Demonstration of AI-Light: an Automation Framework to Optimize the Channel Powers Leveraging a Digital Twin

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Abstract: We demonstrate a network automation framework called AI-Light able to: create a digital twin based on the monitoring, perform an SNR-based optimization by leveraging the digital twin and, push the optimized configuration into the network.

1. Overview and Innovation

The continuous increase of internet traffic is driving the need for the operators to carefully optimize their network in order to maximize the return on the investment. For this reason, in the ETSI specification for the future, fifth generation fixed network (F5G) architecture, that includes the optical transport segment, improved intelligence and automation are key enabler for high capacity, highly resilient transport networks [1]. Therefore, the network capacity and margins are two key figures of merit for the performance and the stability of the system respectively [2]. Hence, many optimization algorithms targeting the maximization of the capacity or the margins have been developed [3-5]. Moreover, nowadays the key elements of every state-of-the art optical network such as transponders, reconfigurable optical add-drop multiplexers (ROADM), and optical amplifiers are fully configurable, enabling the potential development of an autonomous driving network (ADN) [6,7]. In this context, many automatic optimization processes have been developed [8-11] by focusing on the optical amplifiers [8-10] or the wavelength selective switches (WSSes) [11]. However, in most of the experiments, the propagation impairments of the fiber, such as the Kerr effect and the stimulated Raman scattering (SRS), are not significant as either the covered distance is short [9] or the number of channels is low [8,11]. Moreover, in [11], the optimization is not fully integrated as a fixed target power is provided and only the iterative configuration of the power per channel is automated. Furthermore, in [9], only the optical signal to noise ratio (OSNR) is taken into account and therefore the fiber non-linear interference (NLI) is neglected.

In this demo, we demonstrate an automation framework to optimize the channel powers that can be used as an auto-commissioning tool. To do that, we use a Python-based software-defined network (SDN) framework called *AI-Light* to demonstrate a complete automation cycle: the telemetry is leveraged to probe the current state of the network and the retrieved information is combined with the static information stored in a database to create a reliable digital twin; an SNR-based optimization algorithm computes the optimum configuration over the digital twin by leveraging a quality-of-transmission estimator (QoT-E); the configuration of the WSSes is used to achieve the optimum power per channel and the amplifiers are configured in *gain-lock mode* to simplify the management of fiber cuts and the deployment of new services. Finally, the optimized configuration is pushed to the physical network equipment.

2. OFC relevance

Network automation has been a hot topic for several years at OFC. The proposed demo is of interest to network operators as it demonstrates a fully automatic optimization process over a state-of-the art optical network.

3. Content of the demo

Fig. 1 reports the test-bed showing the network topology (Fig. 1 left) and a set of photos depicting the commercial equipment (Fig. 1 right): the erbium-doped fiber amplifiers (EDFAs), the WSSes and the transponders. The network is composed of 6 reconfigurable add-drop multiplexers (ROADMs) nodes interconnected by 8 optical multiplex sections (OMSes). The details of each OMS are reported in table 1: the OMS length variates between 20 km and 500 km and the fibers can be standard single-mode fibers (SMFs), pure-silica-core single-mode fibers (PSCFs), true-wave fibers (TW) or large effective area fibers (LEAFs). Moreover, two identical commercial transponders have been used to generate two channels under test (CUTs) used to measure the real-time bit-error-rate (BER). Finally, shaped ASE noise is used to emulate a large number of services used to get a realistically populated spectrum triggering a realistic amount of SRS and NLI.

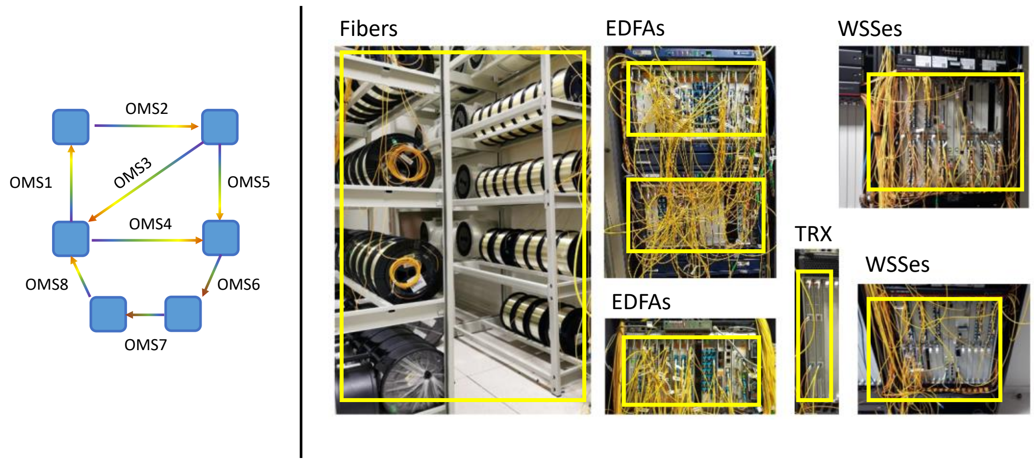

Fig. 1: The network topology (left) and a set of photos of the network equipment (right).

Table 1: Details of each OMS

Name	OMS1	OMS2	OMS3	OMS4	OMS5	OMS6	OMS7	OMS8
Number of spans	5 spans	5 spans	5 spans	2 spans	3 spans	1 span	2 spans	2 spans
Fiber length	5x80 km	5x100 km	5x100 km	2x80 km	3x80 km	20 km	80 km + 40 km	80 km + 20 km
Fiber type	5xSMF	5xPSCF	5xPSCF	LEAF + TW	3xSMF	SMF	2xLEAF	2xSMF

Fig. 2 depicts how some AI-Light functionalities are used to build the demo: the controller collects all the data necessary to have a complete and accurate representation of the network state both by probing the network equipment and by reading from a database static information such as the fiber type and the fiber length. Then, all the data are harmonized and used to create a *digital twin* which is then exploited to optimize the network. In this demo, the optimizer computes the optimum power per channel of each OMS by iteratively modifying the attenuation of the WSSes in the digital twin and evaluating the corresponding SNR using the QoT-E. Once the optimization algorithm has converged, the final configuration is pushed to the real network.

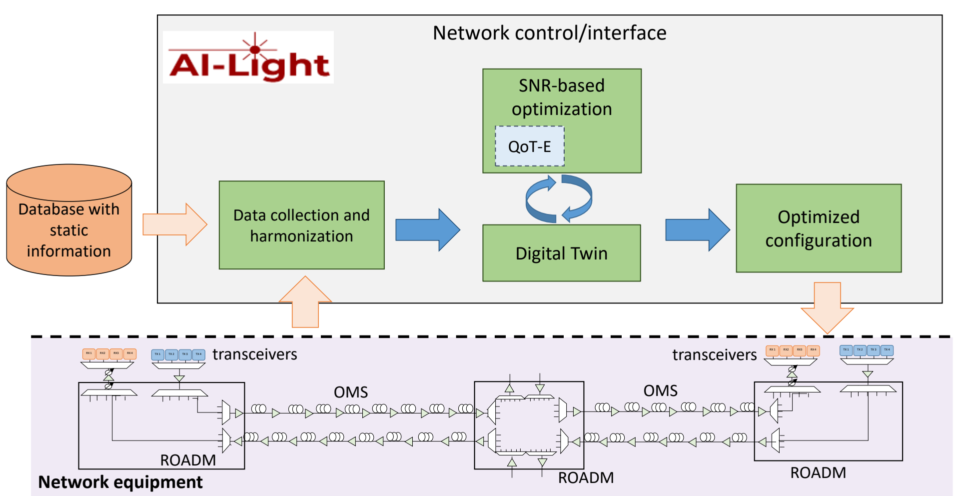

Fig. 2: structure of the demo: (top) AI-Light SDN framework; (bottom) network equipment.

The demo will be remote and the process will be shown by means of a GUI as depicted in Fig. 3. The GUI is organized in two main sections: 1) a *monitoring* section showing the spectrum before the optimization (in red) and the real-time the spectrum (in green) after the booster of the selected OMS and the real-time BER measured by the two transponders over time (blue and orange lines); 2) an *equalization* menu in which it is possible to select and run the power configuration strategy (flat, tilted or SNR-optimized). An OSA is used for the only purpose of showing the spectrum after the booster in the *monitoring* section of the GUI. After selecting the desired method, the monitoring section shows the optimized power spectrum and the change in the BER of the two signals over time.

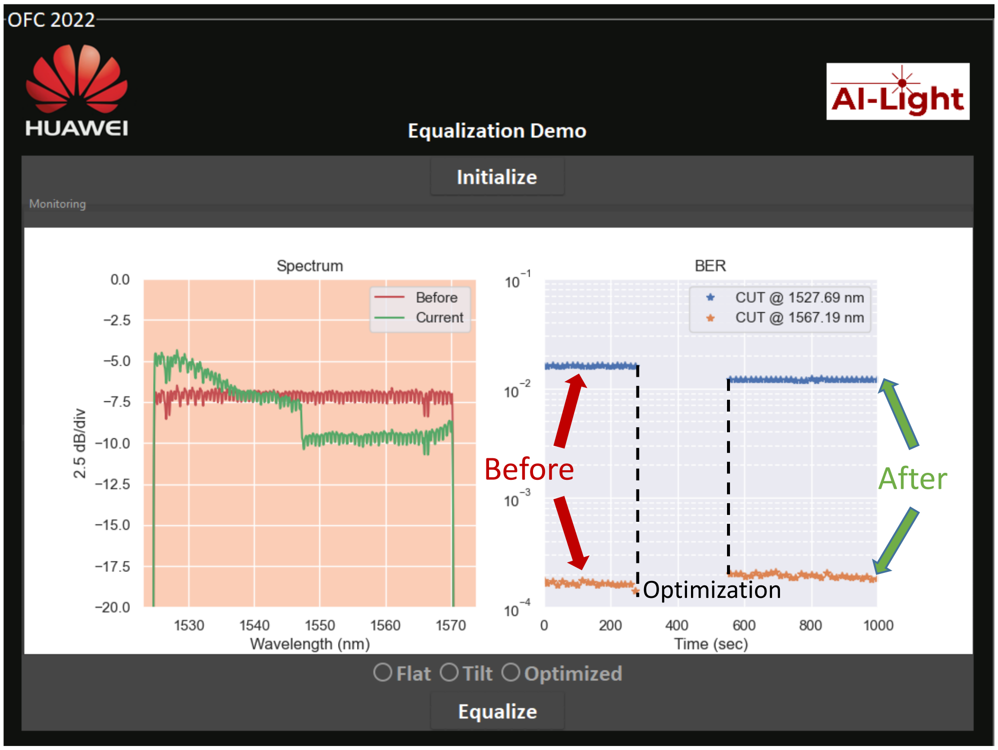

Fig. 3: GUI showing the monitored spectrum and the BER over time before (left) and after (right) the optimization

Fig. 3 reports an example where 80 services are allocated in 6 THz (75 GHz grid). 40 services (one CUT at 1527.69 nm and 39 ASE channels) are routed through OMS1 at the shortest wavelengths and the PDM-16QAM modulation is assigned to them. Then, the other 40 services (one CUT at 1567.19 nm and 39 ASE channels) are routed through OMS1, OMS2 and OMS3 at the longest wavelengths and a PDM-QPSK modulation is assigned. After the optimization, the *monitoring* section shows the flat spectrum before the optimization (red) and the real-time spectrum after the optimization (green) in OMS1. The configuration process required 200 seconds, the BER at 1527.69 nm (blue line) changed from 1.6e-2 to 1.2e-2 (6.6 dB to 7.1 dB in Q-factor) and, the one at 1567.19 nm (orange line), moved from 1.7e-4 to 1.9e-4 (11.1 dB to 11.0 dB in Q-factor). The algorithm has slightly increased the BER of the non-critical service (1567.19 nm) to improve the BER of the services closer to the FEC limit making the overall system more robust.

In this demo we demonstrate that, compared to flat power equalization, the SNR-based optimization is able to reduce the BER of the most critical services (the one closer to the FEC limit) at the price of increasing a little the BER of the non-critical services (with very low BER). This makes the overall system more robust against BER fluctuations and aging.

3. References

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