CSE 534 HOMEWORK 3

PART A:

A1

The topo.py is submitted in the folder and the topology figure is as shown below.

```
mininext> pingall

*** Ping: testing ping reachability

h1 -> h2 r1 r2 r3 r4

h2 -> h1 r1 r2 r3 r4

r1 -> h1 h2 r2 r3 r4

r2 -> h1 h2 r1 r3 r4

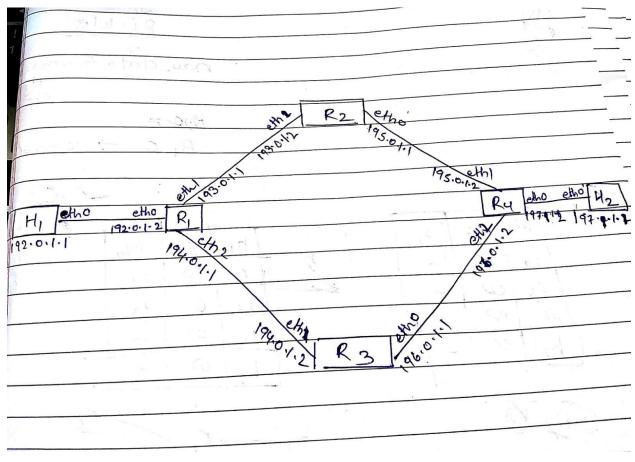
r3 -> h1 h2 r1 r3 r4

r4 -> h1 h2 r1 r2 r4

r4 -> h1 h2 r1 r2 r3

*** Results: 0% dropped (30/30 received)

mininext>_
```



The steps to be followed for enabling routing at each node are:

1. Enable the IP routing

```
net.get("r1").cmd("sysctl net.ipv4.ip_forward=1")
```

The above command enables the ip forward for node R1. Similarly, we need to set this to 1 for every node.

2. Configure and Assign Ips to all Interfaces.

We need to closely follow the topo.py file created and assign the ip address to each interface at each node. The interface Ip's should be in proper subnets which depends on the node it is being connected to.

```
net.get("r4").cmd("ifconfig r4-eth1 195.0.1.2")
```

The above command assigns the ip to r4 eth1 interface.

3. Add Proper routes between nodes

```
net.get("r1").cmd("ip route add 197.1.1.0/24 via 193.0.1.2")
```

The above command helps us add route to different destination from r1. The first ip addresses from left is the destination Ip address along with its subnet information. The second ip is the address through which the packet is being routed forward. We also set h1 and h2 as default gateway

mininext> hi route -n								
Kernel IP routi	ng table							
Destination	Gateway	Genmask	Flags	Metric	Ref		Iface	
0.0.0.0	192.0.1.2	0.0.0.0	UG	0	0		h1-eth0	
192.0.1.0	0.0.0.0	255.255.255.0	U	0	0	0	h1-eth0	
mininext> r1 ro								
Kernel IP routi								
Destination	Gateway	Genmask	_	Metric			Iface	
192.0.1.0	0.0.0.0	255.255.255.0	U	0	0	0	r1-eth0	
193.0.1.0	0.0.0.0	255.255.255.0	U	0	0		r1-eth1	
194.0.1.0	0.0.0.0	255.255.255.0	U	0	0		r1-eth2	
195.0.1.0	193.0.1.2	255.255.255.0	UG	0	0		r1-eth1	
196.0.1.0	194.0.1.2	255.255.255.0	UG	0	0		r1-eth2	
197.1.1.0	193.0.1.2	255.255.255.0	UG	0	0	0	r1-eth1	
mininext> r2 ro								
Kernel IP routi	_							
Destination	Gateway	Genmask		Metric			Iface	
192.0.1.0	193.0.1.1	255.255.255.0	UG	0	0		r2-eth0	
193.0.1.0	0.0.0.0	255.255.255.0	U	0	0		r2-eth0	
194.0.1.0	193.0.1.1	255.255.255.0	UG	0	0		r2-eth0	
195.0.1.0	0.0.0.0	255.255.255.0	U	0	0		r2-eth1	
196.0.1.0	195.0.1.2	255.255.255.0	UG	0	0		r2-eth1	
197.1.1.0	195.0.1.2	255.255.255.0	UG	0	0	0	r2-eth1	
				v	v	·	I D VVIII	
mininext> r3 ro		B001B001B001V			·	v	10 0011	
Kernel IP routi	ng table	200120012001					10 0011	
Kernel IP routi Destination	ng table Gateway	Genmask		Metric			Iface	
Kernel IP routi Destination 192.0.1.0	ng table Gateway 194.0.1.1	255.255.255.0	UG -	0	0	0	r3-eth0	
Kernel IP routi Destination 192.0.1.0 193.0.1.0	ng table Gateway 194.0.1.1 194.0.1.1	255.255.255.0 255.255.255.0	ug - ug	0 0	0 0	0 0	r3-eth0 r3-eth0	
Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0	ng table Gateway 194.0.1.1 194.0.1.1 0.0.0.0	255.255.255.0 255.255.255.0 255.255.255.0	ug - ug u	0 0 0	0 0 0	0 0 0	r3-eth0 r3-eth0 r3-eth0	
Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0	ng table Gateway 194.0.1.1 194.0.1.1 0.0.0.0 196.0.1.2	255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0	ug ug ug	0 0 0	0 0 0	0 0 0	r3-eth0 r3-eth0 r3-eth0 r3-eth1	
Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0 196.0.1.0	ng table Gateway 194.0.1.1 194.0.1.1 0.0.0.0 196.0.1.2 0.0.0.0	255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0	UG UG U UG U	0 0 0 0	0 0 0 0	0 0 0 0	r3-eth0 r3-eth0 r3-eth0 r3-eth1 r3-eth1	
Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0 196.0.1.0	ng table Gateway 194.0.1.1 194.0.1.1 0.0.0.0 196.0.1.2 0.0.0.0 196.0.1.2	255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0	ug ug ug	0 0 0	0 0 0	0 0 0 0	r3-eth0 r3-eth0 r3-eth0 r3-eth1	
Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0 196.0.1.0 mininext> r4 ro	ng table Gateway 194.0.1.1 194.0.1.1 0.0.0.0 196.0.1.2 0.0.0.0 196.0.1.2 oute -n	255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0	UG UG U UG U	0 0 0 0	0 0 0 0	0 0 0 0	r3-eth0 r3-eth0 r3-eth0 r3-eth1 r3-eth1	
Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0 196.0.1.0 mininext> r4 ro Kernel IP routi	ng table Gateway 194.0.1.1 194.0.1.1 0.0.0.0 196.0.1.2 0.0.0.0 196.0.1.2 oute -n ing table	255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0	UG U U UG U UG	0 0 0 0 0	0 0 0 0 0	0 0 0 0	r3-eth0 r3-eth0 r3-eth0 r3-eth1 r3-eth1 r3-eth1	
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Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0 196.0.1.0 mininext> r4 ro Kernel IP routi Destination 192.0.1.0	ng table Gateway 194.0.1.1 194.0.1.1 0.0.0.0 196.0.1.2 0.0.0.0 196.0.1.2 oute -n ing table Gateway 195.0.1.1	255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0	UG UG UG UG UG Flags UG	0 0 0 0 0 0 0	0 0 0 0 0 0 0	0 0 0 0 0 Use	r3-eth0 r3-eth0 r3-eth1 r3-eth1 r3-eth1 Iface r4-eth1	
Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0 196.0.1.0 mininext> r4 ro Kernel IP routi Destination 192.0.1.0 193.0.1.0	ng table Gateway 194.0.1.1 194.0.1.1 0.0.0.0 196.0.1.2 0.0.0.0 196.0.1.2 oute -n ing table Gateway 195.0.1.1	255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 Genmask 255.255.255.0 255.255.255.0	UG UG U UG U UG Flags UG UG	0 0 0 0 0 0 0 Metric 0	0 0 0 0 0 0 0 Ref 0	0 0 0 0 0 Use 0	r3-eth0 r3-eth0 r3-eth1 r3-eth1 r3-eth1 r4-eth1 r4-eth1	
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Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0 196.0.1.0 mininext> r4 ro Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0	Ing table Gateway 194.0.1.1 194.0.1.1 0.0.0.0 196.0.1.2 0.0.0.1 196.0.1.2 oute -n Ing table Gateway 195.0.1.1 196.0.1.1	255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0	UG UG UG UG UG Flags UG UG UG	0 0 0 0 0 0 Metric 0 0	0 0 0 0 0 0 0 Ref 0 0 0	0 0 0 0 0 Use 0 0	r3-eth0 r3-eth0 r3-eth1 r3-eth1 r3-eth1 r4-eth1 r4-eth2 r4-eth1	
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Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0 197.1.1.0 mininext> r4 ro Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 196.0.1.0 196.0.1.0	ng table Gateway 194.0.1.1 194.0.1.1 0.0.0.0 196.0.1.2 0.0.0.0 196.0.1.2 oute -n ing table Gateway 195.0.1.1 195.0.1.1 196.0.1.1 0.0.0.0 0.0.0.0	255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0	UG UG UG UG UG Flags UG UG UG	0 0 0 0 0 0 Metric 0 0	0 0 0 0 0 0 0 Ref 0 0 0	0 0 0 0 0 Use 0 0	r3-eth0 r3-eth0 r3-eth1 r3-eth1 r3-eth1 r4-eth1 r4-eth2 r4-eth1	
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Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0 197.1.1.0 mininext> r4 ro Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0 197.1.1.0 mininext> h2 ro Kernel IP routi	ng table Gateway 194.0.1.1 194.0.1.1 0.0.0.0 196.0.1.2 0.0.0.0 196.0.1.2 oute -n ing table Gateway 195.0.1.1 195.0.1.1 196.0.1.1 0.0.0.0 0.0.0.0 oute -n ing table	255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0	UG UG UG UG Flags UG UG UG U	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 Use 0 0 0	r3-eth0 r3-eth0 r3-eth1 r3-eth1 r3-eth1 Iface r4-eth1 r4-eth2 r4-eth2 r4-eth0	
Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0 196.0.1.0 mininext> r4 ro Kernel IP routi Destination 192.0.1.0 193.0.1.0 195.0.1.0 197.1.1.0 mininext> h2 ro Kernel IP routi Destination	ng table Gateway 194.0.1.1 194.0.1.1 0.0.0.0 196.0.1.2 0.0.0.0 196.0.1.2 oute -n ing table Gateway 195.0.1.1 195.0.1.1 0.0.0.0 0.0.0.0 oute -n ing table Gateway	255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0	UG U	0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	r3-eth0 r3-eth0 r3-eth0 r3-eth1 r3-eth1 r3-eth1 Iface r4-eth1 r4-eth2 r4-eth2 r4-eth0	
Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0 197.1.1.0 mininext> r4 ro Kernel IP routi Destination 192.0.1.0 193.0.1.0 194.0.1.0 195.0.1.0 197.1.1.0 mininext> h2 ro Kernel IP routi	ng table Gateway 194.0.1.1 194.0.1.1 0.0.0.0 196.0.1.2 0.0.0.0 196.0.1.2 oute -n ing table Gateway 195.0.1.1 195.0.1.1 196.0.1.1 0.0.0.0 0.0.0.0 oute -n ing table	255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0 255.255.255.0	UG UG UG UG Flags UG UG UG U	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 Use 0	r3-eth0 r3-eth0 r3-eth1 r3-eth1 r3-eth1 Iface r4-eth1 r4-eth2 r4-eth2 r4-eth0	

```
mininext> h1 traceroute h2
traceroute to 197.1.1.1 (197.1.1.1), 30 hops max, 60 byte packets
1 192.0.1.2 (192.0.1.2) 0.023 ms 0.004 ms 0.007 ms
2 193.0.1.2 (193.0.1.2) 0.010 ms 0.005 ms 0.004 ms
3 195.0.1.2 (195.0.1.2) 0.011 ms 0.006 ms 0.005 ms
4 197.1.1.1 (197.1.1.1) 0.009 ms 0.006 ms 0.006 ms
mininext>
```

PART B:

B1

The steps followed in this question are as follows:

- We need to modify the files inside the configs folder. In configs folder you will find a folder pertaining to each node. Initially these folders are empty and we need to add 4 files into each folder namely daemons, ripd.conf, debian.conf and zebra.conf.
- Daemons We need to create a file called daemons using command sudo vim daemons.
 This file you need to create at each node and add the same lines. In the daemon file created we add the following lines

```
zebra =yes
bgpd=no
ospfd=yes
ospf6d=no
ripd=no
ripngd=no
```

- **debian.conf** We need to copy this file from /etc/quagga/debian.conf using the command cp source destination with destination being our config folder having directories for each node. We do not modify this file.
- **zebra.conf** We need to copy this file from /usr/share/doc/quagga/examples/zebra.conf.sample using the command cp source destination with destination being our config folder having directories for each node. We rename this file as zebra.conf. We do not modify this file.
- **ripd.conf** We need to copy this file from /usr/share/doc/quagga/examples/ripd.conf.sample using the command cp source destination with destination being our config folder having directories for each node. We rename this file as ripd.conf. In this file we add every interface ip at each node. For eg in file for R1 we add:

```
router rip
network 192.0.1.2/24
network 193.0.1.1/24
network 194.0.1.1/24
```

After this we start the quagga services by sudo services quagga start. Also remember that in start.py we need to remove the routes that we added in part 1,RIP protocol will set up the routes. To check type pingall command in mininet CLI

<u>A</u>

1. Daemons at Each Node

winingut\	h1									
mininext>			MTIM		200				-	COMMAND
USER		иCPU		VSZ		TTY		START		COMMAND
root	1	0.0	0.0	12652	1444	tty1	S	23:21	0:00	bash -ms minine
t:h1										
quagga	35	0.0	0.0	24452	1100	?	Ss	23:21	0:00	/usr/lib/quagga
/zebrad	aemon	-A 1	27.0.	0.1						1 00
quagga	39	0.0	0.0	24336	1212	?	Ss	23:21	0:00	/usr/lib/quagga
/ripdda	emon	-A 12	7.0.0	.1						1 33
${f root}$	44	0.0	0.0	15404	512	?	Ss	23:21	0:00	/usr/lib/quagga
/watchquag	ga	daemo	m zebi	ra ripd						
root	58	0.0	0.0	1868 8	1296	tty1	R	23:48	0:00	ps aux
mininext>	h2 ps	aux								
USER	PID	>CPU	×MEM	VSZ	RSS	TTY	STAT	START	TIME	COMMAND
root	1	0.0	0.0	12652	1444	tty1	S	23:21	0:00	bash -ms minine
t:h2						_				
quagga	35	0.0	0.0	24452	1100	?	Ss	23:21	0:00	/usr/lib/quagga
/zebradaemon -A 127.0.0.1										
guagga	39	0.0	0.0	24336	1212	?	Ss	23:21	0:00	/usr/lib/quagga
ripddaemon -A 127.0.0.1										
root				15404	512	?	Ss	23:21	0:00	/usr/lib/quagga
/watchquaggadaemon zebra ripd										
root	5 7		0.0	18688	1296	tty1	R	23:48	0:00	ps aux
			·	·	The state of the s	_	The state of the s		The state of the s	•

mininext> r1 ps aux USER									
root 1 0.0 0.0 12652 1444 tty1 S 23:21 0:00 bash -ms minine t:r1 quagga 45 0.0 0.0 24452 1104 ? Ss 23:21 0:00 /usr/lib/quagga /zebradaemon -A 127.0.0.1 quagga 49 0.0 0.0 24336 1216 ? Ss 23:21 0:00 /usr/lib/quagga /ripddaemon -A 127.0.0.1 root 54 0.0 0.0 15404 512 ? Ss 23:21 0:00 /usr/lib/quagga /watchquaggadaemon zebra ripd root 69 0.0 0.0 18688 1296 tty1 R 23:22 0:00 ps aux mininext> r2 ps aux USER PID /CPU /MEM USZ RSS TTY STATT TIME COMMAND root 1 0.0 0.0 12652 1440 tty1 S 23:21 0:00 bash -ms minine t:r2									
t:r1 quagga									
quagga 45 0.0 0.0 24452 1104 ? Ss 23:21 0:00 /usr/lib/quagga /zebra daemon -R 127.0.0.1 Ss 23:21 0:00 /usr/lib/quagga /ripd daemon -R 127.0.0.1 Ss 23:21 0:00 /usr/lib/quagga /watchquagga daemon zebra ripd Ss 23:21 0:00 /usr/lib/quagga /watchquagga daemon zebra ripd Ss 23:21 0:00 /usr/lib/quagga /watchquagga daemon zebra ripd R 23:22 0:00 /usr/lib/quagga /watchquagga daemon zebra ripd R 23:22									
/zebradaemon -A 127.0.0.1 quagga									
quagga 49 0.0 0.0 24336 1216 ? Ss 23:21 0:00 /usr/lib/quagga /ripd daemon A 0.0 0.0 15404 512 ? Ss 23:21 0:00 /usr/lib/quagga /watchquagga daemon zebra ripd R 23:22 0:00 ps aux mininext> r2 ps aux USER PID xCPU xMEM VSZ RSS TTY STAT STAT TIME COMMAND root 1 0.0 0.0 12652 1440 tty1 S 23:21 0:00 bash -ms minine t:r2									
/ripddaemon -A 127.0.0.1 root 54 0.0 0.0 15404 512 ? Ss 23:21 0:00 /usr/lib/quagga /watchquaggadaemon zebra ripd root 69 0.0 0.0 18688 1296 tty1 R 23:22 0:00 ps aux mininext> r2 ps aux USER PID %CPU %MEM VSZ RSS ITY STAT START TIME COMMAND root 1 0.0 0.0 12652 1440 tty1 S 23:21 0:00 bash -ms minine t:r2									
root 54 0.0 0.0 15404 512 ? Ss 23:21 0:00 /usr/lib/quagga /watchquaggadaemon zebra ripd root 69 0.0 0.0 18688 1296 tty1 R 23:22 0:00 ps aux mininext> r2 ps aux USER PID //CPU /MEM USZ RSS TTY STAT TIME COMMAND root 1 0.0 0.0 12652 1440 tty1 S 23:21 0:00 bash -ms minine t:r2									
/watchquaggadaemon zebra ripd root 69 0.0 0.0 18688 1296 tty1 R 23:22 0:00 ps aux mininext> r2 ps aux USER PID ::CPU ::MEM USZ RSS TTY STAT START TIME COMMAND root 1 0.0 0.0 12652 1440 tty1 S 23:21 0:00 bash -ms minine t:r2									
root 69 0.0 0.0 18688 1296 tty1 R 23:22 0:00 ps aux mininext> r2 ps aux USER PID XCPU XMEM VSZ RSS TTY STAT START TIME COMMAND root 1 0.0 0.0 12652 1440 tty1 S 23:21 0:00 bash -ms minine t:r2									
mininext> r2 ps aux USER PID %CPU %MEM VSZ RSS TTY STAT START TIME COMMAND root 1 0.0 0.0 12652 1440 tty1 S 23:21 0:00 bash -ms minine t:r2									
USER PID %CPU %MEM VSZ RSS TTY STAT START TIME COMMAND root 1 0.0 0.0 12652 1440 tty1 S 23:21 0:00 bash -ms minine t:r2									
root 1 0.0 0.0 12652 1440 tty1 S 23:21 0:00 bash -ms minine $t:r2$									
t:r2									
quagga 40 0.0 0.0 24452 1100 ? Ss 23:21 0:00 /usr/lib/quagga									
/zebradaemon -A 127.0.0.1									
quagga 44 0.0 0.0 24336 1216 ? Ss 23:21 0:00/usr/lib/quagga									
/ripddaemon -A 127.0.0.1									
root 49 0.0 0.0 15404 512 ? Ss 23:21 0:00/usr/lib/quagga									
/watchquaggadaemon zebra ripd									
root 63 0.0 0.0 18688 1296 tty1 R 23:22 0:00 ps aux									

	2				-1	0091				Po aax
mininext>										
USER	PID	>CPU	>MEM	VSZ		TTY	STAT	START		COMMAND
root	1	0.0	0.0	12652	1444	tty1	S	23:21	0:00	bash -ms minine
t:r3										
quagga	40	0.0	0.0	24452	1100	?	Ss	23:21	0:00	/usr/lib/quagga
∕zebrad	laemor	1 –A 1	127.0.	0.1						
quagga	44	0.0	0.0	24336	1216	?	Ss	23:21	0:00	/usr/lib/quagga
∕ripdda	emon	-A 12	7.0.0	.1						
root	49	0.0	0.0	15404	512	?	Ss	23:21	0:00	/usr/lib/quagga
∕watchquag	ga	-daemo	m zeb	ra ripd						
root	63	0.0	0.0	18688	1292	tty1	R	23:24	0:00	ps aux
mininext>	r4 ps	aux								
USER	PIĎ	%CPU	×MEM	VSZ	RSS	TTY	STAT	START	TIME	COMMAND
root	1	0.0	0.0	12652	1444	tty1	S	23:21	0:00	bash -ms minine
t:r4										
quagga	45	0.0	0.0	24452	1100	?	Ss	23:21	0:00	/usr/lib/quagga
∕zebrad	laemor	1 –A 1	127.0.	0.1						
quagga	49	0.0	0.0	24336	1216	?	Ss	23:21	0:00	/usr/lib/quagga
/ripddaemon -A 127.0.0.1										
root	54	0.0	0.0	15404	512	?	Ss	23:21	0:00	/usr/lib/quagga
/watchquaggadaemon zebra ripd										
root	70	0.0	0.0	18688	1296	tty1	R	23:24	0:00	ps aux
								The second secon		

2. Routing Table at Each Node

	- aroppoa - cooroo						
mininext> h1 re							
Kernel IP rout	ing table						
Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
192.0.1.0	0.0.0.0	255.255.255.0	U	0	0	0	h1-eth0
193.0.1.0	192.0.1.2	255.255.255.0	UG	Z	0	0	h1-eth0
194.0.1.0	192.0.1.2	255.255.255.0	UG	2	0	0	h1-eth0
195.0.1.0	192.0.1.2	255.255.255.0	UG	3	0	0	h1-eth0
196.0.1.0	192.0.1.2	255.255.255.0	UG	3	0	0	h1-eth0
197.1.1.0	192.0.1.2	255.255.255.0	UG	4	0	0	h1-eth0
mininext> r1 r	oute -n						
Kernel IP rout	ing table						
Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
192.0.1.0	$0.0.0.\bar{0}$	255.255.255.0	U	0	0	0	r1-eth0
193.0.1.0	0.0.0.0	255.255.255.0	U	0	0	0	r1-eth1
194.0.1.0	0.0.0.0	255.255.255.0	U	0	0	0	r1-eth2
195.0.1.0	193.0.1.2	255.255.255.0	UG	2	0	0	r1-eth1
196.0.1.0	194.0.1.2	255.255.255.0	UG	2	0	0	r1-eth2
197.1.1.0	193.0.1.2	255.255.255.0	UG	3	0	0	r1-eth1
mininext> r2 r	oute -n						
Kernel IP rout	ing table						
Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
192.0.1.0	$193.0.\overline{1.1}$	255.255.255.0	UG -	2	0	0	r2-eth1
193.0.1.0	0.0.0.0	255.255.255.0	U	0	0	0	r2-eth1
194.0.1.0	193.0.1.1	255.255.255.0	UG	2	0	0	r2-eth1
195.0.1.0	0.0.0.0	255.255.255.0	U	0	0	0	r2-eth0
196.0.1.0	195.0.1.2	255.255.255.0	UG	2	0	0	r2-eth0
197.1.1.0	195.0.1.2	255.255.255.0	UG	2	0	0	r2-eth0

```
mininext> r3 route -n
Kernel IP routing table
Destination
                                                          Flags Metric Ref
                                                                                  Use Iface
                                      Genmask
                   Gateway
192.0.1.0
193.0.1.0
                   194.0.1.1
194.0.1.1
                                      255.255.255.0
255.255.255.0
                                                                 2
2
                                                                                    0 r3-eth1
                                                          UG
                                                                         0
                                                          UG
                                                                          0
                                                                                    0 r3-eth1
                                      255.255.255.0
194.0.1.0
                   0.0.0.0
                                                          ш
                                                                 0
                                                                          0
                                                                                    0 r3-eth1
195.0.1.0
                   196.0.1.2
                                      255.255.255.0
                                                          UG
                                                                 2
                                                                         0
                                                                                    0 r3-eth0
                   0.0.0.0
                                      255.255.255.0
255.255.255.0
                                                                 0
2
196.0.1.0
                                                          ш
                                                                         0
                                                                                    0 r3-eth0
                                                          UG
                                                                          0
197.1.1.0
                   196.0.1.2
                                                                                    0 r3-eth0
mininext> r4 route -n
Kernel IP routing table
Destination
                   Gateway
                                                                                  Use Iface
                                      Genmask
                                                          Flags Metric Ref
                                      255.255.255.0
                                                          UG
192.0.1.0
                   195.0.1.1
                                                                          0
                                                                                    0 r4-eth1
                                                                 3
2
2
193.0.1.0
                   195.0.1.1
                                      255.255.255.0
                                                          UG
                                                                          0
                                                                                    0 r4-eth1
194.0.1.0
195.0.1.0
                   196.0.1.1
                                      255.255.255.0
                                                                          0
                                                                                    0 r4-eth2
                                                          UG
                   0.0.0.0
                                      255.255.255.0
                                                                 0
                                                                         0
                                                                                    0 r4-eth1
                                                          U
                                                                                    0 r4-eth2
196.0.1.0
197.1.1.0
                   \substack{0.0.0.0\\0.0.0.0}
                                      255.255.255.0
                                                          П
                                                                 0
                                                                         0
                                      255.255.255.0
                                                          U
                                                                 0
                                                                         0
                                                                                    0 r4-eth0
mininext> h2 route -n
Kernel IP routing table
Destination
                   Gateway
                                      Genmask
                                                          Flags Metric Ref
                                                                                  Use Iface
                   197.1.1.2
197.1.1.2
197.1.1.2
192.0.1.0
193.0.1.0
                                                                                    0 h2-eth0
0 h2-eth0
                                      255.255.255.0
                                                          UG
                                                                 4
3
                                                                         0
                                      255.255.255.0
                                                          UG
                                                                          0
194.0.1.0
                                      255.255.255.0
                                                                 3
                                                                                    0 h2-eth0
                                                          UG
                                                                          0
                                                                 2
                   197.1.1.2
                                                                                    0 h2-eth0
195.0.1.0
                                      255.255.255.0
                                                          UG
                                                                         0
                   197.1.1.2
0.0.0.0
                                                                                    0 h2-eth0
                                      255.255.255.0
196.0.1.0
                                                          HG
                                                                         0
                                                                                    0 h2-eth0
                                      255.255.255.0
                                                                 o
                                                                          o
197.1.1.0
                                                          U
```

В

```
mininext> h1 traceroute h2
traceroute to 197.1.1.1 (197.1.1.1), 30 hops max, 60 byte packets
    192.0.1.2 (192.0.1.2) 0.020 ms 0.004 ms
                                                          0.003 \, \text{ms}
2
    193.0.1.2 (193.0.1.2)
                                 0.010 \text{ ms}
                                              0.004 \, \text{ms}
                                                          0.004 \text{ ms}
    195.0.1.2 (195.0.1.2)
                                 0.012 \text{ ms}
                                              0.007 \, \text{ms}
                                                          0.006 \, \text{ms}
                                 0.010 ms
                                                          0.008 ms
    197.1.1.1 (197.1.1.1)
                                              0.007 \, \text{ms}
4
mininext>
```

C

```
mininext> h1 ping -c 10 h2

PING 197.1.1.1 (197.1.1.1) 56(84) bytes of data.

64 bytes from 197.1.1.1: icmp_seq=1 ttl=61 time=0.032 ms

64 bytes from 197.1.1.1: icmp_seq=2 ttl=61 time=0.061 ms

64 bytes from 197.1.1.1: icmp_seq=3 ttl=61 time=0.055 ms

64 bytes from 197.1.1.1: icmp_seq=4 ttl=61 time=0.066 ms

64 bytes from 197.1.1.1: icmp_seq=5 ttl=61 time=0.082 ms

64 bytes from 197.1.1.1: icmp_seq=6 ttl=61 time=0.086 ms

64 bytes from 197.1.1.1: icmp_seq=7 ttl=61 time=0.070 ms

64 bytes from 197.1.1.1: icmp_seq=8 ttl=61 time=0.103 ms

64 bytes from 197.1.1.1: icmp_seq=9 ttl=61 time=0.066 ms

64 bytes from 197.1.1.1: icmp_seq=9 ttl=61 time=0.080 ms

--- 197.1.1.1 ping statistics ---

10 packets transmitted, 10 received, 0% packet loss, time 9000ms

rtt min/avg/max/mdev = 0.032/0.070/0.103/0.018 ms
```

The ping time is 0.07 ms

D.

I took the convergence time manually(using stop watch) by calculating the time between the typing of start command to getting the first ping response.

Convergence time= 14.60 ms

В3

1.

Initial Route R1- R2

```
traceroute to 197.1.1.1 (197.1.1.1), 30 hops max, 60 byte packets
 1 192.0.1.2 (192.0.1.2)
                                    0.019 ms
                                                  0.003 \, \text{ms}
                                                               0.003 \, \text{ms}
                                    0.011 \text{ ms}
 2 193.0.1.2 (193.0.1.2)
                                                  0.004 \, \text{ms}
                                                               0.004 \, \text{ms}
 3 195.0.1.2 (195.0.1.2)
                                    0.012 \text{ ms}
                                                  0.007 \, \text{ms}
                                                               0.005 \, \text{ms}
 4 197.1.1.1 (197.1.1.1)
                                    0.009 \, \text{ms}
                                                  0.007 \, \text{ms}
                                                               0.007 \text{ ms}
mininext>
```

Bring route down by command link r1 r2 down

2.

The time taken for connecting the link is again is 29.34 ms. This time path R1-R3 is used.

3.

```
mininext> h1 traceroute h2
traceroute to 197.1.1.1 (197.1.1.1), 30 hops max, 60 byte packets
1 192.0.1.2 (192.0.1.2)
                                 0.021 ms
                                              0.004 ms
                                                           0.003 \, \text{ms}
2 194.0.1.2 (194.0.1.2)
                                 0.011 \text{ ms}
                                              0.005 \text{ ms}
                                                           0.005 \, \text{ms}
   196.0.1.2 (196.0.1.2)
                                 0.010 \text{ ms}
                                              0.006 \, \text{ms}
                                                           0.006 \, \text{ms}
 4 197.1.1.1 (197.1.1.1) 0.012 ms
                                              0.007 \text{ ms}
                                                          0.007 \, \text{ms}
mininext>
```

PART C

C1

Initially I have maintained a dictionary of neighbors and dictionary of addresses of nodes present in topology. At each node I have a csv file which has information such nodes, its distance to other nodes and next hop to that node. For implementing topology, I have implemented a client Server model where I call class Server with parameters. This class creates a Server per node by spawning a Server Thread which the interacts with the clients at neighboring nodes. I also have a client thread at each node whose job is to accept the distance data frame sent by server thread and run Bell man ford on it and write the updated values to a file. The Server thread is continuously checking this file and if there is update in its distance vector it propagates this data frame to its neighbors. Also, for convergence I maintain a single file which I use to read the value of converge variable and when all variables are converged I say that the algorithm is converged. I have implemented bellman ford logic on the pandas data frame and when I get updated data frame I write to the common file at each node. For sending of data between the noes I have used pickle.

```
Nodes,Distance,NextHop
h1,1000,N
r1,1000,N
r2,6,r4
r3,7,r4
r4,2,r4
h2,0,N
mininet@mininet-vm:~/FCN/examples/q3c/quagga-ixp$__
```

C3

The Bellman ford algorithm can be used to detect the negative edge in the graph. We can used this to modifying the algorithm to changing the way it works. If in the Nth iteration where n is number of vertices the algorithm finds a loop we can make it backtrack until we reach edge through which we reach a node still not explored. Another way of thinking this is modifying the weight of negative link to average of the sum of weight of other links. Otherwise replacing it with 0 or median of weights of other links.