Orchestrating Inter-DC Quality-Enabled VNFFG Services in Packet / Flexi-Grid Optical Networks: An Experimental View

Ricardo Martínez, Ramon Casellas Ricard Vilalta Raül Muñoz

Optical Network and Sytems Dept., CND, CTTC/CERCA

Abstract

Upcoming 5G advanced network services will demand heterogeneous functions and requirements covering multiples use cases and applications such as eHealth, Industry4.0, connected car, etc. In this framework, the integration and combination of cloud and network resources become essential for deploying such demanded end-to-end services in a cost-effective manner. To this end, virtualization mechanisms is seen as key enabler for providing the instantiation of network functions constituting a network service from a dedicated physical appliance toward the cloud (i.e., data-center, DC). This does attain notable benefits with respect to the higher flexibility and agility to deploy new and tailored network services, reduced CapEx and OpEx, eliminating vendor lock-in, etc. This work describes the architecture for automatically orchestrating end-to-end services whose set of network functions are deployed in multiple inter-connected DCs. This results on a defined ordered set of virtual network functions (VNFs) to be executed. Such a VNF set is referred to as VNF Forwarding Graph (VNFFG). The goal is, from an experimental perspective, to detail which are the building blocks and their inter-connection needs from an orchestration perspective enabling dynamically processing incoming VNFFG requests, as well as computing and allocating the required cloud and network resources satisfying the set of service requirements in terms of IT, bandwidth and latency.

I. INTRODUCTION

Network Services (NSs) to be supported over the upcoming 5G infrastructure are envisioned to be very heterogeneous demanding different network functions (NFs) such as Deep Packet Inspection, mobile Evolve Packet Core functions, etc. with various levels of QoS (in terms of bandwidth, latency, etc.). To this end, virtualization techniques as being defined by ETSI Network Function Virtualization (NFV) architecture provides an appealing framework and context where effectively deploying such NSs. Specifically, NFV virtualizes NFs over general-purpose servers hosted in datacenters (DCs). DCs may have different size (in terms of total IT resources) which can be located at different geographical locations. In general, DCs need to be inter-connected via a Wide Area Network (WAN) infrastructure. NFs deployed in DCs are referred to as Virtual Network Functions (VNFs). In light of this, a generic NS encompassing multiple VNFs may require that a myriad of VNFs are computed and allocated throughout multiple DCs. In other words, at the time of deploying a NS it is needed that an ordered set of VNFs (potentially located at different DCs) must be determined. This is called as VNF Forwarding Graphs (VNFFG) [1].

Fig. 1 depicts an example of a VNFFG request to be deployed encompassing the allocation of different VNFs (VNFa..e) at different DCs (DC1..2). For each VNFFG supporting a specific NS, besides describing the set of ordered VNFs (herein a single VNF is considered to be deployed in a Virtual Machine (VM) instantiated in a DC's server), it is also specified the resource requirements for each VNF/VM (i.e., CPU, DISK and STORAGE) and the networking requirements (i.e., bandwidth in Bytes/s, Bw and maximum tolerated latency in ms, L) for the inter-DC connectivity. As shown, the inter-DC connections are provided via packet virtual links created over a Multi-Layer Network (MLN) using packet and flexi-grid optical switching.

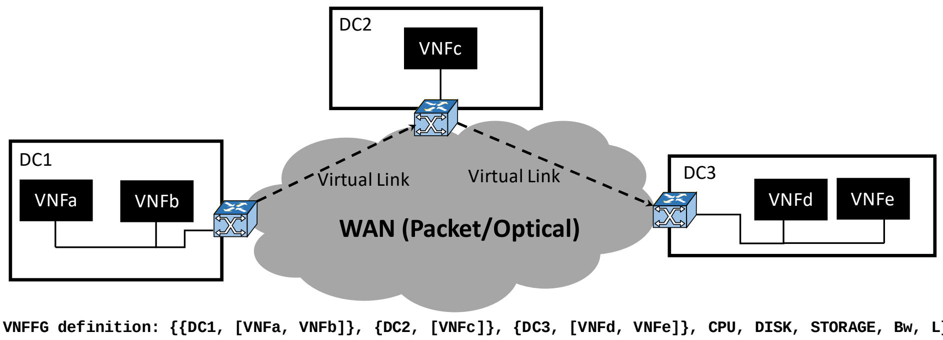

Fig. 1. Example of VNFFG request definition

This work describes the deployed and implemented architecture of a Cloud/Network Orchestrator for automatically and dynamically computing and deploying NSs as VNFFG instances. The Cloud/Network Orchestrator is composed of two main entities: the Allocator for processing VNFFG requests and DC resource allocation; and a Transport SDN (T-SDN) controller (based on a PCE Central Controller, PCECC [2][3]) to compute/configure MLN connections. In this regard, two different orchestration approaches (*no network info*, NNI and *abstracted network info*, ANI) are proposed. They differ from the amount of network resources information (i.e., topology and resources) disseminated by the T-SDN controller towards the Allocator. In the NNI, the Allocator only performs DC resource allocation delegating the inter-DC connectivity computation to the T-SDN controller. In the ANI, in addition to the DC resource allocation, the Allocator operates with partial network information at the packet level which allows computing inter-DC connections. Each approach relies on a different MLN path computation mechanism for computing packet inter-DC paths. The devised Cloud/Network Orchestrator and both approaches are experimentally validated and evaluated within the CTTC ADRENALINE testbed in terms of blocking, setup delay and IT/network resource consumption

II. NETWORK SERVICE ORCHESTRATION ARCHITECTURE IN MULTILAYER NETWORKS

Fig.2 shows the two building blocks forming the Cloud/Network Orchestrator: the Allocator and the T-SDN controller. As mentioned above, the Allocator receives, computes and dynamically accommodates VNFFG requests (req). Each received req is specified with the requirements described in Fig. 1. Hence, the Allocator keeps track of all DC resources via the Cloud database (DB). By doing so, upon receiving a new req the Allocator checks whether it can be accommodated with regard to the Cloud/IT resources. The Allocator then interfaces the T-SDN controller (depending on the adopted approach, i.e., ANI or NNI) to request inter-DC path computations, to retrieve network information and to instantiate inter-DC connections.

The T-SDN Controller supports the following functions: processing packet connection requests from the Allocator (via a NBI API that uses the PCEP protocol), performing path computations, and configuring the computed packet and optical network elements (i.e., switches and Sliceable Bandwidth Variable Transceivers, SBVTs).

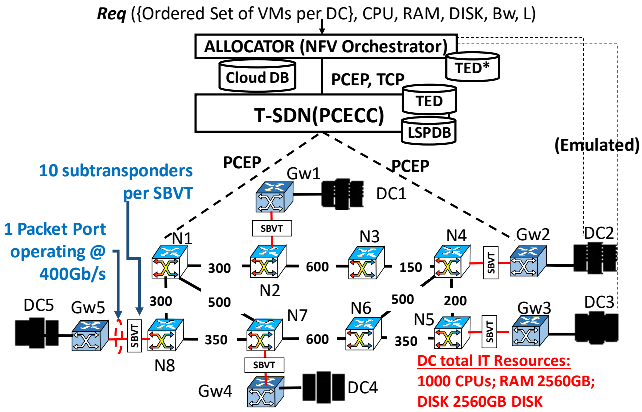

Fig. 2. Cloud/Network Orchestrator Architecture

Depending where the path computation is triggered according to the available network information, two algorithms are used. On the one hand, in the NNI, MLN path computation for the inter-DC connectivity is always tackled at the T-SDN controller using the information gathered in the Traffic Engineering Databse (TED). Recall that in the NNI, the Allocator is unaware of the underlying WAN details. To do this, the considered mechanism relies on a modified Yen algorithm providing K-CSPF calculations. This path computation provides the shortest path cost satisfying the Bw requirement where both electrical and optical grooming opportunities are fostered. The K-CSPF algorithm sorts the computed kth MLN paths with respect to their total cost. Paths with the same cost are sorted by the lowest latency. The first resulting computed MLN path satisfying the latency restriction is chosen. On the other hand, in the ANI, the Allocator leverages the abstracted vision of existing virtual links (collected in TED*) and aims at reusing the spare bandwidth of the existing virtual links to compute inter-DC connections for the req as long as the Bw and L requirements are satisfied. This is done, applying a modified CSPF algorithm. If the Allocator is unable to find a feasible inter-DC connectivity, it delegates the path computation to the T-SDN controller which applies the k-CSPF algorithm described above.

III. NETWORK SERVICE ORCHESTRATION ARCHITECTURE IN MULTILAYER NETWORKS

The experimental validation of the protocol interactions between the Allocator and the T-SDN controller as well as the performance evaluation of the whole system under dynamic VNFFG request generation is carried out within the CTTC ADRENALINE testbed. For the latter, it is varied both the inter-arrival and duration of the req to attain a more exhaustive performance comparison of both ANI and NNI models. The comparison is made relying on different performance metrics: connection blocking, the average setup delay, the average use of Cloud/IT resources, average number of created virtual links.

IV. ACKNOWLEDGMETS

This work is partially funded by the EU H2020 5G TRANSFORMER project (761536)

V. REFERENCES

[1] M. Zeng, et. al., “Orchestrating Tree-Type VNF Forwarding Graphs in inter-DC Elastic Optical Networks”, J. Lightwave Technol., Vol. 34, no. 14, p. 3330 (2016).

[2] A. Farrel, Q. Zhao, Ed. “An Architecture for Use of PCE and the PCE Communication Protocol (PCEP) in a network with Central Control”, IETF RFC8283, Dec. 2017.

[3] R. Martínez et al “Experimental Evaluation of a PCE Transport SDN Controller for Dynamic Grooming in Packet over Flexi-Grid Optical Networks” ECOC2017.