User Guide

Network Reliability Optimizer

by SIM-NET 1

July 2024

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1. Introduction

1.1. Overview of the App

The **Network Reliability Optimization App** is developed using MATLAB App Designer, a flexible and robust environment for creating graphical user interfaces in MATLAB. This app seamlessly integrates MATLAB's powerful computational capabilities with an intuitive, user-friendly interface, making it accessible even to those with little or no programming experience.

The app is designed to assist users in analyzing and enhancing the reliability of network structures through various optimization techniques. MATLAB App Designer facilitates the creation of complex interfaces with ease, utilizing a drag-and-drop toolset that includes a wide range of UI components such as buttons, drop-down menus, and axes for plotting network arrangements.

Key features of the Network Reliability Optimization App include:

- **User-Friendly Interface:** The app's graphical interface is designed to be easy to use, allowing users to interact with the tool without needing extensive programming knowledge.
- **Advanced Computational Capabilities:** Leveraging MATLAB's extensive libraries, the app provides powerful tools for mathematical computations, data analysis, and visualization, essential for complex network analysis algorithms.
- **Optimization Techniques:** The app employs various methods to optimize network reliability, providing users with detailed analysis and enhancement suggestions.
- **Integrated Code Editor:** The App Designer includes a robust code editor, enabling developers to write and manage the underlying logic efficiently.

1.2. Purpose and Objectives

The primary purpose of the **Network Reliability Optimization App** is to assist users in improving and maintaining the reliability of network structures. The app achieves this through the following objectives:

- **Calculate Network Reliability:** Determine the reliability of an existing network based on its topology. This involves using advanced algorithms to compute reliability metrics and providing users with clear and actionable results.
- **Enhance Network Reliability:** Offer various tools and methods to suggest improvements for increasing network reliability. The app provides users with optimization techniques and strategies to enhance network performance.
- **Visualize Network Topology:** Allow users to view and interact with the network topology. This feature helps users identify critical nodes and links, making it easier to pinpoint areas for potential improvement.

- **Custom Link Addition:** Enable users to manually add links between nodes and immediately see the impact on network reliability. This functionality provides users with the flexibility to implement and test their own optimization strategies.

1.3. Target Audience

The **Network Reliability Optimization App** is designed for the following groups:

- **Network Engineers:** Professionals responsible for designing and maintaining network infrastructures.
- **Researchers and Academics:** Individuals studying network reliability and related fields.
- **IT Professionals:** Those involved in the planning and optimization of network systems.
- **Students:** Learners in courses related to network engineering, computer science, and reliability engineering.

1.4. System Requirements

To ensure smooth installation and operation of the **Network Reliability Optimization App**, the following system requirements must be met:

1.4.1 Hardware Requirements

- **Processor:** 1 GHz or faster processor
- **RAM:** 2 GB or more (4 GB recommended)
- **Storage:** At least 500 MB of free disk space
- **Display:** 1024x768 resolution or higher

1.4.2 Software Requirements

- **Operating System:**
  - Windows 7 or later
  - macOS 10.12 or later
  - Recent version of a Linux distribution
- **MATLAB:** R2020b or later
- **MATLAB Toolboxes:**
  - MATLAB Compiler
  - MATLAB Network Analysis Toolbox
  - MATLAB Graph Toolboxes

2. Installation and Setup

2.1. Downloading the App

To download the **Network Reliability Optimization App**, follow these steps:

- Open Microsoft Teams.
- Navigate to the group named **DID_SPEC_PROJECT_SW_2024**.
- Select the **SIMNET 1** channel.
- In the **SIMNET 1** channel, go to the **Materials** section and open the **04 Presentation** folder.
- Within the **04 Presentation** folder, find and open the **App** folder.
- Download the latest version of the app and its associated functions by downloading the entire **'app_final_ver'** folder, or locate the `NRO.exe` file inside the **NRO APP (exe)** folder and download it. Choose the preferred method.

2.2. Installation Guide

After downloading the app, follow these steps to install it:

2.2.1 Using `NRO.exe`

If you choose to use the `NRO.exe` file, ensure you have the MATLAB Compiler Runtime installed. For more information and to download the runtime, visit `https://it.mathworks.com/help/compiler/compiler.runtime.download.html`. In this case, you do not need to download the additional functions.

2.2.2 Using the `NRO.mlapp` file

If you prefer to use the `NRO.mlapp` file, follow these steps:

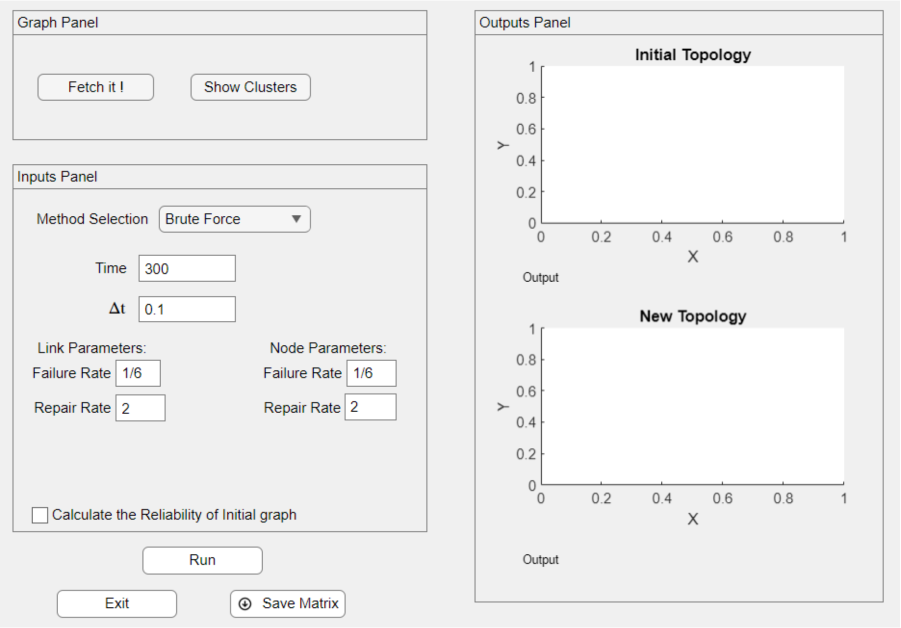
1. Open MATLAB on your computer.
2. Extract the downloaded files if they are in a compressed format (e.g., ZIP).
3. Add the directory containing the extracted files to your MATLAB path. This can be done using the `addpath` function or through MATLAB's environment setup options.
4. Ensure that the required MATLAB toolboxes (MATLAB Network Analysis and Graph Toolboxes) are installed. You can check and install these via MATLAB's Add-Ons manager.
5. Click on the `NRO.mlapp` file to launch the app.

3. App Overview

3.1. Main Dashboard Layout

The **Network Reliability Optimization App** features a user-friendly main dashboard designed to provide quick access to all essential functions. The main dashboard includes the following components:

- **Graph Panel:** Contains buttons for fetching the network graph and displaying clusters.
- **Inputs Panel:** Provides input fields for entering parameters and selecting methods for network reliability calculation and optimization.
- **Outputs Panel:** Displays the network graph and the results of the reliability calculations.



Method Selection: Brute Force

Time: 300

Δt: 0.1

Link Parameters:
Failure Rate: 1/6
Repair Rate: 2

Node Parameters:
Failure Rate: 1/6
Repair Rate: 2

□ Calculate the Reliability of Initial graph

Figure 3.1: Network Reliability Optimization App Interface

3.2. Navigation Guide

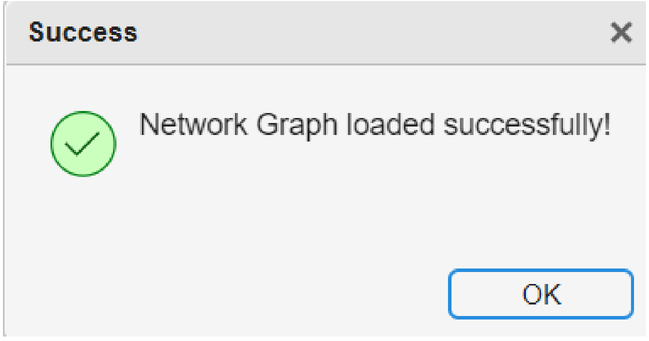
The following step-by-step instructions will help you navigate the **Network Reliability Optimization App**:

- **Load the Adjacency Matrix:**

  Begin by loading the adjacency matrix of the network topology:

  1. Click the **Fetch it!** button.
  2. Select the `.mat` file containing the adjacency matrix. A standard topology of 8 nodes and 8 links used throughout the project is already present in the folder, named '8node_topology.mat'. In case you would like to insert another topology ensure that the .mat file includes a variable named *cities_network*.

3. A confirmation message will appear once the matrix is successfully loaded, indicating that the input was correct.



Success

Network Graph loaded successfully!

Figure 3.2: Successful Input Message

The network topology will then be displayed in the first image of the **Outputs Panel**.

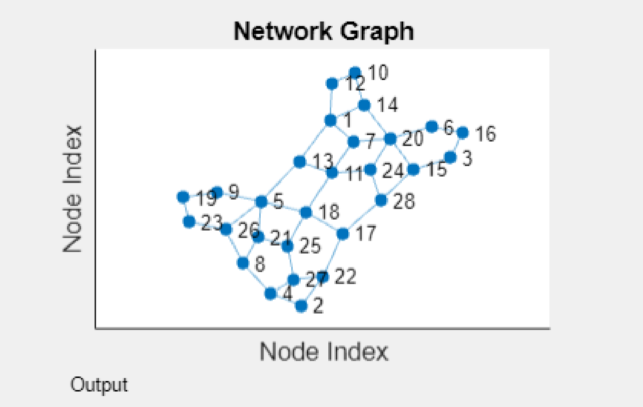
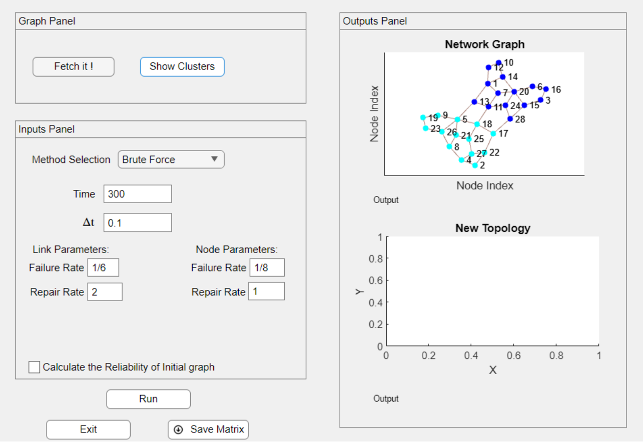


Figure 3.3: Network Topology Display

For visualizing clusters within the topology, click the **Show Clusters** button.



Graph Panel

Inputs Panel

Method Selection: Brute Force

Time: 300

Δt: 0.1

Link Parameters:
Failure Rate: 1/6
Repair Rate: 2

Node Parameters:
Failure Rate: 1/8
Repair Rate: 1

□ Calculate the Reliability of Initial graph

Figure 3.4: Network Topology with Clusters

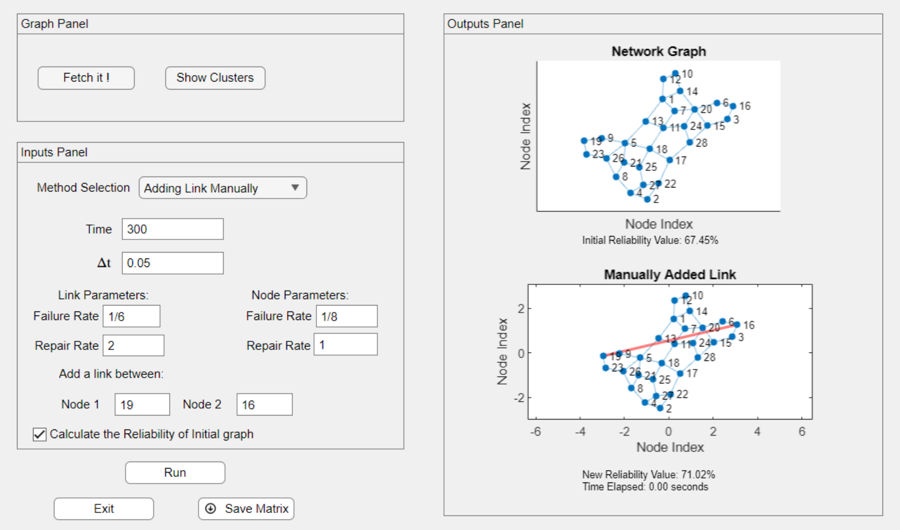
Viewing clusters can assist in deciding where to manually place a new link.

- **Set Parameters:**

  Next, enter the necessary parameters in the **Inputs Panel** for reliability calculations or the optimization process:

  - **Simulation Time:** Specify the duration for the simulation. Please keep in mind that the time of the transient state of the measured reliability might differ for different network topologies.
  - **Failure Rate for links and nodes (λ):** Enter the failure rate of the components, a number smaller than 1. It is the inverse of the crashes frequency in months. For example, if there is one failure every six months, set λ to $\frac{1}{6}$.
  - **Repair Rate for links and nodes (μ):** This is the inverse of the Mean Downtime of the component. For example, if the Mean Downtime is 2 weeks (which is $\frac{1}{2}$ months), then μ is 2. If the Mean Downtime is 1 month, then μ is 1.
  - **Time Resolution (Δt):** This parameter is critical and must be carefully adjusted based on the method used for link addition. Δt determines how frequently measurements are taken within a unit time, typically a month. To ensure accurate discretization of Poisson processes, set Δt such that the product $\mu \Delta t$ is less than 0.1 (or at most 0.2) for the largest μ in the system, whether for nodes or links. For computationally demanding methods, like the brute force approach, it may be necessary to reduce the simulation time if keeping $\mu \Delta t$ below 0.2 becomes very computationally demanding. For more details, please refer to the project report.

- **Select Link Addition Method:** Choose the method for link addition from the dropdown menu. Available methods include Brute Force, Clustering, Degree, Degree with Clustering, Diameter, or Adding the Link Manually. If you choose to add the link manually, an additional section will appear in the interface prompting you to specify the two nodes between which the link should be added. The added link will show up in **red** in the new topology. (See fig.3.5)



Method Selection: Adding Link Manually

Time: 300

Δt: 0.05

Link Parameters:
Failure Rate: 1/6
Repair Rate: 2

Node Parameters:
Failure Rate: 1/8
Repair Rate: 1

Add a link between:
Node 1: 19 Node 2: 16

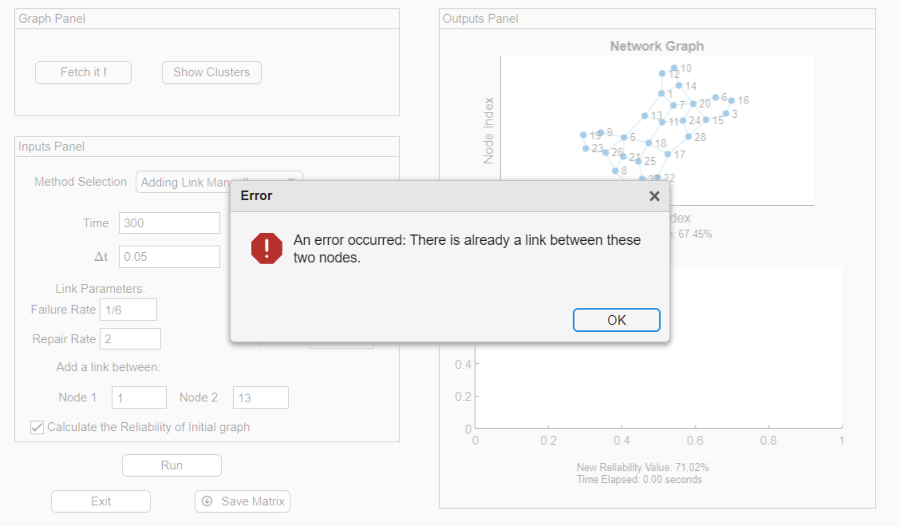
☑ Calculate the Reliability of Initial graph

Initial Reliability Value: 67.45%

New Reliability Value: 71.02%
Time Elapsed: 0.00 seconds

Figure 3.5: Specify Nodes for Link Addition

If you attempt to add a link that already exists, the app will notify you accordingly.



Error

An error occurred: There is already a link between these two nodes.

Method Selection: Adding Link Man...

Time: 300

Δt: 0.05

Link Parameters:

Failure Rate: 1/6

Repair Rate: 2

Add a link between:

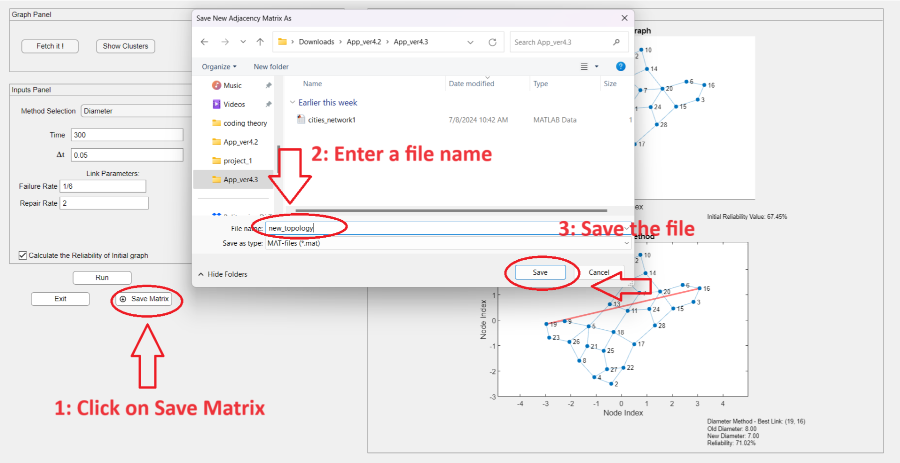
Node 1: 1   Node 2: 13

☑ Calculate the Reliability of Initial graph

New Reliability Value: 71.02%
Time Elapsed: 0.00 seconds

Figure 3.6: Notification of Existing Link

- **Run the Calculation:** Click the **Run** button to compute the reliability of the new topology with the added link. To compare the improvement, you can check the **Calculate the Reliability of Initial Graph** option to calculate the reliability of the initial graph before adding the link.
- **Saving the New Topology:** It is possible to save the newly obtained topology in the form of a `.mat` file. There is no need to manually set the variable name to *cities_network* since the app handles that automatically. Follow these steps to save the new matrix:
  1. Ensure that you have completed the network modifications and the new reliability calculations.
  2. Click the **Save Matrix** button to save the new adjacency matrix.



1: Click on Save Matrix

2: Enter a file name

3: Save the file

File name: new_topology

Save as type: MAT-files (*.mat)

Method Selection: Diameter

Time: 300

Δt: 0.05

Link Parameters:

Failure Rate: 1/6

Repair Rate: 2

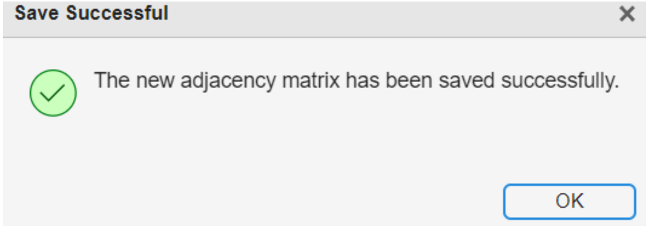
☑ Calculate the Reliability of Initial graph

Initial Reliability Value: 67.45%

Diameter Method - Best Link: (19, 16)
Old Diameter: 8.00
New Diameter: 7.00
Reliability: 71.02%

Figure 3.7: Save Matrix Button

  3. A dialog box will appear, prompting you to choose a location and filename for the new matrix.
  4. Select the desired location, enter a filename, and click **Save**.
  5. At the end of the procedure, you should be able to see this pop-up:



The new adjacency matrix has been saved successfully.

Figure 3.8: Successful download of the topology

- **Exit the App:** Use the **Exit** button to close the app when you are finished.

3.3. Interpreting the Results

1. Once the calculation is complete, the results will be displayed in the **Outputs Panel**. The panel includes two sections:
   - **Network Graph:** Displays the visual representation of the network topology with the added link.
   - **Reliability Results:** Shows the reliability values for both the initial and modified network topologies.
2. Compare the reliability values to evaluate the effectiveness of the added link. The app provides a clear indication of the improvement in network reliability.
3. If the reliability improvement is not satisfactory, you can try different methods or manually adjust the links to achieve better results.

4. Advanced Features

4.1. Custom Link Addition

The **Network Reliability Optimization App** allows users to manually add links between nodes. This can be useful for testing specific hypotheses or implementing custom optimization strategies.

1. Select the **Adding Link Manually** method from the dropdown menu in the **Inputs Panel**.
2. Enter the node numbers for **Node 1** and **Node 2** in the input fields that appear.
3. Click **Run** to compute the reliability of the modified network.
4. The app will display the new topology and update the reliability metrics accordingly.

4.2. Optimization Techniques

The app provides several optimization techniques to enhance network reliability:

1. **Brute Force:** Evaluates all possible link additions and selects the one that maximizes network reliability.
2. **K-means Clustering:** Uses K-means clustering to identify and enhance key network clusters.
3. **Degree:** Adds links to nodes with the highest degree to improve robustness.
4. **Degree with Clustering:** Combines degree and clustering methods for strategic enhancements.
5. **Diameter:** Reduces the network diameter to enhance overall reliability.

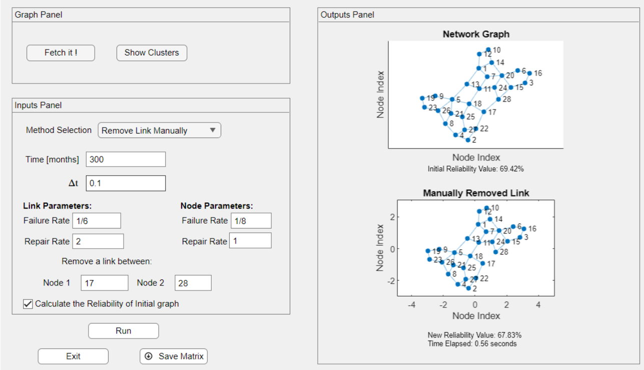
4.3. Visualizing Network Clusters

Understanding network clusters can be crucial for effective reliability optimization:

1. Click the **Show Clusters** button in the **Graph Panel** to visualize network clusters.
2. Clusters help identify critical areas where adding links can most effectively improve reliability.
3. Use the cluster visualization to inform your decisions on manual link additions or to understand the optimization methods' suggestions.

4.4. Link Removal for Debugging

For debugging purposes, the app also allows users to remove a link from the original topology. This helps in analyzing the impact of specific links on network reliability and in determining whether to add new links or reinforce existing ones.



Method Selection: Remove Link Manually ▼

Time [months]: 300

Δt: 0.1

Link Parameters:
Failure Rate: 1/6
Repair Rate: 2

Node Parameters:
Failure Rate: 1/8
Repair Rate: 1

Remove a link between:
Node 1: 17 Node 2: 28

☑ Calculate the Reliability of Initial graph

Initial Reliability Value: 69.42%

New Reliability Value: 67.83%
Time Elapsed: 0.56 seconds

Figure 4.1: Link removal feature from the dropdown menu

1. Select the **Remove Link Manually** method from the dropdown menu in the **Inputs Panel**.
2. Enter the node numbers for **Node 1** and **Node 2** corresponding to the link you wish to remove.
3. Click **Run** to compute the reliability of the modified network.
4. The app will display the new topology without the removed link and update the reliability metrics accordingly.
5. Analyze the updated reliability metrics to make informed decisions on whether to add new links or enhance existing ones.

5. Troubleshooting and FAQs

5.1. Common Issues and Solutions

Here are some common issues you might encounter while using the app, along with their solutions:

- **Issue: The adjacency matrix file does not load.**
  - **Solution:** Ensure that the file is in the correct format (`.mat`) and contains the variable named `cities_network`.
- **Issue: The app crashes during reliability calculation.**
  - **Solution:** Verify that all input parameters are correctly entered and within valid ranges.
- **Issue: The new adjacency matrix does not save correctly.**
  - **Solution:** Ensure you have write permissions for the selected directory and that the filename is valid.
- **Issue: The new reliability value is smaller than the original one.**
  - **Solution:** If the reliability of the system is decreasing instead of increasing, it may be due to an incorrect setting of the Time Resolution (Δt). Since the simulator operates in discrete time, Δt determines how frequently measurements are taken. To accurately capture the Poisson processes, Δt must be set such that the product $\mu\Delta t$ is less than 0.1 (or at most 0.2) for the largest μ in the system, whether for nodes or links. If Δt is too large, not enough measurements are taken, which can lead to inaccuracies and a decrease in perceived reliability. Ensure Δt is appropriately small to maintain accurate simulations. Please consider to also analyze the transient state of the network topology at hand for accurate results. For further details, refer to the project report.

5.2. Frequently Asked Questions

1. **How do I load a new network topology?**
   - Click the **Fetch it!** button and select the appropriate `.mat` file containing the adjacency matrix.
2. **Can I manually add multiple links at once?**
   - No, links must be added one at a time using the **Adding Link Manually** method.
3. **How do I reset the app to its default state?**
   - Restart the app to reset all settings and clear loaded data.

6. Appendix

6.1. Glossary of Terms

Poisson Process A stochastic process that models the occurrence of events over time, where events happen independently and at a constant average rate.

Adjacency Matrix A square matrix used to represent a finite graph, where the elements indicate whether pairs of vertices are adjacent or not.

Network Reliability The percentage of time the network remains in a fully connected state.

Transient State of Network Reliability The oscillations observed in the reliability values of a network before it settles into a steady state. During this period, the reliability can fluctuate due to various factors before achieving a stable long-term behavior.

Clustering The process of grouping a set of objects in such a way that objects in the same group are more similar to each other than to those in other groups. In this project clustering is done by considering the distance between nodes.

6.2. Contact Information for Support

For further assistance, please contact our support team:

- **Anamali Bjorna**
  Email: s322621@studenti.polito.it
- **Gorji Fatemeh**
  Email: s326721@studenti.polito.it
- **Jamishi Sadegh**
  Email: s314215@studenti.polito.it
- **Jasson Olivier**
  Email: s321275@studenti.polito.it

Moreover, please consider reading the report of this project, which provides detailed information about the project's development, methodologies, and results.