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SDN/NFV-enabled satellite communications networks: Opportunities, scenarios and challenges

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ABSTRACT

In the context of next generation 5G networks, the satellite industry is clearly committed to revisit and revamp the role of satellite communications. As major drivers in the evolution of (terrestrial) fixed and mobile networks, Software Defined Networking (SDN) and Network Function Virtualisation (NFV) technologies are also being positioned as central technology enablers towards improved and more flexible integration of satellite and terrestrial segments, providing satellite network further service innovation and business agility by advanced network resources management techniques. Through the analysis of scenarios and use cases, this paper provides a description of the benefits that SDN/NFV technologies can bring into satellite communications towards 5G. Three scenarios are presented and analysed to delineate different potential improvement areas pursued through the introduction of SDN/NFV technologies in the satellite ground segment domain. Within each scenario, a number of use cases are developed to gain further insight into specific capabilities and to identify the technical challenges stemming from them.

1. Introduction

The combination of satellite and terrestrial components to form a single/integrated telecom network has been regarded for long time as a promising approach to significantly improve the delivery of communications services [1,2]. Despite the important and continued advances in satellite communications technologies, satellite communication offerings have not evolved at the same pace as terrestrial communications systems have done due to much lower economies of scale and inherent associated technological complexities [3]. In this context, the satellite industry is clearly committed to revisit and revamp the role of satellite communications in the path towards next generation 5G networks [4,5]. Indeed, considering the actual and future challenges being pursued under 5G, it is of utmost importance that next generation network architecture supports multiple layers and heterogeneity of network technologies, including satellite communications.

Advances in satellite communications are being addressed from multiple angles such as High Throughput Satellites (HTS) with multi-beam and frequency reuse capabilities [6], low-cost micro-satellites in low-orbit constellations and higher millimetre wave frequencies [7,8]

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List of Acronyms

API: Application Programming Interface
ASP: Application Service Provider
CPE: Customer Premises Equipment
EPC: Evolved Packet Core
FL: Forwarding Link
GW: Gateway
HTS: High Throughput Satellite
IMS: IP Multimedia Subsystem
ISP: Internet Service Provider
MEC: Mobile Edge Computing
MNO: Mobile Network Operator
MPLS: Multi-Protocol Label Switching
MSP: Media Service Provider
NAP: Network Access Provider
NCC: Network Control Centre
NFV: Network Function Virtualisation
NFVI: NVF Infrastructure
NMC: Network Management Centre
NMS: Network Management System
NSP: Network Service Provider
Ln: Layer n ($n = 0..7$)
ODU: Outdoor Unit
PEP: Performance Enhancing Proxy
PoP: Point of Presence
QoE: Quality of Experience
QoS: Quality of Service
RAN: Radio Access Node
RL: Returning Link
RRM: Radio Resource Management
SatNaaS: Satellite Network—as-a-Service
SDN: Software Defined Networking
SLA: Service Level Agreement
SNO: Satellite Network Operator
SO: Satellite Operator
SP: Service Provider
ST: Satellite Terminal
SVNO: Satellite Virtual Network Operator
vHub: Virtual Hub
VNF: Virtual Network Function
VNFaaS: VNF-as-a-Service
VPN: Virtual Private Network
VSAT: Very Small Aperture Terminal

and more flexible payloads components to dynamically modify satellite antenna beam patterns in orbit to respond to market demands [9]. Likewise, within the satellite ground segment (satellite hubs, satellite terminals and networking equipment within the satellite networks), main innovations are being pursued through the introduction of Software Defined Networking (SDN) and Network Function Virtualisation (NFV) technologies [10,11]. The handicap here is that, in current satellite ground segment network architectures (referred simply to as satellite networks in the following), there is a lack of prevalent standards and much functionality is mainly deployed on vendor-specific network appliances, which execute specific functions. This leads to a network infrastructure settings too prone to vendor locking, too complicated to manage when operating together solutions from various vendors, and too hard to change in behaviour. With the introduction of SDN and NFV, greater flexibility is expected to be achieved by satellite network operators, in addition to the much-anticipated reduction of both operational and capital expenses in deploying and managing SDN/NFV-compatible networking equipment within the satellite networks. Furthermore, the adoption of SDN/NFV into the satellite networks is seen as a key enabler towards more flexible and agile integration of satellite and terrestrial networks. This should allow overcoming several existing limitations in terms of operational flexibility, evolvability and end-to-end service provisioning.

Through the description of relevant scenarios and use cases, this paper investigates how SDN and NFV technologies can enhance the operation of the satellite networks and the deployment and management of communications services across hybrid satellite–terrestrial configuration variants. Though scenarios and use cases can be approached from multiple perspectives (business-centric, service-centric, technology-centric, network architecture-centric, actor-centric, etc.), the selected scenarios presented in this paper have been defined to delineate different potential improvement areas pursued through the introduction of SDN/NFV technologies in the satellite domain:

- Scenario 1—*Virtualisation and multi-tenancy of satellite networks*. This scenario focuses on the exploitation of SDN/NFV technologies internally, within the satellite ground segment. In particular, the scenario aims to improve flexibility and reconfigurability in the delivery of satellite network services by supporting virtualisation (i.e. *softwarisation*) of key satellite network functions together with network abstraction and resource control programmability. In addition, enhanced multi-tenancy support is envisioned to facilitate the sharing of satellite network infrastructures and the implementation of satellite virtual network operator (SVNO) models.
- Scenario 2—*4G/5G satellite backhauling services*. Building on the capabilities envisioned under Scenario 1 for SDN/NFV-enhanced satellite networks, the improvement area pursued here is the combination of satellite and terrestrial networks when the satellite part is used for the delivery of backhauling services. In particular, this scenario focuses on the use of satellite communications so as to provide connectivity to ground-based network components, which may be either fixed platforms, e.g. fixed base stations, or moving ones, e.g. small cells installed in moving vehicles such as ships or trains.
- Scenario 3—*Satellite–terrestrial hybrid access services*. Building on the capabilities envisioned under Scenario 1 for SDN/NFV-enhanced satellite networks, the improvement area pursued here is the delivery of satellite–terrestrial hybrid access services. Hybrid access is used in this paper to refer to access networks combining a satellite component and a terrestrial component in parallel [12]. In particular, Scenario 3 focuses on the cost-efficient integrated operation of satellite communication services as complementary to terrestrial fixed and mobile access so as to increase the Quality of Service/Quality of Experience (QoS/QoE) level delivered to end-users.