SDN/NFV-enabled Satellite Communications: Ground Segment Network Architecture for 5G Integration

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***Abstract*—This paper describes a novel architecture for SDN/NFV-enabled satellite ground segment systems that is conceived to facilitate the integration of the satellite component within 5G systems so that ubiquitous, highly available and reliable connectivity can be better supported.**

Keywords—Satellite network; Network Function Virtualization; Software-Defined Networking

I. INTRODUCTION

The introduction of Software Defined Networking (SDN) and Network Function Virtualization (NFV) technologies within the satellite ground segment networks (referred simply to as satellite networks in the following) is anticipated to be a necessary step in their evolution [1][2]. SDN and NFV technologies can bring greater flexibility to Satellite Network Operators (SNOs), reducing both operational and capital expenses in deploying and managing SDN/NFV-compatible networking equipment within the satellite networks. In addition, the adoption of SDN/NFV into the satellite networks can eventually pave the way for a more flexible and agile integration and operation of combined satellite and terrestrial networks [3].

This paper describes an innovative architecture for SDN/NFV-enabled satellite networks. The proposed architecture improves flexibility and reconfigurability in the delivery of satellite network services by supporting virtualization (i.e. softwarisation) of key satellite network functions together with network abstraction and resource control programmability. Moreover, the proposed architecture supports multi-tenancy to facilitate virtual network operator models and federation capabilities for the multi-domain orchestration of network functions and SDN-based control and management across terrestrial and satellite domains.

II. ARCHITECTURE OF SDN/NFV-ENABLED SATELLITE NETWORKS

The satellite gateway (GW) is the central component in a satellite network. A satellite GW typically comprises: (1) the Out-Door Unit (ODU), composed of the antenna and radio head units; (2) the Satellite Baseband Gateway (SBG) subsystems for satellite access and transmission; and (3) a set of Satellite Network Functions (SNFs), in charge of the L2/L3 interconnection with the satellite core network, Performance Enhancing Proxy (PEP) functions (e.g. TCP optimization, content caching) and other generic functions such as firewalling. The virtualization of the satellite GW is studied in [4], identifying different variants with regard to which functions can be implemented as Virtualized Network Functions (VNF) and which remain as specialized hardware appliances (i.e. Physical Network Functions, PNFs). Without being conditioned to any particular variant, in the following we denote SNF-VNF to the implementation of the SNFs as VNFs, SBG-VNF to the implementation of part of the SBG functions as VNFs and SBG-PNF to the non-virtualized part of the SBG functions.

A. Physical network infrastructure

As depicted in Fig. 1, the physical network infrastructure of a SDN/NFV-enabled satellite networks is assumed to consist of the following elements:

- NFV Infrastructure-Point(s) of Presence (NFVI-PoP(s)) for the deployment of SNF-VNFs. The main resources in this NFVI-PoP are network, computing (CPU) and storage.

- NFVI-PoP(s) for SBG-VNFs. This represents the virtualization infrastructure over which the SBG functions would be deployed. This infrastructure is likely to be located in or close to the satellite hub premises.

- One or several SBG-PNFs. These elements host the non-virtualized part of the satellite gateway, which is directly connected to the ODUs.

- Transport network between the several NFVI-PoPs (backhaul) and between the NFVI-PoP where the SBG-VNFs are run and the location that hosts SBG-PNFs (fronthaul).

B. Virtualized satellite network

On top of the above described physical network infrastructure, one or several virtualized satellite networks could be deployed, as illustrated in Fig. 1. A Virtualized Satellite Network (VSN) is conceived here as a satellite network in which most of their functions are supplied as software components running in one or several NFVI-PoPs of the SNO physical network infrastructure. Each of the VSNs may include a variety of different entities (e.g. PEP, security). In particular, as illustrated in Fig. 1, the following entities could form part of a given VSN:

- One or several SNF-VNFs and one or several SBG-VNFs. All these functions are part of the data plane processing.

- Control applications and SDN controllers (all running as VNF instances) for the control and management planes of the VSN.

- Network Management (NM) and Element Management (EM) functions of the VSN. This provides a package of functions (to be used by the operator of a particular VSN) for the management of the VSN (e.g. FCAPS management).

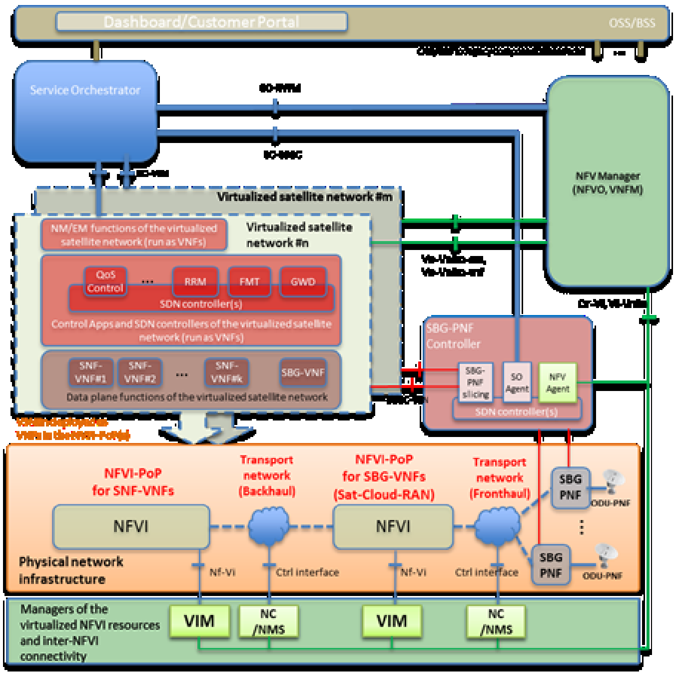

Fig. 1. Architecture reference model of the SDN/NFV-enabled satellite ground segment

C. *Management components*

The creation and management of the lifecycle of the VSNs is realized through a set of functional entities within the SNO domain. In particular, VSNs can be instantiated, terminated, monitored, and modified through the following management entities:

- Service Orchestrator (SO). Decides on the composition and capabilities of the VSN. Once a network service is defined, the SO provides the necessary deployment templates to the NFV management infrastructure. In parallel, the SO allocates and configures the required resources in the SBG-PNFs that will be used by the VSN.

-NFV management entities. Comprised of the NFV Manager, the Virtual Infrastructure Managers (VIMs) for each involved NFVI-PoP and the Network Controllers (NC)/Network Management Systems (NMS) in charge of the connectivity between the NFVI-PoPs and between NFVI-PoPs and SBG-PNFs. The NFV Manager handles NFV Orchestration (NFVO) and VNF Management (VNFM) functions as per ETSI ISG MANO specifications.

- SBG-PNF-Controller. This element hosts a set of control programs and a SDN controller to manage the pool of SGB-PNFs. Through a SO agent application, the SO can request the allocation of SGB-PNFs resources for a given VSN. Therefore, the SBG-PNF-Controller will be in charge of slicing the resources of the SBG-PNF so that a logically isolated portion of those resources is allocated to a particular VSN. Through a NFV agent, the SBG-PNF-Controller will also provide support to the NFV Manager. In addition, the SBG-PNF-Controller provides a SDN abstraction of the allocated resources so that control and management of these resources can be integrated within the VSN.

- SNO's OSS/BSS components such as dashboards/customer portals that the customers of the SNO can use to order the provisioning of VSNs and related SLA management.

D. *Integrated satellite-terrestrial networks*

To facilitate the integration with terrestrial networks, the proposed architecture is intended to support multi-domain service orchestration capabilities through federation functions that will be part of the SO entities within each domain. Therefore, federation manager/agent will be in place to establish the end-to-end network service settings and to partition the overall service graph into multiple subgraphs which can be given to each of the domains for further decomposition and instantiation. Moreover, the architecture is also intended to support multi-domain SDN-based control and management. In this regard, the VSN would expose SDN-based interfaces for enabling unified management when interworked with terrestrial networks for e.g. end-to-end (E2E) Traffic Engineering (TE) and QoS control.

III. CONCLUSIONS

This paper has described an architecture reference model for SDN/NFV-enabled satellite networks. The proposed architecture is built on (1) the virtualization of satellite core network functions and satellite baseband gateway functions, and on (2) the adoption of SDN principles in the architectural design of the data and control plane components of a virtualized satellite network. The resulting architecture supports multi-tenancy as well as federation capabilities for the multi-domain orchestration of network functions and SDN-based control and management across terrestrial and satellite domains.

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