SNA: A tool for Stochastic Network Analysis (CE737 Course Project)

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Abstract

This document is the user manual to the SNA: Stochastic Network Analysis tool. It provides complete information on how to use the system as well as description of tools and algorithms which are provided in the software. The Examples provided in this tutorial are all tested properly by the software.

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1 Introduction

SNA is a software for stochastic flow network analysis. It enables the user to accomplish basic and more advanced network analysis under uncertain conditions. The software is designed and implemented for audiences majoring in math and engineering. Background on network and graph analysis will help in using the system, but the manual is complete enough to help the users not familiar with graph theory as well.

Stochastic network analysis is used to describe the behavior of many complex systems including lifeline networks. The analysis of the performance of such networks should be done under uncertainty. Uncertainties stem from the natural variations in the availability of network components and due to failures, degradations. Also in real world networks, usually partial information is provided about the demand in the system and it may also follow a distribution other than being a completely known value. These issues reveal the need to a tool which gives the opportunity to perform network analysis under uncertainties.

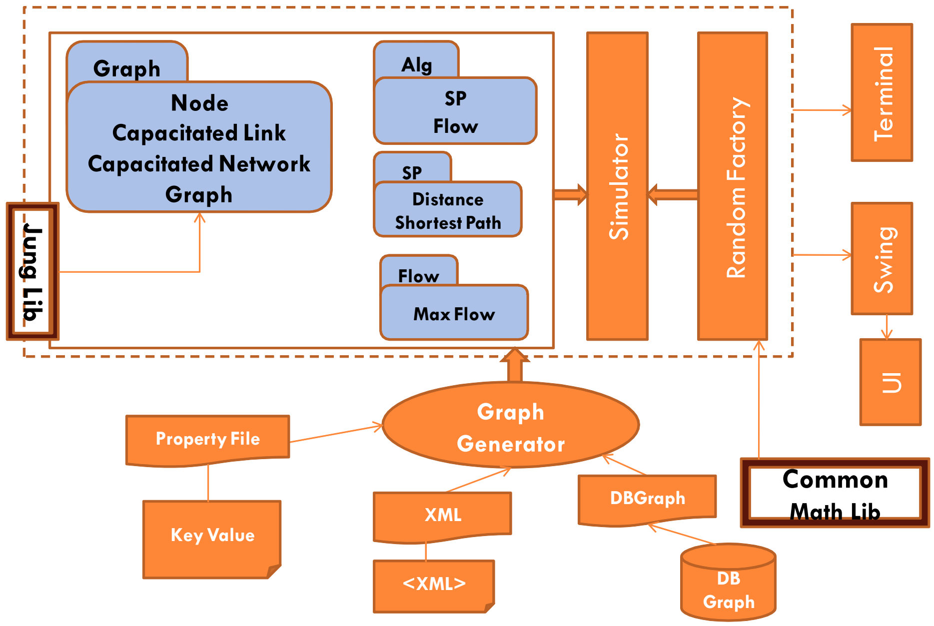
In addition to the basic famous network analysis problems such as shortest path and connectivity analysis, this tool estimates more advance network metrics such as capacity reliability of the system under uncertainties conditions. Also this tool provides good visualization capabilities.

The software is based on two different yet interacting tools:

- Monte Carlo Simulation
- Network Analysis tool

The uncertainty analysis is done by means of Monte Carlo simulation. The results of the simulations are passed to the network analysis tool as the input data.

The following figure depicts the high level architecture of SNA.



2 SNA's Technology Dependencies

SNA depends on two java libraries: Commons Math 2.1 API and Jung 2.0 (Java Universal Network/Graph).

- *Commons Math API:*

This library is used for generating random numbers from some of the famous probability distribution functions. The library is available for free download at :

http://commons.apache.org/math/download_math.cgi
and the javadoc of the library is reachable at :
http://commons.apache.org/math/api-2.1/index.html

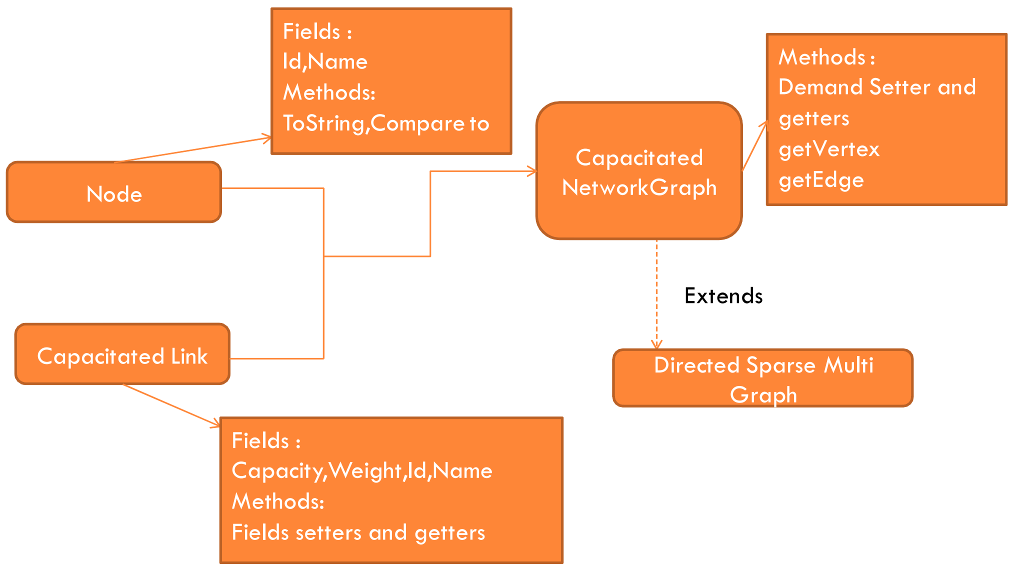
- *JUNG 2.0:*

Graph and network classes of SNA extend some of the classes of this library. Also it is used for graph visualizations in SNA. The library is available for free download at :

http://jung.sourceforge.net/doc/index.html
and the javadoc of the library is reachable at :
http://jung.sourceforge.net/doc/api/index.html

3 SNA Network Basics

SNA is an object oriented software. It represents a network as a directed graph which has been read through its incidence matrix. Although SNA uses some of the classes and interfaces of JUNG and JGRAPHT libraries, it introduces its own classes for a lot of objects needed for its specific purposes. The structure of a network in SNA is briefly introduced in the following. For a more complete list of the classes please see the SNA javadoc. The following figure depicts the high level SNA network architecture.



3.1 How to Create a network

There are three alternatives for forming a network in SNA :

- Creating a network manually
- Reading from a file
- Generating a random network

3.1.1 Creating a network manually

In SNA nodes should be of the defined "Node" class and links should be of the defined "CapacitatedLink" class. The following command initiates a network named g :

CapacitatedNetworkGraph<Node, CapacitatedLink> g = new CapacitatedNetworkGraph<Node, CapacitatedLink>();

As class *CapacitatedNetworkGraph* of SNA extends the *DirectedOrderedSparse-Multigraph* of Jung library, it inherits its methods, so you can add a node with the id i to your network by :

g.addVertex(i);

You can also add an edge e to between nodes "source" and "sink" by :

g.addEdge(e, source, sink);

For a complete set of commands like setting the link distributions, demand and etc , please see the javadoc of SNA.

3.1.2 Reading a network from file

In this method creating the network begins by defining a properties file. You need to determine the following to be able to form your network. The names between " " are key values.

- "Graph_Nodes" : Set of Graph Nodes.
- "Random_Capacity" : Your graph capacity data is random ? True or False.
- "Graph_Capacity" : If the data is not random provide it here.
- "Graph_Weight" : Edge weights go here.
- "Probability_Distribution": If the capacity data is probabilistic, provide the distributions here.
- "Demand_Mean": The mean of demand of the network
- "Demand_Sigma" : The standard deviation of demand of the network

Here is a sample set of data for properties file of a network with 5 nodes :

Graph_Nodes =(Node0, Node1, Node2 , Node3, Node4)
Random_Capacity = True
Graph_Capacity={(Null,6,Null,Null,Null);(Null,Null,3,3,Null);(Null,Null,Null,3,Null);
(Null,Null,Null,Null,6);(Null,Null,Null,Null,Null)}
Graph_Weight={(Null,1,Null,Null,Null);(Null,Null,1,2,Null);(Null,Null,Null,1,Null);
(Null,Null,Null,Null,4);(Null,Null,Null,Null,Null)}
(Comment :N:Normal,E=Exponential,U=uniform)
Probability_Distribution = {(Null,N[6-1],Null,Null,Null);(Null,Null,U[2-4],U[2-4],Null);
(Null,Null,Null,E[3],Null);(Null,Null,Null,Null,N[6-1]);(Null,Null,Null,Null,Null)}
Demand_Mean = 2.5
Demand_Sigma = 0.5

4 Working with algorithms

After creating a network using one of the methods introduced earlier, you can try some algorithm on your network. The following will show you how you can run these algotithms in the software.

4.1 Connectivity

There are a lot of explorations you can do using this tool , connectivity of a pair of node, connectivity of the over all network and etc. As an example we have provided the code to investigate whether a given node of the network is connected to all the other nodes.

```
GraphGenerator<Node, CapacitatedLink> gg = PropertyFileGraphGenerator.getInstance();
CapacitatedNetworkGraph<Node, CapacitatedLink> cng = gg.getGraph();
ConnectivityLabeler<Node, CapacitatedLink> cl = new ConnectivityLabeler<Node, CapacitatedLink>();
System.out.println("Is Graph Connected : " + ((cl.isConnected(cng, cng.getVertex(fromNode)) ? "Yes" : "No")));
System.out.println("Number of Nodes " + fromNode + " is disconnected from : " + cl.disconnectedNodesCount(cng, cng.getVertex(fromNode)) + " Nodes");

System.out.println("Number of Nodes " + fromNode + " is directly disconnected from : " + cl.disconnectedNodesDirectlyCount(cng, cng.getVertex(fromNode)) + " Nodes");
```

4.2 Shortest Path

To calculate the shortest path between a pair of nodes using Dijkastra's algorithm you can use the following sample code. The transformer is used to return the links weight.

```
GraphGenerator<Node, CapacitatedLink> gg = PropertyFileGraphGenerator.getInstance();
CapacitatedNetworkGraph<Node, CapacitatedLink> cng = gg.getGraph();
Transformer<CapacitatedLink, Double> wTransformer = new Transformer<CapacitatedLink, Double>() {
public Double transform(CapacitatedLink link) { return link.getWeight(); }
};
DijkstraShortestPath<Node, CapacitatedLink> spAlgorithm = new DijkstraShortestPath<Node, CapacitatedLink>(cng, wTransformer);
java.util.List<CapacitatedLink> path = spAlgorithm.getPath(cng.getVertex(fromNode), cng.getVertex(toNode));
Number distance = spAlgorithm.getDistance(cng.getVertex(fromNode), cng.getVertex(toNode));
```

```
System.out.println(" Distance from :" + "Node-" + fromNode + " to " +
toNode + " is : " + distance);
System.out.println(" Path from :" + "Node-" + fromNode + " to " + toNode
+ " is : " + path);
```

4.3 Max Flow

To calculate the maximum flow passing through a pair of nodes considering the link capacities the sofware uses Edmonds Karp algorithm which is an implementation of Ford Folkerson method. You can use the following sample code to calculate the max flow on your network between desired nodes.

```
GraphGenerator<Node, CapacitatedLink> gg = PropertyFileGraphGenera-
tor.getInstance();
CapacitatedNetworkGraph<Node, CapacitatedLink> cng = gg.getGraph();
Transformer<CapacitatedLink, Double> capTransformer = new Transformer<CapacitatedLink,
Double>() {
public Double transform(CapacitatedLink link) { return link.getCapacity();
} };
Map<CapacitatedLink, Double> edgeFlowMap = new HashMap<CapacitatedLink,
Double>();
// This Factory produces new edges for use by the algorithm
Factory<CapacitatedLink> edgeFactory = new Factory<CapacitatedLink>()
{
public CapacitatedLink create() { return new CapacitatedLink(1, 1.0, 1.0);
} };
try { EdmondsKarpMaxFlow<Node, CapacitatedLink> maxFlowAlgorithm
= new EdmondsKarpMaxFlow(cng, cng.getVertex(fromNode), cng.getVertex(toNode),
capTransformer,
edgeFlowMap, edgeFactory); maxFlowAlgorithm.evaluate();
System.out.println(" Maximum Flow from :" + "Node-" + fromNode + " to
" + toNode + " is : " +
maxFlowAlgorithm.getMaxFlow()); }
catch (IllegalArgumentException e) {
System.out.println(" Maximum Flow from :" + "Node-" + fromNode + " to
" + toNode + " is : No Flow"); }
```

4.4 Capacity Reliability Estimation

The capacity reliability estimation method has the following steps :

1. Sampling from all the link capacities
2. Calculating the Max Flow of the network using the data provided in step 1.

3. Sample the demand from its distribution

4. Comparing the demand and the maximum flow

5. For the desired number of iterations do steps 1-4

6. return the percentage of times the maximum flow the network is able to provide exceedes the demand.

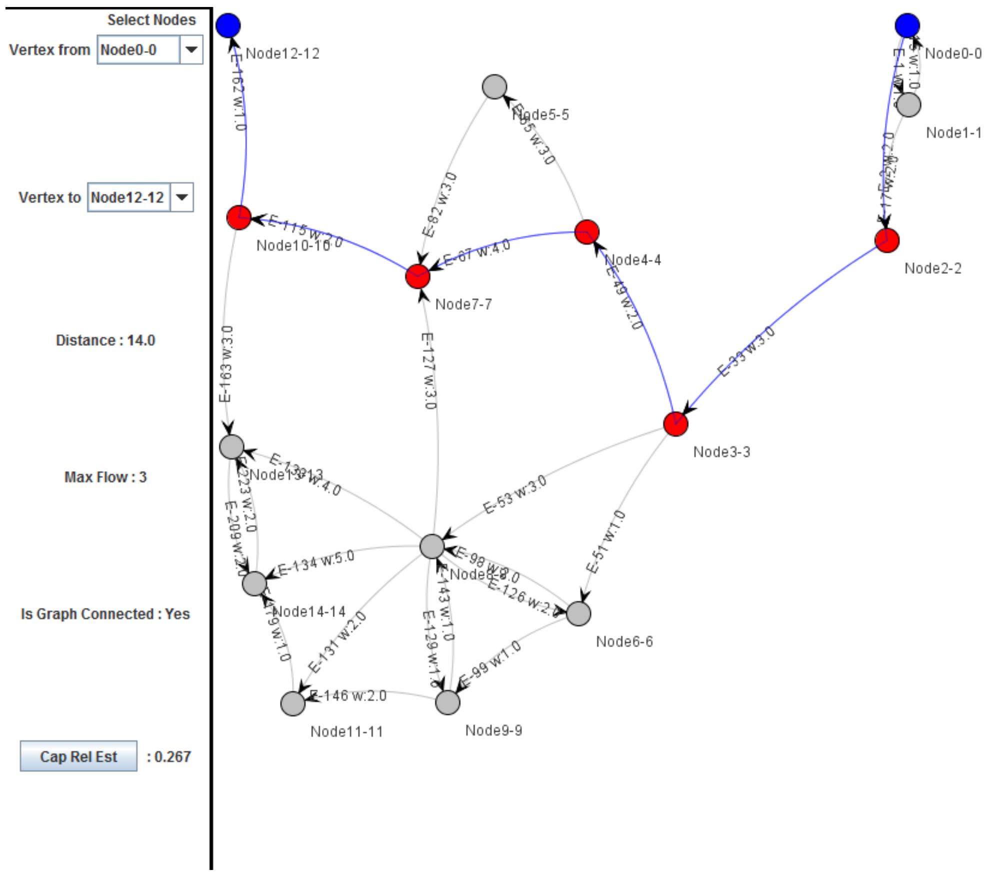
You can use the following commands to run such a simulation for 1000 times for the flow between your hypothetical 0 and 4 nodes and get the results.

GraphGenerator graphGenerator = PropertyFileGraphGenerator.getInstance();

ReliabilityEvaluation re = new ReliabilityEvaluation(1000);
System.out.println("Capacity Reliability Estimation" + re.estimate(graphGenerator, 0, 4));

5 Network Visulalization

By now, you have created your desired graph and implemented some algorithms. SNA also gives the ability to visualize your work. SNA's network visualization takes advantage of the great visual features of Jung library. You can use the Visual Demo class in SNA as a user interface for implementing most of the algorithms discussed so far. Here is a sample view of what SNA is able to provide.



6 An extended example

Implementation of all the methods and algorithms available through the software is provided here using an extended example. As all the necessary commands have been discussed in the previous sections, here we only introduce a case for which the creating is via "reading from file" and implementing the algorithm is by using the interface.

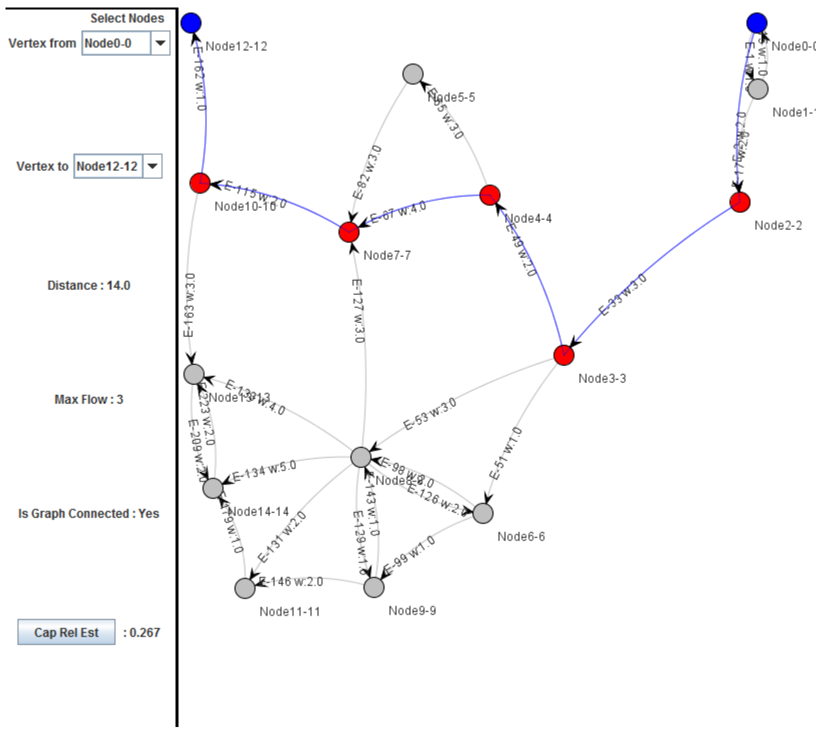
1. Create a properties file in your project directory, the name of the file can be : exam1.properties . The sample of the file for a 15 node graph is provided in the appendix.

2. Run Visula Demo.java file

3. From the first combo box choose the desired source (origin) node.

4. From the second combo box choose the desired sink (destination) node.

5. The sofware will calculate and return the followings :
   (a) Minimum Distance between the node pair
   (b) Maximum Flow between the node pair
   (c) If the node is connected to all other nodes of the network
6. By clicking on the "CapRelEst" the program will run a simulation and returns the capacity reliability estimation.
7. Here is how the result look like for the sample graph at one of the runs:



7 How to install the project

To run the program on Windows or Linux you need to have java run time environment (JRE) 1.6+ installed. To install the project download the binary files at the following address:

http://www4.ncsu.edu/~sazizza/737/project/sna/sna-1_0_source.jar

unzip the compressed file into a folder.

7.1 Run on Windows

Before running the project on windows set the JAVA_HOME in windows Environment Variables or open run.bat with notepad and change the line pointing to your java home directory by removing “REM” from the following statement. For example change

REM set JAVA_HOME=C:\Program Files\Java\jdk1.6.0_18

to

set JAVA_HOME=<YOUR JAVA HOME DIRECTORY>

after modifying run.bat file, simply execute the file by double clicking or using Command Prompt.

7.2 Run on Linux

Make sure that JRE 1.6+ is installed and java bin directory is added to system PATH variables then run.sh by either one of these commands:
./run.sh
sh run.sh

8 Appendix 1:A Sample Data set

Sample properties file data set for the discussed network:

Comments#15NodeConnectedNetwork
#N:Normal,E=Exponential,U=uniform

Probability_Distribution=
{(Null,U[0-3],N[10-1.5],Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null);(U[0-3],Null,N[8-1],Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null);(Null,Null,Null,N[18-2],Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null);(Null,Null,Null,Null,N[3-0.5],Null,N[3-0.5],Null,N[12-2],Null,Null,Null,Null,Null,Null);(Null,Null,Null,Null,Null,E[3-1],Null,N[2-0.25],Null,Null,Null,Null,Null,Null,Null);(Null,Null,Null,Null,Null,Null,Null,E[3-1],Null,Null,Null,Null,Null,Null,Null);(Null,Null,Null,Null,Null,Null,Null,Null,N[3-0.5],N[3-0.5],Null,Null,Null,Null,Null);(Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,N[3-1],Null,Null,Null,Null);(Null,Null,Null,Null,Null,Null,N[3-0.5],N[5-1],Null,U[3-6],Null,N[6-

2],Null,N[7-2],N[8-1]);(Null,Null,Null,Null,Null,Null,Null,Null,U[3-6],Null,Null,N[5-1],Null,Null,Null);(Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,N[3-0.5],N[2-0.25],Null);(Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,U[2-4]);(Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null);(Null,Null,Null,Null,Null,Null,N
2]);(Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,N[18-2],Null)}

Graph_Capacity= {(Null,1,2,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null);(1,Null,2,Null,Null,Null,Null,Null,Nu

Graph_Weight= {(Null,1,2,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null,Null);(1,Null,2,Null,Null,
Graph_Nodes =(Node0, Node1, Node2 , Node3, Node4,Node5, Node6, Node7 , Node8, Node9,Node10, Node11, Node12 , Node13, Node14)