Part C: RIP-Lite

Distance Vector Routing is implemented using distributed Bellman-Ford algorithm. For periodically exchanging information between neighbors, socket programming is used. Client and Server programs are written. Each node has been assigned a different port number and same IP address. So overall, they will have unique identity. Initially, on all nodes servers are run, then clients are executed. All the initial weights are written in a file which is run for each node and distance vector for each node is initialized using that. After initialization, each client sends its distance vector to all its neighboring nodes. After this information exchange, Bellman Form algorithm is run on each node. If a path through a neighboring node results in a lesser weight, it is updated in its distance vector table. Client checks the modified time of the pickled file dumped after update. If it is modified, then client sends the updated information to all its neighbors.

C.1. a. Routing protocol code is present in the Part C folder.

b. Time taken to find the shortest path between h1 and h2: We started the start_timer after initialization. We started end_timer when the client first sends out its distance vector. On every update sent out by client to the servers, we keep on updating the end_timer. We check if the current and end_time is increasing, which means there is no update sent out, so the distance vector is stabilized. So, we report the time difference of end_timer and start_timer as the time taken to find the shortest route. Check client code for more details.

c. Screenshot of routing table at each node is present below along with time taken by each node for finding the shortest route.

```
/Users/abhinavadarsh/PycharmProjects/pap_analyser/venv/bin/python /Users/abhinavadarsh/Desktop/FCN_HW3/PartC/my_main.py 1 h2
('r4', ('2', 'h2'))
('r1', ('inf', '-'))
('r2', ('inf', '-'))
('r3', ('inf', '-'))
('h2', (0, 'h2'))
('h1', ('inf', '-'))
Server
('Node = ', 'h2')
('Port = ', 51006)
Socket created successfully
('Socket binded to ', 51006)
Socket is listening...
('Got connection from ', 51142)
('Got connection from ', 51148)
('Got connection from ', 51154)
('Got connection from ', 51160)
('Got connection from ', 51166)
('Got connection from ', 51172)
('Got connection from ', 51178)
('Got connection from ', 51184)
('Got connection from ', 51190)
('Got connection from ', 51196)
('Got connection from ', 51202)
('Got connection from ', 51208)
('Got connection from ', 51214)
```

```
/Users/abhinavadarsh/PycharmProjects/pap_analyser/venv/bin/python /Users/abhinavadarsh/Desktop/FCN_HW3/PartC/my_main.py 1 r1
('r4', ('inf', '-'))
('r1', (0, 'r1'))
('r2', ('10', 'r1'))
('r3', ('6', 'r1'))
('h2', ('inf', '-'))
('h1', ('2', 'r1'))
Server
('Node = ', 'r1')
('Port = ', 51002)
Socket created successfully
('Socket binded to ', 51002)
```

```
Socket is listening...
('Got connection from ', 51139)
('Got connection from ', 51145)
('Got connection from ', 51151)
('Got connection from ', 51157)
('Got connection from ', 51163)
('Got connection from ', 51169)
('Got connection from ', 51175)
('Got connection from ', 51181)
('Got connection from ', 51187)
('Got connection from ', 51193)
('Got connection from ', 51199)
('Got connection from ', 51205)
('Got connection from ', 51211)
```

```
/Users/abhinavadarsh/PycharmProjects/pap_analyser/venv/bin/python /Users/abhinavadarsh/Desktop/FCN_HW3/PartC/my_main.py 1 r2
('r4', ('4', 'r2'))
('r1', ('10', 'r2'))
('r2', (0, 'r2'))
('r3', ('inf', '-'))
('h2', ('inf', '-'))
('h1', ('inf', '-'))
Server
('Node = ', 'r2')
('Port = ', 51003)
Socket created successfully
('Socket binded to ', 51003)
Socket is listening...
('Got connection from ', 51140)
('Got connection from ', 51146)
('Got connection from ', 51152)
('Got connection from ', 51158)
('Got connection from ', 51164)
('Got connection from ', 51170)
('Got connection from ', 51176)
('Got connection from ', 51182)
('Got connection from ', 51188)
('Got connection from ', 51194)
('Got connection from ', 51200)
('Got connection from ', 51206)
('Got connection from ', 51212)
```

```
/Users/abhinavadarsh/PycharmProjects/pap_analyser/venv/bin/python /Users/abhinavadarsh/Desktop/FCN_HW3/PartC/my_main.py 1 r3
('r4', ('5', 'r3'))
('r1', ('6', 'r3'))
('r2', ('inf', '-'))
('r3', (0, 'r3'))
('h2', ('inf', '-'))
('h1', ('inf', '-'))
Server
('Node = ', 'r3')
('Port = ', 51004)
Socket created successfully
('Socket binded to ', 51004)
Socket is listening...
('Got connection from ', 51141)
('Got connection from ', 51147)
('Got connection from ', 51153)
('Got connection from ', 51159)
('Got connection from ', 51165)
('Got connection from ', 51171)
('Got connection from ', 51177)
('Got connection from ', 51183)
('Got connection from ', 51189)
('Got connection from ', 51195)
('Got connection from ', 51201)
```

```
('Got connection from ', 51207)
('Got connection from ', 51213)
```

```
/Users/abhinavadarsh/PycharmProjects/pap_analyser/venv/bin/python /Users/abhinavadarsh/Desktop/FCN_HW3/PartC/my_main.py 1 r4
('r4', (0, 'r4'))
('r1', ('inf', '-'))
('r2', ('4', 'r4'))
('r3', ('5', 'r4'))
('h2', ('2', 'r4'))
('h1', ('inf', '-'))
Server
('Node = ', 'r4')
('Port = ', 51005)
Socket created successfully
('Socket binded to ', 51005)
Socket is listening...
('Got connection from ', 51138)
('Got connection from ', 51144)
('Got connection from ', 51150)
('Got connection from ', 51156)
('Got connection from ', 51162)
('Got connection from ', 51168)
('Got connection from ', 51174)
('Got connection from ', 51180)
('Got connection from ', 51186)
('Got connection from ', 51192)
('Got connection from ', 51198)
('Got connection from ', 51204)
('Got connection from ', 51210)
```

```
/Users/abhinavadarsh/PycharmProjects/pap_analyser/venv/bin/python /Users/abhinavadarsh/Desktop/FCN_HW3/PartC/my_main.py 2 h1
('r4', ('inf', '-'))
('r1', ('2', 'h1'))
('r2', ('inf', '-'))
('r3', ('inf', '-'))
('h2', ('inf', '-'))
('h1', (0, 'h1'))
Client
('Node = ', 'h1')
('Port = ', 51001)
Socket created successfully
Node        Distance    Next Hop
r4                      inf                     -
r1                      2                       h1
r2                      inf                     -
r3                      inf                     -
h2                      inf                     -
h1                      0                       h1
Socket created successfully
Node        Distance    Next Hop
r4                      inf                     -
r1                      2                       h1
r2                      inf                     -
r3                      inf                     -
h2                      inf                     -
h1                      0                       h1
Socket created successfully
Node        Distance    Next Hop
r4                      inf                     -
r1                      2                       h1
r2                      inf                     -
r3                      inf                     -
h2                      inf                     -
h1                      0                       h1
Socket created successfully
Node        Distance    Next Hop
```

```
r4      inf     -
r1      2       h1
r2      inf     -
r3      inf     -
h2      inf     -
h1      0       h1
Socket created successfully
Node    Distance    Next Hop
r4      inf     -
r1      2       h1
r2      inf     -
r3      inf     -
h2      inf     -
h1      0       h1
Socket created successfully
Node    Distance    Next Hop
r4      inf     -
r1      2       h1
r2      inf     -
r3      inf     -
h2      inf     -
h1      0       h1
Node    Distance    Next Hop
r4      13      r3
r1      2       h1
r2      12      r1
r3      8       r1
h2      15      r4
h1      0       h1
Node    Distance    Next Hop
r4      13      r3
r1      2       h1
r2      12      r1
r3      8       r1
h2      15      r4
h1      0       h1
Node    Distance    Next Hop
r4      13      r3
r1      2       h1
r2      12      r1
r3      8       r1
h2      15      r4
h1      0       h1
Node    Distance    Next Hop
r4      13      r3
r1      2       h1
r2      12      r1
r3      8       r1
h2      15      r4
h1      0       h1
Node    Distance    Next Hop
r4      13      r3
r1      2       h1
r2      12      r1
r3      8       r1
h2      15      r4
h1      0       h1
Node    Distance    Next Hop
r4      13      r3
r1      2       h1
r2      12      r1
r3      8       r1
h2      15      r4
h1      0       h1
Convergence Time for h1 = 217.180967331 milliseconds
```

```
/Users/abhinavadarsh/PycharmProjects/pap_analyser/venv/bin/python /Users/abhinavadarsh/Desktop/FCN_HW3/PartC/my_main.py 2 h2
('r4', ('2', 'h2'))
('r1', ('inf', '-'))
('r2', ('inf', '-'))
('r3', ('inf', '-'))
('h2', (0, 'h2'))
('h1', ('inf', '-'))
Client
('Node = ', 'h2')
('Port = ', 51006)
Socket created successfully
Node    Distance    Next Hop
r4      2           h2
r1      inf         -
r2      inf         -
r3      inf         -
h2      0           h2
h1      inf         -
Socket created successfully
Node    Distance    Next Hop
r4      2           h2
r1      inf         -
r2      inf         -
r3      inf         -
h2      0           h2
h1      inf         -
Socket created successfully
Node    Distance    Next Hop
r4      2           h2
r1      inf         -
r2      inf         -
r3      inf         -
h2      0           h2
h1      inf         -
Socket created successfully
Node    Distance    Next Hop
r4      2           h2
r1      inf         -
r2      inf         -
r3      inf         -
h2      0           h2
h1      inf         -
Socket created successfully
Node    Distance    Next Hop
r4      2           h2
r1      inf         -
r2      inf         -
r3      inf         -
h2      0           h2
h1      inf         -
Socket created successfully
Node    Distance    Next Hop
r4      2           h2
r1      inf         -
r2      inf         -
r3      inf         -
h2      0           h2
h1      inf         -
Node    Distance    Next Hop
r4      2           h2
r1      inf         -
r2      6           r4
r3      7           r4
h2      0           h2
h1      inf         -
Node    Distance    Next Hop
```

r4	2	h2
r1	inf	-
r2	6	r4
r3	7	r4
h2	0	h2
h1	inf	-
Node	Distance	Next Hop
r4	2	h2
r1	inf	-
r2	6	r4
r3	7	r4
h2	0	h2
h1	inf	-
Node	Distance	Next Hop
r4	2	h2
r1	inf	-
r2	6	r4
r3	7	r4
h2	0	h2
h1	inf	-
Node	Distance	Next Hop
r4	2	h2
r1	inf	-
r2	6	r4
r3	7	r4
h2	0	h2
h1	inf	-
Node	Distance	Next Hop
r4	2	h2
r1	inf	-
r2	6	r4
r3	7	r4
h2	0	h2
h1	inf	-
Node	Distance	Next Hop
r4	2	h2
r1	13	r3
r2	6	r4
r3	7	r4
h2	0	h2
h1	15	r3
Node	Distance	Next Hop
r4	2	h2
r1	13	r3
r2	6	r4
r3	7	r4
h2	0	h2
h1	15	r3
Node	Distance	Next Hop
r4	2	h2
r1	13	r3
r2	6	r4
r3	7	r4
h2	0	h2
h1	15	r3
Node	Distance	Next Hop
r4	2	h2
r1	13	r3
r2	6	r4
r3	7	r4
h2	0	h2
h1	15	r3
Node	Distance	Next Hop
r4	2	h2
r1	13	r3
r2	6	r4

```
r3          7          r4
h2          0          h2
h1          15         r3
Node    Distance   Next Hop
r4          2          h2
r1          13         r3
r2          6          r4
r3          7          r4
h2          0          h2
h1          15         r3
Convergence Time for h2 = 416.51391983 milliseconds
```

```
/Users/abhinavadarsh/PycharmProjects/pap_analyser/venv/bin/python /Users/abhinavadarsh/Desktop/FCN_HW3/PartC/my_main.py 2 r1
('r4', ('inf', '-'))
('r1', (0, 'r1'))
('r2', ('10', 'r1'))
('r3', ('6', 'r1'))
('h2', ('inf', '-'))
('h1', ('2', 'r1'))
Client
('Node = ', 'r1')
('Port = ', 51002)
Socket created successfully
Node    Distance   Next Hop
r4          inf        -
r1          0          r1
r2          10         r1
r3          6          r1
h2          inf        -
h1          2          r1
Socket created successfully
Node    Distance   Next Hop
r4          inf        -
r1          0          r1
r2          10         r1
r3          6          r1
h2          inf        -
h1          2          r1
Socket created successfully
Node    Distance   Next Hop
r4          inf        -
r1          0          r1
r2          10         r1
r3          6          r1
h2          inf        -
h1          2          r1
Socket created successfully
Node    Distance   Next Hop
r4          inf        -
r1          0          r1
r2          10         r1
r3          6          r1
h2          inf        -
h1          2          r1
Socket created successfully
Node    Distance   Next Hop
r4          inf        -
r1          0          r1
r2          10         r1
r3          6          r1
h2          inf        -
h1          2          r1
Socket created successfully
Node    Distance   Next Hop
r4          inf        -
r1          0          r1
```

```
r2          10          r1
r3          6           r1
h2          inf         -
h1          2           r1
Node    Distance   Next Hop
r4          11          r3
r1          0           r1
r2          10          r1
r3          6           r1
h2          13          r4
h1          2           r1
Node    Distance   Next Hop
r4          11          r3
r1          0           r1
r2          10          r1
r3          6           r1
h2          13          r4
h1          2           r1
Node    Distance   Next Hop
r4          11          r3
r1          0           r1
r2          10          r1
r3          6           r1
h2          13          r4
h1          2           r1
Node    Distance   Next Hop
r4          11          r3
r1          0           r1
r2          10          r1
r3          6           r1
h2          13          r4
h1          2           r1
Node    Distance   Next Hop
r4          11          r3
r1          0           r1
r2          10          r1
r3          6           r1
h2          13          r4
h1          2           r1
Node    Distance   Next Hop
r4          11          r3
r1          0           r1
r2          10          r1
r3          6           r1
h2          13          r4
h1          2           r1
Convergence Time for r1 = 232.665061951 milliseconds
```

```
/Users/abhinavadarsh/PycharmProjects/pap_analyser/venv/bin/python /Users/abhinavadarsh/Desktop/FCN_HW3/PartC/my_main.py 2 r2
('r4', ('4', 'r2'))
('r1', ('10', 'r2'))
('r2', (0, 'r2'))
('r3', ('inf', '-'))
('h2', ('inf', '-'))
('h1', ('inf', '-'))
Client
('Node = ', 'r2')
('Port = ', 51003)
Socket created successfully
Node    Distance   Next Hop
r4          4           r2
r1          10          r2
r2          0           r2
r3          inf         -
h2          inf         -
h1          inf         -
```

```
Socket created successfully
Node	Distance	Next Hop
r4		4		r2
r1		10		r2
r2		0		r2
r3		inf		-
h2		inf		-
h1		inf		-
Socket created successfully
Node	Distance	Next Hop
r4		4		r2
r1		10		r2
r2		0		r2
r3		inf		-
h2		inf		-
h1		inf		-
Socket created successfully
Node	Distance	Next Hop
r4		4		r2
r1		10		r2
r2		0		r2
r3		inf		-
h2		inf		-
h1		inf		-
Socket created successfully
Node	Distance	Next Hop
r4		4		r2
r1		10		r2
r2		0		r2
r3		inf		-
h2		inf		-
h1		inf		-
Socket created successfully
Node	Distance	Next Hop
r4		4		r2
r1		10		r2
r2		0		r2
r3		inf		-
h2		inf		-
h1		inf		-
Node	Distance	Next Hop
r4		4		r2
r1		10		r2
r2		0		r2
r3		9		r4
h2		6		r4
h1		12		r1
Node	Distance	Next Hop
r4		4		r2
r1		10		r2
r2		0		r2
r3		9		r4
h2		6		r4
h1		12		r1
Node	Distance	Next Hop
r4		4		r2
r1		10		r2
r2		0		r2
r3		9		r4
h2		6		r4
h1		12		r1
Node	Distance	Next Hop
r4		4		r2
r1		10		r2
r2		0		r2
r3		9		r4
```

```
h2              6               r4
h1              12              r1
Node    Distance    Next Hop
r4              4               r2
r1              10              r2
r2              0               r2
r3              9               r4
h2              6               r4
h1              12              r1
Node    Distance    Next Hop
r4              4               r2
r1              10              r2
r2              0               r2
r3              9               r4
h2              6               r4
h1              12              r1
Convergence Time for r2 = 210.383892059 milliseconds
```

```
Users/abhinavadarsh/PycharmProjects/pap_analyser/venv/bin/python /Users/abhinavadarsh/Desktop/FCN_HW3/PartC/my_main.py 2 r3
('r4', ('5', 'r3'))
('r1', ('6', 'r3'))
('r2', ('inf', '-'))
('r3', (0, 'r3'))
('h2', ('inf', '-'))
('h1', ('inf', '-'))
Client
('Node = ', 'r3')
('Port = ', 51004)
Socket created successfully
Node    Distance    Next Hop
r4              5               r3
r1              6               r3
r2              inf             -
r3              0               r3
h2              inf             -
h1              inf             -
Socket created successfully
Node    Distance    Next Hop
r4              5               r3
r1              6               r3
r2              inf             -
r3              0               r3
h2              inf             -
h1              inf             -
Socket created successfully
Node    Distance    Next Hop
r4              5               r3
r1              6               r3
r2              inf             -
r3              0               r3
h2              inf             -
h1              inf             -
Socket created successfully
Node    Distance    Next Hop
r4              5               r3
r1              6               r3
r2              inf             -
r3              0               r3
h2              inf             -
h1              inf             -
Socket created successfully
Node    Distance    Next Hop
r4              5               r3
r1              6               r3
r2              inf             -
r3              0               r3
```

```
h2                      inf                     -
h1                      inf                     -
Socket created successfully
Node        Distance    Next Hop
r4                      5                       r3
r1                      6                       r3
r2                      inf                     -
r3                      0                       r3
h2                      inf                     -
h1                      inf                     -
Node        Distance    Next Hop
r4                      5                       r3
r1                      6                       r3
r2                      9                       r4
r3                      0                       r3
h2                      7                       r4
h1                      8                       r1
Node        Distance    Next Hop
r4                      5                       r3
r1                      6                       r3
r2                      9                       r4
r3                      0                       r3
h2                      7                       r4
h1                      8                       r1
Node        Distance    Next Hop
r4                      5                       r3
r1                      6                       r3
r2                      9                       r4
r3                      0                       r3
h2                      7                       r4
h1                      8                       r1
Node        Distance    Next Hop
r4                      5                       r3
r1                      6                       r3
r2                      9                       r4
r3                      0                       r3
h2                      7                       r4
h1                      8                       r1
Node        Distance    Next Hop
r4                      5                       r3
r1                      6                       r3
r2                      9                       r4
r3                      0                       r3
h2                      7                       r4
h1                      8                       r1
Node        Distance    Next Hop
r4                      5                       r3
r1                      6                       r3
r2                      9                       r4
r3                      0                       r3
h2                      7                       r4
h1                      8                       r1
Convergence Time for r3 = 209.877967834 milliseconds
```

```
/Users/abhinavadarsh/PycharmProjects/pap_analyser/venv/bin/python /Users/abhinavadarsh/Desktop/FCN_HW3/PartC/my_main.py 2 r4
('r4', (0, 'r4'))
('r1', ('inf', '-'))
('r2', ('4', 'r4'))
('r3', ('5', 'r4'))
('h2', ('2', 'r4'))
('h1', ('inf', '-'))
Client
('Node = ', 'r4')
('Port = ', 51005)
Socket created successfully
Node        Distance    Next Hop
```

```
r4        0         r4
r1        inf       -
r2        4         r4
r3        5         r4
h2        2         r4
h1        inf       -
Socket created successfully
Node    Distance    Next Hop
r4        0         r4
r1        inf       -
r2        4         r4
r3        5         r4
h2        2         r4
h1        inf       -
Socket created successfully
Node    Distance    Next Hop
r4        0         r4
r1        inf       -
r2        4         r4
r3        5         r4
h2        2         r4
h1        inf       -
Socket created successfully
Node    Distance    Next Hop
r4        0         r4
r1        inf       -
r2        4         r4
r3        5         r4
h2        2         r4
h1        inf       -
Socket created successfully
Node    Distance    Next Hop
r4        0         r4
r1        inf       -
r2        4         r4
r3        5         r4
h2        2         r4
h1        inf       -
Socket created successfully
Node    Distance    Next Hop
r4        0         r4
r1        inf       -
r2        4         r4
r3        5         r4
h2        2         r4
h1        inf       -
Node    Distance    Next Hop
r4        0         r4
r1        11        r3
r2        4         r4
r3        5         r4
h2        2         r4
h1        13        r3
Node    Distance    Next Hop
r4        0         r4
r1        11        r3
r2        4         r4
r3        5         r4
h2        2         r4
h1        13        r3
Node    Distance    Next Hop
r4        0         r4
r1        11        r3
r2        4         r4
r3        5         r4
h2        2         r4
```

```
h1                  13                  r3
Node        Distance    Next Hop
r4                  0                   r4
r1                  11                  r3
r2                  4                   r4
r3                  5                   r4
h2                  2                   r4
h1                  13                  r3
Node        Distance    Next Hop
r4                  0                   r4
r1                  11                  r3
r2                  4                   r4
r3                  5                   r4
h2                  2                   r4
h1                  13                  r3
Node        Distance    Next Hop
r4                  0                   r4
r1                  11                  r3
r2                  4                   r4
r3                  5                   r4
h2                  2                   r4
h1                  13                  r3
Convergence Time for r4 = 217.298030853 milliseconds
```

C2. A. If any weight is changed in the weights file, we keep on checking it periodically every 15 seconds. If there is any change in the weight, we update the distance vector of the connecting nodes of the link updated. Time taken for convergence is measured in similar way as for part C1.b.
The distance vector, for this example r1 and r3 are initialized again from the weights file and algorithm is run again for convergence.

C3. If one of the links has a negative weight, explain how you handle this situation.
If a network topology contains a negative weight, then on each comparison the weight lowers and it can keep on running forever. But, Bellman ford algorithm can detect the negative weights in a graph and can signal that. It adds a check after the relax function to see if there is a negative cycle. If there are no negative cycles, then after relaxation function, all weights should be at their lowest value. But, if the below check is true for any edge, then that edge is negative.

```
// Step 3: check for negative-weight cycles
for each edge (u, v) with weight w in edges:
    if distance[u] + w < distance[v]:
        error "Graph contains a negative-weight cycle"
```

Reference: https://en.wikipedia.org/wiki/Bellman%E2%80%93Ford_algorithm

One way to handle the negative weights would be to limit the number of times the algorithm runs (similar to number of hops limited to 16).