“MANAGEMENT DES SI”

PROJECT 1:
Network Reliability and Resilience of Rapid Transit Systems

ELABORATED BY:

ARFAOUI
FAIROUZ

MARNISSI
SKANDER

M2 SIA

I. Introduction:

The daily discussions at work, while having dinner, or any moment of a citizen's life, have started or ended about transport. Whether it is reliable or not, would it be simple, or complex. The reliability assessment exists on every layer of the process' elaboration. We have grasped that an overload entails the possible risk of disruptions. Our algorithms are now striving to minimize the failures and enhance the rapid transit system's robustness.

The "Network Reliability and Resilience of Rapid Transit Systems" report, details metrics that would allow us to achieve accurate results and directs our analysis towards the most efficient thinking. Our project hence shows the results we have been able to extract out of the obtained output and determine the reliability of its resilience. The adjacency matrix is set as our pointer in what follows.

II. Methodology:

1. **<u>Rod Matrix:</u>**

   Rod measures the reliability for each possible path between two nodes,Is the reliability between 'O' (origin) and 'D' (destination) on network G. It is computed by the summation of the probabilities of k disjoint event paths p(Dk) for an o-d pair.
   To compute all paths from one to the other, the article mentions the use of a k-shortest path algorithm.

$$R^{od} = \sum_{k=1}^{3} p(D_k)$$

2. **<u>Reliability Measures:</u>**

   Rnode, ***Rrange*** and ***Rsys*** are based on Rod. They all take the Rod Matrix as an input and compute the metrics with it. This way, the measures are obtained very quickly once the Rod Matrix is done, since the Rods are never recomputed.

   a. **Rnode:**
      Is the average reliability from a specific origin 'O' to all destinations.

$$R^{\mathrm{node}}(G,\ p) = \frac{1}{(N-1)} \sum_{d=1}^{n} R^{od}$$

b. **Rrange:**

Is the average reliability from a specific origin ‘O’ to all destinations.

$$R^{\text{range}}(G,\ p) = |\max R^{od} - \min R^{od}|$$

c. **Rsys:**

Is defined as the system’s criticality with average reliability from all origins ‘O’ to all other destinations ‘K’.

$$R^{\text{sys}}(G,\ p) = \frac{1}{N(N-1)} \sum_{o=1}^{n} \sum_{\substack{d=1 \\ (o \neq d)}}^{n} R^{od}$$

In order to obtain a reliable rod function which is the essence of the upcoming calculations, we have to define certain metrics.

The Origin-Destination has numerous but calculatible possible paths. With the use of Dijkstra features, we have implemented the K-ShortestPaths algorithm to determine all the different scenarios of every pair and consequently the total number of the unique edges in between. The output is utilized to calculate **p(ei).**

We monitored the Rod for all O-D pairs thus the Nodal reliability of each junction.

Afterwards, we proceeded with calculating fluctuation of reliability limited by its minimum and maximum values on every node.

This method leads us to determine the Rsys, our network’s criticality. The execution generated a Reliability.mat file displaying all the results.

III. Results:

1. Result of Reliability.mat

```
>> x = load("/home/fairouz/Bureau/Reliability project/Reliability.mat")
x =

  scalar structure containing the fields:

    rods =
    {
      [1,1] = 0
      [1,2] =  0.74707
      [1,3] =  0.71188
      [1,4] =  0.90844
      [1,5] =  0.88890
      [1,6] = 0
      [1,7] =  0.25000
      [1,8] =  0.88890
      [1,9] =  0.99339
      [1,10] = 0
      [1,11] = 0
      [1,12] =  0.87336
      [1,13] = 0
      [1,14] = 0
      [1,15] = 0
      [1,16] =  0.81481
      [1,17] =  0.74707
      [1,18] =  0.93335
      [1,19] =  0.90844
      [1,20] = 0
      [1,21] = 0
      [1,22] =  0.90844
      [1,23] =  0.99578
      [1,24] = 0
      [1,25] = 0
      [1,26] =  0.88890
      [1,27] = 0

      [1,28] = 0
      [1,29] = 0
      [1,30] = 0
      [1,31] = 0
      [1,32] =  0.25000
      [1,33] =  0.29630
      [1,34] = 0
      [1,35] = 0
      [1,36] =  0.29630
      [1,37] =  0.71188
      [1,38] = 0
      [1,39] = 0
      [1,40] =  0.31641
      [1,41] = 0
      [1,42] = 0
      [1,43] = 0
      [1,44] = 0
      [1,45] = 0
      [1,46] = 0
      [1,47] =  0.25000
      [1,48] = 0
      [1,49] = 0
      [1,50] =  0.25000
      [1,51] =  0.74707
      [1,52] = 0
      [1,53] = 0
      [1,54] =  0.29630
      [1,55] = 0
      [1,56] = 0
      [1,57] = 0
      [1,58] = 0
      [1,59] = 0
      [1,60] = 0
      [1,61] = 0

      [1,61] = 0
      [1,62] = 0
      [1,63] = 0
      [1,64] = 0
      [1,65] =  0.81481
      [1,66] = 0
      [1,67] = 0
      [1,68] =  0.25000
      [1,69] = 0
      [1,70] = 0
      [1,71] = 0
      [1,72] = 0
      [1,73] = 0
      [1,74] = 0
      [1,75] = 0
      [1,76] = 0
      [1,77] = 0
      [1,78] = 0
      [1,79] = 0
      [1,80] = 0
      [1,81] = 0
      [1,82] = 0
      [1,83] = 0
      [1,84] = 0
      [1,85] = 0
      [1,86] =  0.80859
      [1,87] =  0.97096
      [1,88] =  0.95937
      [1,89] =  0.99565
      [1,90] =  0.99354
      [1,91] =  0.76186
      [1,92] =  0.99354
      [1,93] =  0.99998
      [1,94] = 0

      [1,95] = 0
      [1,96] =  0.99134
      [1,97] = 0
      [1,98] = 0
      [1,99] = 0
      [1,100] = 0
      [1,101] = 0
      [1,102] =  0.25000
      [1,103] =  0.85547
      [1,104] =  0.78746
      [1,105] = 0
      [1,106] =  0.78746
      [1,107] =  0.97571
      [1,108] = 0
      [1,109] = 0
      [1,110] =  0.74801
      [1,111] = 0
      [1,112] = 0
      [1,113] = 0
      [1,114] = 0
      [1,115] = 0
      [1,116] = 0
      [1,117] = 0
      [1,118] = 0
      [1,119] = 0
      [1,120] = 0
      [1,121] = 0
      [1,122] = 0
      [1,123] = 0
      [1,124] = 0
      [1,125] = 0
      [1,126] = 0
      [1,127] = 0
      [1,128] = 0

      [1,161] = 0
      [1,162] =  0.25000
      [1,163] =  0.88890
      [1,164] =  0.99339
      [1,165] = 0
      [1,166] =  0.87336
      [1,167] = 0
      [1,168] = 0
      [1,169] = 0
      [1,170] = 0
      [1,171] = 0
      [1,172] = 0
      [1,173] = 0
      [1,174] = 0
      [1,175] = 0
      [1,176] = 0
      [1,177] = 0
      [1,178] = 0
      [1,179] = 0
      [1,180] = 0
      [1,181] = 0
      [1,182] = 0
      [1,183] = 0
      [1,184] = 0
      [1,185] = 0
      [1,186] =  0.25000
      [1,187] =  0.29630
      [1,188] =  0.31641
      [1,189] = 0
      [1,190] = 0
      [1,191] =  0.31641
      [1,192] =  0.69032
      [1,193] = 0
      [1,194] = 0

      [1,178] = 0
      [1,179] = 0
      [1,180] = 0
      [1,181] = 0
      [1,182] = 0
      [1,183] = 0
      [1,184] = 0
      [1,185] = 0
      [1,186] =  0.25000
      [1,187] =  0.29630
      [1,188] =  0.31641
      [1,189] = 0
      [1,190] = 0
      [1,191] =  0.31641
      [1,192] =  0.69032
      [1,193] = 0
      [1,194] = 0
      [1,195] =  0.32768
      [1,196] = 0
      [1,197] = 0
      [1,198] =  0.25000
      [1,199] =  0.71188
      [1,200] =  0.69032
      [1,201] =  0.88890
      [1,202] =  0.87336
      [1,203] = 0
      [1,204] =  0.29630
      [1,205] =  0.87336
      [1,206] =  0.99091
      [1,207] = 0
      [1,208] = 0
      [1,209] =  0.86078
      [1,210] = 0
    }
```

"rods" is the output of the **Rods** function, that calculates the Rod for each pair from origin to destination. Some pairs have Rod = 0, it's either because no existing path between the two nodes or there's only one arc between them (p(ei) = 1 - 1/1 = 0).

- **Rnode:**

```
rnode =

 Columns 1 through 8:

   0.44728   0.44263   0.13363   0.11024   0.07606   0.00000   0.60535   0.31458

 Columns 9 through 15:

   0.00000   0.00000   0.63340   0.44728   0.00000   0.15694   0.45970
```

Is the result of the ***Rnode*** function, that calculates the average reliability for each node.

Node 11 and 7 are the nodes with the greatest Rnode esteem; That could imply that those two stations speak to stations or hubs that are connected to a ton of different nodes since Rnode depends on the topological structure of the network.

- **Range:**

```
range =

 Columns 1 through 8:

   0.99339   0.99578   0.71188   0.74707   0.81481   0.00000   0.99998   0.97571

 Columns 9 through 15:

   0.00000   0.00000   0.99997   0.99339   0.00000   0.69032   0.99091
```

Is the output of the ***Range*** function, that computes the average reliability for each node. The node 11 has the biggest value, which may represent Bridge stations, linking hubs to the peripheral nodes.

- **Rsys:**

```
rsys =  0.25514
```

Is the yield result from the ***Rsys*** function, a capacity that holds all the ***Rnodes*** and partitions them by the number of nodes to have average reliability of the network

2. **Discussion:**

Generally speaking, the Rsys = 0.25514 shows that our graph has a low resilience to disruption situations. In any case, this measure isn't that significant at business as usual alone, since the Rsys is only a normal of all ***Rnodes***.

Henceforth, for homogeneous diagrams, as haphazardly created charts, the Rsys would give a decent estimation anytime, yet it would not speak to the internal inconsistencies for heterogeneous structures. The strength of the Rsys metric shows up while presenting nodal interruptions in the framework. At that point, by contrasting Rsys for various interruption occasions, we can decide the basic hubs for framework dependability.

Truth be told, the most dependable nodes are not really the ones affecting the framework if there should arise an occurrence of disturbance. Consequently, after our norm examination, we can evaluate the unwavering quality of every individual node, to finally shape a structure to our organization. A last observation allows us to express that the framework is moderately unresilient to interruptions. We aim to define the specific nodes where high criticality values are continuous and optimize the system and achieve better results.