Master's Thesis

Electrical Network and Optical Network Dependability

The dependability that the electrical and optical networks have on each other is a critical factor in ensuring uninterrupted services to the large population of the landscape of urban infrastructure. This thesis aims to delve into the complexity of different protection schemes in optical networks and explore their interconnection with electrical networks through different kinds of failures. The motivation behind this thesis comes from the increasing reliance on digital and electrical services, making the importance of the robustness of the underlying infrastructure very critical. Additionally, the focus will be on urban areas due to their large number of population and complex infrastructural needs.

Protection schemes

Optical networks are backbone technologies that provide telecommunication services to urban areas and to safeguard these networks from failures and ensure continuity, different protection schemes are implemented.

- **Unprotected scheme:** Basic configuration without any backup paths for the feeder fiber, leaving the network vulnerable to service disruptions.
- **Type A Protection (Feeder Fiber Protection):** Incorporates a backup path for the feeder fiber's working path, enhancing reliability.
- **Type B Protection (Dual Parented):** Each subscriber is connected to two Optical Line Terminals (OLTs) located in different geographical areas. This setup provides a secondary OLT as a backup, significantly reducing the risk of service interruption.
- **Type C Protection:** Offers complete redundancy with two independent links extending to the subscriber's location, ensuring the highest level of network reliability.

The initial phase of this thesis involves mapping these protection schemes onto real-world urban layouts using OpenStreetMap data and Python scripting.

Failure Analysis and Impact Assessment

A critical aspect of network dependability is understanding how networks respond to failures and for this reason, this thesis implements different types of failures.

- **Node Failure:** Focuses on the failure of Optical Line Terminals (OLTs) and Remote Nodes (RNs), excluding Optical Network Units (ONUs) since their failure impacts are isolated.
- **Edge Failure:** Involves simulating failures of all network connections (edges) to assess the extent of impact on ONUs.
- **Disaster Failure:** Examines the effects of large-scale disasters, using a defined centroid and radius, to determine the number of affected ONUs within the disaster zone.
To explain the impacts on network functionality and ONUs, for each failure type the thesis will present visualizations and statistical analysis like boxplots or histograms. Interdependence with Electrical Networks Parallel to the exploration of optical networks, this thesis will study power network topologies, design constraints, and requirements necessary for integrating electrical network functionalities into the same urban layouts. Similar to the optical network, will simulate various power network failures and analyze their impacts on ONU connectivity. This approach aims to highlight and enhance the mutual dependability between electrical and optical networks, thereby increasing overall system robustness against failures.

All the work in this thesis is based on a combination of advanced scripting, data analysis libraries, and geospatial data sources to achieve its objectives. The primary tools and technologies used are Python, OpenStreetMap (OSM), and Python libraries. Some Python libraries are NetworkX which is used for creating and studying the structure of complex networks, and Pandas which is crucial for managing and analyzing the large datasets generated from OpenStreetMap and network simulations. Matplotlib and Seaborn to create static and interactive visualizations in Python.

Prerequisites

Knowledge of:

- Python
- Object Oriented Programming
- GIT
- Optical Networks
- Linux

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