TOWARDS PHYSICAL IMPAIRMENT AWARE SOFTWARE-DEFINED PARTIALLY DISAGGREGATED NETWORKS

Arturo Mayoral Lopez-de-Lerma[1], Victor López[2], Oscar Gonzalez de Dios[2], Andrea Campanella[3], Rafał Szwedowski[4], Konrad Mrówka[4], Dominique Verchere[5], Lubo Tancevski[6], Alessio Giorgetti[7], Ramón Casellas[8], Hiroki Okui[9], Juan-Pedro Fernandez Palacios[2]*

[1]Universitat Politècnica de Catalunya (UPC), Spain
[2]Telefónica I+D/Global CTO, Spain
[3]Open Networking Foundation, Menlo Park, USA
[4]ADVA Optical Networking, Gdynia, Poland[5]Nokia Bell-Labs, France
[6]Nokia, Germany
[7]Scuola Superiore Sant'Anna / CNIT, Pisa, Italy,
[8]CTTC/CERCA, Castelldefels, Spain
[9]NTT Communications, Tokyo, Japan
**victor.lopezalvarez@telefonica.com*

Keywords: SDN, Optical disaggregation, OpenConfig, TAPI.

Abstract

Partially disaggregated networks require physical layer information to validate end-to-end characterization of WDM signals' integrity. Transport-API 2.1 includes the photonic-media layer characterization, enabling external wavelength provisioning over an Open Line System. This work presents the first proof-of-concept on a disaggregated multi-vendor testbed with TAPI 2.1.

1 Introduction

There is a great interest around the disaggregation of hardware and software components in the networking community. Such approach enables flexibility to deploy advance solutions and achieves efficiency and cost reduction within certain network scenarios. Network operators have paid attention to this technological evolution, because it can help to maintain the margin as the revenues are decreasing [1]. The deployment in optical network, following the traditional schemas, is based on end-to-end solutions where there is no interoperability of the optical components. Disaggregation enables to mix solutions from different partners to have a completer design that copes with the needs of each scenario. While the disaggregation enables create ad-hoc solution, it fragments the complexity of the system. The recent advances of Software Defined Network (SDN) allow having a common view of the network elements, so the network operators can have an end-to-end optical channel design. SDN solutions enable network operators to deploy different hardware components but still have a common view of the network elements. This enables mixing of network elements from different vendors to deploy network infrastructures. There are different scenarios demonstrating such concept in packet/optical networks like in [2, 3]. The authors in [4] presented the concept of Software Defined Transport Network (SDTN) architecture, which is depicted in Fig.1. The SDTN architecture is based on the concept of hierarchical orchestration, where each switching technology is managed by an SDN controller (SDNc).

Optical networks are the basis of the Telecommunications Operators (TELCOs) transport infrastructure in the different aggregation network domains (metropolitan, regional and long-haul). TELCOs deploy in the different aggregation domains the solution from a single vendor. The reasons behind this choice are the complexity of connectivity service provisioning in optical networking, the low-level interoperability requirements and the increase of maintenance activities. This paper demonstrates for the first time a software-defined disaggregated multi-vendor testbed with TAPI 2.1 service data model. The utilization of TAPI 2.1 enables the validation of external wavelengths into an Open Line System (OLS).

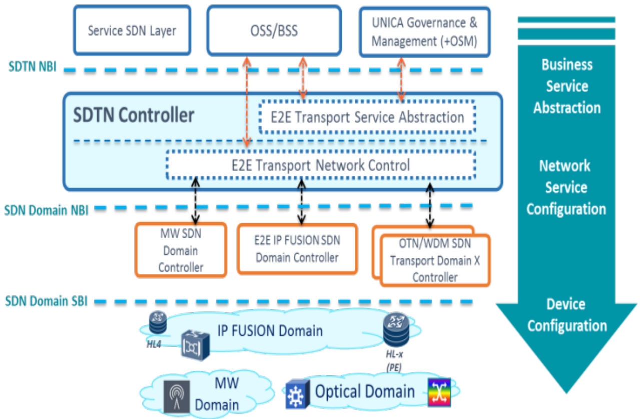

Service SDN Layer
OSS/BSS
UNICA Governance & Management (+OSM)
SDTN NBI
SDTN Controller
E2E Transport Service Abstraction
E2E Transport Network Control
SDN Domain NBI
MW SDN Domain Controller
E2E IP FUSION SDN Domain Controller
OTN/WDM SDN Transport Domain X Controller
SDN Domain SBI
HL4
IP FUSION Domain
HL-x (PE)
MW Domain
Optical Domain
Business Service Abstraction
Network Service Configuration
Device Configuration

Fig. 1 Software Defined Transport Network architecture

2. Partially Disaggregated Optical Networks

Partially Optical Disaggregation decouples the open terminals (transponders) from the components of a line system (ROADMs, amplifiers, etc.), thus eliminating the lock-in situations and requiring the interoperability between vendors, as shown in Fig. 2. The Optical SDN Domain Controller (OSDNc) is responsible of the individual configuration and monitoring of Open Terminals (OTs) and OLS separately. Moreover, OSDNc is in charge of the coordinated management of end-to-end services, understood as services starting and terminating in Open Terminal (OT) devices (transponders, muxponders). The partially disaggregated optical network architecture proposed, includes open and standard interfaces (OpenConfig and ONF Transport API) based on YANG modelling and NETCONF/RESTCONF in the OSDNc SBI to manage OTs and OLS. On the other hand, the OSDNc exposes, through TAPI on the NBI a unified management context through the NBI to the upper layers.

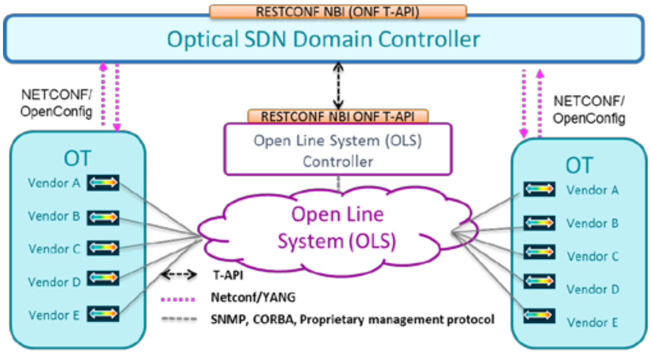


Fig. 2 Partially disaggregated optical architecture.

The TAPI provides six services to an SDN controller: (1) Network Topology, (2) Connectivity Requests, (3) Path Computation, (4) Network Virtualization, (5) Notification and (6) OAM [5], and three technology specific models for the L2/L0 transport layers (Ethernet, ODU and Photonic Media). Network Topology service exports the context, which is the scope of control, interaction and naming of a particular T-API provider (SDN controller). The context describes Service Interface Points (SIPs), which refer to the customer-edge, and also the network topology. The network identifiers help to carry out path computation and to integrate the nodes for an end-to-end scenario. Moreover, the controllers can provide information about the links and nodes in the domain. There are different alternatives to share the information depending on the details that the domain is exposing to the upper layer consumer. The second service is Connectivity Service which enables requesting for connectivity between two or more SIPs. Connectivity service includes other constraints that can be included in the query, like (a) excluding or including nodes/links, (b) defining the protection level, (c) defining its bandwidth or (d) requesting for disjointness from other connections. The Path Computation service is a fundamental feature because it enables that individual controllers in each domain can learn about alternatives in the paths. As they only know abstracted information for the domain, this function enables learning alternative paths from the upper layer. A use case for this function is an orchestrator with its global end-to- end view, which can optimize end-to-end connections that individual controllers cannot configure. The Network Virtualization service allows exposing a subset of the network resources to different tenants. Lately, a Notification service allows a 'publish and subscribe' mechanism, to receive asynchronous notifications through a protocol such as websockets or Server Sent Events (SSE).

In a partially disaggregated optical network, the OSDNc will receive a TAPI Connectivity request to create an end-to-end optical channel connection. The TAPI defined connectivity request issued to the OSDNc will include the User Connectivity Layer (DSR) for the end-to-end request. However, the OSDNc requires doing two operations: (1) configuration of the OLS and (2) configuration of the OTs. To carry out the OLS configuration, the OSDNc must send a photonic layer request to the OLS controller. This request handles the provisioning of a Layer 0 photonic path between the line side ports of the transponders, across the OLS or the ROADM devices. This request will contain the photonic parameters needed both by the Transponders to configure their line-side port and from the OLS or ROADM devices to create an end to end path across the underlying equipment.

As soon as the configuration of the OLS is completed, OSDNc configures the transponders with central frequency and the power level. In order to use a standard interface, this work uses OpenConfig [6].

3 Results

3.1 Optical Network Lab setup

The experimental work was done in Telefonica's Future Network Lab in Madrid. The setup is composed of three main parts: an SDN controller, an OLS and two open terminals. The SDN controller is implemented based on ONOS [7] within the Open Disaggregated Transport Network (ODTN) project. The ODTN project has worked on the plugins to support OpenConfig/TAPI and providing the mapping for the workflow. The OLS setup is composed by three color-fixed directionless ROADM nodes based on ADVA FSP3000 product family including its OLS Controller (Ensemble Controller) exposing TAPI v2.1.. The OLS segment was built based on fixed filters. Finally, the two open terminals Nokia 1830PSSECX-10.1-1 muxponders are connected directly to the ADVA ROADMs, exposing their management capabilities through OpenConfig/NETCONF.

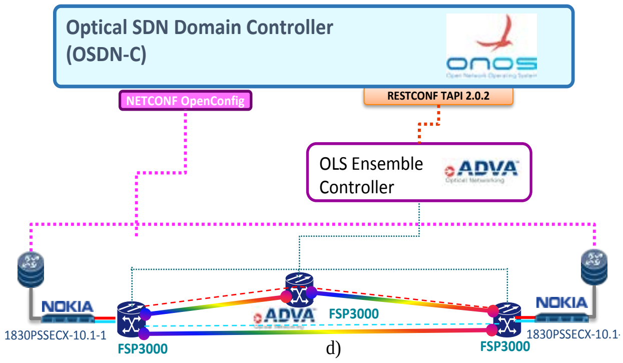
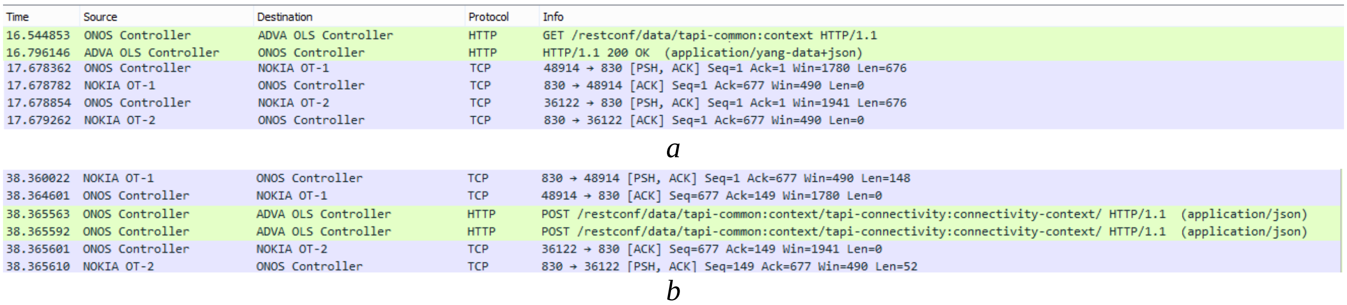


Fig. 3 Experimental lab setup in Telefonica premises.



```
Time       Source             Destination        Protocol  Info
16.544853  ONOS Controller    ADVA OLS Controller  HTTP    GET /restconf/data/tapi-common:context HTTP/1.1
16.796146  ADVA OLS Controller  ONOS Controller    HTTP    HTTP/1.1 200 OK  (application/yang-data+json)
17.678362  ONOS Controller    NOKIA OT-1         TCP       48914 → 830 [PSH, ACK] Seq=1 Ack=1 Win=1780 Len=676
17.678782  NOKIA OT-1         ONOS Controller    TCP       830 → 48914 [ACK] Seq=1 Ack=677 Win=490 Len=0
17.678854  ONOS Controller    NOKIA OT-2         TCP       36122 → 830 [PSH, ACK] Seq=1 Ack=1 Win=1941 Len=676
17.679262  NOKIA OT-2         ONOS Controller    TCP       830 → 36122 [ACK] Seq=1 Ack=677 Win=490 Len=0
```

a

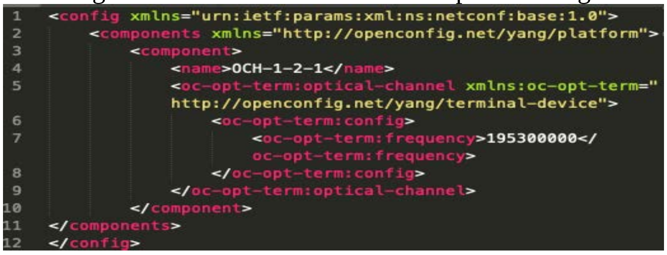
```
38.360022  NOKIA OT-1         ONOS Controller    TCP       830 → 48914 [PSH, ACK] Seq=1 Ack=677 Win=490 Len=148
38.364601  ONOS Controller    NOKIA OT-1         TCP       48914 → 830 [ACK] Seq=677 Ack=149 Win=1780 Len=0
38.365563  ONOS Controller    ADVA OLS Controller  HTTP    POST /restconf/data/tapi-common:context/tapi-connectivity:connectivity-context/ HTTP/1.1  (application/json)
38.365592  ONOS Controller    ADVA OLS Controller  HTTP    POST /restconf/data/tapi-common:context/tapi-connectivity:connectivity-context/ HTTP/1.1  (application/json)
38.365601  ONOS Controller    NOKIA OT-2         TCP       36122 → 830 [ACK] Seq=677 Ack=149 Win=1941 Len=0
38.365610  NOKIA OT-2         ONOS Controller    TCP       830 → 36122 [PSH, ACK] Seq=149 Ack=677 Win=490 Len=52
```

b

Fig. 3 Workflow traffic captures in the lab demonstration. (a) Topology discovery for the OLS and the Open Terminals, (b) TAPI Connectivity service for the OLS and configuration of the Open Terminals.

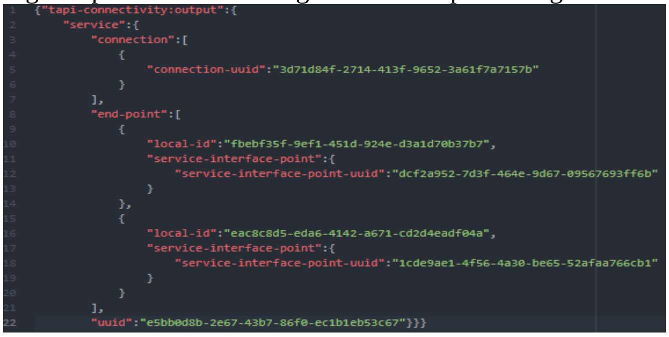
3.2 Work flow operations

There is an initial configuration providing to OSDNc is given the IP addresses and credentials of the open terminals and the OLS. With this information, OSDNc opens a NETCONF session over SSH to the terminal devices. Once the session has been established, transponder's capabilities are discovered by querying the device components, ports and interfaces, exposed by OpenConfig data model. Moreover, OSDNc employs TAPI interface to retrieve OLS topology and SIPs. In this work, the OLS exposes a node abstracting view of the network hiding optical components such as WSS, muxponders and amplifiers, but exposing the map of wavelengths available for media channels provisioning .



```
<config xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
    <components xmlns="http://openconfig.net/yang/platform">
        <component>
            <name>OCH-1-2-1</name>
            <oc-opt-term:optical-channel xmlns:oc-opt-term="
            http://openconfig.net/yang/terminal-device">
                <oc-opt-term:config>
                    <oc-opt-term:frequency>195300000</
                    oc-opt-term:frequency>
                </oc-opt-term:config>
            </oc-opt-term:optical-channel>
        </component>
</components>
</config>
```

Fig. 4 Open Terminal configuration via OpenConfig



```
{"tapi-connectivity:output":{
    "service":{
        "connection":[
            {
                "connection-uuid":"3d71d84f-2714-413f-9652-3a61f7a7157b"
            }
        ],
        "end-point":[
            {
                "local-id":"fbebf35f-9ef1-451d-924e-d3a1d70b37b7",
                "service-interface-point":{
                    "service-interface-point-uuid":"dcf2a952-7d3f-464e-9d67-09567693ff6b"
                }
            },
            {
                "local-id":"eac8c8d5-eda6-4142-a671-cd2d4eadf04a",
                "service-interface-point":{
                    "service-interface-point-uuid":"1cde9ae1-4f56-4a30-be65-52afaa766cb1"
                }
            }
        ],
        "uuid":"e5bb0d8b-2e67-43b7-86f0-ec1b1eb53c67"}}}
```

Fig. 5 ONOS TAPI Connectivity Service JSON reply.

Once OSDNc knows the topology interconnection between OLS and terminals information, the OSDNc can setup of an end-to-end connection between two client ports of the terminals exposed as SIPs through OSDNc TAPI NBI. To carry out such connectivity service, the OSDNc receives a T-API connectivity service request at the NBI RESTCONF interface. OSDNc breaks this request to trigger: (1) the TAPI phonic media channel connectivity service to configure the OLS segment; and two NETCONF configurations to modify the port state, power and frequency on the transponders line side (Fig.4). The transponder configuration is based on OpenConfig optical-transport models. Finally, the OSDNc will reply to the OSS/BSS with the JSON shown in Fig.5.

4 Conclusion

Network disaggregation is a concept that is relevant for all the industry including network operators. Partially disaggregated network is an evolution from single vendor optical network infrastructures that requires integrated standard interfaces to move forward to such multi-vendor scenario. Moreover, it requires validating the physical impairments for each end-to-end optical signal that goes through the Open Line System. This work demonstrates for the first time, the provisioning of end-to-end photonic media channel connectivity service over a partially disaggregated scenario using TAPI 2.1.

5 Acknowledgements

The research leading to these results has received funding from the European Commission for the H2020-ICT-2016-2 METRO-HAUL project (G.A. 761727).

6 References

[1] E. Riccardi, et al.: ‘An Operator's view on introduction of White Boxes in Optical Networks’, in Journal of Lightwave Technology, August 2018, Vol. 36, Issue 15, pp. 3062-3072.

[2] F. Pederzolli, et al.: ‘SDN application-centric orchestration for multi-layer transport networks (Invited)’, in proc. IEEE International Conf. on Transparent Optical Networks ICTON, paper Th.A4.2, Trento, Italy, July 2016.

[3] Arturo Mayoral Lopez-de-Lerma, et al.: ‘Multi-layer service provisioning over resilient Software-Defined partially disaggregated networks’, OFC 2019, Tu3H. 6.

[4] V. López, et al.: ‘Control Plane Architectures for Elastic Optical Networks’, J. Opt. Commun. Netw. **10**, A241-A249 2018.

[5] Transport API, https://github.com/OpenNetworkingFoundation/TAPI , 2018

[6] OpenConfig, https://github.com/openconfig/public/tree/master/release/models/optical-transport, 2018.

[7] ONF, ONOS Whitepaper, http://onosproject.org/wp-content/uploads/2014/11/Whitepaper-ONOS-final.pdf, 2014