CS 6385

Algorithmic Aspects of Telecommunication Networks

SUMMER 2017

Project 1
An Application to Network Design

Submitted

By

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Objective

In the project, we simulate a basic network model. The network simulations models network topology based on a given number of low cost links for each node in the network. Each node is assigned a predefined (k) number of low unit data cost outgoing links. All the other outgoing links are assigned a high unit cost value. The simulations calculates the cost of sending a demand value (dynamically generated) by finding the shorted path between any two nodes and then multiplying the total unit cost of that path with the demand value. The Simulations has to determine the lowest cost possible for the given network topology. Finally the project evaluates the relation between the number of low cost links (k- value) of the nodes with the total network cost and Network density.

Program Methodology

The Project requires us to determine the minimum cost of the given network topology and load. Each of the nodes has a defined number of low cost outgoing links and the network is a fully connected network. In order to find the minimum cost network of any topology, we have to find the minimum path tree between a node to the all the other nodes. For example we need to find the minimum path from node j = 1 to all the other nodes k=2,3,4,…,30. For finding the minimum path between any two nodes, we can use the Dijkstra’s shortest path algorithm. On generation of the shortest path between any two nodes the calculation of the network cost simply becomes

$$Network\ Cost = \sum b_{jk}(a_{i_1,i_2} + \ldots + a_{i_{r-1},i_r})$$

Where bjk – The demand load to send between the node j and node k.

a_{i_k,i_r} – the unit cost of the link between intermediary nodes ik and ir in the shortest path.

Implementation

Technologies used

Programming Language	Java
Operating System	Windows 10
IDE	NetBeans
Visualization Tools	Gephi, MS Excel,MS Visio

Program Details

Main Program	ShortestPath.java

- The shortestPath.java contains the entire program.
- The main program generates the network topology using the input values of N and K.
- The low cost links are determined randomly using java Random function.
- dijkstra(int graph[][], int src) contains the Dijkstra's path algorithm that calculate the shortest path for a source node to all other nodes.
- We use the Greedy implementation of Dijkstra's Algorithm [1].
-
- The link[][] matrix keep track of all the used links in the shortest paths of the network
- b[] array contains the load for each of the links and it is determined by the formula $load_{ij} = |b[i] - b[j]|$
- The program runs the shortest path algorithm with all the nodes as the source.
- The total cost is calculated by using cost of each optimal path.
- The Network topology is generated for each run of the program.

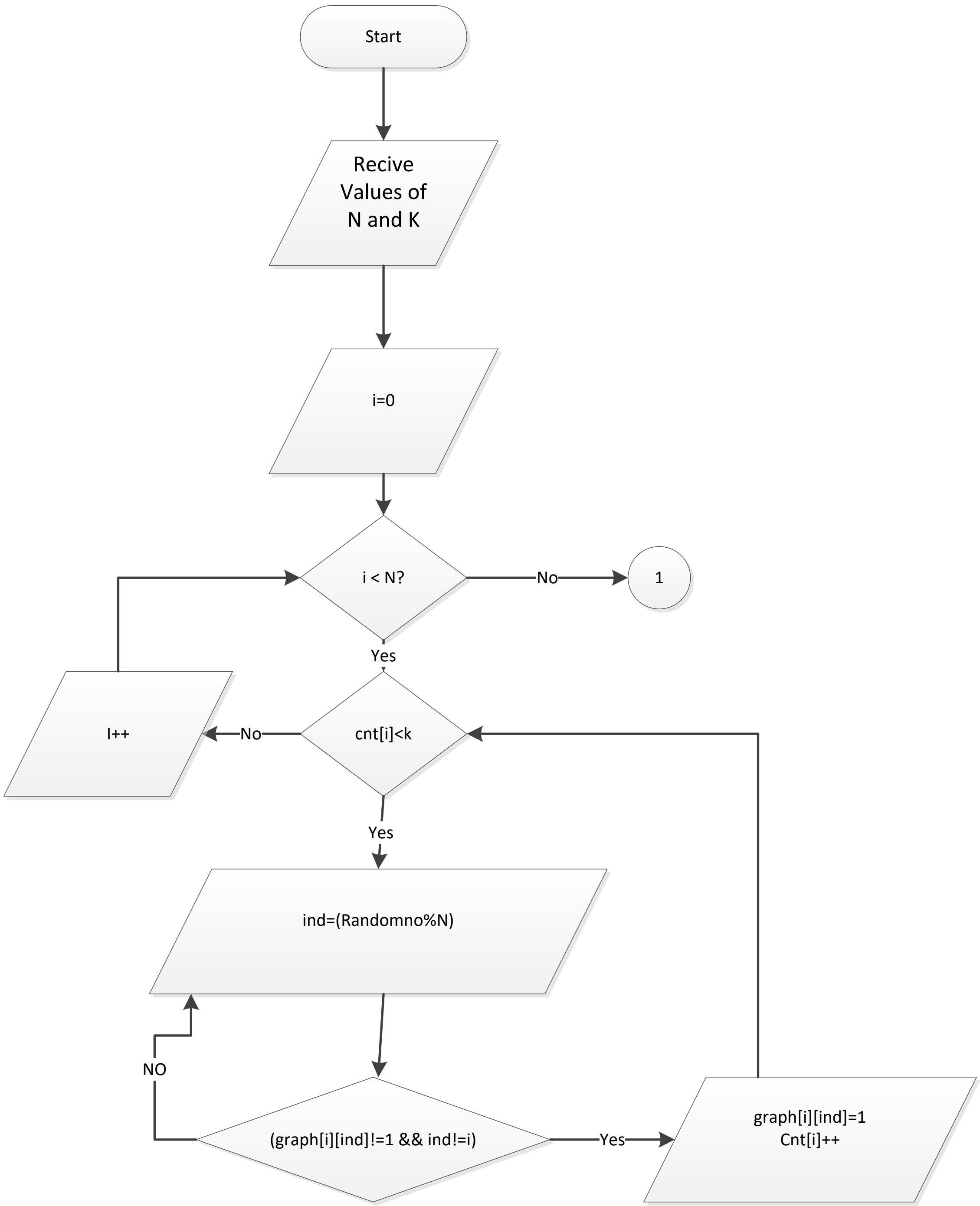
Algorithm

The simulation can be done as follows:

1. Receive the number of nodes and number of low cost links(k) for each nodes as inputs from the user.
2. Generate the network topology by randomly assigning the low cost value to k outgoing links of each node.
3. Initialize the load matrix by repeating 10 digits 3 times.
4. For each of the node i , generate the shortest path with node i as the source and the rest of the other nodes as the destination using Dijkstra's algorithm.
5. Mark the links in the shortest path as 1 in the solution path matrix Link[j][k]=1.
6. Calculate the cost of the shortest path between node i and every other node j using formula *cost i,j = ∑aij*
7. Generate the total Network cost using the formula: NW cost+= bi,j*costi,j
8. If i!= final node , goto step 4
9. Print the Network cost.
10. Determine used link count = ∑ Link[j][k]==1
11. Determine the total link count = N*(N-1) and unused count = Total count –used count.

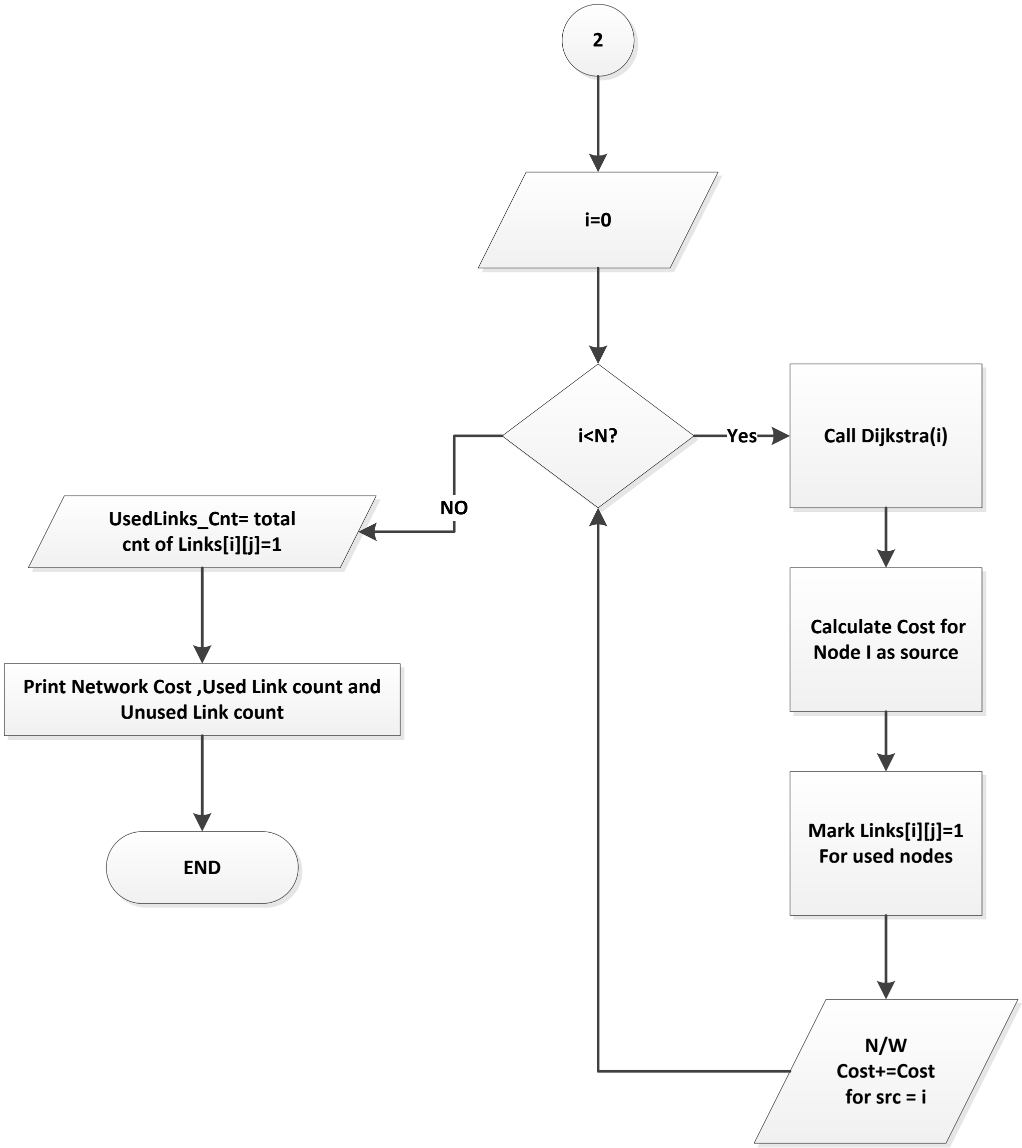
Flow Chart

1) Intialization

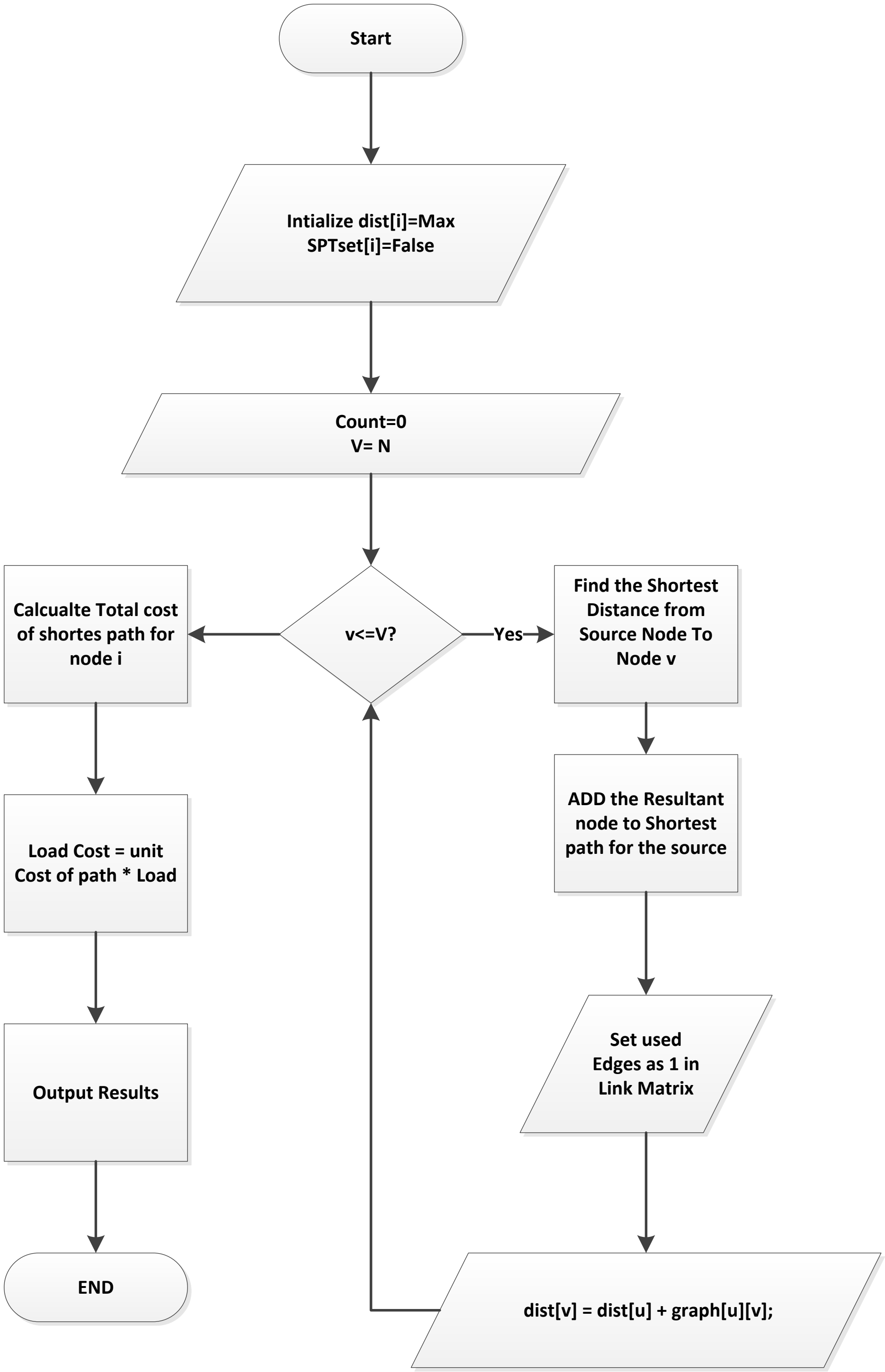


Generates the random network topology with each nodes having k low-cost outgoing links.

2) Generating the Statistics



3) Dijkstra's Algorithim

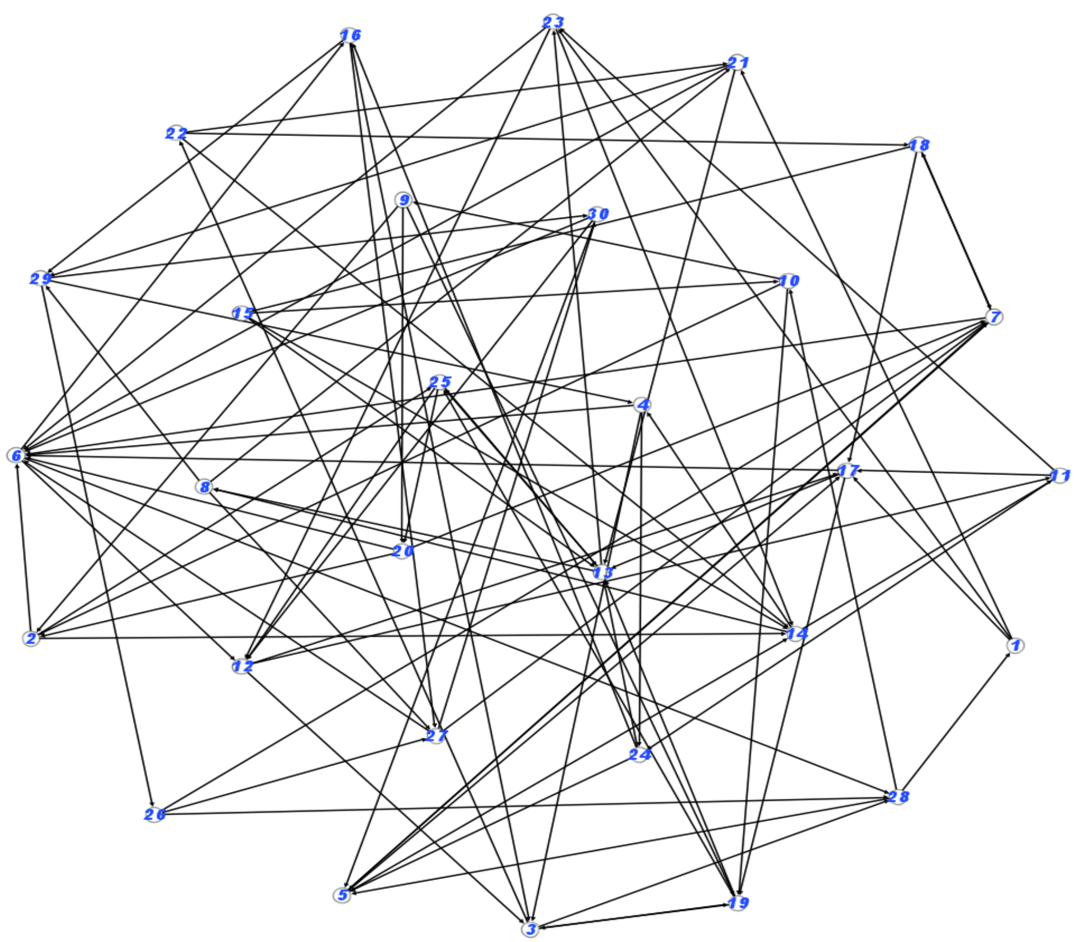

Start
Intialize dist[i]=Max
SPTset[i]=False
Count=0
V= N
v<=V?
Yes
Find the Shortest Distance from Source Node To Node v
ADD the Resultant node to Shortest path for the source
Set used Edges as 1 in Link Matrix
dist[v] = dist[u] + graph[u][v];
Calcualte Total cost of shortes path for node i
Load Cost = unit Cost of path * Load
Output Results
END

Running the Program

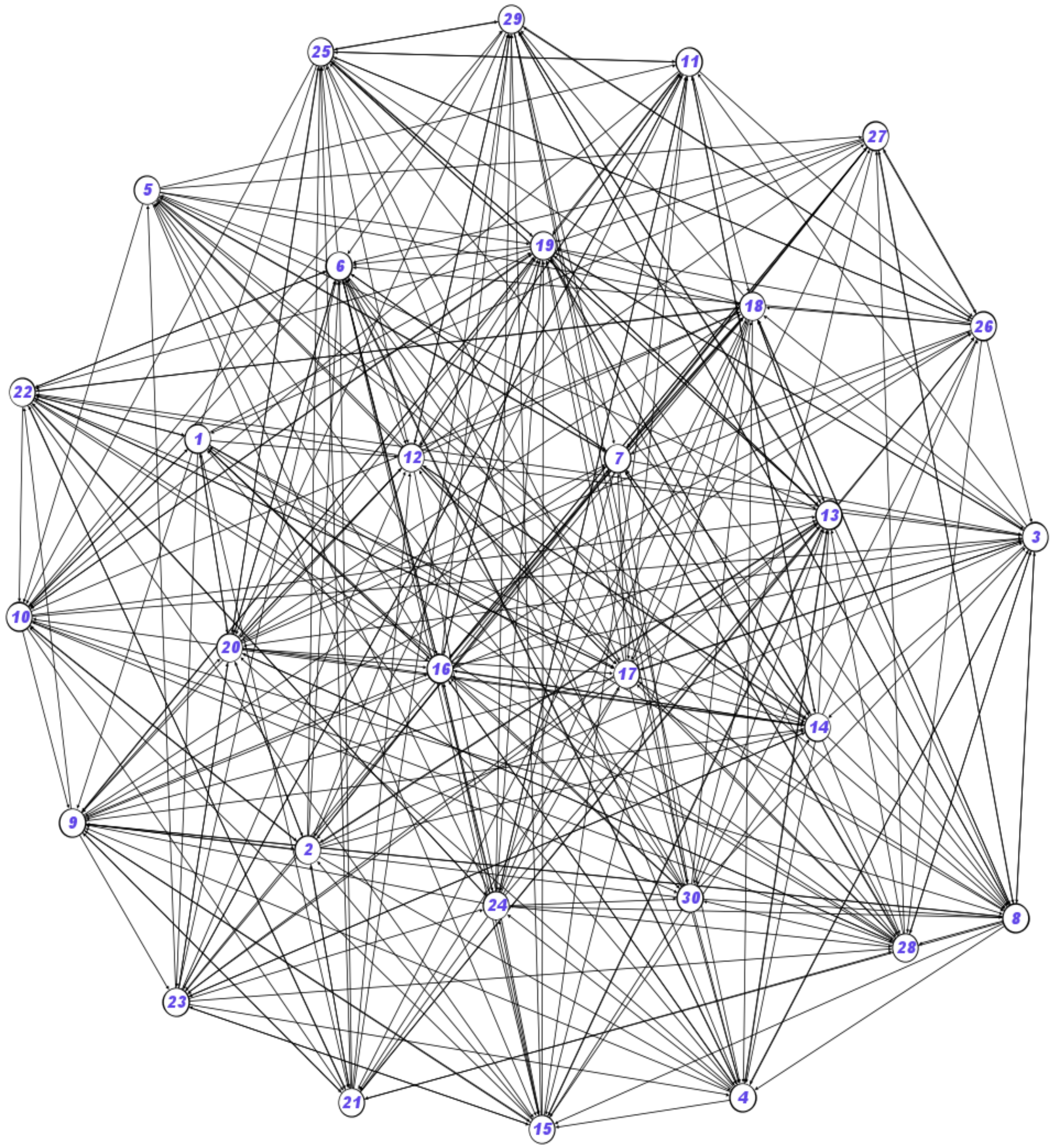
1. Copy the ShortestPath.java program to the location to run.
2. To Compile Javac ShortestPath.java.
3. To run the program Java ShortestPath.

Topology generated

K=3
Used Link : 90
Unused Link : 780
Cost: 6979
Network Density : 0.103448276

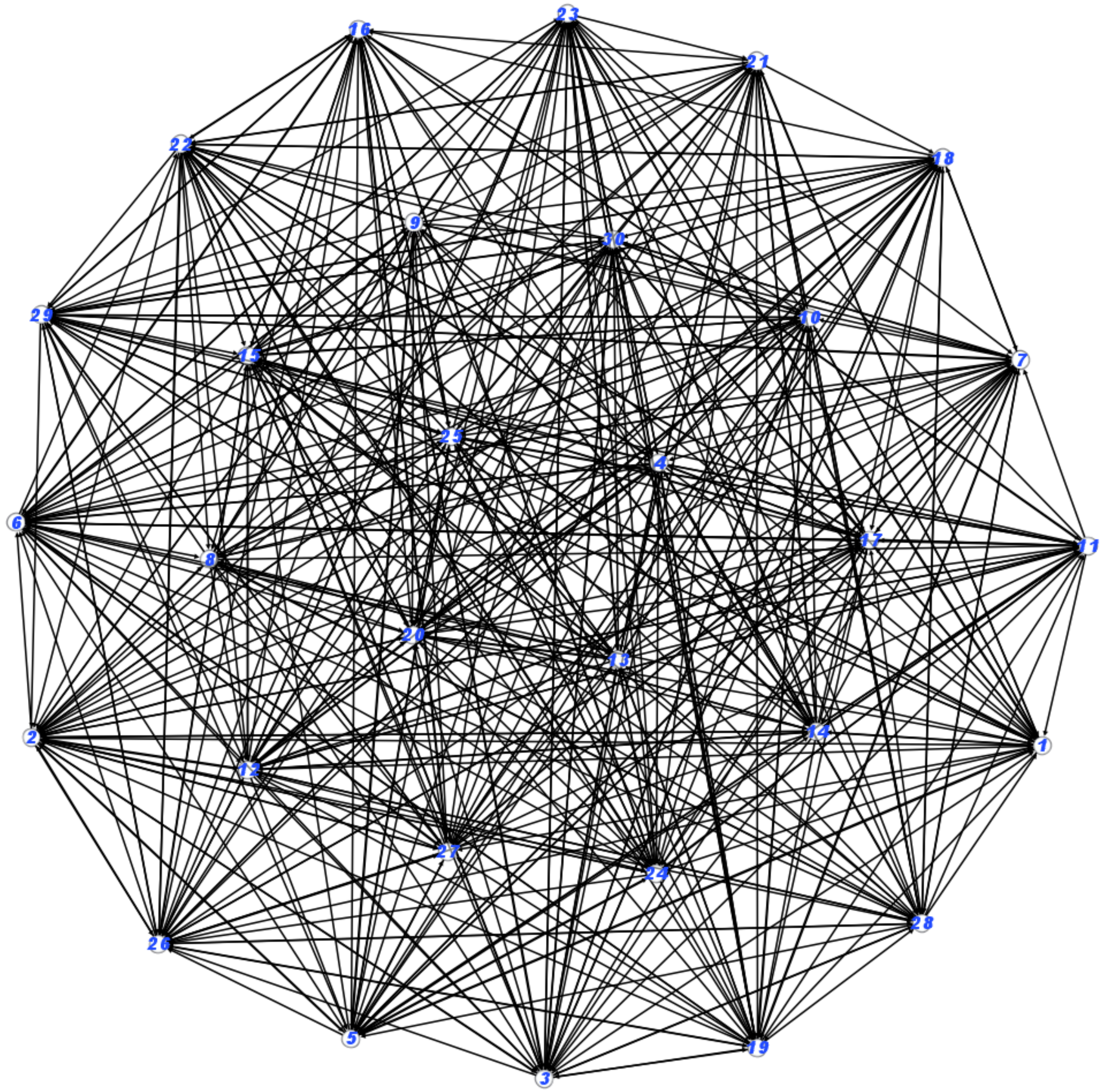


K=9



Used Link : 270
Unused Link : 600
Cost: 4078
Network Density : 0.310344828

K=15



Used Link : 450
Unused Link : 420
Cost: 3581
Network Density : 0.517241379

Program

```
package shortestpath;
import java.util.*;
import java.util.Scanner;
class ShortestPath
{
    int V;
    int sum;
    int link[][];
    public ShortestPath(int n)
    {
        link=new int[n][n];
    }
    void set_v(int x)
    {
        V=x;
        sum=0;
    }
    void printSolution(int dist[], int n,int src)
   {
      int b[]= {2,0,2,1,2,7,7,2,5,6,2,0,2,1,2,7,7,2,5,6,2,0,2,1,2,7,7,2,5,6};
      System.out.println("Vertex   Distance from Source :"+src);
      for (int i = 0; i < V; i++)
      {
         int s=dist[i]*Math.abs(b[src]-b[i]);
         sum+=s;
         System.out.println(i+" \t\t "+dist[i]+"\t\t"+s);
```

```
    }
    if((src+1)==V)
    {
        System.out.println("Total cost of Network : "+sum+"\nlinks: "+"\n");
        int cnt=0;
        for(int k=0;k<V;k++)
        {
            for(int j=0;j<V;j++)
            {
                if(link[k][j]==1&& k!=j)
                {
                    System.out.println((k+1)+","+(j+1));
                    cnt++;
                }
            }
        }
        System.out.println("Used link count:"+cnt+"\nUnused links:"+(870-cnt));
    }
}
int minDistance(int dist[], Boolean sptSet[])
{
    // Initialize min value
    int min = Integer.MAX_VALUE, min_index=-1;
     for (int v = 0; v < V; v++)
        if (sptSet[v] == false && dist[v] <= min)
        {
            min = dist[v];
            min_index = v;
        }
```

```
        return min_index;
    }
    void dijkstra(int graph[][], int src)
    {
        int dist[] = new int[V];
        Boolean sptSet[] = new Boolean[V];
        for (int i = 0; i < V; i++)
        {
            dist[i] = Integer.MAX_VALUE;
            sptSet[i] = false;
        }
         dist[src] = 0;
        for (int count = 0; count < V-1; count++)
        {
            int x=0;
            int u = minDistance(dist, sptSet);
            sptSet[u] = true;
            for (int v = 0; v < V; v++)
              if (!sptSet[v] && graph[u][v]!=0 && dist[u] != Integer.MAX_VALUE &&
dist[u]+graph[u][v] < dist[v])
              {
                      dist[v] = dist[u] + graph[u][v];
                      //System.out.println("link : "+u+" - "+v+" : "+dist[v]);
                      x=v;
                      if(graph[u][v]==1)
                      {
                         link[u][v]=1;
                      }
             }
         printSolution(dist, V,src);
```

```
}
public static void main (String[] args)
{
    System.out.println("Enter the nmber of nodes:");
    Scanner in = new Scanner(System.in);
    int no_of_nodes = in.nextInt();
    System.out.println("Enter the value of k:");
    int k = in.nextInt();
    Random r=new Random();
    int graph[][] = new int[no_of_nodes][no_of_nodes];
   for(int i=0;i<no_of_nodes;i++)
   {
      for(int j=0;j<no_of_nodes;j++)
      {
         if(i!=j)
          graph[i][j]=300;
      }
   }
   int cnt[]=new int[no_of_nodes];
   for(int i=0;i<no_of_nodes;i++)
   {
      while(cnt[i]<k)
      {
         int ind=(r.nextInt(10000)%no_of_nodes);
         if(graph[i][ind]!=1 && ind!=i)
         {
            graph[i][ind]=1;
            cnt[i]++;
         }
      }
```

```
        }
        for(int i=0;i<no_of_nodes;i++)
        {
          System.out.print("graph["+i+"]:\t");
          for(int j=0;j<no_of_nodes;j++)
          {
            System.out.print("\t" +graph[i][j]);
          }
          System.out.println("\n");
        }
         ShortestPath t = new ShortestPath(no_of_nodes);
         t.set_v(no_of_nodes);
         for(int i=0;i<no_of_nodes;i++)
         {
            t.dijkstra(graph, i);
         }

      }
   }
```

Analysis

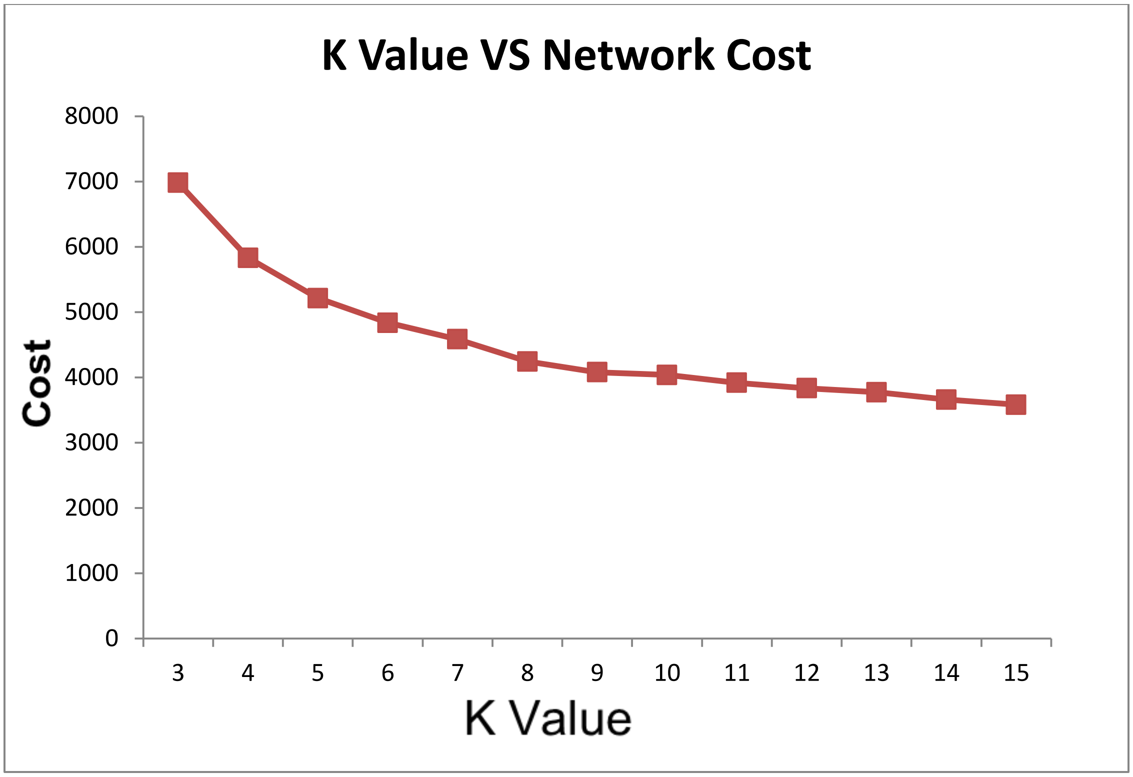
N	K	Total links	Unused Links	Used Links	Desnity	Cost
30	3	870	780	90	0.103448276	6979
30	4	870	750	120	0.137931034	5831
30	5	870	720	150	0.172413793	5213
30	6	870	690	180	0.206896552	4837
30	7	870	660	210	0.24137931	4584
30	8	870	630	240	0.275862069	4243
30	9	870	600	270	0.310344828	4078
30	10	870	570	300	0.344827586	4037
30	11	870	540	330	0.379310345	3918
30	12	870	510	360	0.413793103	3833
30	13	870	480	390	0.448275862	3771
30	14	870	450	420	0.482758621	3660
30	15	870	420	450	0.517241379	3581

- As the K value increases the Network density also Increases. This is because the number of available paths for the shortest path also increases. This results in a denser Network
- Cost decreases as the K value increases.
- Used links count increase as k value increases.

Conclusions

1) Total cost of the network depends on *k*

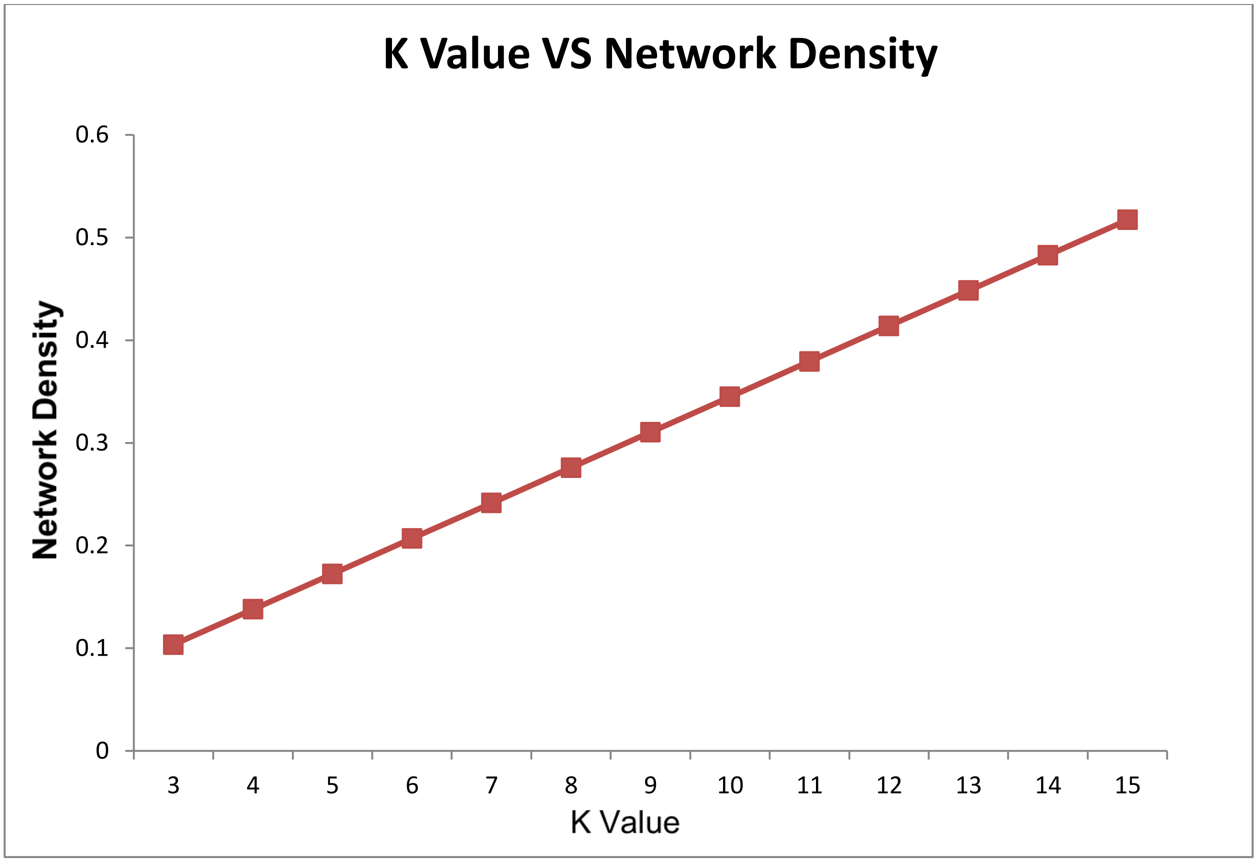
K	Cost
3	6979
4	5831
5	5213
6	4837
7	4584
8	4243
9	4078
10	4037
11	3918
12	3833
13	3771
14	3660
15	3581



The values obtained by inputting various values k , we see that the cost of the network reduces as the k value increases. This is because as the number of the low cost links per node increases then the nodes reachable though low cost nodes increase. This indirectly results in lower overall cost. Dijkstra's algorithm always selects the lowest cost path. As increase in K value results in more number of nodes reachable from the current considered node through lower cost links, the network cost reduces.

2) Density of the obtained network depends on k

K	Density
3	0.103448
4	0.137931
5	0.172414
6	0.206897
7	0.241379
8	0.275862
9	0.310345
10	0.344828
11	0.37931
12	0.413793
13	0.448276
14	0.482759
15	0.517241



The network density is given by the formula

Network Density = Used Links/ Total links in NW

Where

Total Links = N * (N-1)

From the above graph plot, we can see that as the k value increases, the density of the network also increases. The is mainly because the increase in low cost links per node will result in the increase in the number of nodes reachable through them . Dijkstra's Algorithim always select the lower cost path for reaching the destination. As a result almost all of the low cost links are selected by the algorithim. That is the reason why the Network density is linearly proportional to the K value of the network.

Output

Output - ShortestPath (run)

```
run:
Enter the nmber of nodes:
30
Enter the value of k:
15
graph[0]:     0    1    300  300  1    1    1    1    300  300  300  1    300  1    1

graph[1]:     300  0    1    1    300  300  1    1    300  300  300  300  300  300  300

graph[2]:     1    1    0    1    300  300  300  300  1    1    1    1    300  300  300

graph[3]:     300  300  300  0    300  1    1    1    1    300  1    300  300  1    1

graph[4]:     300  300  1    300  0    300  1    1    1    300  300  1    1    300  1

graph[5]:     300  300  300  1    1    0    300  1    300  300  300  300  1    1    1

graph[6]:     1    300  300  1    300  300  0    1    1    300  1    1    300  1    1

graph[7]:     1    300  1    300  300  300  300  0    1    1    1    1    1    1    300

graph[8]:     300  300  1    300  1    300  1    1    0    300  300  1    300  300  300

graph[9]:     1    300  300  1    1    1    1    300  300  0    300  300  300  1    300
```

Output - ShortestPath (run)

```
graph[10]:    1    300  1    1    300  300  300  1    1    1    0    1    300  300  1

graph[11]:    1    300  300  300  1    300  1    300  300  300  1    0    1    300  1

graph[12]:    300  300  1    1    1    300  1    1    300  1    1    300  0    300  300

graph[13]:    1    300  300  300  1    1    1    1    1    300  1    1    300  0    300

graph[14]:    1    1    1    1    1    300  1    1    1    1    300  300  1    1    0

graph[15]:    1    300  300  1    300  1    1    1    300  1    1    1    300  300  1

graph[16]:    1    1    300  300  1    1    1    1    300  1    300  300  1    300  300

graph[17]:    300  1    300  1    300  1    1    1    1    300  300  1    1    300  1

graph[18]:    1    1    300  300  300  1    1    1    1    1    300  300  1    300  1

graph[19]:    1    300  300  300  300  300  1    1    1    1    300  1    1    300  300

graph[20]:    1    1    300  300  300  300  300  1    1    1    1    1    300  300  300

graph[21]:    1    300  1    300  1    1    300  300  1    1    1    300  1    300  1
```

Output - ShortestPath (run)


```
graph[20]:    1    1    300  300  300  300  300  1    1    1    1    1    300  300  300

graph[21]:    1    300  1    300  1    1    300  300  1    1    1    300  1    300  1
```


```
graph[22]:    1    300  300  300  1    300  300  1    300  1    1    1    300  1    1

graph[23]:    300  300  1    1    300  1    1    1    1    1    300  300  300  300  1

graph[24]:    300  1    300  1    300  1    1    300  300  300  300  1    300  300  1

graph[25]:    1    1    300  1    300  300  300  1    1    1    300  1    1    1    1

graph[26]:    300  300  1    1    300  300  1    300  1    300  300  1    1    300  300

graph[27]:    1    300  300  300  300  300  1    1    1    1    1    300  1    300  300

graph[28]:    300  1    1    300  1    300  300  300  1    1    300  1    1    300  1

graph[29]:    1    1    300  300  1    300  1    1    1    1    1    1    300  300  1
```

Vertex	Distance from Source :0	
0	0	0
1	1	2
2	2	0
3	2	2
4	1	0
5	1	5
6	1	5
7	1	0
8	2	6
9	2	8
10	2	0
11	1	2
12	2	0
13	1	1
14	1	0
15	1	5
16	1	5
17	2	0
18	1	3
19	2	8
20	1	0
21	1	2
22	2	0
23	2	2
24	1	0
25	1	5
26	2	10
27	2	0
28	2	6
29	2	8

links:

1,2
1,5
1,6
1,7
1,8
1,12
1,14
1,15
1,16
1,17

1,19
1,21
1,22
1,25
1,26
2,3
2,4
2,7
2,8
2,16
2,17
2,18
2,19
2,20
2,21
2,22
2,24
2,25
2,29
2,30
3,1
3,2
3,4
3,9

```
3,10
3,11
3,12
3,17
3,18
3,20
3,23
3,26
3,27
3,28
3,30
4,6
4,7
4,8
4,9
4,11
4,14
4,15
4,16
4,18
4,19
4,21
4,27
4,28

Used link count:450
Unused links:420
```

Reference

1. Class notes
2. Dijkstra's Algorithim http://www.geeksforgeeks.org/greedy-algorithms-set-6-dijkstras-shortest-path-algorithm/
3. www.gephi.org
4. Greedy Algorithm : https://en.wikipedia.org/wiki/Greedy_algorithm
5. http://www.sanfoundry.com/java-program-represent-graph-adjacency-matrix/