
R(n) 192.168.1.0/24  192.168.2.1           2 192.168.2.1       0 02:47
C(i) 192.168.2.0/24  0.0.0.0               1 self              0
C(i) 192.168.3.0/24  0.0.0.0               1 self              0
R(n) 192.168.4.0/24  192.168.2.1           2 192.168.2.1       0 02:47
R(n) 192.168.5.0/24  192.168.3.12          2 192.168.3.12      0 02:55
R(n) 192.168.6.0/24  192.168.3.12          2 192.168.3.12      0 02:55
r2>
```

Router 3:

Kernel Routing Table

mininet@mininet-vm: ~/hw3

```
mininext> r3 route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.1.0     192.168.4.1     255.255.255.0   UG    2      0        0 r3-eth0
192.168.2.0     192.168.4.1     255.255.255.0   UG    2      0        0 r3-eth0
192.168.3.0     192.168.5.12    255.255.255.0   UG    2      0        0 r3-eth1
192.168.4.0     0.0.0.0         255.255.255.0   U     0      0        0 r3-eth0
192.168.5.0     0.0.0.0         255.255.255.0   U     0      0        0 r3-eth1
192.168.6.0     192.168.5.12    255.255.255.0   UG    2      0        0 r3-eth1
mininext>
```

Quagga Routing Table:

Node: r3

```
Connected to localhost.
Escape character is '^]'.

Hello, this is Quagga (version 0.99.22.4).
Copyright 1996-2005 Kunihiro Ishiguro, et al.


User Access Verification

Password:
r3> show ip rip
Codes: R - RIP, C - connected, S - Static, O - OSPF, B - BGP
Sub-codes:
      (n) - normal, (s) - static, (d) - default, (r) - redistribute,
      (i) - interface

     Network         Next Hop         Metric From            Tag Time
R(n) 192.168.1.0/24  192.168.4.1           2 192.168.4.1      0 02:34
R(n) 192.168.2.0/24  192.168.4.1           2 192.168.4.1      0 02:34
R(n) 192.168.3.0/24  192.168.5.12          2 192.168.5.12     0 02:40
C(i) 192.168.4.0/24  0.0.0.0               1 self             0
C(i) 192.168.5.0/24  0.0.0.0               1 self             0
R(n) 192.168.6.0/24  192.168.5.12          2 192.168.5.12     0 02:40
r3>
```

Router 4:

Kernel Routing Table

mininet@mininet-vm: ~/hw3

```
mininext> r4 route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.1.0     192.168.3.1     255.255.255.0   UG    3      0        0 r4-eth0
192.168.2.0     192.168.3.1     255.255.255.0   UG    2      0        0 r4-eth0
192.168.3.0     0.0.0.0         255.255.255.0   U     0      0        0 r4-eth0
192.168.4.0     192.168.5.1     255.255.255.0   UG    2      0        0 r4-eth1
192.168.5.0     0.0.0.0         255.255.255.0   U     0      0        0 r4-eth1
192.168.6.0     0.0.0.0         255.255.255.0   U     0      0        0 r4-eth2
mininext>
```

Quagga Routing Table:

Node: r4

```
Connected to localhost.
Escape character is '^]'.

Hello, this is Quagga (version 0.99.22.4).
Copyright 1996-2005 Kunihiro Ishiguro, et al.


User Access Verification

Password:
r4> show ip rip
Codes: R - RIP, C - connected, S - Static, O - OSPF, B - BGP
Sub-codes:
      (n) - normal, (s) - static, (d) - default, (r) - redistribute,
      (i) - interface

     Network         Next Hop         Metric From            Tag Time
R(n) 192.168.1.0/24  192.168.5.1           3 192.168.5.1       0 02:33
R(n) 192.168.2.0/24  192.168.3.1           2 192.168.3.1       0 02:40
C(i) 192.168.3.0/24  0.0.0.0               1 self              0
R(n) 192.168.4.0/24  192.168.5.1           2 192.168.5.1       0 02:33
C(i) 192.168.5.0/24  0.0.0.0               1 self              0
C(i) 192.168.6.0/24  0.0.0.0               1 self              0
r4>
```

Host 2:

Kernel Routing Table

mininet@mininet-vm: ~/hw3

```
mininext> h2 route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         192.168.6.1     0.0.0.0         UG    0      0        0 h2-eth0
192.168.1.0     192.168.6.1     255.255.255.0   UG    4      0        0 h2-eth0
192.168.2.0     192.168.6.1     255.255.255.0   UG    3      0        0 h2-eth0
192.168.3.0     192.168.6.1     255.255.255.0   UG    2      0        0 h2-eth0
192.168.4.0     192.168.6.1     255.255.255.0   UG    3      0        0 h2-eth0
192.168.5.0     192.168.6.1     255.255.255.0   UG    2      0        0 h2-eth0
192.168.6.0     0.0.0.0         255.255.255.0   U     0      0        0 h2-eth0
mininext>
```

Quagga Routing Table:

Node: h2

```
Connected to localhost.
Escape character is '^]'.

Hello, this is Quagga (version 0.99.22.4).
Copyright 1996-2005 Kunihiro Ishiguro, et al.


User Access Verification

Password:
h2> show ip rip
Codes: R - RIP, C - connected, S - Static, O - OSPF, B - BGP
Sub-codes:
      (n) - normal, (s) - static, (d) - default, (r) - redistribute,
      (i) - interface

     Network         Next Hop         Metric From            Tag Time
R(n) 192.168.1.0/24  192.168.6.1           4 192.168.6.1       0 02:48
R(n) 192.168.2.0/24  192.168.6.1           3 192.168.6.1       0 02:48
R(n) 192.168.3.0/24  192.168.6.1           2 192.168.6.1       0 02:48
R(n) 192.168.4.0/24  192.168.6.1           3 192.168.6.1       0 02:48
R(n) 192.168.5.0/24  192.168.6.1           2 192.168.6.1       0 02:48
C(i) 192.168.6.0/24  0.0.0.0               1 self              0
h2>
```

b) Traceroute Output:

Path between Nodes H1 -> H2

mininet@mininet-vm: ~/hw3

```
mininext> h1 traceroute h2
traceroute to 192.168.6.12 (192.168.6.12), 30 hops max, 60 byte packets
 1  192.168.1.12 (192.168.1.12)  0.115 ms  0.011 ms  0.005 ms
 2  192.168.2.12 (192.168.2.12)  0.019 ms  0.008 ms  0.006 ms
 3  192.168.3.12 (192.168.3.12)  0.017 ms  0.009 ms  0.008 ms
 4  192.168.6.12 (192.168.6.12)  0.018 ms  0.011 ms  0.010 ms
mininext>
```

Path between Nodes H2 -> H1

mininet@mininet-vm: ~/hw3

```
mininext> h2 traceroute h1
traceroute to 192.168.1.1 (192.168.1.1), 30 hops max, 60 byte packets
 1  192.168.6.1 (192.168.6.1)  0.022 ms  0.006 ms  0.005 ms
 2  192.168.3.1 (192.168.3.1)  0.011 ms  0.007 ms  0.007 ms
 3  192.168.2.1 (192.168.2.1)  0.017 ms  0.054 ms  0.011 ms
 4  192.168.1.1 (192.168.1.1)  0.017 ms  0.011 ms  0.018 ms
mininext>
```

Ping output for H1->H2

mininet@mininet-vm: ~/hw3

```
mininext> h1 ping -c 10 h2
PING 192.168.6.12 (192.168.6.12) 56(84) bytes of data.
64 bytes from 192.168.6.12: icmp_seq=1 ttl=61 time=0.039 ms
64 bytes from 192.168.6.12: icmp_seq=2 ttl=61 time=0.101 ms
64 bytes from 192.168.6.12: icmp_seq=3 ttl=61 time=0.102 ms
64 bytes from 192.168.6.12: icmp_seq=4 ttl=61 time=0.129 ms
64 bytes from 192.168.6.12: icmp_seq=5 ttl=61 time=0.099 ms
64 bytes from 192.168.6.12: icmp_seq=6 ttl=61 time=0.083 ms
64 bytes from 192.168.6.12: icmp_seq=7 ttl=61 time=0.126 ms
64 bytes from 192.168.6.12: icmp_seq=8 ttl=61 time=0.097 ms
64 bytes from 192.168.6.12: icmp_seq=9 ttl=61 time=0.097 ms
64 bytes from 192.168.6.12: icmp_seq=10 ttl=61 time=0.117 ms

--- 192.168.6.12 ping statistics ---
10 packets transmitted, 10 received, 0% packet loss, time 9002ms
rtt min/avg/max/mdev = 0.039/0.099/0.129/0.024 ms
mininext>
```

Ping output for H2->H1

mininet@mininet-vm: ~/hw3

```
mininext> h2 ping -c 10 h1
PING 192.168.1.1 (192.168.1.1) 56(84) bytes of data.
64 bytes from 192.168.1.1: icmp_seq=1 ttl=61 time=0.040 ms
64 bytes from 192.168.1.1: icmp_seq=2 ttl=61 time=0.109 ms
64 bytes from 192.168.1.1: icmp_seq=3 ttl=61 time=0.082 ms
64 bytes from 192.168.1.1: icmp_seq=4 ttl=61 time=0.103 ms
64 bytes from 192.168.1.1: icmp_seq=5 ttl=61 time=0.099 ms
64 bytes from 192.168.1.1: icmp_seq=6 ttl=61 time=0.098 ms
64 bytes from 192.168.1.1: icmp_seq=7 ttl=61 time=0.100 ms
64 bytes from 192.168.1.1: icmp_seq=8 ttl=61 time=0.097 ms
64 bytes from 192.168.1.1: icmp_seq=9 ttl=61 time=0.097 ms
64 bytes from 192.168.1.1: icmp_seq=10 ttl=61 time=0.113 ms

--- 192.168.1.1 ping statistics ---
10 packets transmitted, 10 received, 0% packet loss, time 9000ms
rtt min/avg/max/mdev = 0.040/0.093/0.113/0.023 ms
mininext>
```

c). Time Taken for Ping

Ping Time = 0.000873 seconds

```
mininet@mininet-vm:~/hw3$ sudo python start.py
h1 h1-eth0:r1-eth0
h2 h2-eth0:r4-eth2
r1 r1-eth0:h1-eth0 r1-eth1:r2-eth0 r1-eth2:r3-eth0
r2 r2-eth0:r1-eth1 r2-eth1:r4-eth0
r3 r3-eth0:r1-eth2 r3-eth1:r4-eth1
r4 r4-eth0:r2-eth1 r4-eth1:r3-eth1 r4-eth2:h2-eth0
h1 -> X X X X X
h2 -> h1 X X X X
Convergence Time:  0.005487
Ping time (h1 -> h2): 0.000873
r1 -> h1 h2 X X X
r2 -> h1 h2 X X X
r3 -> h1 h2 X X X
r4 -> h1 h2 X X X
```

To calculate ping time, two timestamp values were calculated:

1. Time taken for host h2 to ping host h1.
2. Time taken by icmp packet to reach host h1.

Hence, ping time is calculated as the difference of these timestamp values.

d). Convergence Time

Convergence Time = 0.005487 seconds

```
mininet@mininet-vm:~/hw3$ sudo python start.py
h1 h1-eth0:r1-eth0
h2 h2-eth0:r4-eth2
r1 r1-eth0:h1-eth0 r1-eth1:r2-eth0 r1-eth2:r3-eth0
r2 r2-eth0:r1-eth1 r2-eth1:r4-eth0
r3 r3-eth0:r1-eth2 r3-eth1:r4-eth1
r4 r4-eth0:r2-eth1 r4-eth1:r3-eth1 r4-eth2:h2-eth0
h1 -> X X X X X
h2 -> h1 X X X X
Convergence Time:  0.005487
Ping time (h1 -> h2): 0.000873
r1 -> h1 h2 X X X
r2 -> h1 h2 X X X
r3 -> h1 h2 X X X
r4 -> h1 h2 X X X
```

To calculate convergence time, I have made changes in start.py file. I have taken reference from Mininext convergence command code to write custom ping command. I have taken two timestamp values:

1. Initial timestamp before the execution of ping command.
2. Timestamp when h2 was able to ping h1.

Hence, convergence time is calculated as the difference of these timestamp values.

B3).

a) I have used the following command to down the link between r1 and r2:

link r1 r2 down

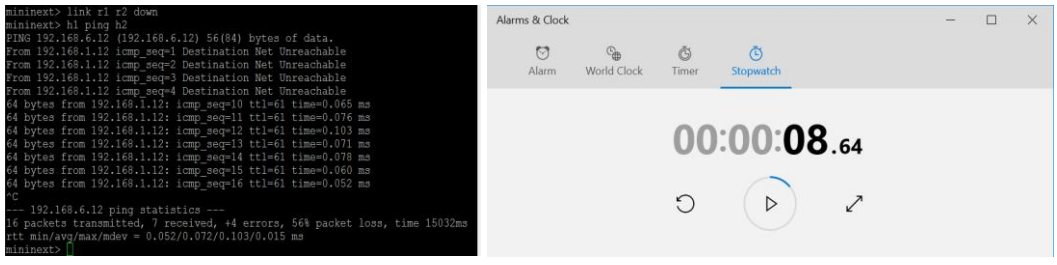
mininet@mininet-vm: ~/hw3

```
mininext> link r1 r2 down
mininext> h1 ping h2
PING 192.168.6.12 (192.168.6.12) 56(84) bytes of data.
From 192.168.1.12 icmp_seq=1 Destination Net Unreachable
From 192.168.1.12 icmp_seq=2 Destination Net Unreachable
From 192.168.1.12 icmp_seq=3 Destination Net Unreachable
From 192.168.1.12 icmp_seq=4 Destination Net Unreachable
64 bytes from 192.168.1.12: icmp_seq=8 ttl=61 time=0.185 ms
64 bytes from 192.168.1.12: icmp_seq=9 ttl=61 time=0.107 ms
64 bytes from 192.168.1.12: icmp_seq=10 ttl=61 time=0.103 ms
64 bytes from 192.168.1.12: icmp_seq=11 ttl=61 time=0.101 ms
64 bytes from 192.168.1.12: icmp_seq=12 ttl=61 time=0.168 ms
64 bytes from 192.168.1.12: icmp_seq=13 ttl=61 time=0.137 ms
64 bytes from 192.168.1.12: icmp_seq=14 ttl=61 time=0.107 ms
64 bytes from 192.168.1.12: icmp_seq=15 ttl=61 time=0.138 ms
64 bytes from 192.168.1.12: icmp_seq=16 ttl=61 time=0.099 ms
64 bytes from 192.168.1.12: icmp_seq=17 ttl=61 time=0.102 ms
64 bytes from 192.168.1.12: icmp_seq=18 ttl=61 time=0.073 ms
64 bytes from 192.168.1.12: icmp_seq=19 ttl=61 time=0.105 ms
64 bytes from 192.168.1.12: icmp_seq=20 ttl=61 time=0.101 ms
64 bytes from 192.168.1.12: icmp_seq=21 ttl=61 time=0.098 ms
^C
--- 192.168.6.12 ping statistics ---
21 packets transmitted, 14 received, +4 errors, 33% packet loss, time 20006ms
rtt min/avg/max/mdev = 0.073/0.116/0.185/0.029 ms
mininext>
```

b) Time taken for re-establishment of connection:

Command used: h1 ping h2

I set a time counter on my system to calculate the time, it was able to re-establish the connection in **08 sec 64 msec.**



c) Traceroute between h1->h2