Experimental Demonstration of Transport Network Slicing with SLA Using the TeraFlowSDN Controller

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Abstract *This demo presents the TeraFlowSDN controller as a solution to provide dedicated transport network slices with SLAs. To this end, the demo details how the interface between an NFV orchestrator and the SDN controller can provide transport network slices using protected disjoint paths. ©2022 The Authors.*

Introduction

Dynamically programmable optical technology is now being deployed to support 5G services and applications, building on years of research and development. It relies on Software-Defined Network (SDN)-based control and orchestration systems to achieve flexible operation and enable responsiveness to changing traffic demands.

The 5G network architecture is heavily dependent on the concept of network slicing, where network resources are reserved or partitioned to accommodate different connectivity services with their own network needs and/or requirements[1].

Diverse end-to-end network slices are built over a common and shared underlying transport networks infrastructure. As automation is advanced in the higher layers and linked to the dynamic provisioning of services, it becomes essential to integrate control and orchestration of the optical network into the management of the whole system. Focused research is now required to bring together SDN-based control and orchestration of terabit IP flows over next generation optical infrastructure. The objective is to provide efficient, reliable, and scalable control for Beyond 5G (B5G) network resources[2].

Alemany *et al.*[3] provides an overview of how Network Slices can be extended with dedicated Service Level Agreements (SLAs). Some of these SLA can be monitored through Key Performance Indicators (KPIs), but other mechanisms, such as isolation, must be imposed by the orchestrator. Thus, it is necessary that the interface between the orchestrator and the SDN controller allows these SLA definitions.

This paper makes use of the novel cloud-native architecture developed in the ETSI TeraFlowSDN community[4] featuring: (*i*) model-driven optical transport network integration; (*ii*) unification of the optical transport and cloud resource management; (*iii*) machine learning for platform security; and (*iv*) distributed ledger technologies for innovative intent-based contract service management. The TeraFlowSDN controller is an open-source holistic control and orchestration platform available for other research communities and projects. It also includes several standards-based Application Programming Interfaces (APIs) developed to integrate with existing 5G transport orchestration systems.

Finally, the paper outlines the experimental demonstration of the TeraFlowSDN controller. It extends previous work presented in[5], by adding novel extensions to Layer 2 Virtual Private Network (VPN) (L2VPN)-based service requests supporting Network Slices with dedicated SLA features. It summarises architectural and data model details for a B5G critical use case that relies on network slicing to meet the application requirements. In addition, it details the functional components, interfaces, and data models used for the optical infrastructure control and orchestration, including contributions to standards. In conclusion, the paper summarises the ongoing challenges and opportunities for further packet and optical resource control research.

Architecture

The architecture used for this demonstration is depicted in Fig. 1. Two geographically-distant Data Centers (DCs) need to be interconnected

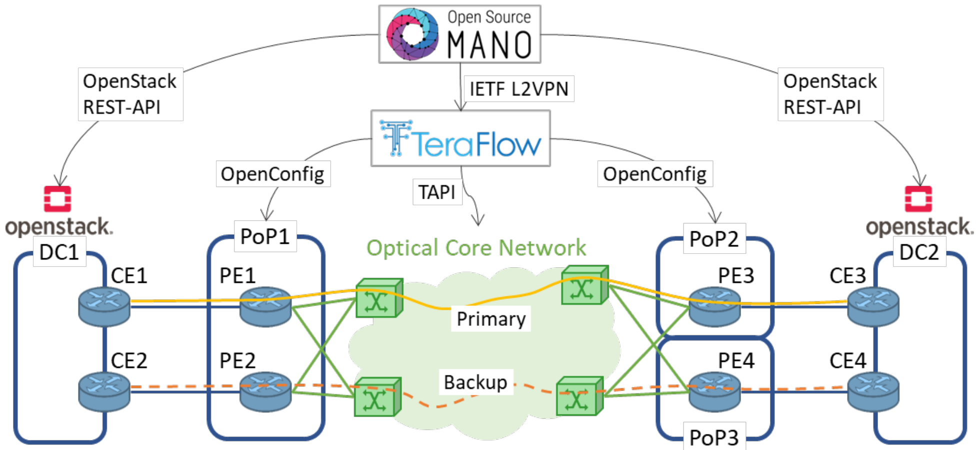

Fig. 1: Disjoint-path–based DC-interconnection Architecture

in a reliable and highly-available manner through an isolated transport network slice. Each DC has network connectivity access through redundant Customer Edge (CE) equipment connected to Provider Edge (PE) equipment, each located at a network operator's Point of Presence (PoP). For instance, DC1 has each of its CEs connected to independent PEs, both belonging to the same PoP, while DC2 has each CE connected to a PE in a different PoP. Further, each PoP is connected to the network operator's optical core network.

A reliable and highly-available transport network slice is deployed over a reliable network connectivity services. To prevent any possible downtime, redundant and completely disjoint paths are established between the sites to be connected, in this case, DC1 and DC2. In the figure, a *Primary* L2 connection, depicted as a yellow solid line, interconnects CE1 at DC1 with CE3 at DC2 through a lightpath established interconnecting PE1 and PE3. The *Backup* L2 connection is depicted as an orange dashed line, and interconnects CE2 at DC1 with CE4 at DC2 through a lightpath between PE2 and PE4.

Data Model

The IETF L2VPN YANG data model for Service Delivery[6] enables to describe the transport network slices required by an Operations Support System (OSS)/Business Support System (BSS) or an Network Functions Virtualization (NFV) orchestrator. The requests can be then consumed by an SDN controller to provision the transport network slices. The data model can be used to define transport network slices by specifying the desired connectivity between sites and a rich set of SLA constraints to be applied. For instance, it can define diverse network accesses per site as shown in Fig. 1, and Quality of Service (QoS) policies, such as traffic shaping, latency and jitter bounds, and acceptable packet loss ratios.

The data model defines the following entities: `ietf-l2vpn-svc:vpn-service` is used to declare the VPN services and `ietf-l2vpn-svc:site` is used to declare a site, e.g., a DC, to be connected to a VPN service. Then, within the `ietf-l2vpn-svc:site` entity, multiple `ietf-l2vpn-svc:site-network-access` registers can be added describing the desired connectivity between the site and the VPN services.

The `ietf-l2vpn-svc:site-network-access` entity contains: (*i*) the `network-access-id` field identifies the network access, (*ii*) the `vpn-attachment` container references the L2VPN service this access relates to, (*iii*) the `bearer` container includes the properties below Layer 2 required by the access, e.g., the physical connection, (*iv*) the `connection` container specifies the L2 protocol-oriented properties, e.g., the frame encapsulation, (*v*) the `availability` and (*vi*) the `access-diversity` containers define multi-access priorities and redundancy preferences for the site-to-network access.

The strategy adopted to generate redundant paths relies on defining different priorities for the primary (`access-priority=10`) and the backup (`access-priority=20`) accesses, and then activating one of them at a time (`single-active`). Next, a constraint is added to enforce the accesses and the underlying lightpaths to follow complete end-to-end disjoint paths. However, the data model only defines constraints for `pe` / `pop` / `linecard` / `bearer-diverse` accesses. Thus, we have augmented the data model with a new diversity constraint, referred to as `end-to-end-diverse`, enabling to request high-availability and resilient slices.

No.	Time	Source	Destin	Protocol	Length	Info
89	*REF*	OSM	TFS	HTTP	305	GET /restconf/data/ietf-l2vpn-svc:l2vpn-svc/vpn-services
101	0.099	TFS	OSM	HTTP/JSON	71	HTTP/1.0 200 OK
121	0.105	OSM	TFS	HTTP/JSON	226	POST /restconf/data/ietf-l2vpn-svc:l2vpn-svc/vpn-services
133	0.233	TFS	OSM	HTTP/JSON	71	HTTP/1.0 201 CREATED
153	0.237	OSM	TFS	HTTP/JSON	643	POST /restconf/data/ietf-l2vpn-svc:l2vpn-svc/sites/site=DC1/site-network-accesses/
161	0.421	TFS	OSM	HTTP	176	HTTP/1.0 204 NO CONTENT
181	0.428	OSM	TFS	HTTP/JSON	643	POST /restconf/data/ietf-l2vpn-svc:l2vpn-svc/sites/site=DC1/site-network-accesses/
189	0.557	TFS	OSM	HTTP	176	HTTP/1.0 204 NO CONTENT
209	0.563	OSM	TFS	HTTP/JSON	643	POST /restconf/data/ietf-l2vpn-svc:l2vpn-svc/sites/site=DC2/site-network-accesses/
217	0.689	TFS	OSM	HTTP	176	HTTP/1.0 204 NO CONTENT
237	0.695	OSM	TFS	HTTP/JSON	643	POST /restconf/data/ietf-l2vpn-svc:l2vpn-svc/sites/site=DC2/site-network-accesses/
245	0.856	TFS	OSM	HTTP	176	HTTP/1.0 204 NO CONTENT
329	0.995	OSM	TFS	HTTP	355	GET /restconf/data/ietf-l2vpn-svc:l2vpn-svc/vpn-services/vpn-service=b93...9f16a4/
341	1.124	TFS	OSM	HTTP/JSON	71	HTTP/1.0 200 OK

Fig. 2: List of Messages Exchanged between OSM and TFS

Experimental Setup

The experimental setup, illustrated in Fig. 1, has been built on top of the CTTC's ADRENALINE Cloud Platform Testbed.

The ETSI OpenSourceMANO (OSM) v10.0 NFV orchestrator is used to provision the network services and delegates to the TeraFlowSDN (TFS) controller, which is used as a WAN Infrastructure Manager (WIM), the establishment of the inter-DC connectivity through the WAN infrastructure. The IETF L2VPN WIM connector is used by the OSM orchestrator to interact with the TFS controller. This OSM WIM connector has been extended to support the request of disjoint paths. The proposed extensions for the IETF L2VPN connector will be contributed to the OSM source code.

On the TFS controller side, it makes use of its OpenConfig Device Driver to control the different PoPs, and the ONF Transport API (TAPI) Device Driver to control the optical core network[5]. The DCs are managed through the OpenStack Virtual Infrastructure Manager (VIM) that is controlled through the OpenStack REST-API by the OSM orchestrator.

The preliminary results of this demonstration include a WireShark capture detailing the interactions between the OSM orchestrator and the TFS controller in Fig. 2, and the detail of a site network access message in Fig. 3.

The interaction starts with a query of services available (message 89), followed by the creation of the VPN service (message 121). Then, each site network access is added to the VPN service (messages 153/181/209/237), and finally, the status of the VPN service is verified (message 329).

The details of the message for creating the site network access from CE1 at DC1 to the VPN service (message 153) are detailed in Fig. 3. This message illustrates the different fields described in Section "Data Model". The other site network accesses are similar to this one.


```
Hypertext Transfer Protocol
JavaScript Object Notation: application/json
 "ietf-l2vpn-svc:site-network-access":
   0:
     "connection":
       "encapsulation-type": "dot1q-vlan-tagged"
       "tagged-interface":
         "dot1q-vlan-tagged":
           "cvlan-id": 300
     "vpn-attachment":
       "vpn-id": "b93d90c0-6b35-4bf5-8593-ac78f09f16a4"
       "site-role": "any-to-any-role"
     "network-access-id": "0a00b6a0-8911-4abd-9b89-f1a318d95456"
     "bearer":
       "bearer-reference": "CE1-PE1"
     "availability":
       "access-priority": 10
       "single-active":
         0: null
     "access-diversity":
       "constraints":
         "constraint":
           0:
             "constraint-type": "end-to-end-diverse"
             "target":
               "all-other-accesses":
                 0: null
```


Fig. 3: Detail of Add Network Site Access to L2VPN Service

The live demonstration will showcase the entire provisioning and configuration procedure from OSM, the changes and operations performed by the TFS SDN controller, and the programming of the underlying network equipment.

Conclusions

The demo presents the necessary protocol extensions for requesting transport network slices with dedicated SLAs from an NFV orchestrator's perspective. The TeraFlowSDN has been demonstrated to be a capable cloud-native SDN controller solution for packet and optical networks in support of transport network slices enforcing SLAs constraints.

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