Ph.D. in Information Technology
Thesis Defenses

July 21, 2022
at 10:00
Room 3.1.6, Bldg. n. 3, and online by Webex

Mëmëdhe IBRAHIMI – XXXIV Cycle

INNOVATIVE CROSS-LAYER OPTIMIZATION TECHNIQUES FOR THE DESIGN OF FILTERLESS AND WAVELENGTH-SWITCHED OPTICAL NETWORKS

Supervisor: Prof. **Massimo Tornatore**

Abstract:

Optical networks are playing a crucial role in the era of 5G-and-beyond communications to support applications requiring unprecedented capacity, reliability, low-latency and guaranteeing lightpath Quality-of-Transmission (QoT). To cope with such stringent requirements, network operators are driven to provide novel solutions while keeping network costs at bay. Recently adopted technologies, such as coherent transmission, allow to support high capacity demands and enable network designers to tune various configuration parameters to achieve better network performance, but at the expense of increased network design complexity. To reduce cost while enabling network expandability, new network architectures in the context of Wavelength Switched Optical Networks (WSON) and Filterless Optical Networks (FONs) are essential.

We devise optimization approaches that minimize network costs by optimizing the deployment of optical equipment at network nodes and along the fiber while ensuring lightpaths' QoT. In particular, we optimize the deployment of Optical Amplifiers at network nodes, i.e., booster amplifiers and pre-amplifiers, and along the fiber, i.e., inline amplifiers, both in the context of WSON based on ROADMs with WSSs and in the context of horseshoe FON. Additionally, we devise a cross-layer optimization approach for the placement of Optical Transport Network (OTN) traffic-grooming boards at the electrical layer while employing coherent and non-coherent transmission technologies, with the objective of minimizing overall network costs. Furthermore, we investigate the problem of DPP in the context of meshed FON and ensure link-disjoint primary and backup paths for each lightpath, by optimizing the deployment of additional equipment (transceivers and wavelength blockers) at network nodes and (colored passive filters) along the link. To solve these problems, we have developed various optimization methods such as greedy heuristic approaches and meta-heuristics such as Genetic Algorithms, and Integer Linear Programming (ILP) models. The objective of these approaches is network cost minimization and depending on the context they are applied to, they are subject to different constraints such as lightpath QoT feasibility constraints, spectrum continuity and contiguity constraints, traffic-grooming constraints, FON-related constraints and capacity constraints.

In addition to the above-mentioned optimization techniques, we investigate the problem of estimating the QoT of unestablished lightpaths in the context of WSON. Estimating lightpaths' QoT

is a complex problem due to the nature of nonlinear impairments characterizing signal propagation in optical fiber, due to uncertainties of parameters used to describe various optical components/equipment, e.g., amplifier noise figure, and fast time-varying penalties, e.g., polarization effects. This problem has been generally tackled utilizing Machine Learning (ML)-classification approaches that estimate if a given lightpath configuration has satisfactory QoT. We address this problem utilizing ML-regression approaches as they allow to make more informed decisions about how conservative or aggressive a network operator can be when taking network planning choices, i.e., deploying a new lightpath. We propose several novel ML-regression approaches to estimate the distribution of a lightpaths' Signal-to-Noise Ratio (SNR).
The research conducted during this PhD thesis has been performed in coordination with an industrial partner, SM-Optics, who have provided very fruitful and practical insights to solve the problems we have addressed.

Marco ZAMBIANCO – XXXIV Cycle

DEEP REINFORCEMENT LEARNING FOR INTER-NUMEROLOGY INTERFERENCE MINIMIZATION IN 5G RAN SLICING

Supervisor: Prof. **Giacomo Verticale**

Abstract:

Radio Access Network (RAN) slicing is an essential technology to unleash the full potential of 5G systems in accommodating heterogeneous applications requirements within the same RAN infrastructure. In this context, the design of spectrum allocation policies covers the fundamental role to ensure that each service obtains a suitable share of the radio resources. However, the stochastic nature of the wireless channel makes the service requirement fulfilment more challenging due to the variability of the achievable data rate provided by the spectrum resources. Moreover, mixed-numerology access schemes on the shared RAN physical layer further exacerbate the policy design complexity since Inter-Numerology Interference (INI) hinders the service provisioning performance. Based on these observations, this thesis investigates the design of spectrum allocation policies having two main features. On one hand, they enhance the network slice performance in terms of aggregate data rate and/or service reliability. On the other hand, they enforce inter-slice isolation by mitigating the inter-numerology interference that affects each slice user. The proposed schemes leverage Deep Reinforcement Learning (DRL) to achieve near-optimal spectrum allocation based on a model-free agent formulation. Furthermore, the designed agents are augmented with ad-hoc schemes that improve the learning effectiveness in complex network scenarios. Results show that an INI-aware spectrum allocation achieves better performance when compared to INI-agnostic schemes. In addition, they also highlight the advantage of the proposed DRL resolution methodology to provide a scalable and computationally efficient spectrum policy computation.

PhD Committee

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