ILLINOIS INSTITUTE
OF TECHNOLOGY

CS 542 PROJECT REPORT

LINK-STATE ROUTING ALGORITHM

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Abstract

The goal or the main purpose of the project is to bring in execution of the link-state routing protocol by using Dijkstra's Algorithm in JAVA

Objectives

The intents of the project are as follows:

- ➢ Create the topology of the network
- ➢ Generate the forwarding table for each router
- ➢ Identify the shortest path from the source to the destination using Dijkstra's Algorithm
- ➢ Modify the topology for any router which is not robust or which is down
- ➢ Figure out the best router from the network topology that can be used for broadcasting

Link-State Routing Protocol

- ➢ It is one of the protocol used for routing in packet switching network
- ➢ In link-state routing the network topology is formed by using the graph
- ➢ Each node in the graph represents the router
- ➢ Each edge represents the link between the routers
- ➢ Also there are weights that are assigned to each link in the graph (R0➔ R1)
- ➢ Here, the weight on the link between the two routers is the cost which would be incurred to send a packet from one router to the other
- ➢ There is no broadcast of the entire routing table taking place by the router
- ➢ All the routers they send the Link state packets (LSP) which has the information related to the links to which it is directly connected to
- ➢ The router sends these information or LSP either periodically (say every hour) or whenever there is modification in the network topology
- ➢ Also every router or node in the network topology computes its own routing table or forwarding table
- ➢ Also this algorithm is used when you have a network topology and also weights assigned to every link in the network topology
- ➢ The routing table is computed by using the shortest path algorithm
- ➢ The shortest path is found from source to all the nodes in the network topology by using Dijkkstra's Algorithm

Dijkstra's Algorithm

- It is used in computation of the shortest path from source to the destination and here the destination is all the other nodes

- After computing the shortest paths the forwarding or the routing table is generated which has two columns

- First column is the destination router no. and the second one is the interface link i.e. the out link to which the router needs to send the packet to in order to forward it to the next router

- It is based on iterations i.e. say if you went for n iterations then you will get the shortest path for n destinations

- The main steps of this algorithm are **initialization** and **looping**

Steps / Pseudocode

1. *Initialization*

2. *Mark the source u = visited*

3. *For all nodes v*

4. *If : v is neighbor of u*

5. *then D(v) = c (u,v)*

6. *Else : D(v) = Infinity*

7. *Loop :*

8. *Find node w not visited and who's D(w) = min*

9. *Mark node w as visited*

10. *Update D(v) for all the neighbor v of w , not visited*

11. *Set D(v) = min (D(v) + D(w) + c(w,v))*

12. */* new cost to v is either the old cost to v or least cost of the path to w + cost from w to v */*

13. *Repeat unless all the nodes are visited*

Explanation

The following are the notations used:

u : Source node , w: Not visited node

D(v) : least cost from source u to destination v

C(u,v) : It is the cost on the link which is incurred to send a packet from node u to v and is infinity when there is no direct connection or link between the node and I have used -1 for the same in the project

- **In the initialization step:**

❏ Mark the source as the visited

❏ Search for all the neighbors of u and if node is neighbor then find the cost from u to v

[c(u,v)] and store in D(v)

❏ And If the node is not neighbor of u then set D(v) = infinity

- **Loop the following steps until and unless all the nodes in the topology are visited:**

❏ Find the node w which is not visited and who's distance i.e. D(w) is min. and mark it as visited

❏ Then set the distance D(v) for each of its neighbor v of w which are not visited as the minimum of the old cost to v or least cost to w + cost from node w to node v

Design of the Project

➢ The simulator or the program takes input as the text file which has the matrix i.e. the values in the matrix are the cost from node/router i to j
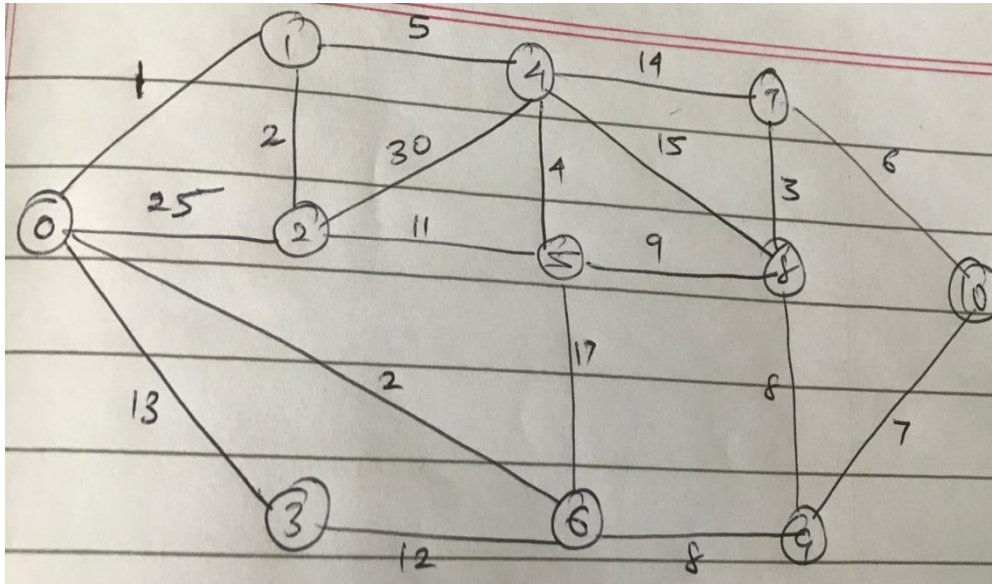➢ The network topology which I created and worked on it is shown below:

Fig. 1: Network Topology

➢ The text file of the above network topology contained the following matrix:

Fig. 2: text file

➢ **The project has 2 java files :**

1. **Simulator.java**
   - This has the main function and when its run it will display the main menu
   - The user here is asked to select the option one by one for which the user wants the simulator to perform. For this switch case is used.
   - This java files calls the functions which are present in SimulatorFunctionality.java according to the user who selects what is need to be done

2. **SimulatorFunctionality.java**
   - This file contains all the functions which are being called by the main file
   - The following are the functions present in this file:
     a. take_file(): This will take text file as input from the user by letting user enter the file path .It will also throw an error if the user inputs the wrong file path
     b. show_matrix() : This displays the network topology in the form of the matrix
     c. getShortestPaths() : It takes input as the source router and the adjacency matrix and generates the shortest path between the source to all other routers in the network topology using findMinimum() function
     d. getShortestPathBetweenRouters(): It will take input as the source router, destination router and the adjacency matrix and displays the shortest path from the source to the given destination
     e. findMinimum(): It takes cost array and visited array as the input and then finds the current minimum cost and its index. Thereafter it returns the min. cost and its index of the router
     f. getForwardingTable(): It will take adjacency matrix and the router for which the forwarding table is to be displayed as an input and evaluates the routing table for that router. Then it displays the table with two columns: Destination and Interface Link
     g. getBroadcastingRouter(): It takes adjacency matrix as an input and calculates sum of the array (using getSumofArray() function) of all the shortest paths for all the routers. And then prints the router that has the min. total cost which is the best broadcasting router and also displays the total cost of all the routers
     h. getSumofArray(): It takes input as an array and returns the sum of that array
     i. isNumeric(): It takes input as a String and if the input is numeric then it returns false.This function I have used to handle the error i.e. the program

does not allow the user to input the router no. as a letter as the router number here are numeric

j. modificationOfTopology(): It will take input as an adjacency matrix and will ask for the router which is down and will make that routers row and column values in the adjacency matrix as -1. Then again it displays the new network topology and the shortest path , shortest distance from source and destination (as in case there can be changes in the shortest path if the router that is down was a part of the shortest path)

Assumptions

➢ If say the node i and node j are not connected directly then value of node(i,j) in the adjacency matrix is -1
➢ Also the value of node(i,i) is 0 i.e. the self-node has the value as zero
➢ If the node i and j are directly connected say with the cost as c then the value of node(i,j) in the adjacency matrix is c

Test Cases / Test Report

Note: The text file which is given as the input (here, topology3.txt) is put in the same folder where the .jar file and .bat file are present

Network topology graph:
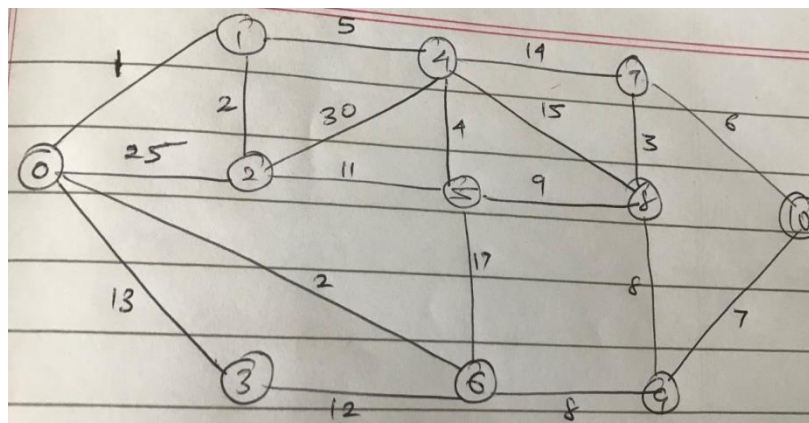
Text file: topology3.txt

Test cases:

1. **Expected output:** Menu displayed when the Simulator.java is run and asks the user to input the choice:

   Actual Output: Menu is displayed after running the program and user is asked to display the choice. As expected

2. **Expected output:** Network topology should be displayed when user selects 1st option and and user should be asked to input the file path or the file name. After the matrix is displayed again the main menu should be displayed

   Actual Output: Below the matrix is displayed for the user's file and again after that main menu is displayed.As expected

Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 12, 2017, 2:28:20 PM)

```
Enter your choice from the Menu displayed
1
********** Network topology **********
Enter the filename (Please Enter the path of the file)
topology3.txt
The # Routers = 11
********** The network topology is shown below: **********
        R0      R1      R2      R3      R4      R5      R6      R7      R8      R9      R10

R0      0       1       25      13      -1      -1      2       -1      -1      -1      -1
R1      1       0       2       -1      5       -1      -1      -1      -1      -1      -1
R2      25      2       0       -1      30      11      -1      -1      -1      -1      -1
R3      13      -1      -1      0       -1      -1      12      -1      -1      -1      -1
R4      -1      5       30      -1      0       4       -1      14      15      -1      -1
R5      -1      -1      11      -1      4       0       17      -1      9       -1      -1
R6      2       -1      -1      12      -1      17      0       -1      -1      8       -1
R7      -1      -1      -1      -1      14      -1      -1      0       3       -1      6
R8      -1      -1      -1      -1      15      9       -1      3       0       8       -1
R9      -1      -1      -1      -1      -1      -1      8       -1      8       0       7
R10     -1      -1      -1      -1      -1      -1      -1      6       -1      7       0

---    Simulator Displays Following Menu    ---
What would you like simulator to perform:
1. Creation of the Network Topology
2. Building a forwarding table
3. Generation of the shortest path from source to destination router
4. Modification in topology
5. Best broadcasting router
6. Exit
```

3. **Expected Output:** The forwarding table for the router is displayed when user selects 2nd option and then again displays the main menu

   Actual Output: Here, forwarding table for router 4 is displayed. As expected

```
Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 12, 2017, 2:28:20 PM)

Enter your choice from the Menu displayed
2
********** Forwarding Table **********
Enter Router number:
4
Destination       Interface Link
    0                 1
    1                 1
    2                 1
    3                 1
    4                 -
    5                 5
    6                 1
    7                 7
    8                 5
    9                 1
   10                 7
---    Simulator Displays Following Menu    ---
What would you like simulator to perform:
1. Creation of the Network Topology
2. Building a forwarding table
3. Generation of the shortest path from source to destination router
4. Modification in topology
5. Best broadcasting router
6. Exit

Enter your choice from the Menu displayed
```

4. **Expected Output:** Generates the shortest path and shortest distance from given source to destination if the user selects 3rd option. Again the main menu should be displayed.

   Actual Output: Here, Source router is 1 and destination router is 6 and shortest distance is 3 and path is 6←0←1.As expected

```
Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 12, 2017, 2:28:20 PM)
Enter your choice from the Menu displayed
3
Enter the Source Router
1
Enter the Destination Router
6
Shortest distance from 1 to 6 is: 3
Shortest path from 1 to 6 is:
6<--0<--1
---   Simulator Displays Following Menu   ---
What would you like simulator to perform:
1. Creation of the Network Topology
2. Building a forwarding table
3. Generation of the shortest path from source to destination router
4. Modification in topology
5. Best broadcasting router
6. Exit

Enter your choice from the Menu displayed
```

5. **Expected Output:** If the router is down then user should be able modify the topology and generate the new shortest path and also shortest distance by selecting the 4th option. Also it should display the new network topology with the router which is shut's value of rows and column in adjacency matrix as -1 (here, the router 0 is down and the new shortest path and distance is calculated from 1 to 6). Again the main menu should be displayed thereafter.

Actual Output: Here, Router 0 is down which was a part of the shortest path from 1 to 6 (see point 4), hence new shortest path is calculated from 1 to 6 as 6←5←4←1 with cost as 26. Hence, output is as expected.

```
Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 15, 2017, 1:14:39 PM)
Enter your choice from the Menu displayed
4
Enter the router # to be shut:
0
```

	R0	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
R0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
R1	-1	0	2	-1	5	-1	-1	-1	-1	-1	-1
R2	-1	2	0	-1	30	11	-1	-1	-1	-1	-1
R3	-1	-1	-1	0	-1	-1	12	-1	-1	-1	-1
R4	-1	5	30	-1	0	4	-1	14	15	-1	-1
R5	-1	-1	11	-1	4	0	17	-1	9	-1	-1
R6	-1	-1	-1	12	-1	17	0	-1	-1	8	-1
R7	-1	-1	-1	-1	14	-1	-1	0	3	-1	6
R8	-1	-1	-1	-1	15	9	-1	3	0	8	-1
R9	-1	-1	-1	-1	-1	-1	8	-1	8	0	7
R10	-1	-1	-1	-1	-1	-1	-1	6	-1	7	0

```
In order to display Shortest path and distance no Source Router was found
Enter the Source Router :
1
In order to display Shortest path and distance no destination Router was found
Enter the Destination Router :
6
Shortest distance from 1 to 6 is: 26
Shortest path from 1 to 6 is:
6<--5<--4<--1
---   Simulator Displays Following Menu   ---
What would you like simulator to perform:
```

6. **Expected Output:** User selects 5th option in order to find the best broadcasting router. The program should also display the total cost for all the routers. Again the main menu should be displayed.

   Actual Output: Here, the best router that can be used for broadcasting is router 0 with min. total cost of 100 among all other routers. As expected

```
Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 12, 2017, 8:56:33 AM)

Enter your choice from the Menu displayed
5
*****Best broadcasting router******
Best Router for Broadcasting is router 0 with a total cost of 100
All other Routers      Total Cost
     0                  100
     1                  100
     2                  118
     3                  203
     4                  112
     5                  125
     6                  100
     7                  156
     8                  142
     9                  121
    10                   157
---   Simulator Displays Following Menu    ---
What would you like simulator to perform:
1. Creation of the Network Topology
2. Building a forwarding table
3. Generation of the shortest path from source to destination router
4. Modification in topology
5. Best broadcasting router
6. Exit
```

7. **Expected Output:** When a user selects some other options before creating the topology the program says : "Please create a network topology before proceeding"

   Actual Output: "Please create a network topology before proceeding" is displayed hence as expected

```
Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 12, 2017, 8:10:01 PM)
---    Simulator Displays Following Menu    ---
What would you like simulator to perform:
1. Creation of the Network Topology
2. Building a forwarding table
3. Generation of the shortest path from source to destination router
4. Modification in topology
5. Best broadcasting router
6. Exit

Enter your choice from the Menu displayed
3
Please create a network topology before proceeding
---    Simulator Displays Following Menu    ---
What would you like simulator to perform:
1. Creation of the Network Topology
2. Building a forwarding table
3. Generation of the shortest path from source to destination router
4. Modification in topology
5. Best broadcasting router
6. Exit

Enter your choice from the Menu displayed
```

8. **Expected Output:** After every time a user selects one of the option and then user gets the output then again the main menu should be displayed every time

   Actual Output: Main menu is displayed as expected (Here, it is displayed after the user selects the 5th option to get the best broadcasting router and gets the output)

```
Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 12, 2017, 8:56:33 AM)


Enter your choice from the Menu displayed
5
*****Best broadcasting router******
Best Router for Broadcasting is router 0 with a total cost of 100
All other Routers      Total Cost
      0                    100
      1                    100
      2                    118
      3                    203
      4                    112
      5                    125
      6                    100
      7                    156
      8                    142
      9                    121
     10                       157
---    Simulator Displays Following Menu    ---
What would you like simulator to perform:
1. Creation of the Network Topology
2. Building a forwarding table
3. Generation of the shortest path from source to destination router
4. Modification in topology
5. Best broadcasting router
6. Exit
```

9. **Expected Output:** When the user selects the 6th option user should be able to exit from the simulation

   Actual Output: The program exits saying "Good Bye" as expected


```
<terminated> Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 12, 2017, 8:10:01 PM)


Enter your choice from the Menu displayed
6
Exiting from simulation
GOOD BYE !
CS542-04 Fall Project 2017
```

10. **Expected Output:** When the user inputs the option no. other than from 1-6,program should not allow it and display that enter valid option no.

   Actual Output: Here the user entered 8 hence program displayed "Your choice should be from 1-6 Menu options" as expected


```
Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 12, 2017, 8:25:39 PM)
Enter your choice from the Menu displayed
8

 Your choice should be from 1 - 6 Menu Options


---   Simulator Displays Following Menu   ---
What would you like simulator to perform:
1. Creation of the Network Topology
2. Building a forwarding table
3. Generation of the shortest path from source to destination router
4. Modification in topology
5. Best broadcasting router
6. Exit

Enter your choice from the Menu displayed
```

11. **Expected Output:** If user enters the choice as the character then it should display "Choice not valid" and ask user to "Enter a valid menu option from 1-6"

   Actual Output: Here the user entered 'a' hence program displayed "Choice not valid" and asked user to "Enter a valid menu option from 1-6" as expected

```
Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 12, 2017, 8:25:39 PM)
Enter your choice from the Menu displayed
a

  ERROR:  Choice not valid
          Enter a valid Menu option from 1 - 6
```

12. **Expected Output:** If user enters wrong file name or path then the program should display "INCORRECT INPUT !"

   Actual Output: Here user entered wrong file name and the above messaged was displayed

```
Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 17, 2017, 12:28:27 AM)

Enter your choice from the Menu displayed
1
********** Network topology **********
Enter the filename (Please Enter the path of the file)
sfe
INCORRECT INPUT !
```

13. **Expected Output:** If user enters the input file in which the matrix is not the square matrix then the program should display "INCORRECT INPUT !"

   Actual Output: Here user entered file which contained a matrix which was not a square matrix then "INCORRECT INPUT !" message was displayed

```
Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 17, 2017, 12:31:28 AM)

Enter your choice from the Menu displayed
1
********** Network topology **********
Enter the filename (Please Enter the path of the file)
topology3.txt
INCORRECT INPUT !
```

14. **Expected Output:** If user enters the router no. > then the no. of routers present then "Not valid router no." and "enter a valid router" should be displayed

    Actual Output: Here the user wants the forwarding table for the router no. 12 but we only have 0 to 10 routers hence it displays enter valid router no.

```
Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 12, 2017, 8:46:50 PM)
Enter your choice from the Menu displayed
2
********** Forwarding Table **********
Enter Router number:
12

 ERROR: Not valid router #
 Enter a valid Router no. from 0 to 10
```

15. **Expected Output:** If user tries to enter router no. other than 0 to the no. of routers present in the text file and also if user enters router no. as character then program displays not valid router no.

    Actual Output: Here the user enter router no. 13 and we don't have 13 routers in topology and also user enters source router as 'b' which is not a valid router no. hence the program displays not valid router no. as shown below

```
Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 12, 2017, 8:46:50 PM)
Enter your choice from the Menu displayed
4
Enter the router # to be shut:
13

 ERROR: Destination router # not valid
 Enter a valid router no. from 0 to 10

In order to display Shortest path and distance no Source Router was found
Enter the Source Router :
b

 ERROR: Source router # not valid
 Enter a valid router no. from 0 to 10
```

16. **Expected Output:** If user has not given source and destination router before then while modification of the topology the simulator should ask for the source and the destination router

   Actual Output: The simulator asks the source and the destination router. As expected

```
Enter your choice from the Menu displayed
4
Enter the router # to be shut:
6
        R0      R1      R2      R3      R4      R5      R6      R7      R8      R9      R10

R0      0       1       25      13      -1      -1      -1      -1      -1      -1      -1

R1      1       0       2       -1      5       -1      -1      -1      -1      -1      -1

R2      25      2       0       -1      30      11      -1      -1      -1      -1      -1

R3      13      -1      -1      0       -1      -1      -1      -1      -1      -1      -1

R4      -1      5       30      -1      0       4       -1      14      15      -1      -1

R5      -1      -1      11      -1      4       0       -1      -1      9       -1      -1

R6      -1      -1      -1      -1      -1      -1      -1      -1      -1      -1      -1

R7      -1      -1      -1      -1      14      -1      -1      0       3       -1      6

R8      -1      -1      -1      -1      15      9       -1      3       0       8       -1

R9      -1      -1      -1      -1      -1      -1      -1      -1      8       0       7

R10     -1      -1      -1      -1      -1      -1      -1      6       -1      7       0

In order to display Shortest path and distance no Source Router was found
Enter the Source Router :
0
In order to display Shortest path and distance no destination Router was found
Enter the Destination Router :
10
Shortest distance from 0 to 10 is: 26
Shortest path from 0 to 10 is:
10<--7<--4<--1<--0
---    Simulator Displays Following Menu    ---
What would you like simulator to perform:
```

17. **Expected Output:** If user enters the router no. which is already shut before then the program prompts "The Router was already down" and displays the shortest path and distance

Actual Output: Here, user already shut the router 6 before so again he shut it then simulator displayed "The Router was already down" and displayed the shortest path and distance

Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 15, 2017, 11:17:50 PM)

Enter your choice from the Menu displayed

4

Enter the router # to be shut:

6

The Router was already down

Shortest distance from 0 to 10 is: 26

Shortest path from 0 to 10 is:

10<--7<--4<--1<--0

---   Simulator Displays Following Menu   ---

18. **Expected Output:** If the user has already shut the router before and then ask for the forwarding table of the same router then the forwarding table should not be displayed and "The router was down so there is no forwarding table for it"

    Actual Output: Here, the router 6 was already down so when user asked for the forwarding table for the same then "The router was down so there is no forwarding table for it" was displayed. Hence it is as expected

Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 16, 2017, 2:01:23 AM)

```
Enter your choice from the Menu displayed
2
********** Forwarding Table **********
Enter Router number:
6
The Router was down so there is no forwarding table for it
---  Simulator Displays Following Menu  ---
```

19. **Expected Output:** If there is no path from the given source and destination then display "There is no path from source router to destination router"

Actual Output: Here, the router 6 was already down so when user asked for the forwarding table for the same then "The router was down so there is no forwarding table for it" was displayed. Hence it is as expected

```
Simulator [Java Application] C:\Program Files\Java\jre1.8.0_151\bin\javaw.exe (Nov 17, 2017, 12:55:17 AM)
6. Exit

Enter your choice from the Menu displayed
4
Enter the router # to be shut:
5
        R0     R1     R2     R3     R4     R5     R6     R7     R8     R9     R10

R0      0      1      25     13     -1     -1     -1     -1     -1     -1     -1

R1      1      0      2      -1     -1     -1     -1     -1     -1     -1     -1

R2      25     2      0      -1     -1     -1     -1     -1     -1     -1     -1

R3      13     -1     -1     0      -1     -1     -1     -1     -1     -1     -1

R4      -1     -1     -1     -1     -1     -1     -1     -1     -1     -1     -1

R5      -1     -1     -1     -1     -1     -1     -1     -1     -1     -1     -1

R6      -1     -1     -1     -1     -1     -1     -1     -1     -1     -1     -1

R7      -1     -1     -1     -1     -1     -1     -1     0      3      -1     6

R8      -1     -1     -1     -1     -1     -1     -1     3      0      8      -1

R9      -1     -1     -1     -1     -1     -1     -1     -1     8      0      7

R10     -1     -1     -1     -1     -1     -1     -1     6      -1     7      0


 There is no path from 0 to 10
```

Execution of Project
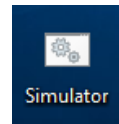
Steps:

Double click the Simulator.bat file

Fig. 3: Simulator.bat

1. The command prompt will open

Fig.: Main menu appears in command prompt

2. Thereafter the Main menu is displayed then choose the options you want the Simulator to perform

3. For this the Simulator.jar ,Simulator.bat and the topology.txt file should be in the same folder

Note : If by double clicking the Simulator.bat file, it doesn't work :

- Execute "java –jar Simulator.jar" command in the command prompt

- For this the Simulator.jar and the topology.txt file should be in the same folder