Gap Analysis on Open Models for Partially-Disaggregated SDN Optical Transport Environments

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Abstract: We report an analysis of completeness and suitability of OpenConfig, OpenROADM and OpenDevice models, for physical-impairment aware network planning, and a proof-of-concept in a partially disaggregated testbed exposing equipment information to Net2Plan through ONOS.

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1. Introduction

Software Defined Networking (SDN) principle establishes a logically-centralized SDN controller that exercises direct control of the data-plane elements through SouthBound Interfaces (SBI) and exposes a NorthBound Interface (NBI) to network applications. SDN controllers, through the NBI, open the door to the Optimization-as-a-Service paradigm: third-party applications to perform automatic optimization [1] of the network at different levels. In optical networks, white-box and openness of the SBI, foster disaggregation models [2], which provide cost-reduction opportunities [3].

At the NBI interface, network planning and optimization applications have been recently presented for IP over WDM resources allocation [1]. However, the applicability of NBI optical planning tools is hindered by the current limitations of the optical device / system models, as they do not expose to the SDN controller through the SBI, and consequently to applications consuming the NBI, a full set of parameters to enable a detailed physical-layer awareness. Today, a planning relying on in-depth characterization of the optical/physical layer is only possible with system vendors' proprietary tools, or network management systems (NMS) that control the so-called vendor islands [4].

In this paper, we present two contributions. First, we propose a minimum set of optical layer parameters that need to be conveyed to NBI applications for them to be able to estimate per optical channel Quality of Transmission (QoT), and thus enabling optical network optimization use cases (e.g. impairment-aware routing and spectrum assignment, optical line engineering). Second, we compare the completeness of OpenConfig [5], OpenROADM [6] and OpenDevice [7] models for providing such information to the SDN controller. Related to this gap analysis, this paper also reports a proof-of-concept (PoC) where a Net2Plan-based [8] NBI application interacts with an ONOS controller [9], which gives access to two NOKIA muxponders via an OpenConfig-based NETCONF SBI, in a testbed at Telefonica premises. As first phase of a research initiative, this PoC focuses on a point-to-point transmission link with no intermediate ROADM nodes.

2. Proposal: minimum information required for network models

This section collects a proposal of minimum information required in the network models, to allow for SDN applications to make QoT estimations considering the architecture in Fig. 1. Specifically, we focus on a QoT engine capable of calculating per channel optical signal-to-noise ratio (OSNR), chromatic dispersion (CD), polarization mode dispersion (PMD) and power budget at the input and output of each network element. The information set proposed here, sits in a well-known trade-off: the more information present in the model, the more accurate are the estimations, but more complex becomes the model, and monitoring these optical parameters with confidence.

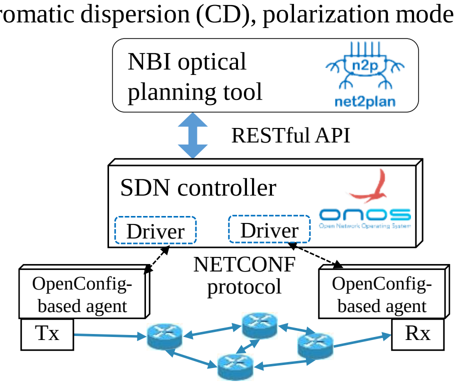

Fig. 1. Architecture illustrating the need of SBI information at the NBI through the SDN controller.

Regarding OSNR, we distinguish two contributions: i) the linear contribution coming from optical amplifiers, ii) the nonlinear contributions coming from high optical powers at the fibers. OSNR decrease caused by nonlinearities is comparatively small (e.g. <1.8 dB [10]) when the optical channel launch power is optimized, but can arbitrarily grow when optical channels are over-powered. The Telecom Infrastructure Project [11] proposes GNPY open-source framework [12], to estimate the OSNR by applying the Gaussian Noise model [13].

Table I. Information set for QoT estimation

Metric (at the receiver)	Operational information	Inventory information
OSNR (linear) (dB) (pp. 170, [14])	Per channel-power at the input of each traversed EDFA, EDFA noise figure at current working point (input power, gain).	Noise figure (dB) (or noise figure as a function of amplifier gain and input power, for more accurate calculations)
OSNR (nonlinear) (dB) [13]	Traversed fiber spans, central wavelength and power of all channels at the input of all traversed fiber spans.	Span lengths (km), attenuation coefficient (dB/km), chromatic dispersion coefficient (ps/nm/km), nonlinear coefficient (1/(W km)), per channel modulation type (for spectrum occupation), baud rate.
CD (ps/nm) (pp. 19, [14])	Traversed fiber spans, central wavelength of the channel.	Per span chromatic dispersion coefficient (ps/nm/km) of each channel.
PMD (ps) (pp. 163, [14])	Traversed spans, traversed multiplexers, amplifiers, OADMs.	Length and Link design value (PMD_Q) of each span (ps/sqrt(km)), PMD contribution of traversed multiplexers, amplifiers, etc.

Recently, validation results were reported in large-scale testbeds [15]. In our study, Net2Plan is enriched with GNPY-inspired computation [16], for estimating the contribution to OSNR coming from nonlinear impairments.

Table I enumerates the minimum information needed for an NBI optical planning tool classified in two types. Operational information depends on channel injection powers, and current equipment configurations. Inventory information is static and comes from the WDM plant and equipment catalogues, needed to perform the analysis.

Note that nonlinear contribution to OSNR significantly expands the requirements to the model. Some of them may be difficult to acquire in dark-fiber based production networks, where information like e.g. nonlinear coefficient of the fiber may be unavailable to the carrier. Incorporating some inventory information into the equipment YANG model, would simplify network operation. E.g., in case noise figure information of the amplifier is included in the model, NBI applications will have it directly available, instead of looking up it from a database of amplifier datasheets.

3. Gap analysis of optical models on physical layer characterization

Table II collects our gap analysis performed between three optical device models for the SBI, all of them described via YANG representations, restricted to transponder and amplifier devices: OpenConfig, OpenROADM and OpenDevice. In our opinion, OpenConfig and OpenROADM are suitable frameworks at both optical network and optical device levels. OpenConfig includes more precise operational information, although some of it is indirectly stated: e.g. the transponder modulation format and transmission rate are described as a terminal-device model code that must be looked up in a vendor-based table. OSNR computations are hindered in OpenROADM due to the absence of amplifier noise figure information, which is only partially present in OpenConfig, and fully represented in OpenDevice. OpenDevice has a good representation at device level of amplifiers masks for noise figure and tilt. Nonetheless, OpenDevice lacks on transmission parameters/information (e.g., no baudrates nor modulation formats), and network level view is limited. All models would benefit in introducing inventory-related information (e.g. PMD, fiber coefficients) of interest for QoT estimation.

At the NBI, details from YANG models of the SBI are commonly encapsulated so as to expose technology-agnostic programming abstractions that ease the development of applications. In this context, although Transport API (TAPI) provides abstracted services of the underlying network infrastructure, standardization efforts toward TAPI 2.1 aim to increase optical technology visibility, thus potentially enabling QoT estimation [17]. In this line, a recent IETF draft [18] extends the optical characteristics of the Traffic Engineering topology with several parameters to enable impairment-aware path computation. Hence, current NBI models need extensions exposing SBI information to enable QoT applications such as Net2Plan/GNPY [16]. In this work, we developed a proprietary NBI that focus on enabling QoT parameters form the SBI as detailed next.

Table II. Gap analysis on physical-layer parameters of interest for QoT estimation classified in operational (O) and inventory (I) at the SBI

	OpenConfig [5]	OpenROADM [6]	OpenDevice [7]
(O) Per-transponder injection power	Yes	Yes	Yes
(O) Per-channel wavelength	Yes	Yes	Yes
(O) Per-channel modulation, baud rate	Yes* (via look up in vendor table)	Yes	No
(O) Total power EDFA input	Yes	Yes	Yes
(O) EDFA gain	Yes	Yes	Yes
(O) Per-channel traversed path	Yes	Yes	Yes
(O) Receiver pre-/post- FEC BER, Q factor	Yes	Yes	No
(O) Receiver CD, PMD	Yes	No	No
Operational completeness	Very high	High	Medium
(I) Per span length, attenuation, CD, PMD nonlinear coefficients	No	Partial	No
(I) Per equipment PMD contribution	No	No	No
(I) EDFA NF mask	Partial (scalar)	No	Yes
(I) Min. acceptable thresholds: OSNR, CD, PMD, min/max power	No	No	No
Inventory completeness	Low	Medium	Low

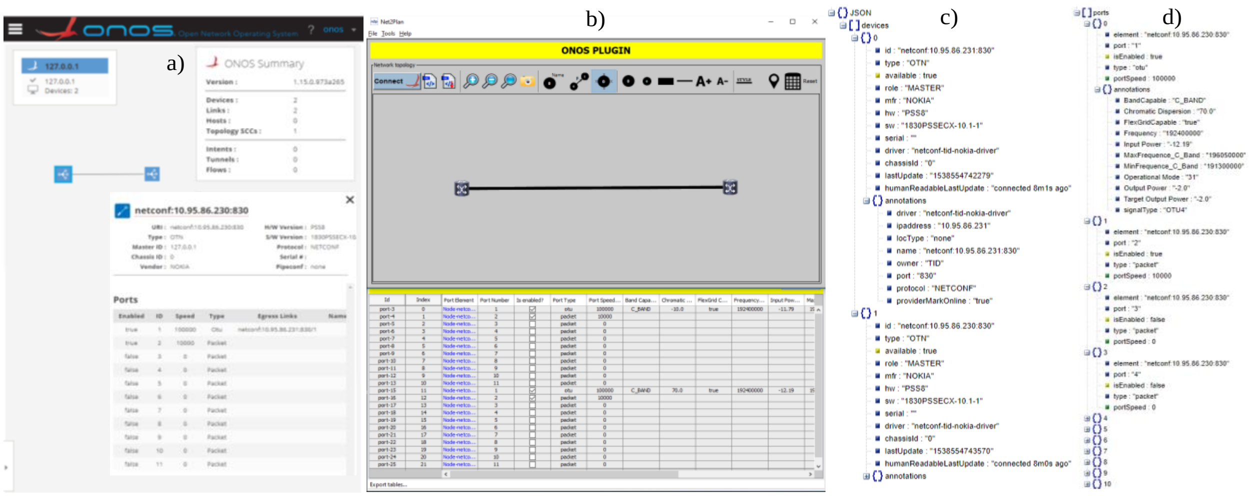

Fig. 2. Experimental validation showing (a) the ONOS and (b) Net2Plan GUI with the NOKIA transponders information. Representation of the JSON messages obtained with a get (c) devices and (d) ports (of a device) request to the ONOS REST API from Net2Plan.

4. Experimental Setup and Proof of Concept

The experimental validation follows the architecture depicted in Fig. 1. Two NOKIA muxponders are connected in a point-to-point using a single 10G ETH in the client side and 100G OTU4 line side. OpenConfig-based agents are accessible through a NETCONF session using a developed driver in ONOS (version 1.14). In particular, the ONOS driver (i) establishes session with the agent following vendor-specific logging-in authentication procedure, (ii) retries device information in XML format by executing a RPC and (iii) parses the received information from XML format to the ONOS hierarchical object model. Fig. 2(a) shows ONOS GUI with the received information of both Nokia transponders, and the inset shows the 11 ports information (one line port and one client port enabled).

A Net2Plan extension specifically developed to interact with ONOS uses a RESTful interface based on OpenAPI. Within Net2Plan, the JSON messages (see Figs. 2(c) and (d)) are parsed into the Net2Plan hierarchy model as illustrated in Fig. 2(b). As shown in Fig. 2, although device model information is available in the planning tool, YANG-modelling limitations can be seen because the ‘operational mode’ needs further process to provide the input for a Net2Plan line engineering algorithm. Indeed, this clearly illustrates the modelling limitations.

5. Conclusions

This paper reports and analyses the gaps in OpenConfig, OpenDevice and OpenROADM models for enabling QoT estimation engines as part of optical planning SDN NBI applications. Despite current high availability on operational information, considered models include limited inventory-related information which hinders QoT estimation opportunities. A proof of concept illustrates the availability of operation information from OpenConfig-based muxponder at the NBI optical planning tool. Future works will evaluate different architectural flavors which include TAPI and NBI models that propagate upwards relevant information for QoT evaluation.

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