Master thesis No. 1084

Machine Learning for Instant Reconfiguration in IP-over-Optical Networks: A Speed-Driven Alternative to ILP Optimization

Methods
Simulation
Machine Learning

Topics
Network control
Reinforcement Learning

Background

Modern IP-over-optical core networks must react to traffic fluctuations on very short time scales. Reconfiguration decisions such as traffic routing and the activation or deactivation of optical circuits are naturally modeled as Integer or Mixed-Integer Linear Programs (ILP/MILP). These formulations accurately capture capacity, reach, and equipment constraints and provide optimal solutions. However, solving such optimization problems for every reconfiguration event is computationally expensive and typically too slow for instant or near-instant network adaptation. Machine learning offers a data-driven alternative: instead of repeatedly solving an optimization problem, a trained model can directly infer a high-quality reconfiguration decision from the current network state with very low latency. In this setting, the ILP/MILP formulation serves as a reference model that precisely defines the problem and provides optimal solutions against which learning-based approaches can be evaluated. The central motivation is to trade strict optimality guarantees for speed, enabling reconfiguration decisions on time scales that are infeasible for classical optimization.

Problem Description

The objective of this thesis is to design and evaluate a machine-learning-based approach for network reconfiguration that significantly outperforms an ILP/MILP baseline in terms of runtime while maintaining acceptable solution quality. The work consists of the following steps:

- Study the considered routing and resource-allocation problem in an IP-over-optical network and its ILP/MILP formulation, including objectives and constraints.
- Generate a dataset of network states and corresponding optimal or near-optimal reconfiguration decisions by solving the ILP/MILP for a wide range of traffic scenarios using a network simulator.
- Train a supervised machine learning model to directly predict reconfiguration decisions from the network state, targeting minimal inference latency.
- Compare the learned approach against the ILP/MILP baseline with respect to reconfiguration time, feasibility, and solution quality.

Acquired Knowledge and Skills

In this thesis, the student will develop a solid understanding of how network reconfiguration problems in IP-over-optical networks are formulated as ILP/MILP models and why these formulations become a bottleneck in time-critical scenarios. The work will provide experience in simulation-based dataset generation and in using optimization results as supervision signals for machine learning

Requirements
Programming Experience
Basic Machine Learning Knowledge

Desirable knowledge
Communication Networks Architecture and Design
Neural Networks

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