Network Slicing Using Dynamic Flex Ethernet over Transport Networks

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Abstract *This paper proposes the introduction of Flex Ethernet and its integration in an optical SDN/NFV architecture to support dynamic deterministic network slicing. Protocol extensions are experimentally validated for the management and control of Flex Ethernet network equipment.*

Introduction

The fifth generation of mobile technology (5G) targets a converged x-haul network and cloud infrastructure, which integrates all transport network segments (access, metro, core) for end-to-end (E2E) transport. 5G infrastructure shall be able to deploy C-RAN, NFV and MEC services[1].

Moreover, it is a requisite to partition this 5G infrastructure into multiple network slices (composed of virtualized network and cloud resources) allowing isolated slices in order to fulfil tenant-specific requirements (e.g., security, latency, resiliency, bandwidth). The ITU has classified 5G network services into three categories: enhanced Mobile Broadband (eMBB), ultra-Reliable and Low-Latency Communications (uRLLC), and Massive Machine Type Communications (mMTC). Each of these services imposes different network requirements, which will be fulfilled through network slicing.

A 5G slice is composed of virtual tenant network (VTN) and cloud resources (dedicated to deploy virtualized network functions). The VTN consists of several E2E connections (e.g., tunnels) between the diferent cloud locations. A 5G slice can be controlled by tenants through their own virtualized management and orchestration (MANO) instance and virtualized SDN controller. Fig.1.a shows the proposed SDN/NFV architecture for network slicing[2].

Currently, MPLS-TP over DWDM is used to support the virtualization of the physical network resources to deploy per-tenant network tunnels over an optical infrastructure. In this context, Flexible Ethernet solution (FlexE) over OTN is an emergent evolutionary technology that is expected to be rapidly adopted. FlexE provides E2E connections, by providing a shim layer enabling the multiplexing in time of several Ethernet clients.

The main advantage of FlexE is that each connection is served as a dedicated data path with deterministic (carrier-graded) performance. Deterministic latency and guaranteed bandwidth are provided to each connection for a tenant or service along with total data separation for privacy and security.

The FlexE implementation agreement[3] provides a generic mechanism for supporting a variety of Ethernet MAC rates that may or may not correspond to any existing Ethernet PHY rate. This is achieved by introducing the three following concepts: a) bonding of several Ethernet connections (Fig.1.b), which allows higher Ethernet rates; b) sub-rating (Fig.1.c), which allows adaptation to client rate; and, c) channelization (Fig.1.d), which allows multiple clients.

This paper presents the integration of control and management of Flex Ethernet over OTN to provide VTNs, which are included in 5G slices, supporting the previously presented network slicing architecture[2].

E2E tunnels are provided for the VTNs assigned to a 5G slice. IETF Abstraction and Control of TE Networks (ACTN)[4] has been demonstrated as a feasible and scalable solution for multi-domain, multi-technology transport network scenarios to provide E2E network services. The Multi-Domain Service Coordinator (MDSC) offers a Transport NBI in order to retrieve network topology and establish tunnel connectivity.

In this work, we propose extensions to enable that specific FlexE capabilities are supported within the YANG data models currently being defined within the context of IETF TEAS working group: topology[5] and tunnel[6], which define a Transport NBI. Later, control and management of FlexE over OTN networks using RESTconf protocol is demonstrated at the control plane platform of ADRENALINE Testbed.

Flex Ethernet Modelling

FlexE is a new of transport technology which imposes its own constraints and limitations. Such constraints need to be accounted / reflected in terms of both network topology and tunnel data models to be integrated into the Transport NBI. The FlexE modelling is currently been applied and discussed within the GMPLS protocols[7-8].

FlexE operates using a calendar mechanism through assigning slot positions on sub-calendars over each Ethernet PHY forming a

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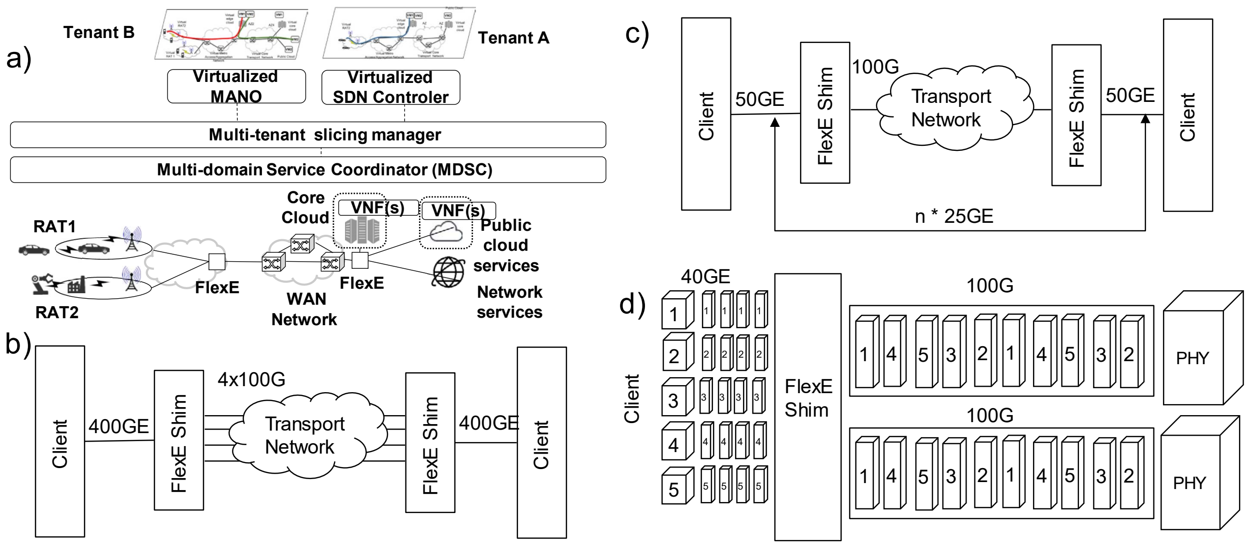

Fig. 1: a) Proposed SDN/NFV network slicing architecture; b) FlexE channel bonding; c) FlexE sub-rating; d) FlexE channelization

FlexE group to each FlexE clients (Fig.1.d). The calendar has a granularity of 5G with a length of 20 slots per a total of 100G FlexE group capacity[3].

The first property is the identification of *unused slots*, which can be allocated to Ethernet clients as available resources.

Another enhancement is the introduction of s*lot granularity, which is* currently fixed to 5GE granularity[3]. *FlexE group number* refers to a bunch of Ethernet PHYs that are bonded together and used as a whole constituting a single FlexE LSP. Finally, *PHY Number* is a dynamic and logical number that is assigned enabling one-to-one correlation with the physical port.

Flex Ethernet Orchestration using IETF TEAS models

Fig.2.a depicts the scenario of FlexE transmission over an optical network (e.g., ODUFlex/ODU4). Nodes A and B are FlexE-capable nodes. In the proposed scenario, the optical network is unaware of the FlexE signal.

Fig.2.b shows the message exchange required to set up an E2E FlexE connection. The Multi-Domain Service Coordinator (MDSC) receives a FlexE connection request specifying endpoints (A and B) and bandwidth (in the example 150G). There are three Ethernet PHYs between nodes A and WAN1, WAN3 and B. Moreover, there are enough ODU4 connections between nodes WAN1 and WAN3 to transport the traffic between the endpoints.

Once received the request, the MDSC, computes the necessary multi-layer path. First, MDSC checks if sufficient Ethernet PHYs are available to carry the demanded FlexE traffic. MDSC determines that two new ODU4 paths need to be set up from node WAN1 to WAN3 to transport the Ethernet PHY traffic. This can be done comparing the switching capabilities in the node descriptions defined by IETF topology[5] augmented model.

The two ODU4 LSPs will behave as the server layer of Ethernet PHY paths. MDSC also determines that two FlexE LSPs will be required to carry the requested FlexE traffic.

Once the feasible path is found, the MDSC triggers the provisioning of the required (IETF tunnel[6]) connections. To this end, firstly the MDSC requests the creation (via HTTP POST) of two ODU4 tunnels between WAN1 and WAN3. The configuration / programmability of the involved network elements (WAN) is performed by the Physical Network Controller (PNC) WAN. When this is completed, the PNC confirms that the establishment of the requested ODU4 paths.

Next, the MDSC requests to the PNC FlexE the establishment of two FlexE LSPs which will be carried on top of two Ethernet PHY. The request message specifies the pair of switching capability and encoding type, which are set to TDM and *FlexE-LSP*, respectively. The PNC FlexE starts the setting up of the two Ethernet PHYs between nodes A and B. Once the FlexE LSPs have successfully been set up, MDSC requests a FlexE tunnel towards the PNC FlexE, with the bandwidth requirement of 150G.

PNC FlexE receives the FlexE tunnel creation message. As there are already two Ethernet PHYs from node A to node B, it determines to set up the FlexE path over the two Ethernet PHYs by carrying the assigned FlexE group number, dynamic PHY number and slot positions for the Ethernet client in the generalized label.

After PNC FlexE confirms the successful establishment of the FlexE path, MDSC notifies the client of the successful setup. The unused bandwidth (50G) on the second provisioned

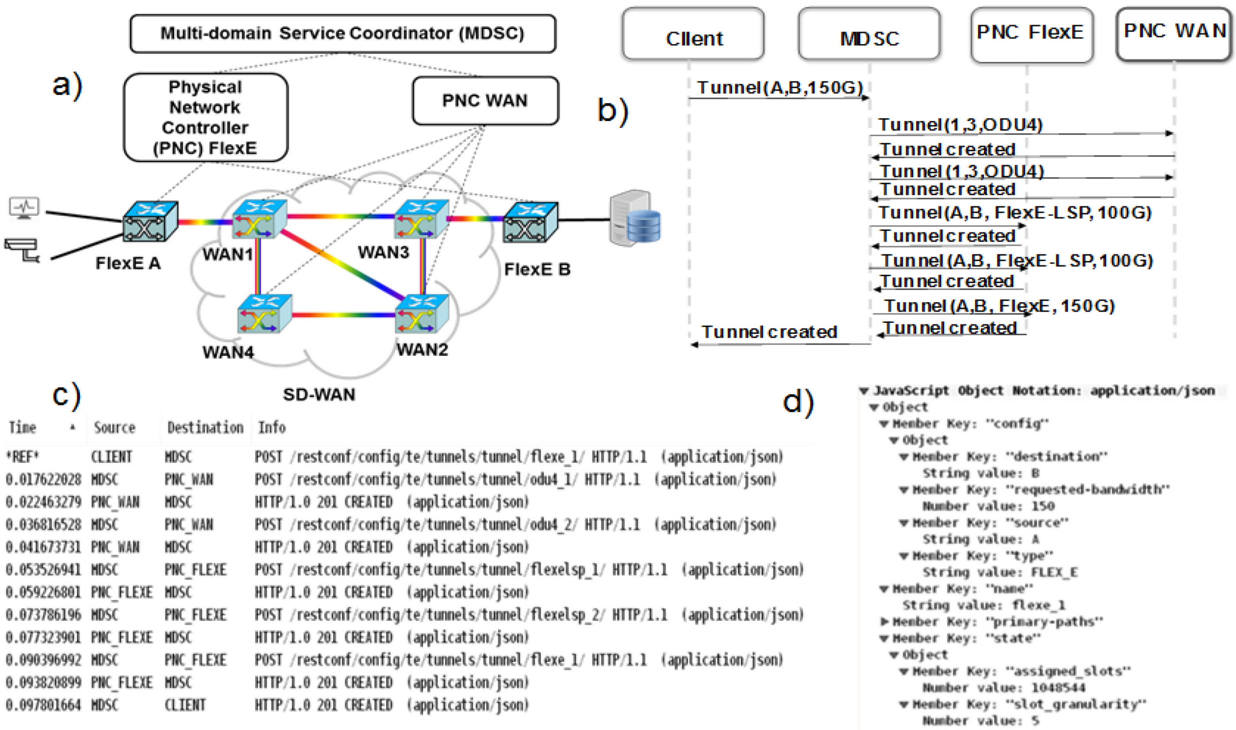

Fig. 2: a) Proposed network architecture; b) Message exchange for E2E service provisioning; c) Wireshark message exchange; d) Wireshark capture of provisioned FlexE tunnel

FlexE LSP, will be used further by another FlexE client.

Experimental validation

The experimental validation has been performed in the control plane platform of the ADRENALINE Testbed as shown in Fig.2.a, where the NEs' data plane are emulated.

The MDSC is implemented using IETF ABNO architecture[2] and extended with the necessary plugins to support IETF drafts for YANG model's topology[5] and tunnel[6], including the extensions to support FlexE, which will be contributed to IETF.

Fig.2.c depicts the messages exchanged from three different perspectives: a) MDSC; b) PNC FlexE; and c) PNC WAN. In order to establish the requested E2E service, a client (e.g., BSS/OSS) sends a HTTP POST command to RESTconf URI for tunnel configuration. Inside the POST command, a JSON object is carried containing the source and destination of the requested tunnel, the tunnel type (i.e., FLEX_E), as well as the requested bandwidth (i.e., 150GE).

The MDSC is responsible for path computation and later, it triggers the provisioning by using HTTP POST operation commands to the underlying PNC (i.e., WAN and FlexE) for the necessary connection/tunnels configuration.

Fig.2.d shows the extensions performed to the TE model to describe FlexE slot assignment (using a 32 bit hexadecimal label), and slot granularity. Inside the primary paths, more parameters are carried such as the required *flexe_group_number* and *phy_number* ids.

Conclusions

This paper proposes the dynamic SDN orchestration of Flex Ethernet connections to support deterministic behaviour in network slices, which are enabled by the proposed SDN/NFV architecture.

Acknowledgements

Spanish MINECO project DESTELLO (TEC2015-69256-R).

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