Ph.D. in Information Technology
Thesis Defense

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Sala Seminari Nicola Schiavoni, Building 20

Oleg KARANDIN – XXXVI Cycle

LOW-MARGIN OPTICAL NETWORK DESIGN INTEGRATING NETWORK OPTIMIZATION AND ML-BASED QOT ESTIMATION

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Abstract:

The combination of data-hungry services and high-throughput access technologies creates unprecedented capacity requirements in today's networks. Optical networks are the backbone of the telecom infrastructure, and optical network operators are challenged to increase capacity while keeping expenses under control.

Expenses can be lowered if optical networks are operated more efficiently. In current deployments, optical transponders are configured with significant safety margins that guarantee very high availability, but are often overly pessimistic. Low-margin design refers to an optical-network design aimed at reducing safety margins and operating closer to channel capacity, while still guaranteeing high availability requirements. We investigate different approaches to low-margin design and quantify the savings achievable with low margin design. We first focus on quantifying the margin decrement that can be achieved using advanced modulation and coding schemes (i.e., Probabilistic Constellation Shaping), using intelligent resource-allocation strategies (i.e., nature-inspired metaheuristics) and precise Quality of Transmission modelling (i.e., considering actual value of nonlinear interference rather than the worst-case one). Then, we focus on reducing the design margins used to account for imprecise knowledge of physical-layer parameters (e.g., connector losses and optical amplifier gain profiles). We propose a design procedure based on Machine Learning (ML) that allows to gradually decrease these margins in presence of multiple physical-layer uncertainties by leveraging monitoring data. To this end, we introduce of a probabilistic ML-based margin estimator that allows to choose between more conservative and more opportunistic margins. We additionally extend our low-margin design framework to the scenario with preplanned restoration and restoration upgrade.

In addition to the low-margin design that applies to long-haul core optical networks, we investigated a form of low-cost design for metro optical networks, focusing on the joint removal of Wavelength Selective Switches (i.e., transitioning from a Wavelength-Switched Optical Network to Filterless Optical Network, FON) and optimized placement of optical amplifiers (OA). In particular, we optimize OA placement to maximize Signal to Noise Ratio (SNR) of the optical signals thus allowing to install fewer transponders operating at higher data rates.

Furthermore, we investigated how Explainable AI can be used to analyze the reasoning of ML-models in optical fault management to increase the sense of trust and foster the adoption of these

ML tools in automatic fault management. Specifically, we analyzed the reasoning of the ML model trained to perform fault localization using Optical Signal-to-Noise Ratio measurements.
In the appendix of the thesis we discuss another research contribution, still in the context of optical networks, but not related to low-margin design. We investigated the problem of the protection of traffic between Optical Network Units (ONUs) in recently-proposed advanced architectures for Passive Optical Networks (PON) that allow inter-ONU communication. We proposed two protection schemes that implement path protection and link protection in the context of advanced PONs and ensure high reliability of inter-ONU connections against fiber cuts.

PhD Committee

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