Optical Networks Virtualization and Slicing in the 5G era

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Abstract: We provide an overview of operationalization and deployment of the different data and control plane technologies used for both Optical Network Virtualization and Network Slicing, which are two key enablers of future 5G networks.
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1. Introduction

Future 5G networks will support a wide range of services and use cases arising from different vertical industries (e.g., IoT, eHealth, Industry4.0, etc.). Each of these services / business cases impose their own set of requirements to the network infrastructure, in terms of security, latency, elasticity, resiliency, and bandwidth. To deal with these challenges, the NGMN proposed the concept of network slicing (NS). Briefly, a network slice instance is formed by a set of network functions, and the resources enabling the deployment of these functions, forming a complete instantiated logical network to meet certain network characteristics for a specific service.

Optical Network Virtualization is a key enabler for network slicing, as it provides the necessary technologies to provide the specified set of network requirements, while providing the necessary isolation between network slices. In this paper, we will review the suggested technologies from both data and control plane perspectives.

Moreover, the authors have proposed and presented candidate architectures aiming at combining NS with transport networks. In this regard, [1] focused on an experimental demonstration of a multi-tenant network slicing architecture that besides dynamically deploying 5G slices (encompassing virtual network and cloud resources, and virtualized network functions), it deploys dedicated SDN/NFV control plane instances for each slice enabling full control of the allocated resources. In [2], cascading of network and cloud resources was proposed as the recursive hierarchical abstraction and virtualization of resources. We have analyzed the current trends for NS [3-4], where a slice manager is introduced in order to interact with a resource orchestrator. This paper presents a novel architecture to both support multi-tenancy and NS on top of interconnected multiple NFVI-PoPs. Each tenant will be able to run a dedicated Service Platform (NFV-O + VNFM), which might be deployed on top of the shared infrastructure

Despite the expected benefits provided by adopting SDN/NFV technologies, a number of issues to cope need to be bypassed. In this sense, some of the most significant difficulties are: the need for interoperability between VNFs and orchestrators (which is being reduced through the open source software community), the combination of SDN and NFV technologies (e.g., lack of flexible support for end-to-end multi-site installations), and the consolidation of the initiatives to avoid the "additional development needed" to integrate the application/service on the platform. In order to mitigate these difficulties, we propose a model introducing DevOps for Networking.

2. (Optical) Network Virtualization

Optical network virtualization (ONV) refers to the partitioning and aggregation of the physical optical infrastructure to create multiple co-existing and independent virtual networks (VN) on top of it. ONV can be introduced at data plane with enabling technologies which support virtualization (packet or circuit based), or with resource virtualization at the control plane level [5]. The usage of such virtualization technologies in NS might accomplish benefits in terms of security, latency, elasticity, resiliency, and bandwidth.

At the data plane, network virtualization can be performed differently according to the considered layer (Fig. 1.a). At the Layer 0, dedicated physical interfaces, wavelengths, cores and modes might be allocated to a VN. At layer 1, OTN tunnels can be considered. At the Layer 2, MPLS and FlexEthernet connections can be adopted. Later, the use of VLANs allows creating up to 4094 virtual networks over the same physical Ethernet interfaces. At the Layer 3, the composition of overlay networks through tunneling mechanisms (e.g., NVGRE, NSH) provides the necessary VN.

From the control plane perspective, several initiatives are currently addressing the ONV framework. In OIF, a Virtual Transport Network Service (VTNS) is the creation and offering of a VN by a provider to a user [6]. VNs may be dynamically created, deleted, or modified and users can perform connection management, monitoring and protection within their allocated VNs. Different types of VTNS could be associated to operators offering, for example, Bandwidth on Demand (BoD) services, Network as a Service (NaaS) or Network Slicing for 5G Networking.

In IETF, the Abstraction and Control of Traffic Engineered Networks (ACTN) architecture [7] defines the requirements, use cases, and an SDN-based architecture, relying on the concepts of network and service abstraction.

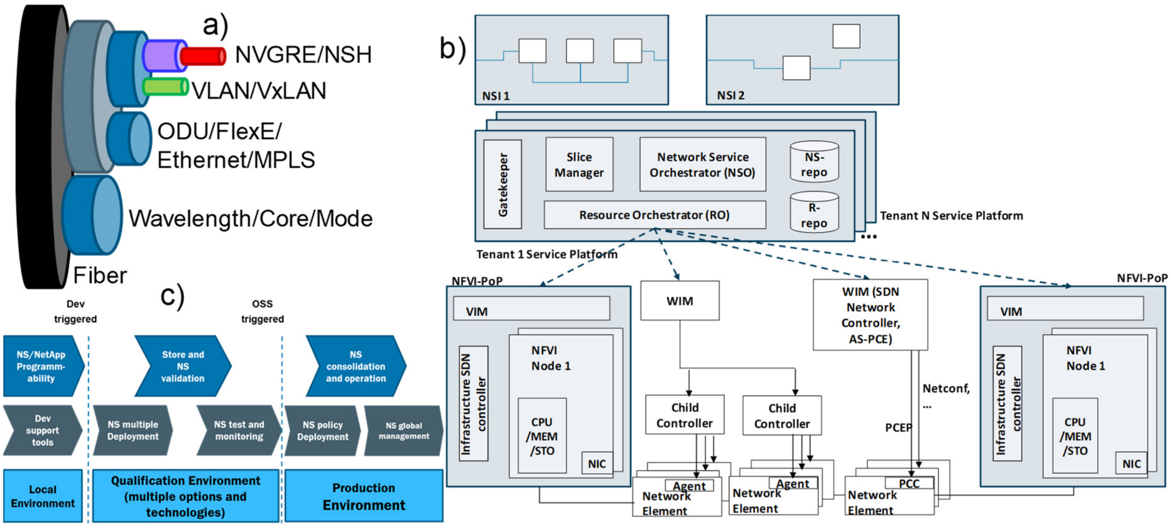

Figure 1. a) Optical Network Virtualization, b) Proposed Network Slicing architecture; c) DevOps for Networking lifecycle

The architecture encompasses Physical Network Controllers (PNCs) which are responsible for specific technology and/or administrative domains. PNCs are then orchestrated by a Multi-Domain Service Coordinator (MDSC). By doing so, MDSC enables abstraction of the underlying transport resources and deployment of virtual network instances for individual customers / applications, which are controlled by each individual Customer Network Controller.

3. Network Slicing for 5G using SDN/NFV

The proposed 5G slicing architecture aims at providing multiple, highly flexible, end-to-end network and cloud infrastructure slices operated in parallel over the same physical infrastructure to fulfill vertical-specific requirements as well as mobile broadband services. Fig.1.b shows the proposed 5G architecture that supports the dynamic deployment of 5G network slices on top of multiple ETSI NFV infrastructure points of presence (NFVI-PoPs) interconnected with multiple SDN transport networks (a.k.a, WAN Infrastructure Manager, WIM). For each tenant, a complete service platform (NFV-O + VNFM) might be deployed on top of the shared infrastructure. The service platform will be able to provide the requested network slice instances for the different verticals.

The NFVI-PoP consists of the infrastructure that is located in a single site and that is offered for the deployment of VNFs and their interconnection. From the networking perspective, it typically consists of a single L2 network controlled through and Infrastructure SDN controller, which uses L2/L3 network virtualization for the instantiation of different network services. Each NFVI-PoP offers its control and management interface towards the service platform through a VIM [3]. The VIM allows to configure multiple tenants in a data-center (DC) site, instantiate the creation / deletion of virtual machine (VM) instances, storage of disk images, and the management of the intra-DC network connectivity for each tenant. The VIM also provides current status for these resources.

VIMs are interconnected using a software-defined network. Several WIMs might be needed as several transport networks could be involved / used. The usage of hierarchical WIM or the ACTN/VTNS architectures is considered in [5]. The WIMs might be able to provide the necessary ONV technologies described in the previous section.

The Service Platform is the responsible for allocating the requested network slice instances, and to deploy on top of them the necessary network services. The gatekeeper module in the service platform processes the incoming and outgoing requests. The slice manager takes over the slice lifecycle interacting with the resource orchestrator. The network service orchestrator (NSO) receives the service packages and performs the placing, deploying, provisioning, scaling, and managing of the services within the existing cloud infrastructures. The service developer can ship the service package to the service platform together with service- or function-specific lifecycle management requirements and preferences, called Service-Specific Managers (SSM) and Function-Specific Managers (FSM), respectively. SSMs and FSMs can influence the Service and VNF lifecycle management operations, e.g., by specifying desired placement or scaling behavior. The resource orchestrator (RO) allows the service platform entities to interact with the infrastructure. It exposes interfaces to manage services and VNF instances, retrieve monitoring information about the infrastructure status, and reserve resources for services deployment.

4. DevOps for Networking

Taking into account the predictions for the adoption of NFV and SDN, it can be observed that although the technologies are already there, the actual adoption has indeed recently started. One of the most promising enterprise NFV use cases is development and operations (DevOps) automation. In this use case, DevOps will increase the ability to deliver NFV applications and services at high velocity, by evolving and improving products at a faster pace than

organizations using traditional software development and infrastructure management processes. It is in view of this that we propose an extended NFV architecture that supports a DevOps methodology.
One of the biggest challenges in 5G will be the Validation & Verification (V&V) of VNFs and network services on top of network slices against different execution platforms so that service operators can ensure that VNFs and NSs behave as expected immediately after they are deployed and put into production. Such a V&V process not only includes functional testing of VNFs and NSs but also non-functional tests, such as performance measurements for gaining insights about resource requirements to fulfil service level agreements (SLAs) and to provide the expected quality of experience (QoE). To fit seamlessly into the anticipated DevOps workflow, all these V&V procedures need to be fully automated and be able to qualify any VNF or service without further human interaction.
Fig. 1.c presents the three natural steps for network service usage: network service development using SDK tools, validation (on the V&V Platform) and operation (Service platform with orchestrator), each driving by conceptual innovation and concrete tooling/software development. These three pillars, service development, service qualification and service platform, are closely linked together. There is a clear need for quick turn-around times in service development and operation, providing support for bringing the DevOps model to the world of network services.
Fig. 2 proposes to add a V&V platform to the NFV reference architecture which allows all involved parties to test, validate and verify single network functions or entire network services before they are deployed to production. The proposed V&V system forms a flexible test platform that is able to handle both generic standardised test-cases as well as specialised test-cases that are custom-tailored to validate, e.g., the compatibility of a service with an operator-specific target platform. This entire V&V process is performed by the following four roles: a)Developer: Develops, tests, publishes network services; b) V&V Platform: Provides testing environment, develops and executes tests, issues digitally signed test results; c) Catalogue: Stores network services and metadata (including test results), offers decision support; and d) Operator: Selects, tests, deploys existing network services.

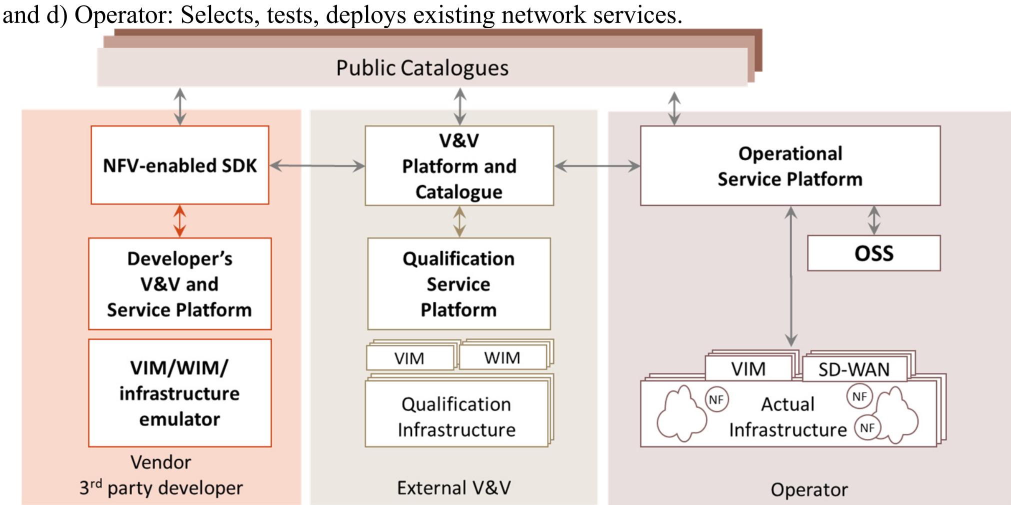

Figure 2 DevOps for Networking architecture [8]

5. Conclusion

We have presented how different ONV technologies might benefit NS. A general architecture for multi-site NFVI-PoP that supports NS and multi-tenancy has been presented. Finally, a DevOps model has been proposed for networking to speed up the time-to-market adoption for novel network services.

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