Virtualized SatCom Networks and Multi-Domain Integration with 5G: Architectural Perspectives from VITAL Project

5GPPP - 1st 5G Architecture Workshop
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VITAL At a Glance

• H2020 RIA (Research and Innovation Action) Project – ICT 2014-1
• Duration: Feb 1, 2015 – July 31, 2017 (30 months)
• Budget: 2,9 MEuros
• Resource: 341 PM effort
• Project Coordinator: Tinku Rasheed, Create-Net
• Website: https://ict-vital.eu
• Twitter: VITAL Project @H2020_VITAL

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Project Vision

Federated SDN/NFV architectural framework (Resource virtualization and federated satellite + terrestrial resource management)

Infrastructure substrate

Satellite hubs/gateways, satellite traffic optimisers, security, transmission and switching, etc.

Terrestrial network infrastructure

Radio/ixed access points/multiplexers, mobile packet core, security, transmission and switching, etc.

Provision of virtual networks (Virtual Network Slice–as-a-Service)

Telecom services combining terrestrial and satellite elements
Main Concepts & Objectives

**Management and control planes**

**End-to-End scope**

- Federated Network Resource Management
- NFV Manager
- SDN Controller(s)
- Satellite network infrastructure
- Satellite user terminal(s)

**Segment-wide scope**

- Radio/fixed access points/multiplexers, mobile packet coresecurity, transmission and switching, etc.

**Infrastructure plane**

(Mix of physical network functions/appliances & virtualized network functions)

- Satellite hubs/gateways, satellite traffic optimisers, security, transmission and switching, etc.
- NFV Infrastructure
- Dual-access user terminals/Terrestrial equipment with satellite backhaul
- Mobile/fixed user terminal(s)

Customer front-end

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Main Concepts & Objectives

Design and proof-of-concept development of virtualized SatCom ground segment, or **Sat-Cloud-RAN**.

Design and validation of the **NFV Manager**, a management and orchestration entity specialized for SatCom service providers.

Design and validation of the **multi-domain network service orchestrator**, for federated resource management over hybrid NFV/SDN-based Satellite-Terrestrial Networks.

Validation and demonstration of the concepts and features through a combination of **real test-beds** and **software emulators**.

To contribute to relevant standardization (ETSI NFV, ETSI SCN) and open-source initiatives (ETSI OSM, ON.LAB).
Application Scenarios

Scenario 1 - Virtualization and sharing of satellite communication platforms

**Improvement area:** SDN/NFV-enhanced satellite ground segment communication platforms

Scenario 2 - 4G/5G Satellite Backhauling Services

**Improvement area:** Combination of SDN/NFV-enhanced satellite ground segment communication platforms for satellite backhauling in terrestrial networks

Scenario 3 - Satellite Terrestrial Hybrid Access Services

**Improvement area:** Combination of SDN/NFV-enhanced satellite ground segment communication platforms and terrestrial networks for hybrid access services
Scenario 1: Virtualization and sharing of satellite communication platforms

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<thead>
<tr>
<th>Scenario</th>
<th>Use Case</th>
<th>Main Focus</th>
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<tbody>
<tr>
<td>Scenario 1 - Virtualization and sharing of satellite communications platforms</td>
<td><strong>UC1.1:</strong> SDN-based flexible satellite bandwidth on demand</td>
<td>Flexibility and customisation of the provided satellite network services</td>
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<td><strong>UC1.2:</strong> Satellite Virtual Network Operator</td>
<td>Support of slicing and multi-tenancy in the satellite ground segment</td>
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<td><strong>UC1.3:</strong> Satellite Network as a Service (SatNaaS)</td>
<td>Cloudification of the satellite ground segment</td>
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**Scenario 2: 4G/5G Satellite Backhauling Services**

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<tr>
<td>Scenario 2 4G/5G satellite backhauling services</td>
<td><strong>UC2.1:</strong> Enhanced control and management of satellite backhauling capacity</td>
<td>Improved integration and management of satellite backhauling services</td>
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<td><strong>UC2.2:</strong> Extending satellite backhauling with edge computing services and multi-operator sharing</td>
<td>Extension and coupling of the backhauling service with virtualization capabilities at the satellite terminal that allow for the delivery of mobile edge computing services.</td>
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### Scenario 3: Satellite Terrestrial Hybrid Access Services

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<tr>
<td>Scenario 3 –Satellite-terrestrial hybrid access services</td>
<td><strong>UC3.1</strong>: SDN-based flexible federation of Satellite and terrestrial networks</td>
<td>SDN-based flexible traffic steering between satellite and terrestrial access network</td>
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<td><strong>UC3.2</strong>: Media distribution over Federated SDN/NFV-enabled terrestrial and satellite network</td>
<td>Federation of SDN and NFV-enabled satellite and terrestrial domains for content distribution</td>
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<td></td>
<td><strong>UC3.3</strong>: Customer functions virtualisation over Federated Terrestrial and Satellite network</td>
<td>VNF-as-a-Service (VNFaaS)</td>
</tr>
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System Architecture – High level view

Service Orchestrator (SO)

Virtualized satellite network #n (VSN#n)

SBG-Controller (SBGC)

NFV Manager (NFVO, VNFM)

OSS/BSS

Dashboard/Customer Portal

Physical network infrastructure

Transport network (WAN)

VSN(s) deployed as VNFs in the NVF-PoP(s)

VIM(s) and NMS(s) for NFVI

OSS/BSS to legacy components interfaces

...
System Architecture – More detailed view

Components to support NFV Manager operation (Managers of the virtualized NFVI resources and inter-NFVI connectivity)

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### Multi-Domain Integration Model

#### MNO domain
- **Service Orchestrator**
  - Federation Manager
- **5G network** (virtualized or not)
  - E2E QoS
  - SDN controller(s)
- **SDN**
  - SDN controllers and apps for control and management of the terrestrial network
  - Data plane terrestrial network functions
- **MNO physical network infrastructure**
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#### SNO domain
- **Service Orchestrator**
  - Federation Agent
- **Virtualised satellite network** #n
  - NM/EM functions of the virtualized satellite network (run as VNFs)
  - BoD
  - xQoS
  - GWD
  - RRM
  - FMT
  - SDN controller(s)
- **Control Apps and SDN controllers of the virtualized satellite network (run as VNFs)**
  - NF-VNF#1
  - NF-VNF#2
  - NF-VNF#k
  - SBG-VNF
- **Data plane functions of the virtualized satellite network**
- **NFVI-PoP for Satellite Core Network functions**
- **L2/L3 transport network** (Backhaul)
- **NFVI-PoP for SGW functions** (Sat-Cloud-RAN)
- **L2/L3 transport network** (Fronthaul)
- **NFVI**
- **SNO physical network infrastructure**
- **NF-VI**
- **Ctrl interface**
- **VIM**
- **NC /NMS**
- **SBG**
- **PNF**
- **ODU-PNF**
- **OSS/BSS**
- **Dashboard/Customer Portal**
- **OSS/BSS to legacy components interfaces**

#### Cross-domain integration
- **Federation Agent**: SO-SO, SO-VSN, Ve-Vsn-em, Ve-Vnf-vnf

### NFVI-PoP for Terrestrial Core Network functions
- **NFVI**
- **SNO physical network infrastructure**
- **NF-VI**
- **Ctrl interface**
- **VIM**
- **NC /NMS**
- **SBG**
- **PNF**
- **ODU-PNF**

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Multi-Domain Integration model

Federation network entities
- E2E QoS
- TE
- SDN controller(s)
- SDN controllers and apps for control and management of federated network services

MNO domain
- Federation Agent
- SDN controllers and apps for control and management of the terrestrial network
- Data plane terrestrial network functions
- MNO physical network infrastructure

Terrestrial network (virtualised or not)
- OSS/BSS
- NFVO, VNFM and Managers of the virtualized NFVI resources and inter-NFVI connectivity
- NMS
- SDN controllers and apps for control and management of the terrestrial network
- Data plane terrestrial network functions
- MNO physical network infrastructure

L2/L3 transport network (WAN)

SNO domain
- Service Orchestrator
- Federation Manager
- Federation network entities
- Control Apps and SDN controllers of the virtualized satellite network (run as VNFs)
- NM/EM functions of the virtualized satellite network (run as VNFs)
- Data plane functions of the virtualized satellite network

Virtualised satellite network #n
- NFVI-PoP for Satellite Core Network functions
- L2/L3 transport network (Backhaul)
- NFVI
- VIM
- NC

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Conclusions

• Unified/Federated network service orchestration and management capabilities will allow the service providers and operators to augment 5G service capabilities, offer hybrid end-to-end services and identify new business models.

• Adoption of SDN/NFV technologies into the satellite domain is a key facilitator to make SatCom industry well integrated within the anticipated multi-layer/heterogeneous 5G network architecture.

• VITAL project research and develops solutions that will enable ‘seamless’ ‘hybrid’ end-to-end services and applications over SatCom & 5G technologies:
  – Mobile Edge Computing services
  – Seamless Emergency services
  – Seamless mobile network management
  – High Speed Trains
  – Broadband 5G European Aviation Networks
  – Integrated Energy Sector Communications
Acknowledgements

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Backup Slides
Overall Satellite network architecture

NMC  NCC  SCC

Satellite Gateway 1

Satellite Gateway n

Satellite Diversity Network

Internet

Satellite Terminal

Customer 1 Network

Customer 2 Network

Satellite spots

Functional Architecture of satellite Gateway

Network Functions
PEP, FW, Router/Switch

Baseband Unit (BBU):
FL/RL Subsystem

Outdoor Unit (ODU):
Radio Unit and Antenna

FL: Forwarding Link
RL: Returning Link
PEP: Performance Enhancement Proxy
FW: Firewall

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Tradeoff analysis of satellite gateway functional split

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SDN/NFV based Sat-Cloud-RAN architecture

- Satellite-domain SDN-based network control and management
- Different architectural options identified (single SDN controller, dedicated controller per tenant, hierarchical controller)
- Three control applications delineated:
  - SDN-based bandwidth on demand
  - SDN-based QoS on demand
  - SDN-based satellite gateway diversity