The Need for a Transport API in 5G networks: the Control Orchestration Protocol

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Abstract: We experimentally assess the first Transport API that provides a research-oriented multi-layer approach using YANG/RESTconf. It defines a functional model of a control plane and enables the integration of optical/wireless networks and distributed cloud resources.
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1. Introduction

The fifth generation of mobile technology (5G) is not only about the development of a new radio interface, but also of an end-to-end system. This end-to-end system includes the integration and convergence of all network segments (radio and fixed access, aggregation, metro and core) with heterogeneous wireless and optical technologies together with massive cloud computing and storage infrastructures [1]. The 5G architecture shall accommodate a wide range of use cases with different requirements in terms of networking (e.g, security, latency, resiliency, bandwidth) or cloud resources (e.g, distributed nodes with cloud capabilities, edge /core data centers -DC). Thus, one of the main challenges will be to provide multiple, highly flexible, end-to-end dedicated network and cloud infrastructure slices over the same physical infrastructure in order to deliver application-specific requirements.

Software Defined Networking (SDN) architecture is the key enabler to integrate both network and cloud resources, which enables advanced end-to-end 5G services upon multi-domain heterogeneous networks and distributed DCs. SDN is defined as a logically centralized control framework that supports the programmability of network functions and protocols by decoupling the data plane from the control plane through a well-defined control protocol (e.g., OpenFlow). The control entity (SDN controller) is responsible for providing an abstraction of the network forwarding technologies (e.g., packet/flow or circuit switching) through an Application Programming Interface (API). This abstraction enables to deploy a network hypervisor in order to perform network virtualization, that is, to slice the physical infrastructure and create multiple co-existing virtual tenant networks (VTN) independent of the underlying transport technology and network protocols. Ideally, the SDN architecture is based on a single control domain comprising multiple network nodes featuring diverse technologies provided by different vendors that are controlled through standard interfaces. However, it is not realistic in the short term in optical networks since they are fragmented into multiple vendor domains. The transport equipment does not interoperate at the data plane level (only at the grey interface level) unlike regular Ethernet switches or IP routers. Moreover, each vendor offers its own control plane technology (e.g., SDN with some proprietary OpenFlow extensions or G/MPLS and PCE) because of the need of configuring vendor-proprietary parameters (e.g., FEC), generating vendor islands.

The solution envisioned in the STRAUSS project (http://ict-strauss.eu/en/) is a multi-domain SDN network orchestrator acting as a unified transport network operating system (or controller of controllers) allowing the control (e.g., E2E transport service provisioning), at a higher, abstracted level, of end-to-end resources across multiple domains with heterogeneous multi-layer multi-vendor transport network technologies regardless of the specific control plane technology employed in each domain (e.g., SDN/OpenFlow or GMPLS/PCE). The conceived multi-domain SDN orchestrator architecture is based on the Application-based Network Operations (ABNO) [2] proposed in the Internet Engineering Task Force (IETF). It has been experimentally validated in [3] and [4]. Typically, the northbound interface (NBI) of a domain controller is technology and vendor dependent, so the multi-domain SDN network orchestrator has to implement different plugins for each of the domain controller's NBI [5]. The STRAUSS project has defined the first Transport API named Control Orchestration Protocol (COP), that abstracts the particular control plane technology of a given transport domain. COP provides a research-oriented multi-layer approach using YANG/RESTconf. The latest OIF/ONF Transport SDN API [6] is in line with COP's objectives. In brief, COP is composed of three main base functions: 1) Topology providing topological information about the network, which includes a common and homogeneous definition of the network topologies included in the TE Databases of the different control instances; 2) Path computation, providing an interface to request and return path objects which contain the information about the route between two endpoints; 3) Call, based on the concept of Call/Connection separation, and providing a common provisioning model which defines an end-to-end connectivity provisioning service. The COP definition is open for discussion and can be downloaded and contributed at https://github.com/ict-strauss/COP. The COP also enables the integration of heterogeneous radio access networks (5G, mmWave, LTE/LTE-A, Wi-Fi, etc) with transport networks as well as the orchestration of cloud resources and transport resources for DC interconnection.

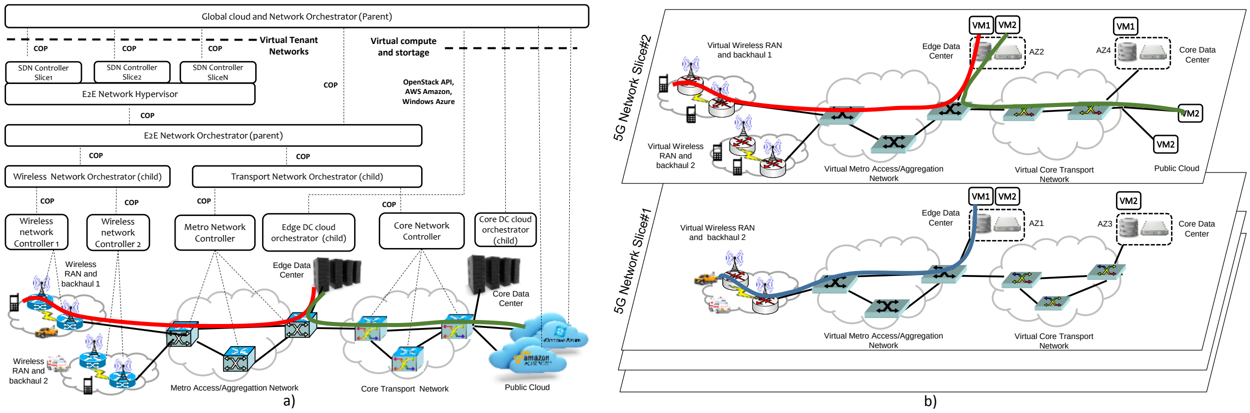

Fig.1. a) 5G network architecture for dynamic provisioning of virtual compute, storage and network across distributed cloud infrastructures and heterogeneous networks b) 5G network slices supporting different cloud and network requirements

2. Proposed network architecture for distributed cloud and heterogeneous network orchestration

The considered network scenario is composed of multiple wireless radio access and backhaul technologies and multi-domain, multi-layer and multi-vendor transport networks, with heterogeneous control domains, interconnecting distributed cloud infrastructures (both private and public). The use of COP between the SDN network orchestrator and control layers allows the simplification and optimization, in terms of scalability and compatibility between the different modules which compose the SDN architecture. COP unifies all the orchestration functionalities into a single protocol paradigm. The proposed COP provides a common NBI API so that all domain controllers can be orchestrated using a single common protocol. One benefit of this architecture resides on the ability to perform unified control and management tasks (e.g., end-to-end provisioning services) of different radio access and transport network technologies by means of the same SDN network orchestrator. However, for scalability, modularity, and security purposes, it may be also desired to consider a hierarchical orchestration approach with different levels of hierarchy (parent/child architecture). Each successively higher level has the potential for greater abstraction and broader scope (e.g., we may considered one orchestrator for the RATs, and another for the transport networks), and each level may exist in a different trust domain. The level interface might be used as a standard reference point for inter-domain security enforcement. In our approach, the COP can be used as the NBI of the child SDN orchestrator and as SouthBound Interface (SBI) of a parent SDN orchestrator in order to provision E2E services. A parent/child SDN orchestrator architecture based on ABNO has been previously validated for E2E multi-layer (packet/optical) and multi-domain transport provisioning across heterogeneous control domains (SDN/OF and GMPLS/AS-PCE) employing dynamic domain abstraction based on virtual node aggregation in [7].

In the proposed system architecture, a network hypervisor is placed on top of the E2E network orchestrator. It is responsible for partitioning and/or aggregating the abstracted resources provided by the E2E network orchestrator into virtual resources, interconnecting them to compose multiple end-to-end virtual tenant networks (VTNs) with different VTN topologies while sharing the same physical infrastructure. It is also responsible for representing an abstracted topology of each VTN (i.e., network discovery) to a tenant SDN controller, and for it to remotely control the virtual network resources (i.e., dynamic provisioning, modification and deletion of connections) allocated to their corresponding VTN, as if they were real resources, through a well-defined interface (e.g., OpenFlow protocol, or the COP). The network hypervisor can dynamically create, modify and delete VTNs in response to application demands (e.g., through a traffic demand matrix describing resource requirements and QoS for each pair of connections). The proposed multi-domain network hypervisor architecture has been proposed and assessed in [8].

Virtualization of compute, storage and networking resources in data centers is provided by private clouds trough distributed cloud orchestrators (children) that may be deployed with different software distributions (e.g. OpenStack, OpenNebula), or by public cloud. Each cloud orchestrator enables to segregate the DC into availability zones for different tenants and instantiate the creation/ migration/ deletion of Virtual Machine (VM) instances (computing service), storage of disk images (image service), and the management of the VM's network interfaces and the intra-DC network connectivity (networking service). On the other hand, the global cloud and network orchestrator (parent) targets the global management of the virtual compute, storage and network resources for the different slices provided by the tenant SDN controllers and the distributed cloud orchestrators. It acts as a unified cloud and network operating system providing, for each slice, the dynamic and global provision, migration and deletion of VMs and the required end-to-end connectivity between the distributed virtual cloud infrastructures across the corresponding multi-layer VTN. A key enabler of such an integration is the COP, which is used as NBI by the tenant SDN controllers, providing a common control of the VTNs. A preliminary architecture of a global cloud and network orchestrator named SDN IT and Network Orchestrator (SINO) has been defined and evaluated in [9] and [10].

3. Experimental Validation

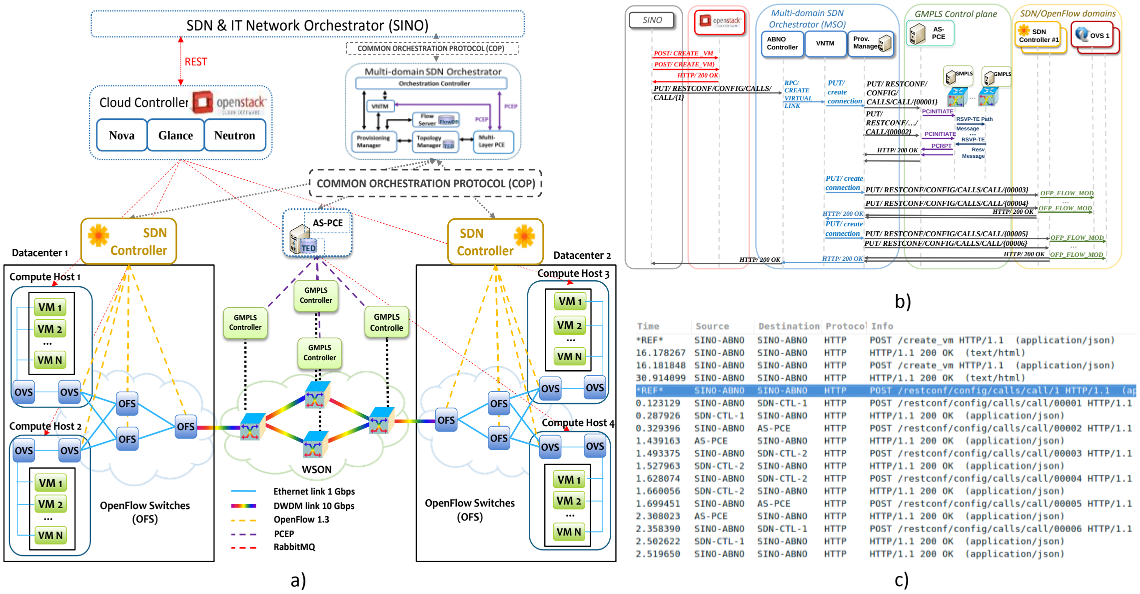

Fig.2. a) Experimental scenario for DC interconnection, b) Integrated IT/SDN orchestration workflow c) Wireshark network traces capture.

The proposed architecture has been validated in the cloud computing platform and transport network of the ADRENALINE Testbed. The cloud computing platform is controlled using OpenStack (Havana release), which has been deployed into servers with 2 x Intel Xeon E5-2420 and 32GB RAM each. An Openstack controller node and four compute nodes have been setup in different network locations. Each DC network is composed of four OpenFlow switches deployed on COTS hardware and using OpenVSwitch (OVS) technology. Two hybrid packet/optical aggregation switches based on OVS as well and with a 10 Gb/s XFP tunable transponder connecting to the DWDM network as alien wavelengths. Finally, the GMPLS/PCE-controlled optical network is composed of an all-optical WSON with 2 ROADMs and 2 OXCs. The multi-domain SDN orchestrator (MSO) and SINO entities have been mostly implemented in Python with the exception of the Multi-layer PCE which has been implemented in C++. The COP has been employed as a Transport API for the orchestration of: two SDN OpenDaylight Helium controllers responsible of controlling the Ethernet intra-DC domains via OpenFlow 1.3; and the optical transport network via an AS-PCE with instantiation capabilities as a single interfacing point for the GMPLS control plane. In the experimental validation, we have introduced COP agents on top of SDN controllers in order to translate the received COP commands to SDN controllers NBI. Fig.2a shows a multi-domain network scenario where two geographically distributed DCs are interconnected through the WSON. Fig.2.b illustrates the integrated IT/SDN orchestration workflow for the on-demand deployment of two VMs in the cloud (one on each DC location) and the E2E connectivity provisioning across the proposed scenario. The network orchestration is performed using the proposed COP between the SINO-MSO and consequently between the MSO and the per-domain controllers. For this experimental validation, a bidirectional CALL_SERVICE is requested by the SINO to provide an E2E connectivity to the previously deployed VMs. The MSO firstly requests the creation of a virtual link in the upper layer topology (L2) which is translated internally by the VNTM MSO module into two unidirectional L0 CALL_SERVICEs sent to the AS-PCE through the Provisioning Manager. They trigger, in the AS-PCE, the creation of the corresponding GMPLS connections (Label Switched Paths (LSPs)). Afterwards the provisioning of the E2E service in the upper layer is requested to the SDN controllers, by two new unidirectional CALL_SERVICESs to each domain. The traffic capture showed in Fig2.c validates the use of the COP.

4. Conclusions

The definition of a Transport API that abstracts a set of control plane functions used by an SDN Controller, allowing the SDN orchestrator to uniformly interact with heterogeneous control domains will pave the way towards the required transport network interoperability as well as the integration with wireless networks and cloud infrastructure.

5. Acknowledgments

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6. References

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