

An OLS Controller for Hybrid Fixed / Flexi Grid Disaggregated Networks with Open Interfaces

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Abstract: We report the design and implementation of an OLS controller in a hierarchical (partial & full) disaggregation, using open standard data models. We detail the constrained path computation in hybrid fixed/flexi networks and its testbed validation. ©2020 The Author(s)

1. Introduction

Disaggregation of optical networks has been a recent topic of interest. Within the multiple models [1], partial disaggregation has received a lot of attention (e.g., the ODTN [2] phase 1.5) with a dedicated Open Line System (OLS) controller for provisioning Network Media Channels (NMC). Finer granularity disaggregation (e.g., full model) is still a topic of debate and research, due to scalability and manageability concerns. In any case, the migration of optical networks to a full flexi-grid scenario will progress at different steps, due to *Return-On-Investment (ROI)* requirements. Operators need to combine hybrid fixed- / flexi- grid networks, using e.g. grid channel spacing (CS) of 50 or 100 GHz. In this paper, we present the design and implementation of a 2-level Software Defined Networking (SDN)-controlled disaggregated optical network. A *partial disaggregation* for the transceiver/OLS parts and a *second finer disaggregation* level within an OLS with node local controllers. We present the functional and protocol architecture, the path computation and the experimental validation.

2. Control Plane Architecture for hierarchical disaggregation

The control plane architecture adopts a hierarchical disaggregation (Fig. 1). A first (partial) level of disaggregation decouples transceiver control from the OLS, under the umbrella of a network orchestrator, based on ONOS [3] using OpenConfig [4] for the transceivers and TAPI southbound interface (SBI) [5] for the OLS. A second level (full) encompasses the nodes (ROADMs), with the OLS controller being responsible for provisioning NMC between ROADM add/drop ports. To scale, local node controllers are also deployed, acting as SDN agents for the OLS and configuring the different sub-devices (Photonic Cross-Connects, PXC; Wavelength Selective Switches, WSS, etc.). This enables a 2-level abstraction (a ROADM model for a node and the abstraction provided by the OLS), targeting, notably, metropolitan deployments. For the *North Bound Interface (NBI)*, clients and/or orchestrators use the OLS NBI to request network media channels. To this end, the Transport API (TAPI) v2.1 photonic media layer has been implemented both in ONOS and in the OLS controller, where each client-facing port maps to a Service Interface Point (SIP) that encompasses spectrum availability, in terms of occupied and in-use media channel pools (MC pools).

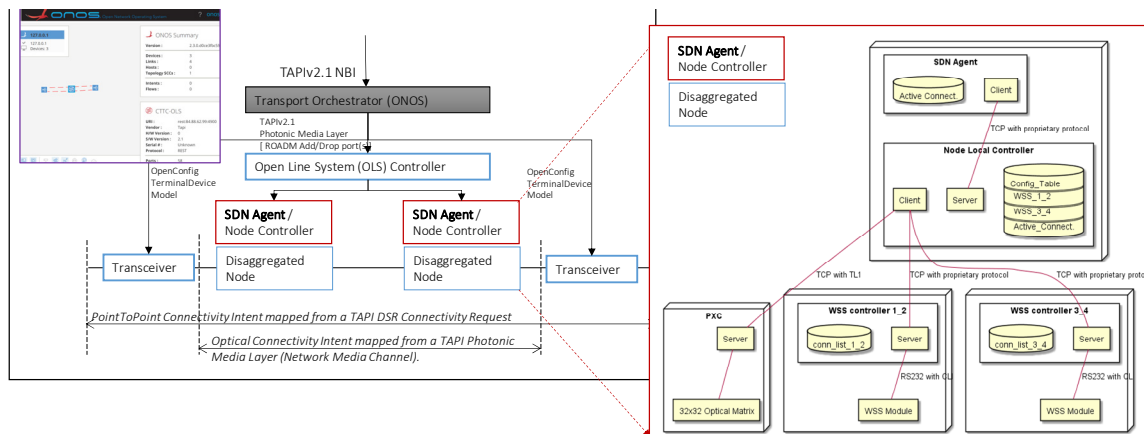


Fig. 1. Hierarchical Control Plane for Disaggregated Optical Network

The agents implement the front-end towards the OLS with the OpenROADM [6] device model or a lightweight model defined in Swagger/OpenAPI (REST interface w/ JSON encodings), enabling the bookkeeping and object lifetime management of add, drop or express connections. A local socket is used to forward the cross-connection request to the *Node Local Controller*, which is responsible for configuring/releasing the cross-connections in the

PXC and programming the WSS involved, if any. It is connected to underlying heterogeneous optical systems by means of TCP connections and proprietary protocols (e.g., TL1 for the PXC and command line interfaces via RS232 for WSS controllers). After a configuration look-up, the controller interacts with the PXC and, if the path involves one or two WSS modules, allocates free ports from each WSS (WSS_1_2 and/or WSS_3_4 databases), and calculates the start and stop slices in each WSS (Fig.1 right), configuring them accordingly.

3. Data Plane Architecture

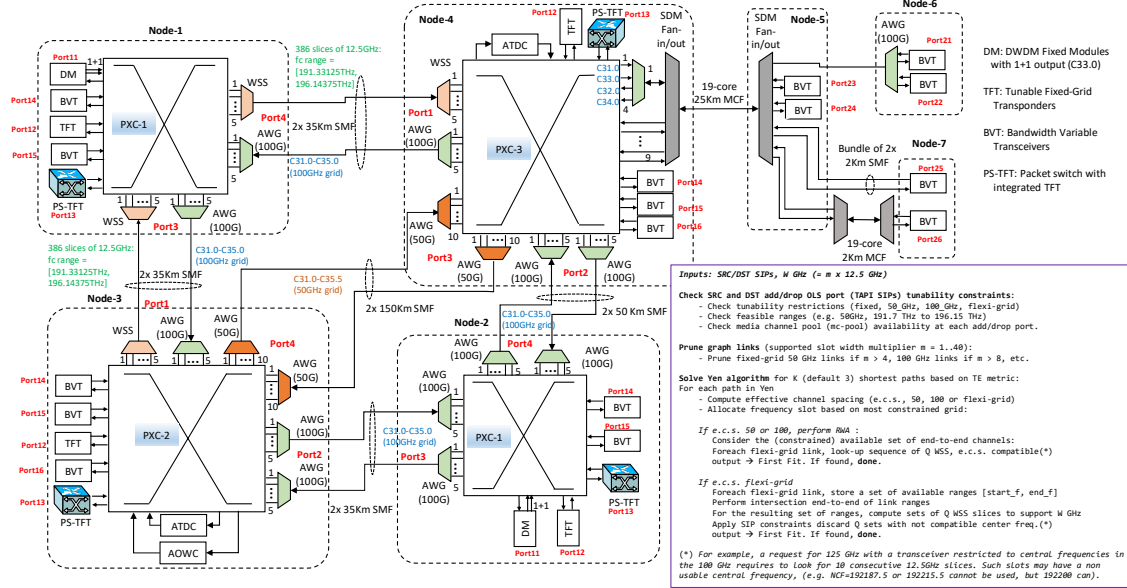


Fig. 2. Fixed / Flexi grid data plane infrastructure and skeleton of the path computation algorithm.

Fig. 2 shows the optical transport network, at the lowest level of the ADRENALINE testbed. It has a hybrid fixed/flexi-grid DWDM core network with 4 whitebox ROADMs/OXC nodes (N1 to N4), sliceable-bandwidth variable transceivers (S-BVTs) and 5 bidirectional amplified optical links of up to 150 km (610 km of G-652 and G.655 SMF total). Links have 100GHz CS (e.g., 35 km between N2 and N3, 50 km between N2 and N4), 50 GHz CS (e.g., 150 km between N3 and N4), or flexi-grid using commercially wavelength WSS (e.g., 35 km from N3 to N1, and N1 to N4). For 50GHz CS, there are 10 available DWDM channels, with a nominal central frequency comprised between 193.1THz and 193.55THz (C31.0-C35.5). For 100GHz CS, 5 DWDM channels are used (193.1THz to 193.5THz). The links with flexi-grid technology can support up to 386 slices of 12.5GHz bandwidth, with central frequencies in the range of 191.33125THz to 196.14375THz, and the capability of programming super-channels of up to 40 slices. Three 32x32 photonic cross-connects (PXC), based on micro-electro-mechanical switching (MEMS) technology, can be divided in order to have smaller and independent symmetrical configurations, such as 16x16. Thus, PXC-1 is shared between N1 and N2, PXC-2 is fully integrated in N3, and PXC-3 fully assigned to N4. Operations involve the use of passive mux/demux connected to fixed-grid links, the cross-connection between pairs of input/output ports in the PXC, the activation of the selected channels at client transceivers, and the configuration of Crystal on Silicon (LCoS) WSS modules connected to flexi-grid links, if any. As frequency slot edges are aligned to the 12.5 GHz ITU grid, flexi channel planning offers full backwards compatibility with both the standard 100 GHz and 50 GHz ITU grids. Several optical transceiver systems are connected to PXC ports, imposing variable *OLS port tunability restrictions*. For example, transceivers with 1310nm SFP module with fixed channel ITU-T C33.0 (Port11); tunable transceivers with 50GHz CS (Port12); client switches with 10 Gb/s XFP transceivers tunable with 50 GHz CS (Port13) or S-BVTs for flexible optical transmission systems (Port 14 to Port16). The infrastructure also includes an optical access network, formed by three nodes (N5 to N7), emulating new fronthaul networks. N4 integrates the connectivity with the access network, which behave passively at the control plane level. Port21 to Port26 represent the S-BVTs of the access network, which are connected to PXC3 of N4, through 25Km of 19-core multicore fiber (MCF) with 2 SDM Fan-in/Fan-out.

4. Path Computation Algorithm and Service Provisioning Workflow

Given the complexity of RWA/RSA in heterogeneous/hybrid fixed-flexi grid networks with tunability constraints, we develop a heuristic that successfully finds paths respecting constraints related to spectrum widths and ensuring continuity (skeleton provided in Fig.2.right). In our scenario, the main cause of blocking is

transceiver availability, the network being able to accommodate the services even if the heuristic yields sub-optimal paths. After the path has been obtained, the system follows the workflow detailed in Fig.3.

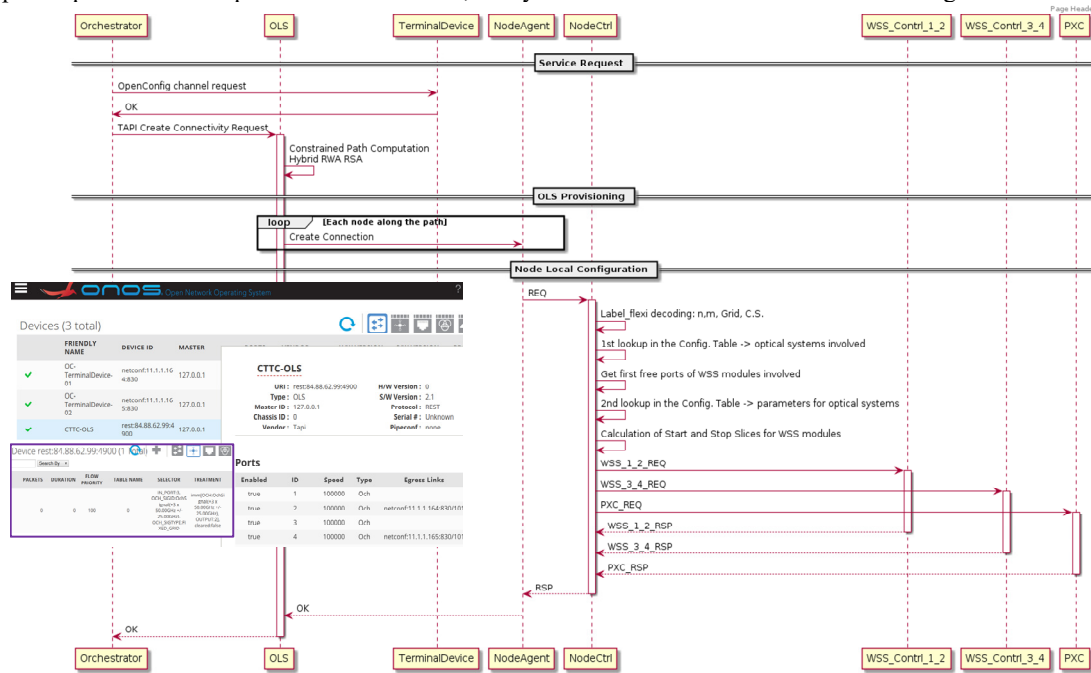


Fig. 3. View of the Orchestrator GUI and detailed Control Plane message sequence / workflow.

5. Experimental Evaluation

To illustrate the approach, consider a service between Port12 of N4 (tunable laser, 50GHz) and Port21 of N6 with $m=8$, the OLS assigns the NMC with $n=0$ (193.1 THz, 1552,524nm). PXC3 cross-connects P#1 (logical port 12) with P#38 (logical port 21, with a detected +0.66 dBm output). At the receiver, we detect -16.09 dBm and 1552.436nm, attenuation due to 100GHz AWG (2dB), MCF (10dB) and optical link (Fig. 4). Finally, and as a second experiment, we validate the algorithm by setting up a sequence of services as per the table below.

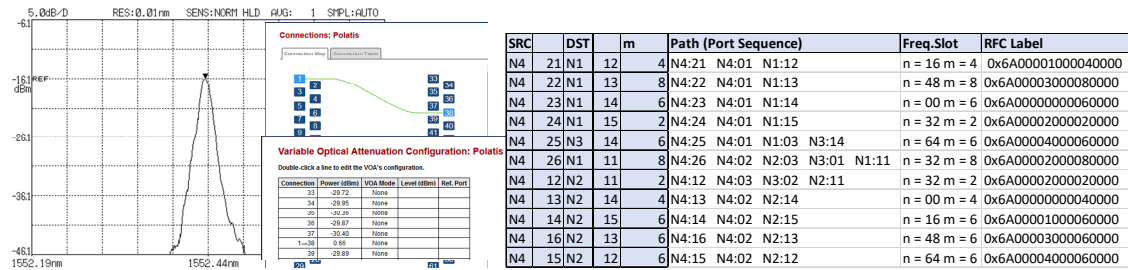


Fig. 4. NMC service between P12, N4 and P21, N6 (left) and sequence of 11 provisioned services (right)

6. Conclusions

We report the successful validation of a 2-level hierarchical disaggregated system combining partial and full models for hybrid fixed-/flexi- grid networks which, along node local controllers, provide a satisfactory trade-off of manageability/scalability while highlighting the advantages of open interfaces and disaggregated designs.

7. Acknowledgements

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8. References

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