TALENT: Towards Integration of Satellite and Terrestrial Networks

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***Abstract*— 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 paper. 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.**

Keywords—Orchestration, 5G, Satellite, Terrestrial networks, MEC, Network Softwarization

I. INTRODUCTION

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 communication (SatCom), including mobile network level, was based on proprietary and custom solutions in previous generations. Telecommunication satellites were considered completely independent of terrestrial networks. Hybrid solutions were uncommon, and the satellite network was mainly used to provide backhaul to some remote and hard to access individual cells, being a non-flexible and 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).

This work focuses on point 3 of the above list and it presents a proposal for a terrestrial satellite resource coordination solution, called TALENT. To do so, section II introduces the overall concept of TALENT. Section III details the architecture of TALENT with explanations of each component. Section IV focuses on an in-flight use case where TALENT is used for provisioning and configuration of an end-to-end video multicasting service from the ground into the airplane cabin. Section V concludes the paper and presents the implementation roadmap of TALENT.

II. TERRESTRIAL SATELLITE RESOURCE COORDINATION FRAMEWORK

TALENT is a coordination solution which supports end-to-end services 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

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ecosystem, e.g. terrestrial and satellite operators as well as different 5G verticals.

Having these objectives in mind and based on the frameworks suggested by ETSI MANO [3] and 3GPP SA5 [4], this paper 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 [3]. ETSI MANO framework targets the lifecycle management and configuration of cloud services over the Network Function Virtualization Infrastructure (NFVI). On [5], 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 [6].

III. 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 2 presents TALENT's high

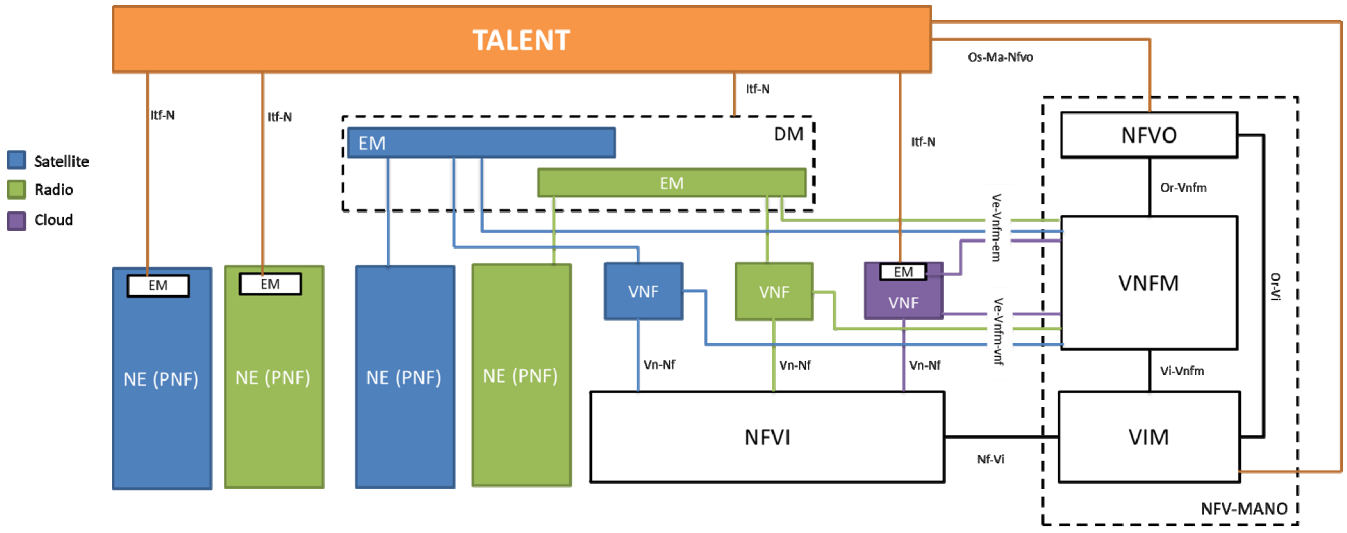

Figure 1: Proposed Integrated Terrestrial Satellite Framework

level architecture, while the following lines elaborates on the different components and modules that compose TALENT:

A. *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.

B. *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.

C. *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.

D. *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 5 and Open Stack Queen. Next, other NFVO / VIM solutions will be included.

E. *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,

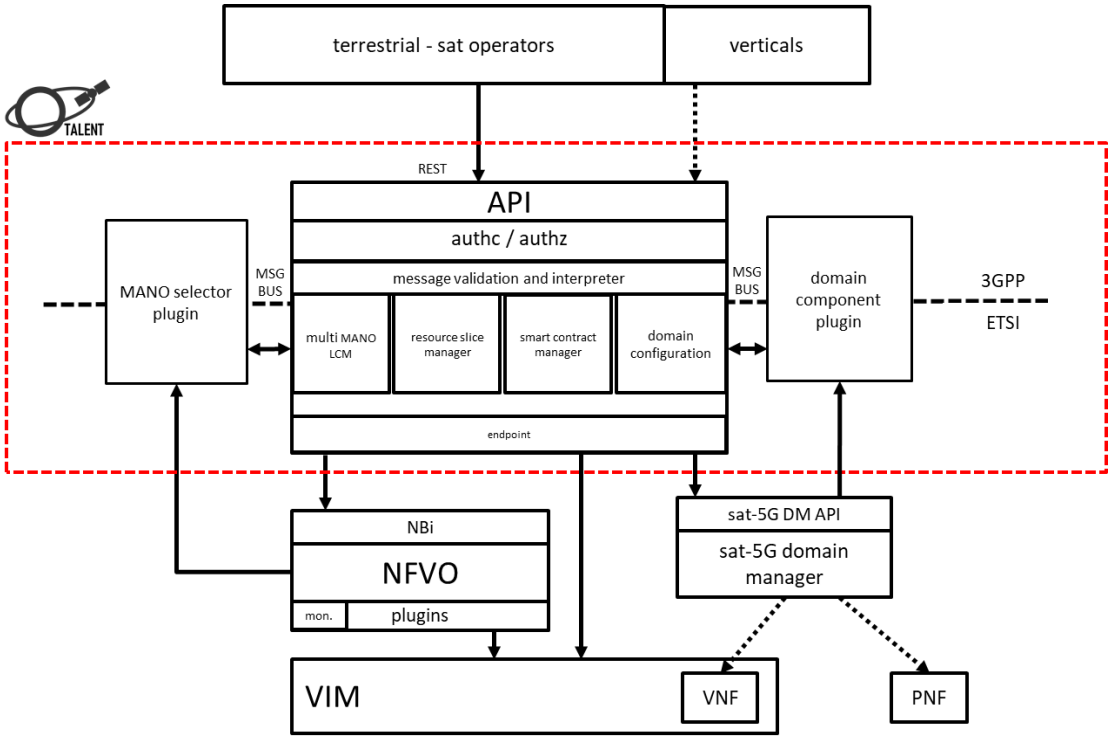

Figure 2: High Level Design

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.

F. 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 [7], coordinated by i2CAT.

G. 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.

H. 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 on boarded.

I. 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.

From operational perspective, TALENT has two main phases:

1. Bootstrapping phase: the MANO selector plugin and domain component plugin are loaded with proper inputs for the supported MANO, radio and satellite solutions. These inputs later will be used during the execution phase.
2. Run-time phase: with the help of its internal components, TALENT automates the interaction between the satellite, terrestrial operators and 5G verticals with the underlying domains. This level of automation, helps improving the service provisioning time, guaranteeing the quality of service, supporting multi-tenancy and trustworthy business relationship between different stakeholders involved in the ecosystem.

IV. IN-FLIGHT CONNECTIVITY USE CASE

Only a few years ago, a single movie could be played simultaneously for all passengers during a flight. Technology evolution delivered further options such as on-demand viewing platforms with built-in screens on the back of the seats, allowing viewers to choose from a variety of TV shows, movies and games. To enhance the passenger's experience of the in-flight entertainment system, the aviation industry targets to have live media contents on board. Other use cases have been presented in [8].

With the help of 5G technology integrated with the satellite systems, now it is possible to deliver live and refreshable contents onboard using multicasting video content delivery over the satellite systems. Figure 3, presents a high level view of the use case, as targeted by SaT5G project for European Conference on Networks and Communications (EuCNC) 2019. TALENT in this demo set up automate the previsioning of resources (satellite and terrestrial connectivity) as well as computational resources at main DC and inflight edge.

As shown in Figure 3, 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

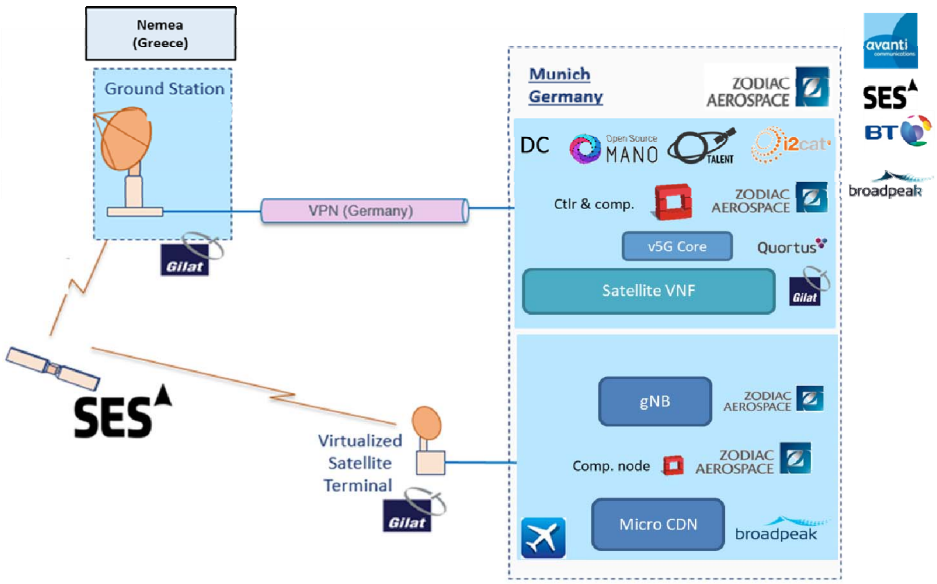

Figure 3: High Level Design

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. The goal of the use case is to demonstrate:

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

TALENT will be employed for the first target of the demonstration. It helps 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 acknowledgement 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 aircrafts 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.

V. CONCLUSION

In this paper 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. We target to do future releases (every ~6 months) where TALENT will be able to support other vendors and lifecycle actions such as scaling up/down and service monitoring. The presented demo in this paper has been demonstrated in EuCNC 2019.

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