D4.2
Integrated Network Management – Analysis, Design and Proof of Concepts

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<th>H2020-ICT-07-2017</th>
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<td>Satellite and Terrestrial Network for 5G</td>
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# Document History

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<td>UE</td>
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<td>URLLC</td>
<td>Ultra-Reliable and Low Latency Communications</td>
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<td>V2X</td>
<td>Vehicle-to-everything</td>
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Executive Summary

In order to achieve SaT5G objectives on implementation of 5G SDN and NFV across satellite networks and integrated network management and orchestration D4.2 presents the proposed solution of the project, namely TALENT (Terrestrial Satellite resource coordination). The solution follows three main principles:

- Satellite RAN and cloud/Edge resource coordination.
- Being NFVO/VIM and vendor independent.
- Being user friendly.

The current document details SaT5G vision and solution in the following order:

Chapter 1 provides a high level overview and scope of this deliverable.

Chapter 2 reviews 5G network management including management and orchestration of the network and standards 3GPP and ETSI standards vision. It demonstrated the most outstanding management and orchestration solution plus latest standardization aspects related to the 5G network and satellite communication systems. Certain features are studied in detail.

Chapter 3 provides a novel coordination solution for the SaT5G project, called TALENT. TALENT is a top-layer solution, modular and extensible, which can support end-to-end services over different domains (such as satellite, cloud/edge and radio).

Chapter 4 demonstrates the implementation, deployment and testing of the first release of the TALENT both in i2cat and Zodiac promises. Current release is able to coordinate satellite and cloud domains. In addition, this chapter provides an insight about software development method to ensure that the developers concentrate on the highest priority features as defined by the project.

Chapter 5 discusses how TALENT manage and provision required end-to-end services inside the aircraft to end-users’ devices.

Chapter 6 concludes this study of SaT5G features, including future work and its release specification.
1 Introduction

1.1 Overview

Innovation of technologies for communication systems, specifically in satellite domain, cloud technologies and 5G terrestrial systems is reaching a point of convergence, which promises a new communication paradigm. It enables a new range of features such as agile service provisioning, multi-tenancy, software controlled and dynamic management, on-demand service-oriented resource allocation, universal multi-access, and ubiquitous connectivity. Standardization bodies as 3GPP and ETSI recognize and promote terrestrial and satellite interworking. The complete integration can be achieved with the combination of radio networks, including core and access, and the satellite systems, with computational resources expanded from the core to the network’s edge. In this novel ecosystem, a coordination framework is an essential enabler to realize 5G vision. Combined management of different resources will be performed through a MANO-like framework, which is the focus of this deliverable. The proposed solution provides a user-friendly single point of interaction for all stakeholders in the ecosystem, i.e. terrestrial and satellite operators as well as 5G vertical providers, where they can launch and manage end-to-end 5G services. The system allows easy integration of multiple applications as well as solutions provided by radio and satellite vendors.

1.2 Scope

Mobile communication is now an essential part of our society; the pervasiveness and ubiquity of connected services and mobile devices is at its higher point, continuously increasing. It is expected that the number of connected mobile devices to fifth-generation (5G) networks exceeds to 11 billion by 2021 [1]. A huge transformation will arrive in the near future as networks continue to evolve in order to meet the global connectivity demand such as significant increase in efficiency, expanded connectivity, instantaneous meeting of user expectations and scalability with a larger number of devices and services. Convergence and interoperability of different telecommunication technologies is a crucial prerequisite [2] so next generation communication goals can be met. This technological convergence happens in all networking levels through diverse technologies, e.g. 5G mobile operators should deliver highly dynamic services that leverage satellite technologies such as High Throughput Satellites (HTS).

Integration of satellite communications (SatCom), including mobile network level, was based on proprietary and custom solutions in previous generations (2G, 3G and 4G). Telecommunication satellites were considered largely independent of terrestrial networks. Hybrid solutions were uncommon, and the satellite network was mainly used to provide backhaul to (a) some remote and hard to access individual cells and (b) moving cells on planes and ships; being a non-flexible and comparatively expensive transport network. This prevented mobile operators from effectively leveraging satellite in mobile networks, creating challenges to service agility and programmability.

Due to the wide-scale growth of 5G networks, it is crucial to foster the development of an attractive plug-and-play SatCom solution for 5G. That enables terrestrial operators and network vendors to accelerate 5G deployment, and creates new and growing market opportunities for the SatCom industry. Thus, significant efforts are required to:

1. Design SatCom solutions, targeting integrated satellite / terrestrial 5G architectures adopting and integrating 5G key features;
2. Exploit SatCom capabilities (e.g. broadcast, ubiquity and reliability) while mitigating its inherent constraints (e.g. propagation latency) in standalone or multi-link network topology;
3. Ensure seamless integration of SatCom in 5G at orchestration levels;
4. Foster satellite inclusion in the 5G ecosystem as a key access network technology, to fulfil 5G implementation in our society (by playing an active role in 3GPP and ETSI standardization efforts).

---

1 Strictly speaking SatCom solutions can be very flexible, however the issues in providing a suitable control interface between terrestrial and satellite operators has often led to a non-flexible implementation.
This work focuses on point 3 of the above list and it presents a proposal for a terrestrial satellite resource coordination solution, called TALENT.

### 1.3 Document structure

This deliverable covers the following:

- Chapter 2 reviews the 5G network management and orchestration architecture, including standardization vision.
- Chapter 3 discusses the satellite and terrestrial coordination solution framework.
- Chapter 4 reviews the implementation, deployment and testing of the first release of proposed solution in the i2cat promises and Zodiac testbed, as well as give an insight about applied software development method.
- Chapter 5 demonstrates TALENT operation and functionality in the Zodiac testbed.
- Chapter 6 summarizes and concludes the deliverable.
2 Review of the 5G network management

2.1 5G context

5G promises a ubiquitous solution featuring aspects like extraordinarily high speeds and capacity, multi-
tenancy, fixed and wireless access network convergence, unconventional resource virtualization, on-demand service-oriented resource allocation and automated management [3]. It calls for a fundamental change on the telecommunication infrastructures, both at the terrestrial and satellite segments, shifting them from only data transport medium to intelligence entities equipped with computational and storage capacities.

To realize 5G in a standard way, 3rd Generation Partnership Project (3GPP) and its associated institutions like European Telecommunication Standards Institute (ETSI), have already taken actions. Meanwhile, programs like European H2020 5G PPP [4] have set a direction for conducted efforts, aiming to significantly improve the technology level towards higher throughputs, lower latencies and more flexibilities / automation. Efforts done so far have led to solutions able to preliminary demonstrate some 5G Key Performance Indicators (KPIs) such as higher radio coverage, more bandwidth per mobile device, increased number of connected devices, logical network slicing, lower latency and cost/energy savings.

Among all 5G enabling technology, network softwarization plays a fundamental role. It represents an overall transformation trend for designing, implementing, deploying, managing and maintaining network equipment / components by software programming. Leveraging on softwarization technologies, i.e. Network Functions Virtualization (NFV) [5] and Software Defined Networking (SDN) [6], higher flexibility, programmability, automation and significant cost/energy reduction are achievable. With the help of NFV and SDN, the embedded IT resources at the network are employed to offer added value services, e.g. innovative media services, aiming to improve the end user’s Quality of Experience (QoE) and creating new business opportunities. With a closer look to the added value services, it is possible to infer that they are complex operations composed by one or a set of software applications, e.g. Virtual Network Functions (VNF), cooperating together towards a common goal. For example, an end to end innovative media service is composed of a series of software each taking a specific responsibility. A virtual machine imitating the functionalities of a specialized “hard-wired” device like a firewall. This virtual device helps pre-filtering the incoming video files from end users to the mobile network edge. Non-blocked contents are directed to a video production application designed for sport events. The processed video by the application is then broadcasted locally to the end users who are interested to have a 360 vision of the goal. To guarantee the Quality of Service (QoS) at any traffic status the whole media service is constantly monitored and optimized by a Self-Optimizing Network (SON/Self-X) functionality against the agreed QoS metrics on the Service Level Agreement (SLA).

This section is dedicated to first review 3GPP and ETSI activates towards realization of 5G vision (focusing mainly on the management and orchestration layer). Next, SaT5G vision will be presented which proposes an effective solution able to simultaneously manage / orchestrate both terrestrial and satellite segments.

2.2 3GPP vision

3GPP is formed by seven telecommunications standard development organizations (from Asia, Europe and North America) known as “Organizational Partners”. It aims to produce reports and specifications for the cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities – covering topics such as work on codecs, security, and quality of service. In this sense, 3GPP supports complete system specifications. It also takes into account the non-radio access to the core network, and interworking with Wi-Fi networks.

3GPP specifications and studies are contribution-driven, produced by member companies at the Working Groups and the Technical Specification Group (TSG) level. The three TSG in 3GPP are:

- TSG Radio Access Network (RAN): it is responsible for the definition of the functions, requirements and interfaces of the UTRA/E-UTRA network in its two modes, Frequency Division Duplex (FDD) and Time Division Duplex (TDD). More precisely:
• Radio performance, physical layer, layer 2 and layer 3 RR specification in UTRAN/E-UTRAN;
• Specification of the access network interfaces (Iu, Iub, Iur, S1 and X2);
• Definition of the Operations and Maintenance (O&M) requirements in UTRAN/E-UTRAN and conformance testing for User Equipment and Base Stations.

• TSG Service and System Aspects (SA): it is responsible for the overall architecture and service capabilities of systems based on 3GPP specifications and, as such, has a responsibility for cross TSG co-ordination. That includes:
  • Definition, evolution and maintenance of the overall system architecture including the assignment of functions to particular subsystems (UTRAN, GERAN, CN, terminal, SIM/USIM), identification of key information flows and definition of required bearers and services offered by these different subsystems;
  • Development of a framework for services, service capabilities, service architecture, charging and consideration of need for «default» services and/or applications;
  • Definition of a security framework and review of security aspects of overall system.

• TSG Core Network and Terminals (CT): it is responsible for specifying terminal interfaces (logical and physical), terminal capabilities (such as execution environments) and the Core network part of 3GPP systems. More specifically:
  • User Equipment - Core network layer 3 protocols in Circuit Switched (CS) and Packet Switched (PS) domain excluding the access technology layers.
  • Core Network internal interfaces for Call Associated and Non Call Associated signalling
  • Interconnection of the Core Network with external networks
  • SIM/USIM/ISIM and its interface specifications
  • Terminal or Network based applications supported by 3GPP terminals
  • Core network protocols for CS and PS domain in legacy and evolved 3GPP system
  • IP Multimedia subsystem
  • Management of the work items placed under its responsibility

Each TSG consists of working groups (WG), each with a particular responsible on a specific topic. WGs meet regularly and come together for their quarterly TSG plenary meeting, where their work is presented for information, discussion and approval. The overall 3GPP structure is presented in the Figure 1. Note that Project Coordination Group (PCG) is the highest decision making body in 3GPP, it meets formally every six months to carry out the final adoption of 3GPP TSG work items, to ratify election results and the resources committed to 3GPP.
The milestones achieved in particular releases measure progress on 3GPP standards. New features are 'functionality frozen' and are ready for implementation when a release is completed. 3GPP works on a number of Releases in parallel, starting future work well in advance of the completion of the current release. Although this adds some complexity to the work of the groups, such a way of working ensures that progress is continuous and stable. Figure 2 shows a time plan for the 3GPP releases.

The term "Stage" derives from the ITU-T method for categorizing specifications:

- "Stage 1" refers to the service description from a service-user’s point of view.
- "Stage 2" is a logical analysis, devising an abstract architecture of functional elements and the information flows amongst them across reference points between functional entities.
- "Stage 3" is the concrete implementation of the functionality and of the protocols appearing at physical interfaces between physical elements onto which the functional elements have been mapped.

In addition, 3GPP often performs feasibility studies the results of which are made available in Technical Reports (TRs). The feasibility study might be considered as a sort of "Stage 0". Furthermore, some Stage 3 specifications require test specifications to be prepared: effectively a "Stage 4".

![Figure 1: 3GPP overall structure](image-url)
Figure 2: 3GPP ongoing releases

Abstract syntax notation (ASN.1) presented in Figure 2 is an object identifiers maintained by ETSI. ASN.1 is a formal notation used for describing data transmitted by telecommunications protocols, regardless of language implementation and physical representation of these data, whatever the application, whether complex or very simple. It was defined by the International Organization for Standardization (ISO), as generic means of allowing different computer systems. With different internal data representations to interchange data.

The term Phase (Figure 2) has two distinct usages within the 3GPP:

- In reference to Global System for Mobile communications (GSM) specifications, Phase 1, Phase 2 and Phase 2+ referred to releases of specifications;
- Some features within GSM/3G specifications have been enhanced over the years. For example, enhancements to the original Customised Applications for Mobile network Enhanced Logic (CAMEL) functionality are referred to as CAMEL phase 2, CAMEL phase 3 and CAMEL phase 4.

The major focus for all 3GPP releases is to make the system backwards and forwards compatible where possible, to ensure that the operation of user equipment is un-interrupted. A good current example of this principle has been the priority placed in the working groups on backward compatibility between LTE and LTE-Advanced, so that an LTE-A terminal can work in an LTE cell and an LTE terminal works in the LTE-A cell.

In the second half of 2017 the focus of 3GPP has shifted to Release 15 (Figure 3), to deliver the first set of 5G standards - including new work as well as the maturing of the LTE-Advanced Pro specifications. In June of 2016, the 3GPP Technical Specifications Groups (TSG#72) agreed on a detailed work plan for Release 15. The plan includes a set of intermediate tasks and check-points to guide the ongoing studies in the WGs.

According to the 3GPP Release 15 standard that covers 5G networking, the first wave of networks and devices will be classed as Non-Standalone (NSA), which is to say the 5G networks will be supported by existing 4G infrastructure. Here, 5G-enabled smartphones will connect to 5G frequencies for data-throughput improvements but will still use 4G for non-data duties such as talking to the cell towers and servers.

The initial roll-out of 5G cellular infrastructure will focus on enhanced mobile broadband (eMBB) to provide increased data-bandwidth and connection reliability via two new radio frequency ranges:
• Frequency Range 1 overlaps and extends 4G LTE frequencies, operating from 450 MHz to 6,000 MHz. Bands are numbered from 1 to 255 and this is commonly referred to as New Radio (NR) or sub-6GHz.

• Frequency Range 2 operates at a much higher 24,250 MHz (~24GHz) to 52,600 MHz (~52GHz). Bands are numbered from 257 to 511 and this is commonly referred to as millimeter wave (mmWave), even though strictly speaking the ‘millimeter’ frequency length starts at 30 GHz.

The 5G Standalone (SA) network and device standard is still under review and is expected to be signed-off by 3GPP. The advantage of Standalone is simplification and improved efficiency, which will lower cost, and steadily improve performance in throughput up to the edge of the network, while also assisting development of new cellular use cases such as ultra-reliable low latency communications (URLLC). Once the SA standard is approved, the eventual migration from 5G NSA to SA by operators should be invisible to the end user.

Having this idea in mind, 3GPP TSG RAN further agreed that the target new radio (NR) scope for Release 15 includes support of the following:

• Standalone and Non-Standalone NR operation (with work for both starting in conjunction and running together):
  o Non-standalone NR in this context implies using LTE as control plane anchor. Standalone NR implies full control plane capability for NR.
  o Some potential architecture configuration options previously presented will be analysed further during the study.

• Target use cases: Enhanced Mobile Broadband (eMBB), as well as Low Latency and High Reliability to enable some Ultra-Reliable and Low Latency Communications (URLCC) use cases.

• Frequency ranges below 6GHz and above 6GHz.
Release 15 produces the following work items:

- The 5G system-phase 1.
- Machine-Type of Communication (MTC) and Internet of Things (IoT).
- Vehicle-to-Everything Communication (V2X) improvement.
- Mission Critical (MC) improvements.
- WLAN and unlicensed spectrum.
- System enhancement.
- LTE improvements.
- Mobile Communication System for Railways.
- Northbound APIs.
- Remote UE access via relay UE.

Release 16 is a major release, which bring variety of topics: Multimedia Priority Service, Vehicle-to-everything (V2X) application layer services, 5G satellite access, Local Area Network support in 5G, wireless and wireline convergence for 5G, terminal positioning and location, communications in vertical domains and network automation and novel radio techniques. Further items being studied include security, codecs and streaming services, Local Area Network interworking, network slicing and the IoT.

Technical Reports (the result of the study phase) are also being developed on broadening the applicability of 3GPP technology to non-terrestrial radio access (initially satellites, but airborne base stations are also to be considered) and to maritime aspects (intra-ship, ship-to-shore and ship-to-ship). Work also progresses on new PMR functionality for LTE, enhancing the railway-oriented services originally developed using GSM radio technology that is now nearing end of life.

As part of Release 16, MC services will be extended to address a wider business sector than the initial rather narrow public security and civil defence services for which they had originally been developed. If the same or similar standards can be used for commercial applications (from taxi dispatching to railway traffic management, and other vertical sector scenarios currently being investigated), this would bring enhanced reliability to those MC services through wider deployment, and reduced deployment costs due to economies of scale— to the benefit of all users.

Release 16 is focusing on "5G phase 2" and should be completed in December 2019 (TSG SA#87). This Release will meet the ITU IMT-2020 submission requirements and the time-plan as presented in Figure 4. It includes the following steps:

**Step 1:** From Sep 2017 to Dec 2017, discussions in RAN ITU-R Ad-Hoc
- Calibration for self-evaluation.
- Prepare and finalize initial description template information that is to be submitted to ITU-R WP 5D#29.

**Step 2:** From early 2018 to Sep 2018, targeting “update & self eval” submission in Sep 2018
- Performance evaluation against eMBB, mMTC and URLLC requirements and test environments for NR and LTE features.
- Update description template and prepare compliance template according to self-evaluation results.
- Provide description template, compliance template, and self-evaluation results based on Rel-15 in Sep 2018.

**Step 3:** From Sep 2018 to June 2019, targeting "Final" submission in June 2019
- Performance evaluation update by taking into account Rel-16 updates in addition to Rel-15.
- Update description template and compliance template to take into account Rel-16 updates in addition to Rel-15.
- Provide description template, compliance template, and self-evaluation results based on Rel-15 and Rel-16 in June 2019.
• Provide description template, compliance template, and self-evaluation results based on Rel-15 and Rel-16 in June 2019.

Figure 4: 3GPP release 16 time-plan

### 2.2.1 Management and Orchestration

3GPP has recently published a documents focusing on management and orchestration aspects of network slicing, use cases and requirements in mobile networks [7]. The 3GPP management system directly manages only the parts of the network that consist of network functions specified in 3GPP (e.g. 5G RAN, 5G CN and IMS). For the network functions specified by other SDOs, the management impact of network slicing is addressed as required. For example, regarding the Transport Network (TN) part supporting connectivity within and between CN and RAN parts, 3GPP management system may provide link requirements (e.g. topology, QoS parameters) to the TN management system.

For the purposes of the 3GPP TS 28.530, the terms and definitions given in 3GPP TR 21.905 [8] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [8].

- Network slice: Defined in 3GPP TS 23.501 v1.4.0 [9].
- Network slice instance: Defined in 3GPP TS 23.501 V1.4.0 [9].
- Network slice subnet: a representation of the management aspects of a set of Managed Functions and the required resources (e.g. compute, storage and networking resources).
- Network slice subnet instance: an instance of Network Slice Subnet representing the management aspects of a set of Managed Function instances and the used resources (e.g. compute, storage and networking resources).
- Network Slice Subnet Template (NSST): subset of attributes' values used for creation of instances of Network Slice Subnet Information Object Class.

Based on the layered model proposed by NGMN [10], 3GPP released the standard 3GPP TR 28.801 [8], which also defines a Network Slice Instance (NSI) as a set of Network Slice Subnet Instances (NSSI), composed by at least one VNF and/or Physical Network Functions (PNFs). For 3GPP, NFV Network Services (NFV-NS) re-present the view of network slices in terms of provided network functionality.

Management aspects of a network slice instance describe by the four phases shown in Figure 5, the phases are: Preparation, Commissioning, Operation and Decommissioning.
Figure 5 Management aspects of network slice instance.

Each phase, described in subsequent clauses, defines high level tasks and should include appropriate verification of the output of each task.

- **Preparation**: In the preparation phase the NSI does not exist. The preparation phase includes network slice template design, network slice capacity planning, on-boarding and, evaluation of the network slice requirements, preparing the network environment and other necessary preparations required to be done before the creation of an NSI.

- **Commissioning**: NSI provisioning in the commissioning phase includes creation of the NSI. During NSI creation all needed resources are allocated and configured to satisfy the network slice requirements. The creation of an NSI can include creation and/or modification of the NSI constituents.

- **Operation**: The Operation phase includes the activation, supervision, performance reporting (e.g. for KPI monitoring), resource capacity planning, modification, and de-activation of an NSI.
  - Activation makes the NSI ready to support communication services.
  - Resource capacity planning includes any actions that calculates resource usage based on an NSI provisioning, and performance monitoring and generates modification polices as a result of the calculation.
  - NSI modification could be including e.g. capacity or topology changes. The modification can include creation or modification of NSI constituents. NSI modification can be triggered by receiving new network slice requirements or as the result of supervision/reporting.
  - The deactivation includes actions that make the NSI inactive and stops the communication services.

**NOTE**: Network slice provisioning actions in the operation phase involves activation, modification and de-activation of an NSI.

- **Decommissioning**: Network slice instance provisioning in the decommissioning phase includes decommissioning of non-shared constituents if required and removing the NSI specific configuration from the shared constituents. After the decommissioning phase, the NSI is terminated and does not exist anymore.

### 2.2.2 SA WG5

Based on the targeted SaT5G D4.2 (Integrated Network Management – Analysis, Design and Proof of Concepts) scope, SA WG5 (Telecom Management) is the right 3GPP track to focus on. SA WG5 specifies the requirements, architecture and solutions for provisioning and management of the network (RAN, CN, IP Multimedia Subsystem – IMS) and services [11]. That includes the specification work pertinent to the provisioning, charging and management of the network and its services. The WG will also ensure that its work is compatible with the management and charging systems of converged networks, and potentially applicable to fixed networks.

### 2.3 ETSI vision

ETSI is a European independent standardization group with a key role in developing standards for information and communications technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies. In 1988, the European Conference of Postal and
Telecommunications Administration (CEPT) established ETSI as a non-profit organization, now representing more than 800 member organizations, over 64 counties.

ETSI is structured into committees and working group (WG) made up of experts from member organizations. Technical bodies tackle technical issues and the development of specifications and standards to support the needs of the broad membership and the European ICT industry in general. There are three recognized types of technical bodies:

- Technical Committees – semi-permanent entities within ETSI organized around standardization activities for a specific technology area.
- ETSI Projects are established based on the needs of a particular market sector and tend to exist for a finite period.
- ETSI Partnership Projects are activities within ETSI that require cooperation with other organization to achieve a standardization goal.

Industry Specification Groups (ISG) supplement the work of technical bodies to address work needed around a specific technology area. For example, launched in January 2013 by seven leading telecoms network operators (AT&T, BT, Deutsche Telekom, Orange, Telecom Italia, Telefonica, and Verizon), the ETSI Industry Specification Group for Network Functions Virtualization (ETSI ISG NFV) was founded as a group in charge of developing requirements and architecture for virtualization of various functions within the telecom sector. Today, ETSI ISG NFV community grew to over 230 individual companies, including network operators, telecoms equipment vendors, IT vendors, and technology providers. ETSI ISG NFV members comprise of both ETSI and non-ETSI members (under some conditions). ISGs have their own voting rules and approve their own deliverables, as they independently choose their own work program.

ETSI publishes between 2,000 and 2,500 standards every year. That sums up to more than 30000 titles since its establishment in 1988. ETSI deliverable types falls into the following categories:

- European Standard, telecommunications series (EN): Used when the document is intended to meet needs specific to Europe and requires transposition into national standards, or when the drafting of the document is required under an EC/EFTA mandate.
- ETSI Standard (ES): Used when the document contains normative requirements and it is necessary to submit the document to the whole ETSI membership for approval.
- ETSI Guide (EG): Used when the document contains guidance on handling of technical standardization activities, it is submitted to the whole ETSI membership for approval.
- Special Report (SR): Used for various purposes, including giving public availability to information not produced within a technical committee. ETSI SRs are also used for "virtual" documents, e.g. documents that are dynamically generated by a query to a database via the web. The technical committee in which the SR was produced publishes it.
- ETSI Technical Specification (TS): Used when the document contains normative requirements and when short time-to-market, validation and maintenance are essential; the technical committee that drafts the TS approves it too.
- ETSI Technical Report (TR): Used when the document contains mainly informative elements, it is approved by the technical committee that drafts it.
- ETSI Group Specification (GS): Used by Industry Specification Groups according to the decision-making procedures defined in the group's Terms of Reference. This deliverable type is approved and adopted by the ISG that drafts it.

The produced materials by ETSI intended to define the requirements and architecture for the virtualization of network functions, aiming to:

- Simplify ongoing operations
- Achieve high performance, portable solutions
- Support smooth integration with legacy platforms and existing EMS, NMS, OSS, BSS and orchestration systems
- Enable an efficient migration to new virtualized platforms
- Maximize network stability and service levels and ensure the appropriate level of resilience
Network virtualization (NV) lays among those original motivations behind the ETSI establishment. The concept originated when service providers attempted to speed up deployment of new network services in order to advance their revenue and growth plans. The constraints of hardware-based appliances led them to applying standard IT virtualization technologies to accelerate service innovation and provisioning. In fact, NV is defined as the ability to simulate a hardware platform, such as a server, storage device or network resource (router, switch), in software. With the help of NV, functionalities are separated from the actual hardware as "virtual instances", imitating similar operational abilities of the traditional hardware devices. Of course, somewhere there is host hardware supporting the virtual instances, but this hardware can be general, off-the-shelf platform. In addition, a single hardware platform can be used to support multiple virtual devices or machines, which are easy to spin up or down as needed. As a result, a virtualized solution is typically much more portable, scalable and cost-effective than a traditional hardware-based solution.

Over the past decade, organizations have been adopting virtualization technologies at an accelerated rate. NV abstracts networking connectivity and services from the traditional dedicated / specialized hardware devices, turn them into logical virtual functions that are decoupled from, and runs independently on top of a general-purpose physical resource in a hypervisor. Beyond L2-3 services like switching and routing, NV typically incorporates virtualized L4-7 services including firewalling and server load balancing. NV solves many of the networking challenges, helping organizations centrally program and provision the network, on-demand, without having to touch physically the underlying infrastructure. With NV, organizations can simplify how they roll out, scale and adjust workloads and resources to meet evolving computing needs.

While networks have been moving towards greater virtualization, it is only recently, with the true decoupling of the control and forwarding planes, as advocated by software-defined networking (SDN) and network functions virtualization (NFV), that network virtualization has become more of a focus. In fact, SDN and NFV are two complementary approaches. They each offer a new way to design deploy and manage the network and its services. SDN separates the network’s control (brains) and forwarding (muscle) planes and provides a centralized view of the distributed network for more efficient orchestration and automation of network services. NFV (also known as virtual network function – VNF) offers a new way to design, deploy and manage networking services. NFV decouples the network functions, such as network address translation (NAT), firewalling, intrusion detection, domain name service (DNS), and caching, to name a few, from proprietary hardware appliances so they can run in software. A VNF takes on the responsibility of handling specific functionality that run on one or more virtual machines (VMs) on top of the virtualized hardware resources – servers, storage, routers, switches, etc. Individual VNFs can be connected or combined together as building blocks to offer a full-scale networking communication service, i.e. the network service (NS). Figure 6 provides a visual overview of the applicability of the concepts.

![SDN and NFV Concept Applicability](image_url)

- Optimize network infrastructure such as Ethernet switches, routers and wireless access points
- OSI Layer 2-3
- Optimize deployment of network functions such as: load balancer, firewall, WAN optimization controller, deep packet inspection, etc.
- OSI Layer 4-7

**Figure 6: SDN and NFV Concept Applicability**
Since both SDN and NFV concepts aim to advance a software-based networking; it is not surprising to see common doctrines guide the development of each. For example, they each aim:

- Move functionality to software
- Use commodity servers and switches over proprietary appliances
- Leverage application program interfaces (APIs)
- Support more efficient orchestration, virtualization, and automation of network services

These approaches are mutually beneficial but are not dependent on one another. You do not need one to have the other. However, the reality is SDN makes NFV more compelling and vice versa. SDN contributes network automation that enables policy-based decisions to orchestrate which network traffic goes where, while NFV focuses on the services, and ensures the network’s capabilities align with the virtualized environments they are supporting.

Virtualization can provide many benefits for the network operator, among all:

- Flexibility: operators looking for quicker deployment of services. It requires more flexible and adaptability at the network and application levels — aiming for easier and quicker installation and provisioning of services.
- Cost: cost is a top consideration for any operator or service provider these days, even more so now that they see Google and others deploying massive datacentres using off-the-shelf merchant silicon (commoditized hardware) as a way to drive down cost. Cost is also reflected in OPEX — how easy it is to deploy and maintain services in the network.
- Scalability: to adapt quickly to users’ changing needs and provide new services, operators must be able to scale their network architecture across multiple servers, rather than being limited by what a single box can do.
- Security: security has been, and continues to be, a major challenge in networking. Operators want to be able to provision and manage the network while allowing their customers to run their own virtual space and firewall securely within the network.
- Virtualization in another service provider network: to meet customers’ needs better, service providers want the ability to substantiate their service anywhere in the world using virtualization.

### 2.3.1 NFV MANO

NFV management and organization (MANO) is a WG of the ETSI ISG NFV in charge of defining an ETSI framework for the management and orchestration of all resources in the cloud. This includes computing, networking, storage, and virtual machine (VM) resources. The focus of NFV MANO is highlighted in Figure 7. It is broken up into three functional blocks:

- **NFV Orchestrator (NFVO):**
  - on-boarding of new Network Service (NS), VNF Forwarding Graph (VNF-FG) and VNF Packages
  - NS lifecycle management (including instantiation, scale-out/in, performance measurements, event correlation, termination)
  - global resource management, validation and authorization of network functions virtualization infrastructure (NFVI) resource requests
  - policy management for NS instances

- **VNF Manager (VNFM):**
  - lifecycle management of VNF instances
  - overall coordination and adaptation role for configuration and event reporting between NFVI and the traditional element / network management system (E/NMS)

- **Virtualized Infrastructure Manager (VIM):**
  - controlling and managing the NFVI compute, storage and network resources, within one operator’s infrastructure sub-domain
  - collection and forwarding of performance measurements and events
To handle its responsibilities the NFV MANO framework includes a group of repositories, namely NS catalog, VNF catalog, NFV Instances and NFVI resources. In addition to MANO internal functional blocks, there are two important external elements (not directly part of the MANO), which continuous exchange of information between them and the MANO framework is essential for meeting the expected operational requirements. Those elements are EMS and OSS/BSS respectively.

NFV entities to deploy and manage by MANO framework are listed below:

- **Network Service (NS):**
  - Described by its descriptor file, orchestrated by NFVO,
  - May cover 1 or more VNF Graphs, VNFs and Physical Network Functions (PNFs)

- **VNF Forwarding Graph (VNF-FG):**
  - Described by its descriptor file, orchestrated by NFVO,
  - May cover VNF-FGs, VNFs and NFs

- **VNF:**
  - Described by its descriptor file, instantiated by the VNF Manager,
  - Covers VNF components (VNFC) each mapped to a VM described with the Virtual Deployment Unit descriptor.

We will go over descriptors in detail in section 4, however just to have an overview:

- Network Service descriptor: end-to-end service description including supported SLA parameter, references to covered VNF-FG and VNFs, list of supported service monitoring parameters.
- VNF Forwarding Graph descriptor: VNFFG description, VNFs and VNFDs needed for orchestration, reference to link information, description of Physical/Logical interfaces
- VNF Descriptor: Links to scripts for initiation and termination, description of internal and external connectivity, dependencies between VNFCs.
- Virtualisation Deployment Unit (VDU) Description: VM specification, required storage and computation resources, initiation and termination scripts, high availability redundancy model, scale out/in limits.
- PNF Descriptor: reference to link information, exposed external interfaces, PNF addresses, PNF status, systems subscribed for notifications
- Network Service Instance Descriptor: Network service category, network attachment points, scaling methodology and policy, list of SLA descriptors, and monitoring parameter.
- VNF Instance Descriptor: VNF category, information on external connectivity, scaling methodology and policy, list of SLAs, and the list of monitoring parameter.

Now, let us focus on the detailed description of MANO building blocks starting with Virtualized Infrastructure Manager (VIM).

**Virtualized Infrastructure Manager (VIM)**

VIM manages NFVI resources in “one domain”. NFVI includes physical (server, storage etc.), virtual resources (Virtual Machines) and software resources (hypervisor) in an NFV environment. The word “one domain” implies that there may be multiple VIMs in an NFV architecture, each managing its respective infrastructure domain / NFVI. In simple words, VIM does:

- Manages life cycle of virtual resources in an NFVI domain. That is, it creates, maintains and tears down virtual machines (VMs) from physical resources in an NFVI domain.
- Keeps inventory of virtual machines (VMs) associated with physical resources.
- Performance and fault management of hardware, software and virtual resources.
- Keeps north bound open application program interfaces (APIs) and thus exposes physical and virtual resources to other management systems.

**Virtual Network Function Manager (VNFM)**
VNFM is to VNFs, what VIM is to NFVI. That is, VNFM manages VNFs (Router VNF, Switch VNF etc.). Specifically, VNFM does the following:

- VNFM manages life cycle of VNFs. That is it creates, maintains and terminates VNF instances. VNFs are software images already installed on the VMs created and managed by VIM.
- It is responsible for the FCAPs of VNFs (i.e. Fault, Configuration, Accounting, Performance and Security Management of VNFs).
- It scales up/scales down VNFs which results in scaling up and scaling down of CPU usage.

There may be multiple VNFM managing separate VNFs or there may be one VNFM managing multiple VNFs.

**NFV Orchestrator (NFVO)**

As stated above, there may be multiple VIMs managing respective NFVI domains. This creates an important challenge. That is who manages/coordinates the resources from different VIMs, when there are multiple VIMs in same or different Point of Presence (PoP).

Moreover, it is possible to have multiple VNFM managing their respective VNFs. This will cause another important challenge in which who manages/coordinates the creation of an end to end service that involves VNFs from different VNFM domains.

These challenges are overcome by the following two functions of NFVO.

- **Resource Orchestration**: NFVO coordinates, authorizes, releases and engages NFVI resources among different PoPs or within one PoP. This does so by engaging with the VIMs directly through their northbound APIs instead of engaging with the NFVI resources, directly. This directly overcomes the first challenge, i.e. resource allocation from different VIMs.

- **Service Orchestration**: It creates end-to-end service between different VNFs. It achieves this by coordinating with the respective VNFM so it does not need to talk to VNFs directly. Example would be creating a service between the base station VNF’s of one vendor and core node VNF’s of another vendor. Moreover, Service Orchestration can instantiate VNFM, where applicable. In addition, Service Orchestration does the topology management of the network.
services instances (also called VNF Forwarding Graphs). With these means, service orchestration overcomes the second challenge, i.e. creation of end-to-end service among different VNFs (that may be managed by different VNFM).

In fact, NFVO is like a glue in NFV that binds together different functions and creates an end-to-end service/resource coordination in an otherwise dispersed NFV environment.

Repositories

It is very important to understand the repositories (like files/lists) that hold different information in NFV MANO. There are four types of repositories:

- **VNF Catalog**: A VNF Catalog is a repository of all usable VNFDs (VNF Descriptor). A VNF Descriptor (VNFD) is a deployment template, which describes a VNF in terms of its deployment and operational behaviour requirements. It is primarily used by VNFM in the process of VNF instantiation and lifecycle management of a VNF instance. The information provided in the VNFD is also used by the NFVO to manage and orchestrate Network Services and virtualized resources on NFVI.

- **Network Services (NS) Catalog**: This is the catalog (list) of the usable network services (composed by several VNFs chained and working together to deliver an overall task). A deployment template for a network service in terms of VNFs and description of their connectivity through virtual links is stored in NS Catalog for future use.

- **NFV Instances**: NFV Instances list holds all details about the running network services instances and related VNF instances.

- **NFVI Resources**: It is a repository of NFVI resources utilized for establishing NFV services.

The following two management systems are not part of NFV MANO but are described because they exchange information with NFVO MANO functional Blocks.

**Element Management System (EMS)**

Element Management is responsible for the FCAPS (Fault, Configuration, Accounting, Performance and Security management) for the functional part of the VNF. Actually, VNFM also does the FCAPS of the VNF but only for the virtual part.

To clarify with an example: Generally MANO is only responsible for the delta of the virtual and physical world. Taking VNFM as an example, it does the life cycle management of VNF and its FCAPS. In terms of fault management it means, if there is any issue with the spinning up of a VNF, it will be reported by the VNFM but if the fault is related to a function (for example, some signalling issue in mobile core) it will be highlighted by the EMS.

VNFM exposes its interface to the EMS in case an operator wishes to use single GUI for all kind of FCAPS (virtual + functional).

**OSS/BSS**

OSS/BSS include collection of systems/applications that a service provider uses to operate its business. NFV is supposed to work in coordination with OSS/BSS. In principle, it would be possible to extend the functionalities of existing OSS/BSS to manage VNFs and NFVI directly, but that may be a proprietary implementation of a vendor. As NFV is an open platform, so managing NFV entities through open interfaces (As that in MANO) makes more sense.

The existing OSS/BSS, however, can value add the NFV MANO by offering additional functions if they are not supported by a certain implementation of NFV MANO. This is done through an open reference point (Or-Ma-NFVO) between NFV MANO and existing OSS/BSS.

**Reference Points**

Last but not the least; it is worth mentioning about the reference points. MANO has multiple reference points that are shown as interconnection points between the functional blocks as shown i.e. Or-Vi, NF-Vi, Or-Vnfm etc.
It is worth to notice that MANO calls them reference points and not interfaces. MANO does not call them interfaces because “interface” relates to allowing two way communication between entities. The reference point is an architectural concept that defines and exposes an external view of a functional block. Since MANO talks about functional blocks so it uses the word “reference point” instead.

2.3.2 NFV PoC

To push the work forward ETSI has already outlined a set of so-called network functions virtualization (NFV) proof of concept (PoC). NFV PoC is a method to delineate goals for NFV adoption. It aims to raise industrial awareness and confidence in NFV’s ability to become a workable and trusted technology. They also are integral to creating a diverse and open environment for NFV adoption. NFV PoCs can take place in many forms, but regardless of whether it is an open exhibit at a major trade show, or an experimental test done behind closed doors, an NFV PoC’s impact reaches beyond the organization hosting it. Below are a list of some NFV PoCs that have been developed according to the ETSI NFV ISG POC framework.

- PoC#1 - CloudNFV Open NFV Framework Project
- PoC#2 - Service Chaining for NW Function Selection in Carrier Networks
- PoC#3 - Virtual Function State Migration and Interoperability
- PoC#4 - Multi-vendor Distributed NFV
- PoC#5 - E2E vEPC Orchestration in a multi-vendor open NFVI environment
- PoC#6 - Virtualised Mobile Network with Integrated DPI
- PoC#7 - C-RAN virtualisation with dedicated hardware accelerator
- PoC#8 - Automated Network Orchestration
- PoC#9 - VNF Router Performance with DDoS Functionality
- PoC#10 - NFV Ecosystem
- PoC#11 - Multi-Vendor on-boarding of vIMS on a cloud management framework
- PoC#12 - Demonstration of multi-location, scalable, stateful Virtual Network Function
- PoC#13 - SteerFlow: Multi-Layered Traffic Steering for Gi-LAN
- PoC#14 - ForCES Applicability for NFV and integrated SDN
- PoC#15 - Subscriber Aware SGi/Gi-LAN Virtualization
- PoC#16 - NFVIaaS with Secure, SDN-controlled WAN Gateway
- PoC#17 - Operational Efficiency in NFV Capacity Planning, Provisioning and Billing
- PoC#18 - VNF Router Performance with Hierarchical Quality of Service Functionality
- PoC#19 - Service Acceleration of NW Functions in Carrier Networks
- PoC#20 - Virality based content caching in NFV framework
- PoC#21 - Network Intensive and Compute Intensive Hardware Acceleration
- PoC#22 - Demonstration of High Reliability and Availability aspects in a Multivendor NFV Environment
- PoC#23 - E2E orchestration of virtualized LTE core-network functions and SDN-based dynamic service chaining of VNFs using VNF FG
- PoC#24 - Constraint based Placement and Scheduling for NFV/Cloud Systems
- PoC#25 - Demonstration of Virtual EPC (vEPC) Applications and Enhanced Resource Management
- PoC#26 - Virtual EPC with SDN Function in Mobile Backhaul Networks
- PoC#27 - VoLTE Service based on vEPC and vIMS Architecture
- PoC#28 - SDN Controlled VNF Forwarding Graph
- PoC#29 - Service orchestration for virtual CDN service over distributed cloud management platform
- PoC#30 - LTE Virtualized Radio Access Network (vRAN)
- PoC#31 - STB Virtualization in Carrier Networks
- PoC#32 - Distributed Multi-domain Policy Management and Charging Control in a virtualised environment
- PoC#33 - Scalable Service Chaining Technology for Flexible Use of Network Functions
- PoC#34 - SDN Enabled Virtual EPC Gateway
- PoC#35 - Availability Management with Stateful Fault Tolerance
- PoC#36 - Orchestrated Assurance enabled by NFV
• PoC#37 - Demonstration high availability vEPC and SDN controlled Service Chain
• PoC#38 - Full ISO 7-layer stack fulfilment, activation and orchestration of VNFs in carrier networks
• PoC#39 - Virtualised service assurance management in vGi-LAN
• PoC#40 - VNFaaS with end-to-end full service orchestration
• PoC#41 - Network Function Acceleration
• PoC#42 - Mapping ETSI-NFV onto Multi-Vendor, Multi-Domain Transport SDN
• PoC#43 - Toward an efficient dataplane processing
• PoC#44 - Dynamic Service-specific VNF Management

2.4 OSS & Network Management

NFV-MANO alone cannot deliver all the NFV business benefits; it needs to integrate and interwork with other management entities for this purpose (e.g. OSS, BSS), using interfaces offered by those entities and offering its own interfaces to be used by external entities.

In order for service providers to achieve the full benefit of NFV, NFV-MANO solutions should be considered holistically alongside OSS/BSS integration and management requirements. Simply extending existing OSS/BSS models to account for virtualisation will not be sufficient, because this approach will not support the new value-added capabilities and services provided by NFV. Efforts are needed to ensure that NFV-MANO and OSS/BSS evolution is coordinated so as to jointly support the following:

• Open and consistent interfaces, to facilitate automation, self-service operations at service and product level that can respond with the speed and agility required by changing business needs.
• Adaptive automation, where service usage drives on-demand resource requirements, triggering feedback from the system that the management functions analyse and make changes to, enabling the infrastructure to provide the resources and services needed at that point in time.
• Orchestration, where policies (and other mechanisms) can guide the decisions required to change all or part of the system to perform a given function.
• Personalized services that are easily configured, by the operator and/or end-user at the service and/or network resource layers, to fit individual customer preferences and requirements.
• Technology-driven innovation, where rapid development, continuous integration, deployment, and experimentation, meet business and service operations agility and enable the migration to next generation operations.

The concluded 3GPP study item (i.e. 3GPP TR 32.842 [12]) has identified the following aspects regarding the management of the networks that include virtualized functions:

• Fault management.
• Configuration management.
• Performance management.
• Core network lifecycle management.

[13] presents the management concept, architecture and requirements for mobile networks with virtualized network functions. The management requirements are organized according to the four management categories extracted from the study item. TS 28500 also presents a management architecture that provides a mapping between 3GPP and the ETSI NFV MANO framework Figure 8. The management architecture was designed for cloud and radio networks composed of both physical and virtualized network elements.
ETSI defines the protocol specification and data model for the interfaces used over the Os-Ma-nfvo reference point (see Figure 8) to represent the boundary between application independent resource oriented service management and application specific service management:

- NSD management interface
- NS life-cycle management interface
- NS performance management interface
- NS fault management interface
- VNF package management interface

All aforementioned interfaces allow the OSS/BSS to invoke NS life-cycle management operations towards the NFVO and is based on the information model and requirements defined in ETSI GS NFV-IFA 013 [14]. Different OSS/BSS components can consume different APIs. For example ETSI GS NFV-SOL 005 specifies the resources and methods that the OSS/BSS can use to perform NS life-cycle managements, which after onboarding the descriptors to the NFVO through NSD management and NFV package interfaces, the OSS/BSS can deploy, manage and modify NS interfaces via Networks Service life-cycle interface.

Management of end-to-end services by OSS/BSS requires convergence on a common approach to presenting management services and management information from both legacy network systems and NFV based systems, so that accurate end-to-end management views can be derived. Standards are essential to achieve this convergence process.

However, experience has taught the industry that this is already a major issue for converged fixed and mobile network management including applications and services. It will be even more acute when managing end-to-end services across a mixture of NFV functions, infrastructure, and legacy interconnected network systems, in a highly dynamic NFV environment.

Nevertheless, merging 3GPP next generation architecture with ETSI MANO framework is a very challenging task, especially if we consider a wide picture that includes both satellite and terrestrial communication technologies. SaT5G targeted to tackle this challenge by introducing a holistic management and orchestration system able to coordinate all terrestrial and satellite elements.

### 2.5 State of the art
This section analyses existing ETSI NFV MANO orchestration platforms in order to see if there is possibility to adopt them in the specific context of SaT5G. The existing ETSI NFV MANO orchestration platforms are listed as follow:

### 2.5.1 Open Source Mano (OSM)

Open Source MANO – OSM [15] is an operator-led ETSI community that is delivering a production quality open source Management and Orchestration (MANO) stack aligned to the ETSI NFV information models and that meets the requirements of production NFV networks. The OSM community has set itself the goal of being an excellent production ready solution. OSM provide a solution for onboarding and instantiation of NS including VNF for different use cases in the virtual and physical network elements.

The OSM is currently developing an open source NFV management and orchestration stack relying on well-known and widely used open source tools. The activity is aligned with the ETSI ISG NFV development. Particularly, OSM relies on the OpenMANO project [16], Canonical’s juju charms [17] and Rift.io orchestrator [18]. One of the pillars of OSM consists in developing an information model-driven architecture, which allows different components of the MANO stack to be interconnected. Through descriptor models, OSM is capable of deploying NFV and NS in a time scale in the order of minutes in a fully automated manner. To achieve this objective, OSM will rely on the following features:

- End-to-end service creation
- Enhanced Platform Awareness (EPA), which ensures high performance virtual nodes.
- SDN control to ensure sufficient bandwidth requirement for the links.
- Multi-site capability for multiple sites involved in the end-to-end process creation.
- Multi-cloud VIM capability, since several VIMs shall coexist.
- Deployment and configuration of multi-tenant and single tenant NFV and NS.

A more detailed view of OSM architecture is illustrated in Figure 9. It consists of three layers:

- **NFVO**: NFV Orchestrator is a component which is responsible for orchestrating different parts of OSM components.
- **VNFM**: VNF Manager is a key component of NFVO architectural framework, which help to standardize the functions of virtual networking and increase the interoperability of SDN elements.
- **VIM**: Virtualized Infrastructure Manager is responsible for managing physical and virtual infrastructure in an NFV environment.

OSM release 5 represents another significant feature, including Network Slicing for the cloud network. The implementation of Network Slicing follows the recommendations in 3GPP-TS28.801, aligning with the data model specified in 3GPP-TS28.541 and follows the guidelines in ETSI-NFV-EVE021.
2.5.2 ONAP

Open Network Automation Platform (ONAP) [19] provides a platform for real-time, policy-driven orchestration and automation of physical and virtual network function, which allow providers and developers to automate new services and support lifecycle management. Figure 10 shows a high-level architecture of the ONAP and its platform components.

The design time framework is a development environment with tools, techniques, and repositories for defining/describing resources, services, and products.

The runtime framework executes the rules and policies distributed by the design and creation environment. This framework distributes policy enforcement and templates among various ONAP modules such as the Service Orchestrator, Controllers, Data Collection, Analytics and Events, Active and Available Inventory, and a Security Framework.

The orchestration stack on ONAP provides for service delivery, change, scaling controller instantiation and capacity management across both the application and network controllers.

- The Service Orchestrator component is responsible for executing the specified processes and automates sequences of activities, tasks, rules and policies needed for on-demand creation, modification or removal of network, application or infrastructure services and resources.
- Controllers are applications that are coupled with cloud and network services and execute the configuration, real-time policies, and control the state of distributed components and services.
  - SDN-C: Cloud computing resource controller.
  - APP-C: Application controller.
  - VF-C: Virtual function controller (provide generic VNFM capability).
- Active and Available Inventory (A&AI) provides real-time views of a system’s resources, services, products and their relationships with each other.
2.5.3 Open Baton

Open Baton is an open source platform [20] that provides a comprehensive implementation of the ETSI NFV MANO specification. The main features and components of OpenBaton are 1) a Network Function Virtualisation Orchestrator (NFVO), 2) a generic Virtual Network Function Manager (VNFM) that manages VNF life cycles based on the VNF description, 3) An Auto-scaling Engine which can be used for automatic runtime management of the VNFs, 4) A Fault Management System for automatic management of faults, 5) an SDK comprising a set of libraries that could be used for building a specific VNFM, and 6) a dashboard for managing the VNFs.

The NFVO is the main component of OpenBaton, which is written in Java using the spring.io framework. To interconnect the NFVO to different VNFM, OpenBaton relies on the Java Messaging System (JMS).

The NFVO is currently using OpenStack as first integrated NFV PoP VIM, supporting dynamic registration of NFV PoPs and deploys in parallel multiple slices one for each tenant, consisting of one or multiple VNFs. Through this functionality, the orchestrator provides a multi-tenant environment distributed on top of multiple cloud instances.
2.5.4 Tacker

Tacker is an official OpenStack project [21] that builds a Generic VNF Manager (VNFM) and a NFV Orchestrator (NFVO) to deploy and operate Network Services (NSs) and Virtual Network Functions (VNFs) on an NFV infrastructure platform like OpenStack (at this moment, the multi VIM is not supported, the tracker only support OpenStack). It is based on ETSI MANO Architectural Framework and provides a functional stack to Orchestrate Network Services end-to-end using VNFs, see Figure 12. It has capability to perform the basic life-cycle of VNF such as create, update and delete.

Figure 11 Open Baton Architecture.
2.5.5 TeNOR

TeNOR orchestrator has been named as TeNoR [22], which is ETSI-NFV compliant VNF deployment and operation. T-NOVA introduces a novel enabling framework, allowing operators to 1) deploy Virtualized Network Functions (VNFs) for their own needs, and 2) offer them to their customers, as value-added services. Virtual network appliances (gateways, proxies, firewalls, transcoders, analysers etc.) can be provided on-demand as-a-Service, eliminating the need to acquire, install and maintain specialized hardware at customers’ premises.

For these purposes, T-NOVA designed and implemented a management/orchestration platform for the automated provision, configuration, monitoring and optimization of Network Functions as-a-Service over virtualized Network/IT infrastructures. It leverages and enhances cloud management architectures for the elastic provision and (re-) allocation of IT resources assigned to the hosting of Network Functions. It also exploits and extends Software Defined Networking platforms for efficient management of the network infrastructure.

T-NOVA establishes a “NFV Marketplace”, in which network services and Functions by several developers can be published and brokered/traded. Via the Marketplace, customers can browse and select the services and virtual appliances which best match their needs, as well as negotiate the associated SLAs and be charged under various billing models. A novel business case for NFV is thus introduced and promoted. The T-NOVA architecture includes three main parts:

- Service Management and Life cycle concentrates all the features at the Network Service level.
- VNF Management and Life cycle concentrates all the features at the Virtual Network Function level.
- WIM (Wide-area network Interconnection Management) abstracts away all the interactions with the WAN (e.g., communication between VNFs that may leave in different DCs, connection to a specific customer’s network, etc.).

2.5.6 Cloudify

Cloudify is an open source TOSCA-based orchestration platform [23], which is designed to fit as an NFVO and a generic VNFM. Virtual Network Functions and Physical Network Function are modelled using the TOSCA language and on-boarded to Cloudify. Cloudify Model Driven Design allows operators to build VNF descriptors and Network Service Descriptors and manage the lifecycle of the network service. As illustrated in Figure 13, Cloudify Pluggable Architecture and the Plugin Framework makes integration to multiple VIMs and other platforms such as SDN Controllers, 3rd party VNFMs or hardware.
based system an easy and painless process. VNF modelling enables to describe the network service with all its resources: infrastructure, functions, service chaining, application code, scripts, configuration management, metrics, and policies, in a generic, descriptive language based on both TOSCA and Cloudify language.

The Orchestration is the core of the Cloudify Platform, it enables to maintain and run the complete life cycle of the service, from onboarding and instantiation to operations such as scaling, healing, maintenance, updates, and termination.

![Cloudify MANO architecture](image)

**Figure 13 Cloudify MANO architecture.**

### 2.5.7 SONATA

SONATA [24] is an orchestration platform based on ETSI MANO that provides development toolchain for virtualized services. The architectural level of SONATA includes two main components: service platform and SDK. The service platform offers customization on service platform operator and service developer. The SDK supports service developers with a programming model and a set of software tools. SONATA provides a modular and flexible MANO framework where a service or function specific manager can be added such as life-cycle management scaling, placement, and etc., thus modifying the provided default managers to a specific service or function needs.

As shown in Figure 14, the Service-Specific Managers (SSM) and Function-Specific Managers (FSM) are introduced in SONATA as main components by specifying desired placement or scaling behaviour for the service and function.

- **SSM** allows third-party service developers with control over specific orchestration and management functionalities pertaining to their own service.
- **FSM** provides NFV MANO flexibility to network operators with customizable platform functionality and ability to add new features via plug-ins.

The Orchestrator provides a default manager for every network service (at the NFVO level) and VNF (at the VNFM level), but allows this generic behaviour to be adapted for each network service/VNF by their developers.
Most of approaches discussed in this deliverable are in line with the ETSI NFV and 3GPP standards and are trying to address service assurance and lifecycle management workflows across cloud and 5G radio access elements. Summaries of the solutions demonstrate that they are limited to the cloud and RAN functionalities and are not explicitly handle solution in the context of our project (none of those approaches have yet provided the integration of virtualized user access satellite function into their current catalogues and repositories with sufficient TRL). For this, we need to design, develop and deploy a new platform to cover various layers of 5G terrestrial network (cloud, edge IoT resources and RANs of diverse standards) and satellite domain simultaneously. New platform should be a coordination layer which leverages on existing orchestration tools in order to guarantee performance and scalability in terrestrial elements. Therefore, the project has chosen to use the ETSI Open Source MANO (OSM) for resource orchestration of cloud domain. The decision was done after analysing the main alternatives available for NFV management and orchestration and taking into consideration the goals to be achieved. Some of the reasons are listed below:

- It is a key open source tool for orchestration in future.
- A python based client library and REST interfaces to enables access to all features.
- It supports an automated service orchestration environment that enables and simplifies the operational considerations of the various lifecycle phases involved in running a complex service based on NFV.
- It has a plugin model for integrating multiple SDN controllers.
- It has a plugin for integrating multiple VIMs, including public cloud-based VIMs and Edge clouds.
- It includes a plugin model for integrating multiple monitoring tools into the environment.
- It brings complete support of 5G Network Slicing.

**2.6 SaT5G vision on management layer**

Convergence of various telecommunication technologies is a key enabler to deliver 5G promises, such as ubiquitous solution featuring aspects like extraordinarily high speeds and capacity [4]. Seamless
integration of satellite communication (SatCom) [2], [25] into 5G networks aims to deliver 5G access everywhere. Although, the idea of having satellite connectivity as backhauling solution along with terrestrial system is not new, 5G calls for more advanced integration at different levels.

In the traditional way, the actual process of launching and managing a complex service requires huge amount of manual operations and processes. Such a complex and manual intervention prevents the end to end service provisioning and lifecycle management. It increases risk of human errors and reduces the satellite and terrestrial services business desirability. To improve the situation, this deliverable focuses on ensuring seamless integration of SatCom in 5G networks at orchestration layer and it presents a proposal for a terrestrial and satellite resource coordination solution, called TALENT. TALENT is a solution proposed to tackle this problem. TALENT is a management layer sit on top of the MANO frameworks with comprehensive view over all available resources and services. The proposed architecture provides a user-friendly single point of interaction for all stakeholders in the ecosystem, i.e. terrestrial and satellite operators as well as 5G vertical providers, where they can launch and manage end-to-end 5G services. The system allows easy integration of multiple applications (e.g. virtual 5G Core, virtual caching, etc.) as well as solutions provided by radio and satellite vendors (e.g. satellite gateway, small cells, etc.).
3 TALENT – Terrestrial Satellite Resource Coordination Framework

TALENT is a coordination solution which supports end-to-end service composed of satellite, radio access, cloud and mobile edge computing resources. TALENT features important aspects, such as:

- TALENT is not vendor-locked and can support satellite and radio elements of different vendors.
- TALENT is NFVO (e.g. OSM, ONAP) and VIM (e.g. OpenStack) agnostic.
- TALENT covers end-to-end service management over cloud and edge computational resources.
- TALENT provides a single and easy to use point of interaction for all stakeholders involved in the ecosystem, e.g. terrestrial and satellite operators as well as different 5G verticals.
- TALENT is completely in-line with 3GPP and ETSI definition, extending them towards satellite system.

Having these objectives in mind and based on the frameworks suggested by ETSI MANO [26] and 3GPP SA5[13], this deliverable proposes an extension towards satellite integration at the management and orchestration level. Figure 1 illustrates the proposal. The NFV-MANO stack, i.e. Network Function Virtualized Orchestrator (NFVO), Virtual Network Function Manager (VNFM), Virtual Infrastructure Manager (VIM) and cloud Virtual Network Functions (VNFs), represents the ETSI MANO framework [26]. ETSI MANO framework targets the lifecycle management and configuration of cloud services over the Network Function Virtualization Infrastructure (NFVI). On [12], the original ETSI MANO framework was reviewed to introduce radio resources. Those resources are presented by Radio VNFs, Radio Physical Network Functions (PNFs) and Domain Manager (DM). Radio Element Managers (EMs) embedded on the DM are included on the 3GPP framework to configure the Radio PNFs, thus supporting end-to-end service lifecycle management (service instantiation, termination, scaling, etc.) in a mixed radio cloud environment. With the same methodology, this work proposes to extend the 3GPP framework by including satellite elements, i.e. satellite VNFs (e.g. propagation impairments mitigation VNF for the satellite ground gateway); satellite PNFs and satellite DM including satellite EMs.

The proposed framework clearly represents three identical domains (cloud/edge, radio and satellite) interworking with each other to deliver end-to-end services. The idea of having satellite connectivity along with radio and cloud/edge capacity is not new. However, in the traditional way, the actual process of launching and managing such a complex service demands huge amount of manual operations and processes. As an example, to provision a media caching service utilizing satellite connectivity, the following manual workflow should be executed. The cloud/edge system admin using the local ETSI MANO framework should first set up the cloud/edge network service, including activities such as setting up the inter cloud/edge network, launching virtual machines (VMs), etc. Besides, the process must guarantee a secure external connectivity, with agreed specification determined by the satellite domain administrator, towards the satellite ground terminal. Upon receiving an acknowledgment message from the cloud/edge administrator, the satellite domain admin needs to first verify the connectivity with the cloud/edge system and then configure the satellite ground terminal to provision the satellite connectivity. At the satellite receiver side similar process between satellite admin and local radio domain system administrator should be executed to ensure the end-to-end service provisioning. Once everything is set and confirmed, only then 5G vertical solution provider could launch its service, in this case media caching service. Of course, the problem gets more complex if we include the service run time. During the service run time, all admins should constantly monitor their systems and communicate its status among themselves to guarantee the end-to-end quality of service. The provided example is just for one service lifecycle event, i.e. service provisioning, and does not include more advance actions like service level agreements (SLA) monitoring and associated billing processes.

Such a complicated and manual process hinders the end-to-end service provisioning and lifecycle management, increases risk of human errors and reduces the satellite terrestrial services business desirability. TALENT is a solution proposed to tackle this problem. It is an over top management layer with holistic view over all available services and resources. TALENT helps building a multi-tier orchestration stack over a heterogeneous environment, featuring a single point of interaction for all stakeholders engaged in the ecosystem (satellite, terrestrial and cloud operators as well as 5G vertical sectors) enabling them to automatically launch and manage end-to-end satellite terrestrial services. It is completely in line with the 5G high level KPIs such as reducing service provisioning from 90 hours to 90 minutes [27].
3.1 Design Principles

This section presents the high level design and internal architecture of TALENT, focused on being a top-layer solution, modular and extensible. As the solution has to be completely agnostic form the underlying layers, the architecture has to offer a high grade of dynamism when it comes supporting different frameworks, tools and proprietary solutions. Figure 16 presents TALENT’s high level architecture, while the following lines elaborates on the different components and modules that compose TALENT:

**Northbound REST API:** TALENT exposes a northbound REST API as the main entry point to the end-users such as operators and verticals. It contains well-defined interfaces having in mind standards related to the realization of the 5G and satellite ecosystems. It also provides an abstraction layer which exposes an extensible set of functions serving different needs of operators and verticals (e.g. service instantiation, check service status, etc.). The main objective of the API is to remain as much as possible user friendly and interoperable with the local NMS solutions of the system users and the TALENT GUI.

**Authentication and Authorization:** This intermediate component works closely to the API and is responsible for identifying end-users through a credential-based authentication process, and evaluates the claims of the end-user within the system, occurring after the authentication, respectively. Furthermore, it supports synchronization with the Domain Managers, including Cloud, Satellite EMS, Radio EMS, and the different levels they might present, in order to control the access and permissions from users, tenants or projects, keeping integrity of the system.

**Message Validation, Exchange and Interpreter:** TALENT is able to use descriptors of different nature either for deploying or configure services. These descriptors are sent through a bundle file or package including the set of descriptors containing all required information and attributes to offer a complete and integrated satellite - 5G services. It helps TALENT to be able to coordinate three different and heterogeneous domains (terrestrial networks, satellite and cloud/edge resources) from a single point. For this purpose, message validation is essential to make sure that any received descriptor file is in a valid format and contains the minimum required attributes for a successful service delivery. This component will intercept all coming descriptor files from their package, and make sure that they are all valid and self-sufficient. Next step for this component is to break down or parse the received descriptors into smaller pieces, specialized for each of supported domains, e.g.: radio network, satellite system and cloud/edge resources. Then, each smaller piece or specialized part of the descriptors is communicated properly into each domain through the exchange or bus channel provided by this component.

**MANO Selector Plugin:** Being NFVO / VIM solution agnostic is one of the TALENT objectives. For this very reason, TALENT architecture includes a module called “MANO selector plugin”. It is a reference point where all the required information (e.g. data model format, IP address, etc.) and interaction procedures of the supported NFVOs and VIMs are kept. In other words, all supported NFVOs / VIMs by TALENT at the bootstrapping phase have to be registered into “MANO selector plugin”. To establish and maintain a proper communication with underlying NFVO / VIM solutions, other TALENT modules...
will inquire “MANO selector plugin”. In release 1, “MANO selector plugin” will support OSM release 4 and 5, and Open Stack Queen. Next, other NFVO / VIM solutions will be included.

**Multi-MANO Lifecycle Manager:** This module is the host of supported NVFO and VIM clients during the execution phase. Each client contains proper communication procedures to handle the actual service and function lifecycle interaction with the supported NFVO/VIM solutions. It will produce the correct request through a template or schema file with the enough attributes to all cloud/edge domains attached to TALENT. To handle the requests correctly, this module first synchronizes with “MANO selector plugin” to load the required dependencies, thus, it will use proper set of information and procedures to interact with underlying solutions. Furthermore, this module also produces the end-to-end acknowledgment message regarding the cloud/edge lifecycle actions.

**Resource Slice Manager:** To support Multi-tenancy features, TALENT includes a dedicated module to coordinate resources on slices. In this setting, the “slice” term is defined as follows: “slice” is a sub-set of cloud/edge, satellite and radio resources assigned to a single operator/tenant. The use case requirements determine the type of resources assigned into one slice. This module is responsible for triggering, managing and coordinating end-to-end slices. It is also the only reference point which keeps track of all assigned slices to tenants. In order to deploy services and functions for a specific tenant, it is essential to inquiry this module to understand critical information such as Slice user, identification, 5G Core IP address, etc. There exist some available solutions in the community, like the resource slice manager developed by H2020 5GCity project [28], coordinated by i2CAT.

**Smart Contract Manager:** TALENT represents a modular multi-player ecosystem, where different stakeholders can interact among them. For this purpose, it is important to keep track of any SLA terms between parties and make sure that the contractual agreements are met. In order to automate the process, TALENT features this module. It is responsible for keeping all SLA agreements between involved parties with the help of technologies as Blockchain, based on the telemetry information extracted from the running services, it applies an automatic penalty/bonus mechanism. SLA agreements have to be loaded to this module during the bootstrapping phase. During this phase, the loaded information will include also a payment account where the automatic penalty/bonus mechanism will be applied.

**Domain Component Plugin:** Similar to the “MANO selector plugin”, this module is a reference point where all the required information (e.g.: data model format, configuration settings, interfaces information, etc.) and interaction procedures of the supported satellite and radio components are kept.
In other words, all supported satellite and radio components by TALENT at the bootstrapping phase have to be registered into this module. Necessary dependencies and libraries can be loaded by TALENT, where other modules will inquire this module to establish and maintain a proper communication with underlying solutions. This module is intended to support both open and proprietary solutions. On release 1, it will support satellite components coming from H2020 SaT5G project (Gilat). Next, other vendors will be onboarded.

**Domain Configuration Module:** This module is the host of supported satellite and radio component clients during the execution phase. Each client contains proper communication procedures to handle the actual configuration and lifecycle interaction with the supported solutions. It generates the correct request from a template file or schema data with enough attributes to all satellite and radio domains attached to TALENT. It is also possible to have multiple domains simultaneously with different solutions installed. In order to handle these processes correctly, this module first needs to synchronize with the “Domain Component Plugin”, thus, it will load any dependency and use the proper set of information and procedures to interact with underlying solutions. This module is also responsible to produce end-to-end acknowledgment message regarding the satellite and radio domain lifecycle actions.

### 3.2 Operation

Following to the management aspect of ta NSI in 3GPP, TALENT has two main operational phases: bootstrapping and run-time. Bootstrapping consist of setting up the TALENT system (which is mapped to the preparation phase – Figure 17) to be ready for the proper operation over an infrastructure. It is a one-time process (every time the system starts from the fresh). The “MANO Selector Plugin” and “Domain Component Plugin” are loaded with proper inputs for the supported MANO and satellite solutions. These inputs later on will be used at the run-time phase. Run-time phase is responsible for execution of operational (which is mapped to the commissioning, operation (i.e. activation) and decommissioning phases – Figure 17) commands coming from different stakeholders. In principle, TALENT supports two categories of operational commands:

- **Network Service-related commands:** these are commands for life-cycle management of end to end connectivity and computational resources. TALENT eases the provisioning/termination of end to end services over satellite and terrestrial resources.
- **5G application-related commands:** over the provision network services, TALENT is able to run and manage different 5G application.

As illustrated in Figure 18, user triggers the operation by browsing to the bootstrapping page to define new project for provisioning network service on satellite and cloud/edge domains. To do so, user must provide information such as vendor (e.g. OSM, Gilat) and API information (e.g. IP address and port number) of MANO Cloud Manager and Satellite Domain Manager to the system. Once the project is created, the bootstrapping phase is over.

The first step on the run-time phase is to upload TALENT’s package, which includes TALENT index file, Network Service Descriptors (NSDs) and Virtual Network Function Descriptors (VNFDs). TALENT performs a set of actions on the uploaded package based on the package definition as follows:

1. Open received TALENT package file to analyse and categorize the information.
2. Check if the index file is included.
3. Parsing the index file to check which files are included in the package (cloud domain and satellite).
4. Retrieve Network Service (NS), Virtual Network Functions (VNFs) and Virtual Deployment Units (VDUs) information, including satellite elements.
5. Test deployed NS, VNFs and satellite elements.
6. Verify if the indicated descriptors are found in the TALENT package file.

Then a request corresponded to the MANO is forward to the OSM and another request correspond to the satellite domain forward to the TotalNMS, which start the service instantiation process. In the generic way, the MANO fetches the NSD; including VNFD from its catalogue, considering that the descriptor was already available in the catalogue and it sends the request to the VIM to deploy the new NS instance. Once the operation is complete from the VIM side, the MANO receives a confirmation message, and it sends a reply to the interface module, which will finally forward the message to the TALENT. In the same way, the TotalNMS fetches the configuration file in order to apply user request on underlying premises. Once the configuration applied, the TotalNMS sends a verification response to the TALENT.

Once the network set up is done, 5G application can use the created network service to offer an added value service. In this case, TALENT over the 5G application tap will allow the 5G application owner to select a proper network service and trigger starting of the service.

![TALENT GUI](image)

**Figure 18 TALENT GUI.**
3.3 **Possible Strategic Outcomes**

TALENT will be introducing to the following communities and standards:

- TALENT will be introduced to the 3GPP as a study item under 3GPP SA2 and SA5 – study on management and orchestration aspects with integrated satellite components in a 5G network.
- TALENT has the potential of being introduced as a study item under ETSI, i.e. proposed skeleton for TR "reference virtualized network functions data model for satellite communication systems".
- TALENT has been linked to into 5GPP via Software Network WG.
- I2CAT will keep continue working on TALENT even after SaT5G project. This can be achieve via European and national projects investments.
4 Deployment

This section focuses on software implementation, development and testing of the TALENT release one. The first release of TALENT defined and designed to support Zodiac testbed objectives, covering coordination between different domains in the framework of the SaT5G project. It supports satellite and cloud/edge domains, interworking with each other to deliver end to end services. As shown in Figure 19, the first release of TALENT is not covering all features mentioned in the section 3, it’s only composed of following modules:

- Northbound API;
- MANO selector plugin;
- Multi MANO LCM;
- Domain configuration;
- Domain component plugin.

As TALENT needs a very small amount of resources for consuming, a stable version of Ubuntu 16.04 64 bits with the minimum requirements could be enough to handle the TALENT. Prerequisites for implementation of the TALENT in Ubuntu are:

- Python: it is an interpreted, high-level general purpose programming language.
- MongoDB: it is a cross-platform document-oriented database program, using JSON-like documents with schema.
- Consul.io: it is a service networking solution to connect and secure services across any runtime platform and public/private cloud.

Once all the prerequisites are installed, a virtual environment (virtualenv) inside the Ubuntu must be created with the necessary requirements. “Virtualenv” is a tool to create isolated python environment, which allows user to work on a specific project without worry of affecting other project in the same machine.

Once the environment and requirements are prepared, all modules of TALENTs can be created separately and register to the system. Modules need to be registered to the “consul.io” [29]. Consul.io is responsible to provide consistent and available information about the modules, including service and
node discovery mechanisms, a tagging system, health checks, to name a few possibilities. Leveraging consul.io within the system allow to build a sophisticated level of awareness into the applications and services. It enables a module to know about status (querying by their names) of running and deployed modules in the system. Once all the modules are registered to the consul.io, they will be ready to accept inputs and start their processes to provide services to the underlying MANO and satellite domains.

Multi MANO LCM and Domain Component Plugin modules are responsible to handle MANO (i.e. OSM release 4 and 5), and satellite domain (i.e. TotalNMS), respectively. To do so, a new library should be created to keep dependencies of each of OSM releases and TotalNMS such as API information. Furthermore, it is necessary to implement Rest API to manage different business logic in different area. API contains the controllers responsible to provide HTTP Rest API. Each controller such as OSM, OpenStack and TotalNMS contain at least three endpoint regarding GET, POST and DELETE methods using core’s validator module to check all business logic needed parameters are present and valid on request’s body. Business contains the business logic layer modules. Mainly they serve as an abstraction layer between the controllers, the model, and client modules. Clients contains the client information in order to support operations in OSM, OpenStack and TotalNMS.

In relation with MANO, the API is implemented to select OSM and its relevant release (either 4 or 5) and configure its parameters. In the first step call, TALENT is creating the MANO cloud manager (i.e. orchestrator name - OSM and its release):

- curl –X POST http://localhost:port/api/v0.1/osm/release

It also needs to retrieve existing MANO release and parameters from the database:

- curl –X GET http://localhost:port/api/v0.1/osm/release

Next is to instantiation a connection to the OSM. It is executed by adding descriptors to the OSM:

- curl -X POST http://localhost:port/multi_mano_manager/v0.1/package

Descriptor file must be include all required information of the OSM like IP address, port number, credentials, VIM etc.

Finally it Instantiation the NS by call passing the descriptor:

- curl -X POST http://localhost:port/multi_mano_manager/v0.1/network_service_instance

In relation with satellite domain, the API is implemented to select and configure TotalNMS. First API call is responsible to create the domain manager passing the details such as IP address, port number, Username and password, vendor, etc.:

- curl -X POST http://localhost:port/domain_manager/v0.1/domain_manager

Then it needs to add connection by onboarding package. Finally Domain component Plugin calls TotalNMS API to instantiate connection between TALENT and TotalNMS:

- curl -X PUT http://localhost:8993/domain_manager/v0.1/connection/<connection_id>

### 4.1 Software Development Method

TALENT will use agile implementation practices, based on NEXUS [30] for multi-team environment, consisting of multiple SCRUM [31] teams. Each partner will have a SCRUM team, and the project as a whole will be the sum of the SCRUM teams, i.e. the NEXUS team. To better understand the situation, it is good to quickly review the SCRUM methodology. In principle, the SCRUM methodology consists of a series of short development cycles (called “sprints”). At the beginning of each sprint, the “project owner” sets the priorities for the upcoming sprint. “Developers” then select tasks from the “product backlog” related to those priorities and commit to implementing them during the sprint. During the sprint, there are short meetings to keep track of the progress of all of the active tasks. At the end of the sprint, the developers demonstrate the implemented tasks. Figure 20 provides an overview of the SCRUM process. A sprint can vary in length, but it is usually 1 month. For TALENT representatives from the selected use cases with guidance from the technical management will act as the “product owner”, driving the evolution of the TALENT development forward.
The use of agile development practices has many benefits, e.g., it ensures that the developers concentrate on the highest priority features as defined by the project owners, keeping the feature set tightly bound to the needs of the selected use cases; it allows the project to refocus its efforts quickly on serious problems. Moreover, the use of tickets for tracking developments during a sprint allows the entire process to be measured and documented with a minimum efforts. TALENT will also produce concise, textual sprint summaries to allow high-level monitoring of the project’s progress.

Figure 20 Iterative process for agile (SCRUM) development.
5 Zodiac testbed

5.1 Scope

As shown in Figure 21, the demo takes place as part of the Zodiac Inflight Innovations (ZII) testbed, in Wessling, Munich, which contains the Data Centre (DC), a pool of computing resources that constitutes the environment for deploying virtualized network functions.

The DC is a key part of the ground infrastructure that allows managing the end-to-end system, which is hosting the TALENT solution along with Open Source MANO (OSM) orchestrator and Openstack as VIM. In the same location, there is an O3b remote user terminal which is responsible for aggregating the 5G data traffic and backhaul it via the O3b MEO HTS space segment to the O3b GW teleport in Sintra, Portugal. From there back to ZII premises, where the 5G Core Network (DC) is located, there is a terrestrial VPN link to backhaul the 5G data traffic.

The demonstration includes an aircraft cabin mock-up network located at ZII premises. The cabin mock-up is able to emulate different speeds and altitudes of the aircraft. Inside the aircraft, there is a network which represents the edge of the end-to-end system, and it hosts the entertainment content and the communication functions that provide connectivity inside the aircraft to end-users' devices, that allows external aircraft connectivity through the satellite terminal mounted on-board. A resource constrained pool of computing resources will also be deployed inside the aircraft for the sake of demonstrating aeronautical scenarios.

5.2 Goals

The goals of the ZII test use case are to demonstrate:

1. How automatically and with the help of TALENT it is possible to provision the required end-to-end services (composed of cloud/edge and satellite resources).
2. Using the benefits of content multicasting, demonstrate how it is possible to efficiently deliver refreshable and live contents on board.

The TALENT resource manager will be employed for the demonstration purposes. This allows the 5G vertical (with no knowledge of cloud and satellite administration) to request and provision the required ground to aircraft service. That service will include satellite connectivity, on ground connectivity (VPN in this case), and cloud/edge computational resources.
Upon receiving the service provisioning acknowledgment message, 5G vertical will launch the multicast content delivery application. This application will constantly multicast popular video contents (e.g. an important sport event, breaking news, etc.) to the aircraft under the sight of the satellite system.

Through the 5G connectivity on board and with the help of the airline app installed on the seat embedded monitors, passengers will be able to watch live and refreshable contents.
6 Summary and conclusions

Merging 3GPP next generation architecture with ETSI MANO framework is a challenging task, especially when we consider it as a wide picture to cover both satellite and terrestrial communication technologies. In the Sat5G project, we presented a solution to coordinate satellite and terrestrial systems from a single point of interaction. The presented solution is totally in line with ETSI and 3GPP SA5 suggestions, extending them towards the satellite integration. High level architecture of the solution is also presented which clearly demonstrated internal components of the solution and their interaction to achieve three main goals: 1- coordinating satellite, radio and cloud/edge resource from a single point; 2- being vendor and NFVO solution agnostic; 3- being user friendly. TALENT is a work on progress. The current version of TALENT targets technology readiness level (TRL) 4, where automatic service provisioning and termination are provided.

Our solution provide a user friendly single point of interaction for all stakeholders in the terrestrial and satellite operators as well as 5G service and vertical provides, where they can run and manage end-to-end 5G services. Basically this coordination tool allows integration of various solution and 5G application provided by different vendors.

We target to do future releases (every ~6 months) where TALENT will be able to support:

- More Satellite domains (e.g. iDirect) and MANO solutions (e.g.ONAP) and VIM (e.g. OpenVIM).
- Radio and Transport domains.
- Multi-tenancy and lifecycle actions such as scaling up/down and service monitoring, etc.
- End-to-end network slicing from core network to the edge and access network.
- Smart SLA and billing process.
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