Doctoral Dissertation
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Cognitive and Autonomous Software-Defined Open Optical Networks

By
Giacomo Borraccini

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Supervisor(s):
Prof. Vittorio Curri

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Driven by the increasing and greedy Internet data traffic request, optical network operators are working to satisfy this need, improving the already installed resources, or updating them with the introduction of new technological discoveries. In this context, boosted by the progressive process of opening and standardization, the most relevant support for service capacity increase and system management is conferred by optical network automation, implying the implementation of software-defined networking (SDN) approaches. Another important characteristic for an efficient usage of optical networks is the capability of the infrastructure to be agnostic with respect to the adopted vendor equipment. Starting from the last decade, cognition has been introduced and theorized as an emerging feature of the next generation of optical networks, implying the autonomous and prompt control of a network at each abstraction layer operating decisions and strategies based on the processing of information related to the status of the system. The response to the increasing complexity of the infrastructure is given by the possibility to probe the condition of the network through monitoring devices and to efficiently analyze the extracted information using flexible software modules. In addition, the proper control, based on an accurate physical layer modeling, of active network elements, such as optical amplifiers – Erbium-doped fiber amplifiers (EDFAs) or Raman amplifiers – and reconfigurable optical add & drop multiplexers (ROADMs), results to be a key point within the described scenario.

The aim of this work is to deepen cognition and automation applied on optical networks at the physical layer, defining vendor agnostic control procedures and architectures capable of autonomously maximize the capacity of the optical infrastructure. The latter implies a larger exploitation of the installed resources, even in case of lack of knowledge about equipment specifications. In particular, it has been proved that the performance of a ROADM-to-ROADM optical link can be optimized maximizing and flattening the quality of transmission (QoT) over all the channels propagating through the link. The developed methodologies have been applied to different use-cases, properly defining each architecture of the corresponding controller: single-span Raman amplifier system; multi-span EDFA-amplified optical line system (OLS); complete optical network with triangular and linear topology. The adopted methodology that brings the considered system to maximize the its capacity can be summarized with a two-step optimization process applied during the provisioning phase of an optical network. The core of this approach is the use of a physical layer model able to simulate the behavior of the considered system. Firstly, the physical layer is completely characterized retrieving in-field the needed features through the available telemetry in order to estimate the corresponding physical layer parameters. Then, on the basis of

the tuned physical layer model, the working point of the system is properly designed. During the first step, the system is set under defined conditions and the physical layer model is tuned in order to match the optical transmission behavior reported by the telemetry, then according to the network controller targets, the working point of the system is optimized manipulating the softwarized representation of the optical system.

As a continuation of the research activity, the orchestration and the management of an optical network within the control system can be improved in terms of flexibility and adaptability with respect to several scenarios. Also, ad-hoc artificial intelligence techniques can be implemented and their impact investigated within various frameworks in order to face soft/hard failures and support the system reaction with proper automatic re-optimization strategies