SDN/NFV orchestration for dynamic deployment of virtual SDN controllers as VNF for multi-tenant optical networks

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Abstract: We propose to virtualize the SDN control functions and move them to the cloud. We experimentally evaluate the first SDN/NFV orchestration architecture to dynamically deploy independent SDN controller instances for each deployed virtual optical network.
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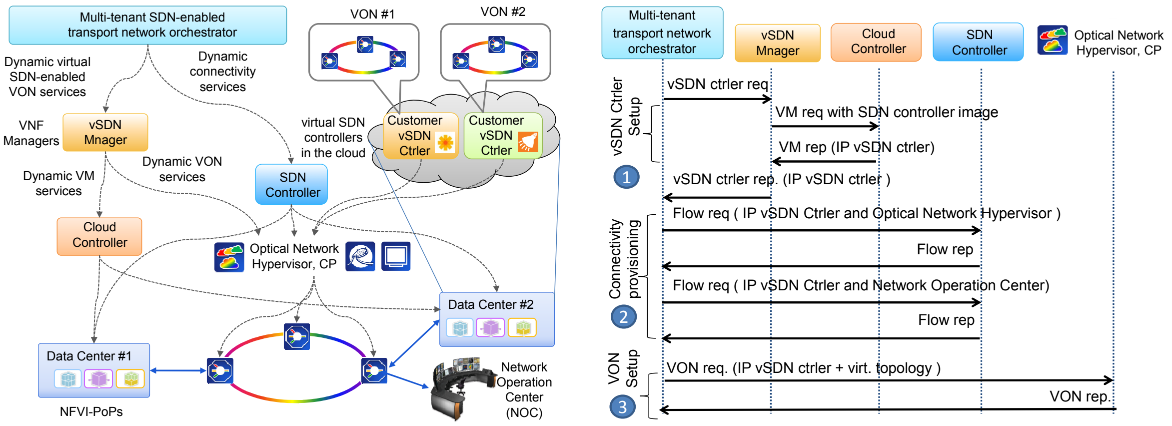
1. Introduction

Optical network virtualization is a key technology to optimize network infrastructure operators. Thanks to virtualization, operators can offer application-specific optical network services to support specific quality of service (QoS) and Service Level Agreement (SLA) requirements. Virtual optical networks (VONs) are created by first partitioning and/or aggregating the physical resources into virtual resources. Once the virtual resources are defined, they are interconnected and offered to the specific applications and services. VONs can coexist using different virtual network topologies while sharing the same physical infrastructure. On the other hand, VON control is a key requirement associated to optical network virtualization, since it allows programming the VON (i.e., direct control and configuration). The users of the VON can dynamically create, modify and delete virtual network slices in response of application demands (e.g., through a traffic demand matrix describing resource requirements and QoS for each pair of connections). Moreover, the allocated virtual network resources can be independently controlled by means of their own customer Software Defined Networking (SDN) controller. These requirements can be achieved through and Optical Network Hypervisor (ONH) [1], also known as Virtual Network Controller (VNC) in [2]. The ONH/VNC is responsible for slicing the transport network into multiple VONs and representing an abstracted topology of each VON (i.e., network discovery) to the corresponding customer SDN controller. Besides, the SDN controllers allow the remote control of the VON (i.e., dynamic provisioning, modification and deletion of connections), through a well-defined interface (e.g., OpenFlow protocol), as the VONs were real physical networks.

Typically, the SDN controller of each VON runs in a dedicated host. It can be deployed using several available open source software implementations such as OpenDaylight, Floodlight, Trema, POX, etc. The use of a standardized interface between the SDN controller and the ONH for network discovery and connection provisioning allows that any SDN controller implementation can be used to control a VON. Thus, when a new VON is dynamically created through the ONH, it is required to manually install and configure a SDN controller implementation on a dedicated server, as well as to provide connectivity between the ONH and the SDN controller servers, typically located in a Network Operation Center (NOC). The whole process can take several days. In this work we propose to also virtualize the network control functions (i.e., the SDN controller) and move them into the cloud in order to dynamically deploy independent SDN controller instances within minutes, whenever new VONs are dynamically deployed. This approach also offers additional advantages such as the lack of hardware maintenance downtime (a virtual SDN controller can be quickly and easily moved between physical hosts within a data center when hardware maintenance is required), and decreased recovery time in case of a disaster or failover (backups and snapshots of the virtual SDN controllers taken throughout the day can be moved from one data center to another and redeployed easier and faster after a failure). To this end, we present and experimentally assess and evaluate in a field-trial the first SDN and Network Function Virtualization (NFV) orchestration architecture for multi-tenant transport networks to dynamically deploy VONs and their corresponding virtual SDN controllers as Virtual Network Functions (VNF) in data-centers. In brief, NFV [3] looks to implement network functions that are typically deployed in specialized hardware servers as software instances running on commodity servers through software virtualization techniques. These virtualized functions are called VNFs, and can be located in the most appropriate places (e.g., data centers), referred to as NFV Infrastructure Point of Presence (NFVI-PoPs). NFV is applicable to any data plane packet processing and control plane function in fixed and mobile network infrastructures. Previous works on control plane function virtualization for optical networks have been focused on the virtualization of the PCE [4].

2. Proposed SDN/NFV orchestration architecture for multi-tenant SDN-enabled optical transport networks



a) b)

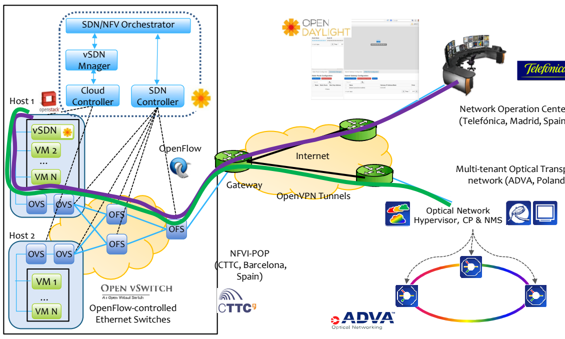
Fig. 1 a) Proposed SDN/NFV orchestration architecture for multi-tenant optical transport networks with virtual SDN controllers as VNF, b) Workflow for deploying a virtual SDN-enabled optical transport network

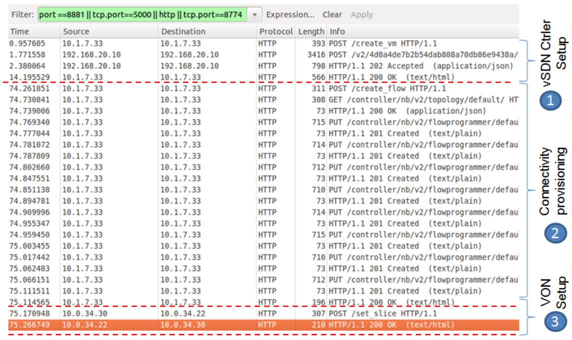
Fig.1.a presents the functional blocks of the proposed SDN/NFV orchestration architecture for deploying virtual SDN-enabled optical transport networks. The NFV Infrastructure – NFVI is composed of an optical transport network (e.g., Fixed-grid or Flexi-grid DWDM network) interconnecting distributed data centers (NFVI-PoPs), providing compute, storage and network hardware resources. On top of this physical infrastructure, we deploy a NFVI virtualization layer responsible for virtualizing the compute, storage and network resources of the NFVI. Specifically, it is based on two NFVI virtualization managers, namely, one for the cloud and storage infrastructure, and another for the network infrastructure. The former is responsible for provisioning and managing virtual machines (VM) and storage resources. It can be based on open source cloud managers such as OpenStack or Opennebula. The latter is responsible for providing programmable virtual optical network services (through the ONH), and virtual connectivity services (through a SDN controller) between VMs of a VNF (if the VNF is deployed in several VMs) or between different VNF instances (if each VNF is deployed in one VM). On top of this virtualization layer we deploy several VNF managers. A VNF manager is responsible for the VNF lifecycle management (i.e., creation, configuration, and removal). We propose a novel VNF manager called virtual SDN controller manager (vSDN manager). The vSDN manager is in charge of requesting to the Cloud controller, the creation of VMs in a data center and the installation of an operating system image with a compiled OpenDaylight or Floodlight SDN controller (referred to as customer vSDN controller in Fig1.a). Finally, on top of the proposed SDN/NFV architecture we find the orchestrator for multi-tenant SDN-enabled transport networks. It is responsible for the management (provisioning, modification and deletion) of the virtual SDN-enabled optical networks by orchestrating the creation of the vSDN controllers (located in the cloud), the virtual optical networks slices, and the connectivity between the vSDN Controllers (located in the cloud) with the ONH and the NOC.

3. Example of dynamic deployment of virtual SDN-enabled optical transport networks

Let us consider the example of Fig.1.b to show the involved workflow between the different functional blocks of the proposed SDN/NFV orchestration architecture. First (step1), the Orchestrator requests to the vSDN manager the provisioning of a virtual of a new vSDN controller specifying the desired customer SDN controller implementation (e.g., OpenDaylight, Floodlight, etc.). To this end, the vSDN manager requests to the cloud controller the creation a new VM with the requested pre-installed SDN controller. In a distributed environment with several data centers, the orchestrator could request to deploy the vSDN controller in the data center nearest to the NOC to minimize the latency. Once the requested vSDN controller is up and running, the vSDN manager controller notifies to the orchestrator and provides the IP address of the vSDN controller. Then (step2), the orchestrator requests to the SDN controller the provisioning of two flows, one between the vSDN controller and the computer terminal within the NOC, and another to between the vSDN controller and the ONH/VNC. Finally (step3), once the connectivity is provided, the orchestrator requests to the ONH the provisioning of a VON with the IP address of the vSDN controller and the desired virtual topology graph. This virtual topology representation can be based either on virtual node or virtual link aggregation mechanisms. The former hides internal connectivity issues by representing the virtual network topology as a single virtual node. The latter represents the virtual network topology as a set of virtual nodes and virtual links, where each virtual link is a connection across physical nodes. Once the VON has been successfully provisioned, the ONH notifies to the Orchestrator. At this point, the virtual SDN-enabled optical network is ready to be used by an operator at NOC through a virtual SDN controller located in the cloud.

4. Experimental assessment and performance evaluation





a) b)

Av. vSDN Ctlrer Setup delay		Av. connectivity provisioning delay	Av. virtual network setup delay	Av. Total deployment delay
VM creation	vSDN Ctrler Conf.			
73.6s	0.4 s	0.9 s	0.1 s	75s

b)

```
*REF*     NOC   vSDN  HTTP      POST /controller/web/flows/fl
0.028925  vSDN  OHV   OpenFlow  Type: OFPT_FLOW_MOD
0.029027  vSDN  OHV   OpenFlow  Type: OFPT_BARRIER_REQUEST
5.698622  OHV   vSDN  OpenFlow  Type: OFPT_BARRIER_REPLY
5.707736  vSDN  NOC   HTTP      HTTP/1.1 200 OK  (text/plain)
```

c)

Fig. 2. a) Experimental network setup b)Wireshark capture at the NFV/SDH orchestrator when provisioning a virtual SDN-enabled optical network c) Performance evaluation in terms of setup delays d) Wireshark capture at a virtual SDN controller when provisioning of a flow.

We have developed a proof-of-concept prototype of the proposed SDN/NFV orchestration architecture in the multi-partner experimental setup shown in Fig.2.a, in order to experimentally assess and evaluate the dynamic provisioning of virtual SDN-enabled optical transport networks. The experimental setup is composed of a data center provided by CTTC in Barcelona (Spain), a Flexi-grid DWDM network with an ONH from ADVA in Poland, and a computer terminal in the NOC of Telefónica in Madrid (Spain). All these three premises are connected using OpenVPN tunnels over the Internet. Specifically, we have setup two OpenVPN tunnels, one between CTTC and Telefónica, and anther between CTTC and ADVA. The CTTC data center is based on Openstack for the cloud computing platform, and OpenDaylight for the control of the OpenFlow-enabled network. The OpenStack Havanna release has been deployed into five physical servers with 2 x Intel Xeon E5-2420 and 32GB RAM each, one dedicated to the cloud controller and the other four as compute pool (hosts) for VM instantiation. Eight OpenFlow switches have been deployed following a tree topology using standard custom off the shelf hardware (Intel Core i7-3770) with OpenVSwitch software, which can be controlled by OpenFlow 1.0. The ADVA ONH is a multi-tenant capable application that creates and exposes abstract representations of the underlying optical transport network and exports that abstracted network to client SDN controllers, based on the single virtual node model. From the perspective of the exposed SDN interface, the ONH acts, for each VON, as one virtual node controlled by OpenFlow. In the experimentation, we request to the SDN/NFV orchestrator the provisioning of virtual SDN controllers (either based on OpenDaylight or OpenFlow) and of VONs with abstracted topologies based on the single virtual node model, as shown in the example of Fig.1.b. Fig.2.b shows a wireshark capture with the exchange of messages between the SDN/NFV orchestrator and the vSDN Manager, OpenDaylight and OpenStack controllers, and the ONH to provision a virtual SDN-enabled optical network. In this experimentation, all these modules have been implemented in a single server (10.1.7.33), with the exception of the ONH that is located in Poland. Fig. 2.c shows the evaluated performance metrics, namely, the average delay for creating a VM and configuring a vSDN controller (74s), for creating a VON (0,1s), and for configuring two OpenFlow flows and two OpenVPN tunnels between the vSDN controller and the CTTC's gateway node (0,9s), as depicted in Fig2.a. The total average setup delay of provisioning a virtual SDN-enabled optical network is 75s. Finally, Fig.2.d shows a wireshark capture at a vSDN controller with the exchange of messages for provisioning a flow between the NOC's computer terminal (webpage) and the ONH, once the virtual SDN-enabled optical network is up: `HTTP POST` request from NOC computer terminal to vSDN controller, OpenFlow `FLOW_MOD` and `BARRIER` messages between the vSDN controller and the ONH (to configure the virtual switch), the OpenFlow `BARRIER_REPLY` from the ONH to the vSDN controller, and finally the `HTTP POST` response to the NOC. The average flow provisioning delay is 6s.

5. Conclusions

We have experimentally assessed and evaluated in a multi-partner experimental setup the first SDN and Network Function Virtualization (NFV) orchestration architecture for multi-tenant transport networks to dynamically deploy VONs and their corresponding virtual SDN controllers as Virtual Network Functions (VNF) in data-centers.

6. Acknowledgments

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7. References

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