Abstract

In this thesis, data-driven techniques for multi-layer optical networks are described. The fast growth in global IP traffic and the advancement in the communication technologies, such as coherent optical transmission, elastic optical networks, and the opening of software-defined optical networks (SDON), introduce many tunable parameters, making the design and operation of optical networks more complex.

In this framework, exact system modeling using closed-form formulations is very challenging, and typically, a "margin" is deployed while adopting the analytical models. The deployment of specific margins leads to the under-utilization of resources and eventually enlarges the network operational cost. To cater to this limitation of analytical models, the telecom industry is strongly pushing the optical community to move towards intelligent optical networks that can perform autonomous and flexible network management and optimize network resources utilization. Thus, smart optical networks are fundamental to the modern optical network to assess the potentialities better and exploit various technologies' capabilities.

Moving towards intelligent optical networks and data centers, large-scale photonic switches and wavelength selective switches play a prominent role due to their wide-band capabilities, minimal latency, and low power consumption. These distinctive properties increase the possibilities of using photonic integrated circuits based network elements, especially photonic switches, and hence it generates a demand for a generic softwarized model for control states and quality of transmission (QoT) degradation to enable full control by a centralized controller.

In developing an intelligent optical network, the basic framework of SDON is the leading enabling technology in the direction of intelligent optical networks, comprising three principal planes, the data plane, control plane, and application plane. The assisting cognitive module is logically centralized and is part of the control plane. In this novel playground of SDON, machine learning-assisted QoT

estimation in optical networks is presented. The machine learning model's training on the generalized signal-to-noise ratio (GSNR) response to specific spectral load configurations of the already deployed *in-service* network, and consider its realization to predict the QoT of an *agnostic/un-used* network. The synthetic dataset is retrieved from lightpath QoT responses against random spectral loads of *in-service* network. This data is generated during the operative phase of the *in-service* network by measuring the optical line system (OLS) response in terms of GSNR for various spectral load configurations

Furthermore, a framework of machine learning-assisted photonic devices management is given, in the context of SDON. This generic topology-agnostic *blind* framework exploits a machine learning inverse design approach to obtain the softwarized control of any $N \times N$ photonic switching system by giving the permutations of the signals (λ_1, λ_2, $\lambda_3 .... \lambda_n$) at the output ports. Moreover, a direct design method is also presented to predict the QoT degradation due to the penalty encounter by crossing the optical switching elements. The previously obtained controls are exploited to predict the QoT degradation in terms of optical signal-to-noise ratio (OSNR) Penalty.

Finally, several supervised machine learning models are also proposed using the two most common open-source machine learning libraries, TensorFlow© and *scikit-learn*©. The performance assessment of these developed models is also performed in terms of assisting the QoT estimation and also for photonic devices management.