OpenConfig-extension for VLAN-based end-to-end network slicing over optical networks

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Abstract: We demonstrate end-to-end VLAN-based network slicing over optical networks using ONOS, based on extended OpenConfig model for hybrid packet-optical terminal devices. Validation is performed by end-to-end interconnected VNFs supporting video streaming use case.
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1. Overview

Due to the recent advancements in the telecommunications, technologies like Software Defined Networking (SDN) and Network Function Virtualization (NFV) are becoming prevalent. This is because increasing traffic demands in 5G networks [1] and specifically inter-datacentre traffic [2] require flexibility and low-cost in terms of provisioning network services; which in turn are essential features of SDN and NFV. In this regard, Metro-Haul project [3] aims to create a system to enable flexible metro-optical networks with high bandwidth, low latency and programmability to meet 5G network requirements. For low latency, Metro-Haul allows placement of VNFs at the edge nodes close to the access network, whereas computationally intensive VNFs may be placed near the metro nodes close to the core [4]. The VNFs are interconnected in a service chain as part of an end-to-end network service (NS) spanning across the metro network. This requires a joint orchestration of the NS for both compute resources using NFV and network resources using SDN for deploying VNFs and the network interconnecting the VNFs respectively. The joint orchestration is performed by a Management and Network Orchestration (MANO) system, for which Metro-Haul is following the ETSI standard to orchestrate end-to-end network services over packet and optical networks. The network interconnecting VNFs over different datacentres, with a VLAN ID assigned to an optical wavelength, is a slice of the overall packet and optical network resources respectively.

Traditionally, the optical networks paradigm consists of single-vendor optical domains, presented as a single entity in the form of an Optical Line System (OLS) to be controlled by an SDN controller [5]. This aggregated deployment model does not allow fine-grained control over individual components; whereas a disaggregated system enables individual control over the optical network elements allowing flexibility and breaking vendor lock-in. Disaggregation is also yielding the development of SDN controllers providing an environment for creating advanced networking application on optical networks. In this scenario, the ONF community has recently established the ODTN (i.e., Open and Disaggregated Transport Networks) [6] working group with the support of many of the most important network operators and vendors. The main ODTN target is to extend the functionality of the ONOS SDN controller to support control and monitoring in disaggregated optical transport networks.

Metro-Haul adopts the disaggregated approach, using vendor-neutral OpenROADM and OpenConfig YANG data models for representing ROADMs and terminal devices respectively; where the terminal device is a hybrid packet-optical network element which switches ethernet traffic from the packet domain (client port) over an optical transponder (line port). The Metro-Haul SDN controller is an extension of the ONOS SDN controller containing southbound drivers for both OpenConfig and OpenROADM based devices. The OpenConfig [7] terminal-device model allows a logical channel assignment between the logical channels over the client and the line side ports [8]. Note that logical channel assignment by default is one client to one line port, irrespective of the client-side VLAN-id.

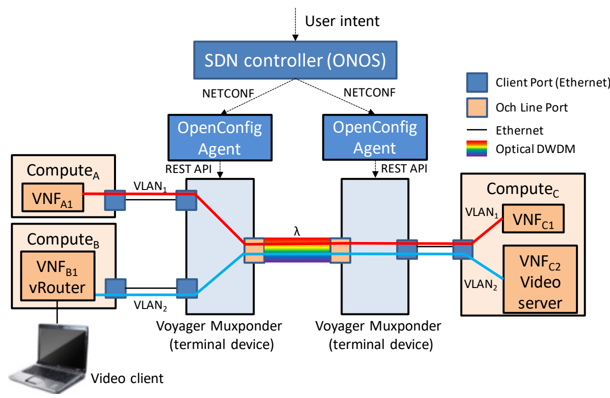
A potential terminal device is the Voyager muxponder from Facebook [9] which can switch traffic at packet layer matching on VLAN headers towards the optical domain using coherent DWDM transponders. This is suitable for Metro-Haul since traffic coming from different VNFs on multiple VLANs on the client side can be switched appropriately to an optical wavelength on the line side. However, even if the ONOS controller already supports both packet-based and optical devices, the utilization of hybrid devices (such as the Voyager muxponder) hasn't been considered and not yet included in the activities scheduled for ODTN future work.

In this demo, we extend the OpenConfig YANG model to account for multiple VLANs at arbitrary client ports switched to arbitrary line ports. The Northbound Interface (NBI) of ONOS consists of the Intent Framework which allows to request an end-to-end network in terms of intents containing endpoints and other relevant information. This work extends the ONOS intent framework and the OpenConfig driver currently included in ONOS that has been developed in collaboration within ODTN and MetroHaul project [10]. Specifically, the Intent Framework has been extended to accept source and destination VLAN and client port pairs to provision a network service suitable for Metro-Haul scenarios, enabling the deployment of ETSI-based network services. To control the Voyager muxponder, a NETCONF-based Conf-D agent with extended OpenConfig YANG model is utilized, where it exchanges appropriate messages with the extended OpenConfig southbound driver in ONOS controller. The subsequent section shows the demo scenario in detail.

2. Demo Overview

```
module: openconfig-terminal-device
    +--rw terminal-device …
        +--rw logical-channels …
        …
        |   + --rw vlans
        |     |    +--rw vlan*        [index]
        |     |    |    | + index      -> ../config/index
        |     |    | +--rw config
        |     |    | | +--rw index?           uint32
        |     |    | | +--rw vlan-id?         uint16
        |     |    | +--rw state
        |     |    |    +--rw index?          uint32
        |     |    |    +--rw vlan-id?        uint16
        +--rw logical-channel-assignments
        |    +--rw assignments * [index]
        …
        |     |    +--rw vlans  ->/terminal-device/logical-channels/vlans
        |     |    |    +--rw state
        …
        |     |    +--rw vlans  ->/terminal-device/logical-channels/vlans
```

(a)



(b)

Fig. 1. (a) OpenConfig extension with list of VLANs per logical channel assignment (b) Demo setup for OpenConfig extension with parallel NSs over multiple VLANs

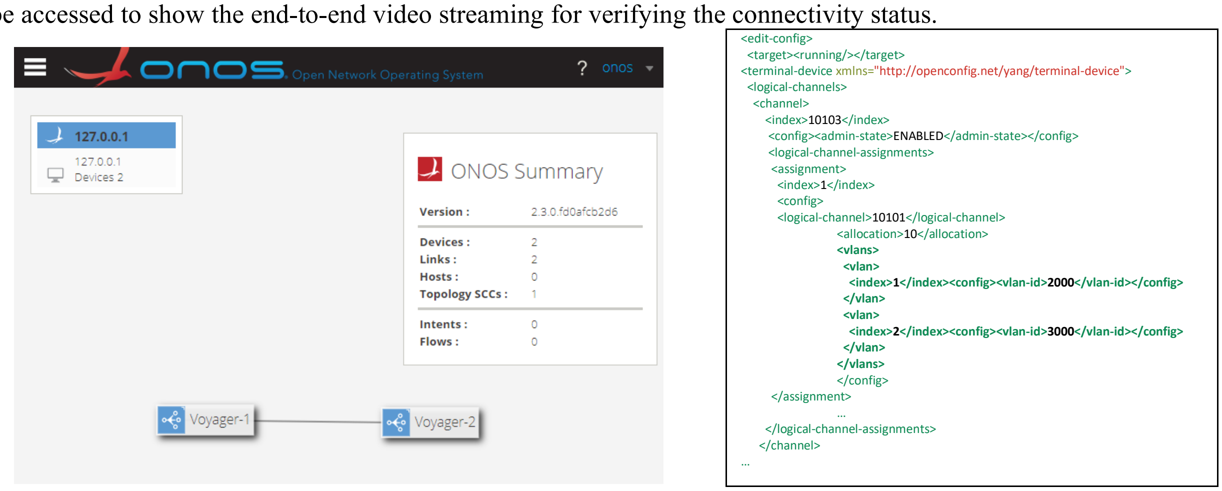
The demonstration validates that ONOS SDN controller can deploy multiple VLAN-tagged Layer 2 networks for multiple NSs consisting of individual VNFs hosted at different data center compute nodes, where each VLAN is a slice running over the optical network interconnecting the Voyager-based muxponder devices. This is enabled by the extensions to the OpenConfig YANG model as shown in Fig. 1a to have a list of VLANs per logical channel assignment of the client port to the line port. In addition, the Intent Framework of ONOS has been extended to consider the VLAN assignment specified in the intent request for including the specified VLAN tags into the generated flow-rules. In turn, OpenConfig driver in ONOS has been extended to consider the VLAN tags arriving in the flow-rules generated by the Intent Framework and for translating them in a NETCONF edit-config message enclosing the XML data compliant with the extended YANG model.

Fig. 1b shows the demo scenario consisting of multiple compute nodes hosting multiple VNFs, where each VNF is connected to a local network with a unique VLAN ID. One of the NSs consists of a Router VNF (vRouter) and a video server VNF_{C2} hosted at Compute nodes *B* and *C* respectively, where a video client can access the video server via the vRouter. Two Voyager muxponder devices are connected back to back on each site. A snapshot of the ONOS GUI is shown in Fig. 2a. The Voyager muxponders are controlled by a NETCONF Conf-D based extended OpenConfig Agent, which is exposed to the ONOS SDN controller as a terminal device via NETCONF SBI. The Voyager muxponder itself exposes a REST API which can be accessed by the extended OpenConfig agent for configuration and validation.

In the demonstration scenario, a user submits a connectivity request to ONOS in the form of an intent containing source VLAN-ID and client port for one Voyager muxponder and the destination VLAN and client port for the other muxponder. The intent framework computes the relevant flow-rules and uses the extended OpenConfig driver to send NETCONF edit-config messages to the Voyager muxponder as shown in Fig. 2b.

The experimental validation will be conducted remotely in University of Bristol, where all the software components will be from the OFC premises. The compute nodes will be based on multiple OpenStack instances. To simplify the demonstration, VNFs will be pre-deployed on the compute nodes before issuing connectivity intents. The ONOS SDN controller and extended OpenConfig agents will run on Ubuntu virtual machines. The GUI (shown in Fig. 1b) and CLI of ONOS SDN controller will be available to submit connectivity intent requests. The logging of all the software components will be visible to show all the relevant events. OpenStack Horizon dashboard will be used to access the

VNFs, whereupon the end-to-end ICMP ping will be conducted between the VNFs. Furthermore, the video client will be accessed to show the end-to-end video streaming for verifying the connectivity status.



(a) (b)

Fig. 2. (a) ONOS GUI showing Voyager muxponders (b) OpenConfig edit-config message from ONOS to the Voyager muxponder with list of VLANs in logical channel assignment

3. Innovation

The demo showcases the deployment of ETSI-based network service spanning multiple data centers with VNFs inter-connected by VLAN-tagged layer 2 networks. This allows network slicing at the packet domain and mapping a VLAN-ID onto a wavelength allows slicing at the optical domain. This system allows the ETSI MANO NFV end-to-end network service orchestration as employed by the Metro-Haul project. The demo highlights the usage of a hybrid packet-optical device (Voyager muxponder) to interface the packet and optical domains. Prior to this work, ONOS did not support the usage of a hybrid packet-optical device in combination with VLAN switching. Hence, both the ONOS intent framework in the NBI and the OpenConfig driver in ONOS SBI have been extended for considering the VLAN tagging on the client side of the transponder.

4. OFC Relevance

This demo is setup particularly for the OFC audience, based on the ongoing trends of the focus on end-to-end network orchestration over optical networks. This work may be of great interest for telecom operators who deploy NFV services based on network slicing across metro-optical networks where the slicing is based on VLANs; and are also interested in vendor-neutral YANG models to model terminal devices and other telecom equipment. The OFC demo zone is a relevant venue for showcasing the Metro-Haul project so the audience can learn more about the contributions of this project towards the optical networks community and the applicability of ETSI-based network slicing in optical networks. Furthermore, we use ONOS as the state-of-the art open source SDN controller, which is the focus of the ODTN project specifically aiming at the support of disaggregated optical networks.

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5. References

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