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Testing TIP Open Source Solutions in Deployed Optical Networks

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Abstract: Standardization in optical networking enables operators to benefit from using open source components. We investigate quality of transmission of open source hard- and software in the Deutsche Telekom R&D SASER network and optimize the working point.
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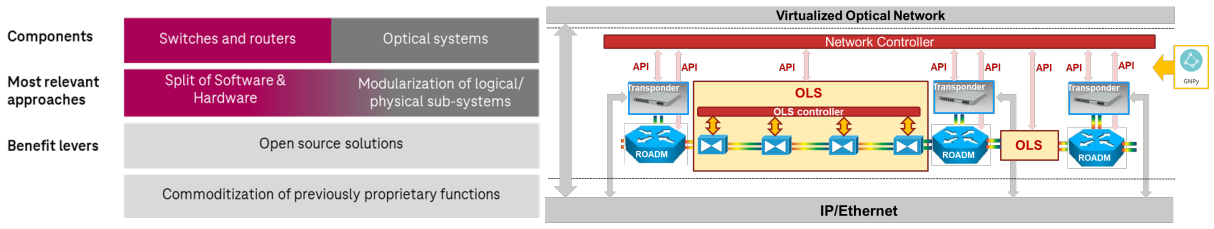
1. Introduction

As the digital economy grows, demand for greater connectivity continues to rise [1]. However, a lack of flexibility in the current solutions, exacerbated by a limited choice in technology providers, makes it challenging for operators to efficiently build and upgrade networks. In the next years, the need for seamless, convenient and efficient optical network upgrades called by the increasing network traffic demand, such as the extension of the transmission bandwidth beyond the C-band [6], will potentially drive the change of paradigm from vendor-locked systems to open and disaggregated networks. This will enable hardware vendor-agnostic interoperability enabled by software-defined network (SDN) controllers implementing standardized APIs and open source solutions, as briefly outlined in Fig.1a. In this paper we present the first results of the testing activities of the TIP GNPy software tool [4, 5] in an open and disaggregated context exploiting the Cassini whiteboxes on the Deutsche Telekom SASER network. Since it is aimed to be a testbed for several operator activities, SASER network does not carry any critical traffic. The starting point of our test was an OLS with the spectrum completely unloaded. However, the previous OLAs configuration was tailored to dismissed spectral loads aimed to test for full C-band transmission. Our goal has been to determine, with the aim of GNPy, the optimal working point of the OLAs for the transmission of a smaller WDM comb generated by CFP2 coherent optics pluggables onto newly deployed Cassini whiteboxes running IPInfusion OcNOS as network operating system. The paper is structured as it follows: In section 2 we outline the operator perspective and drawing forces towards disaggregated and open networking. Section 3 describes the installed SASER test network of Deutsche Telekom used for testing. In section 4 we comment the results of the optimization of a 8x 100G channels wavelength-division-multiplexing (WDM) comb over a 450km OLS, carried out using GNPy . Finally, in section 5, we draw the conclusions.

2. Operator Demands and Telecom Infra Project

Today's optical operators transport networks are built as vertically integrated solutions – a vendor is selected for a network segment or part of and then all transponders, reconfigurable add-drop multiplexers (ROADMs), amplifiers and even the necessary optical design tools for planning and provisioning are provided by the vendor. This trend was mainly driven by the high technical complexity due to the analog nature of the optical transport technology which in turn limited the drive to define standardized interfaces and interoperable solutions. Once deployed, every design and planning step in such a scenario is under full control of the selected vendor and the upgrade choices over the life-time of the system are strongly limited. Such networking silos ended up in inhibiting flexibility and



(a) (b)

Fig. 1: (a) Basic concepts of open and disaggregated optical networks. (b) Schematic of a partially disaggregated optical network. Network controller orchestrates OLSs and other network elements such as ROADMs and transponders from different vendors.

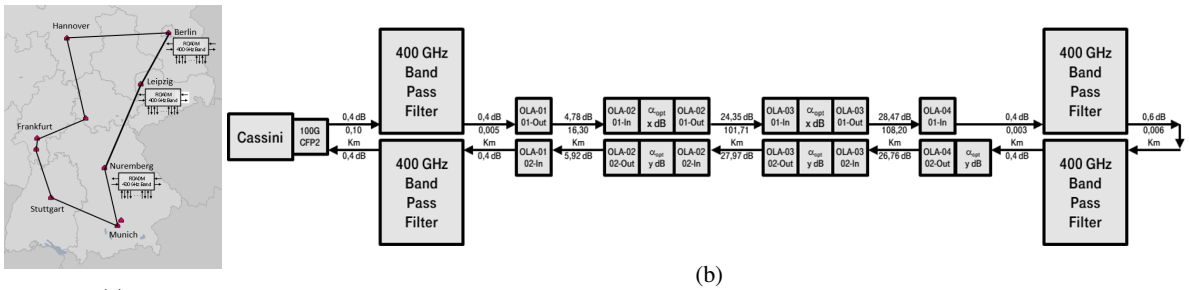
innovation, particularly in the terminal equipment, where over the last decade rapid innovation happened. In a typical european national network, ultimate performance in terms of optical reach is not always needed, thus allowing the use of less complex modulation schemes and also providing some margin for mixed vendor scenarios in an open, disaggregated network environment. This opens up the avenue to prevent a vendor lock-in by applying disaggregated optical transport solutions with open source components based on well-defined and standardized interfaces as proposed by the Telecom Infra Project (TIP), and the Open Network Foundation (ONF) [2, 3]. TIP, in particular, is accelerating the development and deployment of open, disaggregated, and standardized solutions by encouraging collaboration among academia, vendors and operators and featuring testing facilities such as the TIP-Labs in Berlin. Within TIP, the Open Optical & Packet Transport (OOPT) group provided the fundamental work on the definition of open technologies, architectures and interfaces in Optical and IP Networking enabling to build optical networks based on open source components. A pivotal element in OOPT is GNPy [4, 5], an open source simulation tool, implementing lightpaths quality of transmission (QoT) estimation, developed by the Physical Simulation Environment (PSE) working group. GNPy enables operators and vendors to collaboratively work on open optical network design and optimize networks with open source network simulations [10]. In the long-run this will reduce network cost, expand supply chain flexibility and thus fostering competition. Fig.1b shows the schematic of an open and partially disaggregated transport network composed of several optical line systems (OLSs) which may belong to one vendor domain and several ROADMs or transponders belonging to other vendor domains. A vendor specific OLS is controlled by a potentially proprietary OLS controller which is then connected to a network controller via API. This network controller ensures end-to-end operation e.g. configuration and management of all attached network elements. To test the viability of an open source based optical network, we started with a simple case, by implementing open Cassini transponder whiteboxes to our R&D SASER OLS with multiplexer, ROADM, amplifiers etc, provided by other vendors, as in Fig.1b.

3. Field Installed German Nationwide R&D Test Network

As previously mentioned, the test have been carried on the SASER ring test network of Deutsche Telekom [7], depicted in 2a. The ring is composed of 2110 km long bidirectional field-installed fibers. We have then identified on the Berlin-Leipzig-Berlin an OLS with completely empty spectrum to conduct the optimization test on, whose layout is represented in Fig.2b, made of 6x standard single mode fiber (SSMF) fiber spans without dispersion compensation and two-stage Erbium doped fiber amplifiers (EDFA). Both Berlin and Leipzing are add-drop sites equipped with ROADMs based on passive, manually controlled, 400 GHz wide optical band-pass filters. 8x 100 Gbps channels, PM-QPSK modulated reaching spectral efficiency of 2 bit/s/Hz, on the 50 GHz grid (from 191.90 THz up to 192.30 THz) are generated on the Cassini transponders installed in Berlin, sento to Leipzig and switched back to Berlin through the two ROADM. The length of the used looped back fiber link amounts to 450 km, containing 6 two-stage EDFAs, 122 dB total link loss, 7926 ps/nm total link chromatic dispersion, and 5 ps differential group delay. The test OLS includes non-ideal realistic environments, due to additional losses in offices, splices, patches, and filtering.

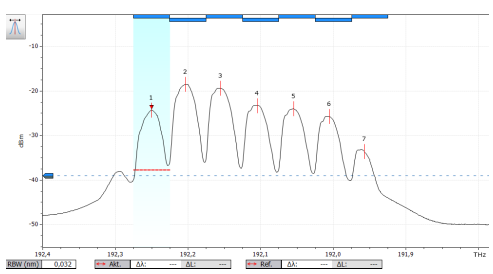
4. Results & Conclusions

As introduced in section 1, since SASER is used as a test network, the previous setting of the OLAs in the considered OLS were tailored for a previous, dismissed test on full spectral load, C-band transmission. Hence, with respect to our 8x channel WDM comb propagation, we were operating in a highly non-optimized configuration. Because of the large amount of power injected into the fiber, this led to an 8-channels test configuration working in highly non-linear regimes, i.e. where the non-linear interference (NLI) noise was predominantly and limiting transmission with respect to amplifier ASE noise. It has been widely shown [5, 8, 10], that the generalized signal-

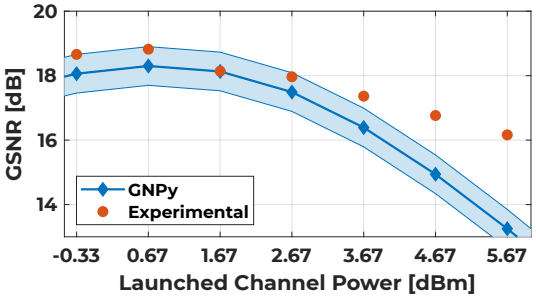


(a) (b)

Fig. 2: (a) German SASER R&D test network. (b) Block diagram of the 450km long OLS used for testing.



(a)



(b)

Fig. 3: (a) 8-channel WDM comb received spectrum measured with OSA. Channel power levels differences are due to the filtering at add-drop sites. (b) GSNR vs launched power per channel. Averaged experimental values (orange) and GNPy estimation (blue), blue bar stands for an +/-0.5 dB of uncertainty around the GNPy prediction.

to-noise ratio (GSNR), encompassing both ASE and NLI noise, portrays completely the QoT of a lightpath.

Hence, we first modeled the OLS in its first, non-optimized, configuration and we compared the GNPy GSNR estimation for the 8x channels WDM comb to the GSNR measured by the pluggable module receiving the channels in the Cassini. After some tune-up we accomplished a good match (9.8 dB experimentally vs 8.7 dB by GNPy) for the third channel of the comb, at 192.2 THz, chosen as channel under test (CuT). We then proceeded with the optimization phase of the 8x channel comb over the OLSs. Optimization has been performed still using GNPy and basically consisted in the determination of the optimum launched power per channel at each fiber span based on the Locally-Optimized, Globally-Optimized (LOGO) strategy [9]. This meant to determine the working point of the OLAs and the Booster (OLA-01 in Fig.2b), i.e. the total output power/gain of the EDFAs. We have then set the obtained values into the OLS EDFAs and performed a power sweep around the optimum power to further check the correctness of the optimization. The comparison of the GNPy estimation and the experimental power sweeps is reported in Fig.3b. Results show that the channel power of 0.67 dBm is correctly predicted as the optimum launch power per channel maximizing the GSNR. Going to lower channel power puts the system in an ASE-limited area worsening the performance. However, it has not been possible to go lower than -0.33 dBm due to limitations in the minimum output power of the EDFAs. Instead, going beyond the LOGO power brings the system in the NLI-limited area, where NLI noise is predominant and each dB more in launched power worsens GSNR by 2 dB. Fig.3b shows an increasing gap as we go further in the NLI zone. This has been explained with the changing of the EDFAs noise figure with respect to the load and set gain. This shows the importance of the EDFAs noise figure exact knowledge when estimating QoT of an OLS. In this case, in fact, we have used the reference values due to the lack of characterization data. However, it should be noted that GNPy still provides good accuracy in the range around the LOGO power, with the experimental GSNR within +/-0.5 dB (blue bar in Fig.3b) from the prediction.

5. Conclusions

We have shown a successful test of implementation of the open and disaggregated paradigm on an installed, realistic OLS in the Deutsche Telekom SASER network. Preliminary tests with GNPy estimated correctly the optimal working point and the GSNR within +/-0.5 dB from the measured value around the LOGO power, given a limited knowledge of EDFAs noise figures. Further testing may expand to more precise network elements characterization and testing with higher spectral efficiencies, larger occupied bandwidth and to longer links in SASER network, or via the whole ring.

Acknowledgment

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