Slice Grouping for Transport Network Slices Using Hierarchical Multi-domain SDN Controllers

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Abstract: This demonstration showcases how TeraFlowSDN provides support for hierarchical control of multiple heterogeneous SDN domains (through IP, microwave and optical technologies). Different transport slices are offered with multiple SLAs and grouped to optimize resources.

1. Overview

Network Slices provide the necessary connectivity with a set of specific commitments of network resources between a number of endpoints over a shared underlay network [1]. It is in this context, where transport network slices are provided to support connectivity with a dedicated Service Level Agreement (SLA), which shall be mapped as a technology abstract intent, regardless of the underlying implementation (e.g., L2VPN or L3VPN). Thus, transport network slices once deployed shall be monitored and enforced, in terms of the established SLA constraints/requirements. Current IETF Network Slice Service YANG Model allows the request for the necessary connectivity constraints [2].

We define a slice group as the entity consisting of one or multiple slices with a unique group identifier. One slice belongs to one and only one slice group. Slice grouping requires a mechanism to map a slice into its slice group, also known as slice template or slice blueprint. From our transport network perspective, slice grouping can be based on the mapping of slice SLA requirements to the existing set of slice groups. Thus, slice grouping introduces the need for a clustering algorithm to find service optimization while preserving the slice SLA.

The orchestration of multiple domains has been a problem that has been tackled in the last years [3]. The introduction of hierarchical SDN controllers can ease the adoption of SDN based on multi-layer and multi-technology approach. The usage of technological-dependant SDN controllers and the introduction of a hierarchical parent SDN controller (i.e., orchestrator) has been recently remarked by network operators in Telecom Infra Project Mandatory Use Case Requirements for SDN for Transport (TIP MUST) [4].

In [5], the authors presented TeraFlowSDN as a cloud-native SDN controller that involved support for white-boxes routers using Network Operative System (NOS) and OpenConfig interfaces [6]. The proposed SDN controller allows interacting with both IP routers and an Optical Line System. That proposed architecture was not completely aligned with a hierarchical approach, i.e., where diverse single domain technological SDN controllers are controlled/coordinated by an SDN orchestrator.

We propose to overcome the limitations of a SDN controller responsible for underlying SDN controllers and SDN devices, by presenting the first cloud-native based SDN hierarchical orchestration on top of multiple technology-specific and SDN-controlled network domains (including IP, microwave, and optical).

2. Innovation

This demo brings multiple innovations tied to the novel release of TeraFlowSDN, both from data and control planes. From the data plane perspective, it is interesting to remark the introduction of whiteboxes that support XR constellation supporting the configuration of optical port bandwidth for point-to-multipoint connections [7]. XR constellations are discovered from Infinera Intelligent Pluggable Manager (IPM) north-bound REST-API using TeraFlowSDN XR driver. Moreover, the support for interfacing to a Microwave SDN controller through the standard ETSI GS mWT 024 REST-based interface is also provided [8].

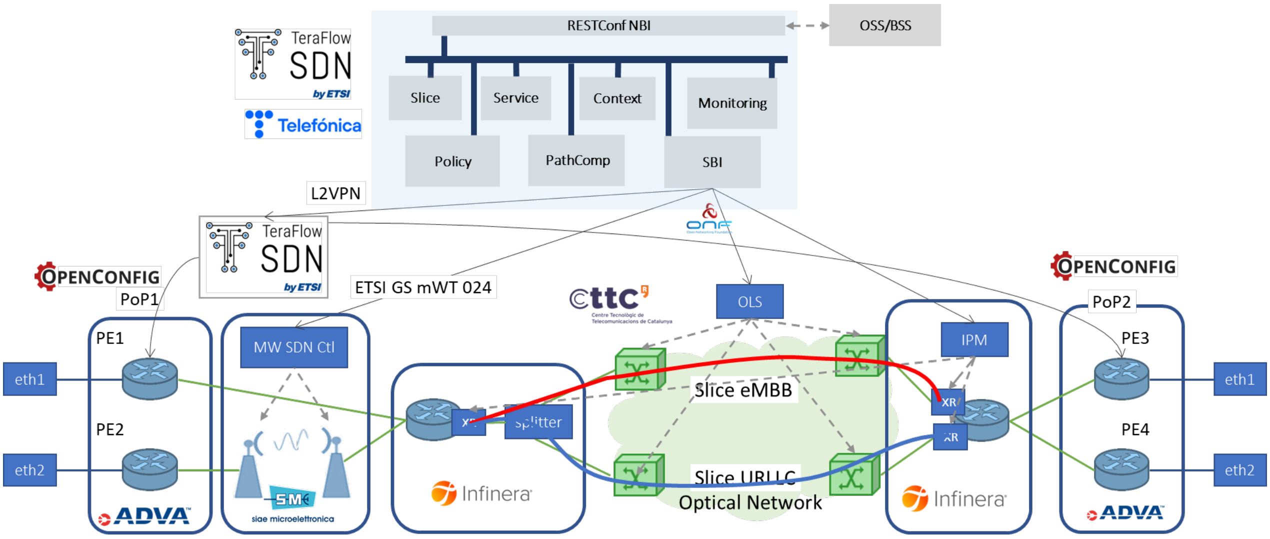

Fig. 1. Proposed demo scenario involving TeraFlowSDN orchestrator on top of multiple SDN controllers.

From the control plane perspective, the TeraFlowSDN acts as a full-featured IP SDN controller which interacts with ADVA NOS based on OpenConfig. We also provide as a novelty the cloud-native end-to-end SDN orchestration architecture via a parent SDN controller (orchestrator) based on TeraFlowSDN. Finally, we introduce the slice grouping concept to transport network slices, by showcasing a clustering algorithm which processes incoming requests to eventually deploy/allocate the transport network slices.

3. Demo Content and Implementation

Fig. 1 shows the demonstration of the hierarchical orchestration/control where the TeraFlowSDN orchestrator interacts and coordinates the underlying dedicated domain SDN controllers, namely: IP TeraFlowSDN controller, Microwave (MW) SDN controller, IPM, and Optical Lines System (OLS). Each domain SDN controller configures a particular network technology, as described above in Section 2.

Fig. 2.a provides an example of a slice request based on [2]. The requested slice includes a service-id along with a requested Service Level Objective (SLO) and Service Level Expectation (SLE) policy. By doing so, several metrics can be included, for example, SLO “one way minimum guaranteed bandwidth” and SLO “guaranteed availability”. These are the two metrics considered in this work, but network slice definition is flexible enough to support multiple SLO/SLE requirements.

Two network slice templates have been considered to allocate the requested transport network slices. The first one, referred to as *gold*, offers a service availability of 90% and a guaranteed bandwidth of 10 Gb/s. The second one, named *platinum*, provides a service availability of 99% with an allocated bandwidth of 100Gb/s.

The demonstration focuses on validating the workflow depicted in Fig. 2.b to provide slice clustering based on slice requests that demand randomly distributed service availability and allocated bandwidth. Step 1 shows the request for the transport network slice, received from the NorthBound Interface (NBI) via a RESTconf interface. Such a request is then translated/mapped into the used TeraFlowSDN protocol buffer and sent to the Slice component for its processing (Step 2). In Step 3, the slice grouping algorithm is triggered, which is detailed below.

The outcome of the slice grouping algorithm can result in two options: *(i)* the slice request is mapped to an existing slice group, or *(ii)* a new slice group might be required. In the first case, the slice resources are related to a current/existing slice group and, using Steps 8 and 9, it is notifed the allocated resources for the request to the Operation Support System (OSS) and Business Support System (BSS).

In case that new resources need to be allocated, the Slice component requests the necessary connectivity services to the Service component. The resources are then allocated following the necessary SDN orchestration mechanisms (steps 4-7). The underlying resource orchestration applied by TeraFlowSDN has been previously demonstrated, for IP over DWDM networks, by the authors in [5]. This demo introduces to novel technological domains through the development of the necessary REST interfaces towards communicating with both MW SDN controller and IPM. Once these interfaces have been introduced to TeraFlowSDN, no workflow modification is needed to provide the connectivity service that supports the requested transport network slice.

To support the slice grouping based on the requested SLO/SLE, we use the K-Means clustering algorithm. This is an unsupervised machine learning algorithm, which groups data into a determined (i.e., K) number of clusters. These number of clusters is defined by the user and, K-means groups the data into that specific number of clusters.

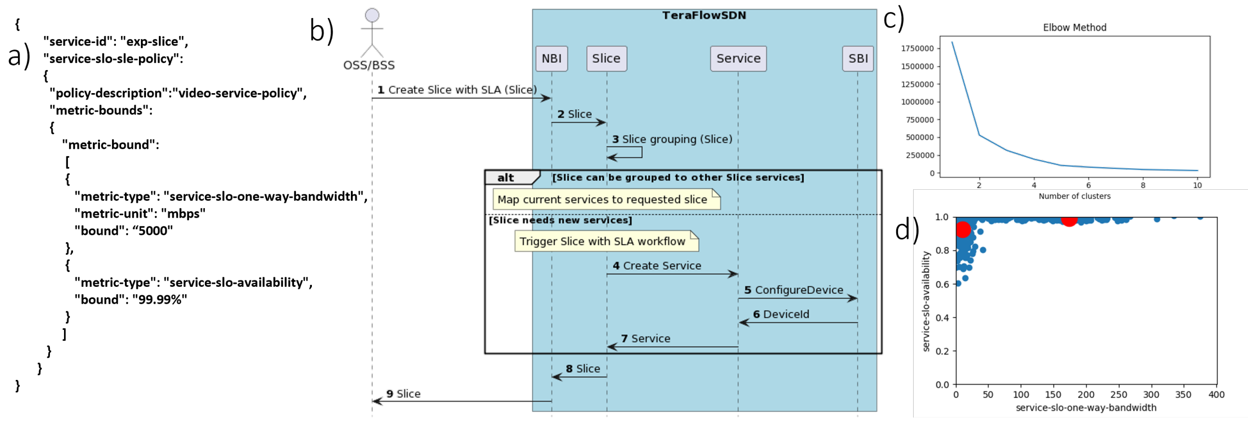

Fig. 2. *(a)* Example of transport network slice request, *(b)* the workflow to provide slice grouping, *(c)* Number of clusters convergence after K-means application, and *(d)* Example of slices grouped in two clusters.

This is the reason why a technique is needed to determine the optimal number of clusters for every specific case. Fig. 2.c shows the application of the Elbow method to select the number of clusters on the received requests. We have run K-means algorithm for a K value ranging from 1 to 10. For each result, we have computed the sum of the squared distances from each point to its assigned center. These plotted values allow us determining the best value of K (i.e., 2 clusters in the proposed demonstration). Finally, Fig. 2.d plots the received transport slice requests and the clusters to which they are related.

4. OFC Relevance

This demonstration will be the first to showcase to the OFC audience a slice grouping mechanism to provide end-to-end SDN orchestration through multiple technology-based SDN domains using the new release of TeraFlowSDN cloud-native controller.

In addition, it aims at bringing awareness to both network operators and equipment vendors of the features and benefits a cloud-native microservice-based Software-Defined Network (SDN) controller. These advantages are specially shown in the context of hierarchical network orchestration, where a multi-layer and multi-technology transport infrastructure handled by dedicated SDN controllers can be effectively orchestrated.

The expected outcome of this demo is to foster interactions with parties attending OFC and from there, to boost further discussions on the introduction, adoption, optimization, and standardization of such novel technologies (including northbound and southbound interfaces) for new breed of transport SDN controllers.

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