Integration of Terrestrial and Non-Terrestrial Networks for Automotive: challenges and perspectives within the S11 RESTART project

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***Abstract*— The Integrated Terrestrial And Non-Terrestrial Networks (ITA NTN) project, in the framework of the PNRR Research Program, is here described; it will study the integration of Terrestrial and Non-Terrestrial Networks, where space network entities cooperate with conventional and emerging terrestrial communication architectures to provide ubiquitous, resilient, and three-dimensional wireless connectivity around the world, supporting heterogeneous services (e.g., improving better coverage, user experience, system capacity, service reliability, and availability, as well as offering high-speed connectivity in remote sites or in disaster-affected areas). As a result, ITA NTN project will contribute to the definition of specific network architectures to support, among other application scenarios, the whole world of the Automotive as assistant to the drive, monitoring of the transportation infrastructures including maritime and railways.**

***Keywords*— 5G, Automotive, Non-Terrestrial**

I. INTRODUCTION

It is now well known that the new wireless communication networks called 5G [1] will also have a fundamental role in specific vertical environments concerning the autonomous movement of vehicles, whether they are cars, buses, trains, and ships and not only for the control of their movements, first of all avoiding collisions [2], but also in the monitoring of the infrastructures in which these vehicles circulate such as roads, bridges, railways, ports, etc. [3]. Specific wireless communications infrastructures have been created with the aim of analyzing the surrounding environment in depth, also with cameras and LIDARs [4], transmitting the information to access points close to the detection where very fast processing is possible to allow appropriate instant decisions (Mobile Edge Computing, MEC) [5]. This can occur through the use of wireless systems capable of transmitting very high capacities, with very low latencies and very high reliability. Generally, these networks are considered *Terrestrial (T)* in the sense that the antennas are mounted on structures that rest on the mainland. However, it is well known that especially in some areas where telecommunications infrastructures are scarce, satellite technologies have a fundamental support role, and the modality of this *Non-Terrestrial* (NT) approach is becoming increasingly important [6-10]. And in fact, in order to meet all the requirements for *automotive*, emerging Non-Terrestrial networks are expected to interwork with technologies to complement the terrestrial component of International Mobile Telecommunications (IMT), including spaceborne systems (i.e., geosynchronous (GSO), and non-geosynchronous (non-GSO) orbiting satellites), and airborne systems (i.e., High-Altitude Platforms Stations (HAPS), and Unmanned Aircraft Systems (UAS)).

In the context of the "*RESearch and innovation on future Telecommunications systems and networks, to make Italy more smart (RESTART)*" program, funded by the European Union under the Italian National Recovery and Resilience Plan (NRRP) of NextGenerationEU, partnership on "Telecommunications of the Future", the "Integrated Terrestrial And Non-Terrestrial Networks (ITA NTN)" structural project aims at contributing to the definition of the future integrated T/NT networks, where spaceborne and airborne network nodes (unmanned aerial vehicles, aircraft, drones) cooperate with conventional and emerging terrestrial communication architectures to provide ubiquitous, resilient, wireless connectivity around the world, while supporting enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communications (URLLC), massive Machine Type Communications (mMTC), and Human-Centric Services [6-10]. From the technical perspective, the project will investigate free-space, optical, and radio communication links, conceive new physical transmission and channel access techniques, and design novel protocols and management facilities based on artificial intelligence and network softwarization. All the proposed techniques and methodologies will improve coverage, user experience, system capacity, service reliability and availability, and environmental sustainability of next-generation communication infrastructure for several potential verticals and in particular for transportation, public safety, and high-speed connectivity in remote sites or disaster-affected areas.

II. WIRELESS COMMUNICATIONS FOR AUTOMOTIVE

One of the many benefits of 5G networks is the ability to provide reliable, secure, and fit-for-purpose cellular connectivity in automotive and transport applications. In fact, while 2G-4G networks can provide sufficient connectivity for numerous Internet of Things (IoT) applications, the higher data rate, lower latency, and improved capacity, provided by 5G New Radio (NR) access, make 5G systems the ideal choice to maximize the safety, efficiency, and sustainability of any transportation.

a) Automotive in road transport services

A wide collection of automotive and road transport services requires cellular connectivity, with many already in

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commercial operation. Following Ericsson [11] classification these services can be divided into eight groups:

- Regulated Cooperative-Intelligent Transport Systems (C-ITS);
- Vehicle Manufactures (VM) Advanced Driver Assistance Systems (ADAS);
- Fleet management (including remote assistance of driverless vehicles);
- Logistics and connected goods;
- Convenience and infotainment services;
- Vehicle-as-a-sensor for general third-party applications (including weather and maps);
- Vehicle-centric and aftermarket services (including telematics);
- Connected road infrastructure services.

Regulated Cooperative-Intelligent Transport Systems (C-ITS) focus on governmental regulated services for road safety and traffic efficiency. Traffic efficiency use cases have relaxed latency requirements, while safety-related data often requires reliable low-latency communication. A benefit of regulation is to encourage VM cooperation in standardized (regulated) information exchange. Regulated C-ITS services may also use dedicated ITS spectrum in certain regions; for example, for direct short-range communication using 3GPP PC5 or IEEE (Institute of Electrical and Electronics Engineers) 802.11p technologies.

The purpose of VM Advanced Driver Assistance Systems (ADAS) is to increase road safety by focusing on the driver and driving behavior. They rely primarily on vehicle sensor information and are typically not collaborative across vehicle brands. ADAS services can also benefit from data provided by traffic authorities such as traffic light information. They are expected to evolve to support the driver-less vehicles of the future.

Fleet management services are aimed at vehicle fleet owners such as logistics or car-sharing companies. The communication service is primarily used to monitor vehicle locations and the vehicle/driver status. When the fleet consists of driver-less vehicles, the fleet management also includes communication support for operations monitoring and remote assistance, which can imply full remote driving.

The primary focus in the logistics and connected goods category is on the tracking of transported objects (commodities, merchandise goods, cargo, and so on) during the production and transport cycle of the object.

Convenience and infotainment services deliver content such as traffic news and audio entertainment for drivers, and gaming and video entertainment for passengers.

In vehicle-as-a-sensor for general third-party use cases, the sensors installed in the vehicle to provide information to solutions aimed at achieving driving improvements (such as ADAS or automated driving) are re-used to provide anonymized data to other parties to monitor city infrastructure and road status, maintain street maps or to give accurate and up-to-date weather information.

Vehicle-centric and aftermarket services focus on vehicle performance and usage. They make it possible for the VM to collect vehicle diagnostics data that enables it to monitor/adjust the vehicle and give advice to the driver for improved driving efficiency. Other examples in this category include vehicle tracking and predictive maintenance.

Connected road infrastructure services are operated by cities and road authorities to monitor the state of the traffic and control its flow, such as physical traffic guidance systems, parking management, and dynamic traffic signs. Each service group contains multiple use cases, and requirements can be diverse within a group.

b) Port and airport

Major transportation hubs like airports and shipping ports are like small cities with different types of communication needs and use cases. For example, multiple wireless networks are used in airports: Radio Local Area Networks (RLANs) for consumer communications and data transmission, Distributed Antenna Systems (DAS) for cellular service within the airport, separate Land Mobile Radio (LMR) systems for public communications safety. Maintaining and managing disparate networks in airport and port environments can be costly. Port operators are looking for a new single system to simplify network management and deliver reliable and secure wireless services that can handle mission-critical operations. Although IMT applications respond to the need to improve the operational efficiency of communication systems in airports and ports with stronger cyber security, some aspects must be highlighted in relation to some specific requirements of these types of vertical sectors.

Having reliable and secure networks to support the numerous procedures can improve operational management efficiency at the airport, starting from the operations of air traffic controllers on the towers to airline ground personnel and security agents.

c) Railways

Over the past 20 years, the ground-to-train communication system has become a critical part of rail operations, enabling harmonization and significant improvement of previously heterogeneous rail services and applications within legacy analog systems.

The evolution of this system, and its integration with IMT networks, should revolutionize many aspects of digitization in the railway sector. Future Railway Mobile Communication System (FRMCS) [12], standardized by 3GPP (in collaboration with UIC and other railway industry stakeholders and authorities), aims to be the future world telecommunications system based on 5G and Mission-Critical Services (MCX) [13] for support critical communications for railway networks.

An example of these critical communication applications is Railway Emergency Communication (REC). REC has two main purposes in railway operation: (1) To warn drivers or other railway personnel in the event of an emergency and (2) based on operating rules, further information on the emergency can be exchanged using voice and/or data communications.

Other use cases for FRMCS include automated train operation and, in the future, fully self-driving trains, which cannot exist without a secure, high-performance telecommunications network. Similarly, sophisticated train monitoring systems will not be possible without a high-quality mobile network. Not to mention remote operations/information or the inevitable use of video support which will be a necessary part of modern railway applications.

III. OVERVIEW OF T/NT NETWORKS

The technical feasibility of using satellite communication for vehicles and transport systems has been studied and proved in several recent and on-going projects.

In the ESA DARWIN Autonomous driving project, through multiple trials under varying environmental conditions, it has been shown that hybrid mobile and satellite connectivity was available 99% of the time [14]. Some of the main European projects that include satellite communications as an option for cars/transport systems connectivity are:

The 5GAllstars project aims to develop a set of technologies for validating a multi-connectivity (cellular/satellite) based on multiple access to support ubiquitous broadband services [15]. The 5G-Autosat initiative, funded by DLR, is focusing on the design of a satellite-capable 5G communication module for automobiles [16]. Moreover, the automotive use cases are key use cases for any project and initiative that involves the development of hybrid 5G and satellite solutions, such as 5GPP, 5G Carmen, and 5G-VINNI. However, while the use of Non-Terrestrial nodes for providing ubiquitous connectivity in the automotive sector is fundamental, there are many challenges to be faced, especially when targeting higher levels of autonomy (autonomous cars, autonomous vessels). The latency and the massive direct access of the huge number of terminals, the long and highly variable propagation delays, and the high Doppler shifts and Doppler rates pose challenges to the design of the air interface, the multiple access, and the choice of the architecture that should use in an optimized way all the components of the 3D architecture, satellites but also drones and eventually HAPs. On the one hand, the mitigation of high delays resulting from communication with GSO satellites can be achieved using Low Earth Orbit (LEO) satellites. On the other hand, the lower the orbit of the satellite, the greater the impact of the Doppler effect resulting from its motion.

ITA-NTN project aims to provide breakthrough solutions to these challenges.

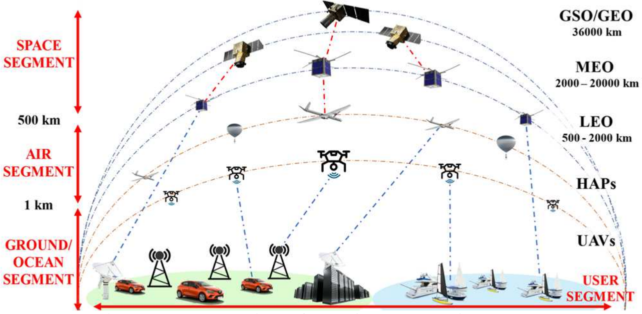

Figure 1 – Integration of T and NT network segments.

There are three main types of satellites in Earth's orbit. Satellites in geosynchronous orbit (GSO) move on a path parallel to the Earth and appear stationary in the sky, at an altitude of approximately 36,000 km. Medium Earth orbit (MEO) satellites orbit the Earth at a lower altitude, about 5,000 km to 12,000 km. Meanwhile, LEO satellites occupy the lower range at about 2,000km.

The resulting T/NT network architecture will appear as a mixture of space nodes that will be transparently integrated with the terrestrial segment for extending coverage, providing resilience and flexibility, offering backhauling services, and improving environmental sustainability. For such an aim a fundamental work will be the integration of Terrestrial (T) and Non-Terrestrial (NT) networks, and it has been initially taken into account, within the 3GPP standardization forum, during the definition of the 5G infrastructure.

Indeed, starting from Rel-15, especially in TR 38.811, the 3GPP has been focusing its efforts on the T/NT network architecture, which enables a wide range of use cases also suitable for the envisioned scenarios, such as automotive applications [9]. Therefore, a series of study phases recently ended up in the first-ever standardized T/NT network infrastructure in Rel-17 of 3GPP (March 2022). However, the current standardized architecture is essentially based on two main components (i.e., T and NT) that appear as loosely integrated and based on a specific adaptation of the Terrestrial architecture and radio access network to the specificity of the Non-Terrestrial link. Differently, 6G would target a much more ambitious vision, according to which T and NT networks will be truly integrated within a novel architecture through a unified design approach. Therefore, it is expected that Rel-20+ of 3GPP (beyond January 2025) will promote a new architecture where the NTN component will be perfectly integrated into the terrestrial communication infrastructure, as shown in Fig. 1.

a) Spectrum policies

An important element on which is needed to work to ensure the implementation of 6G by 2030, is the analysis of the frequency resources that will have to be used for the management of future 6G networks at an international level, including the Non-Terrestrial segment.

The World Radiocommunication Conference (WRC)-23 next November will lay the foundations of the spectrum for 6G, and the WRC-27 will be very important for the definition of the spectrum for 6G. In parallel, the market-oriented approach to the spectrum to be dedicated to 6G can be an element to consider.

6G will integrate the terrestrial and non-terrestrial networks and for this reason it is necessary to define a regulatory and spectrum management framework that takes into account both networks.

The growing convergence of satellite and mobile technologies is a key element for next generation networks. In the past terrestrial systems and satellite systems have often been rivals for the same spectrum, but satellite integration is now seen as increasingly important for future generations of mobile technology, including 6G.

The large first-generation constellations, currently in use, work on frequencies in the Ku- (10.7-14.5 GHz) and Ka (17.3-30 GHz) bands, which provide satellite connectivity. Future generation large constellations plan to use the Q/V bands (37.5-52.4 GHz). Spectrum sharing is an important component in satellite regulation as the growth in the number of satellites will mean that spectrum is often shared. A robust framework is needed to ensure that satellite systems do not cause harmful interference to other services and in parallel that coexistence conditions accurately reflect the planned operations of non-geostationary orbital systems. As part of the work in preparation for WRC-23, some AIs look at the satellite interconnectivity relating to both the Earth Stations in Motion in the Ku band using GSO satellites and in the Ka-band using NGSO satellites and the interconnectivity relating to Inter-Satellite Links (ISL) for extending coverage using low orbits.

IV. THE S11 RESTART PROJECT FOR AUTOMOTIVE

The "REsearch and innovation on future Telecommunications systems and networks, to make Italy more smart (RESTART)" program is funded by the European Union under the Italian National Recovery and Resilience Plan (NRRP) of NextGenerationEU. RESTART aims to foster scientific and technological developments and innovation in the sector of telecommunications and related applications through the realization of specific research projects, with concrete and measurable results. In this context, the Integrated Terrestrial And Non-Terrestrial Networks (ITA NTN) project represents the 11-th structural project of the overall RESTART structure and is connected to the Spoke 2 namely "Integration of Networks and Services. Here we report the ITA NTN targets that will help the Automotive development:

a): Design a 3D multi-layered communication architecture for integrated T/NT networks supporting seamless high-capacity demanding applications and massive access by heterogeneous devices. Starting from the reference use cases and the accurate analysis of their communication and computational requirements, ITA NTN will provide a high-level definition of the overall 3D multi-layered communication architecture [1,2] and the involved terrestrial and non-terrestrial network elements. A first description of the protocol stack for both data and control planes - based on Network Function Virtualization (NFV), Software Defined Networking (SDN), and state-of-the-art Cloud-Radio Access Network (CRAN) paradigms - and the interaction among satellite, aerial, and terrestrial elements will be clarified as well. The architecture will also provide functional specifications for the links, e.g., in terms of capacity, latency, availability, etc.

b): Design of advanced transmission techniques for integrated T/NT networks based on a novel (e.g., optical) antennas and electronic technologies, optical wireless system solutions, waveforms, multiple access techniques, and Multiple Input Multiple Output (MIMO) schemes aided by Distributed Antenna Systems (DAS) and Coordinated Multi-Point and operating in the millimeters-wave and optical bands. The objective is the investigation of a robust, beyond OFDM, multicarrier waveforms for time-varying channels (for instance, due to the Doppler effects in case of high mobility, low-orbit satellites, and coherent reception), such as Non-Orthogonal Multiple Access (NOMA) techniques with Successive Interference Cancellation that can achieve the multiple access capacity region by superposing multiple users in the power-domain.

c): Conceive innovative methodologies for the dynamic, energy-efficient, and QoS/QoE-aware orchestration of communication and computational resources exposed in the considered 3D multi-layered communication architecture. This objective aims at realizing intelligent, self-sustainable control plane protocols to optimally exploit resources in a 3D environment. Furthermore, it is necessary to monitor the working conditions and QoS/QoE levels over multiple traffic types and links adopting different access technologies (terrestrial, aerial, and satellite), to promptly identify and mitigate events that significantly impact network performance and its information flows. This could be achieved by leveraging NFV, SDN, and network slicing principles, which enable the employment of dedicated orchestration strategies to manage resources and deploy services and functions, and advanced solutions based on Artificial Intelligence (AI). The benefits provided by the Mobile Edge Computing (MEC) technology will be leveraged as well.

D): Future 6G systems will be based on a strict integration among communication, computing, and intelligence bringing to a new architectural framework often named at AI-native network. ITS will gain a lot from this architectural framework considering its complexity and the strict requirement to be respected, where AI-based solutions are a necessity. When a terrestrial ITS is also extended toward air and space layers additional solutions should be taken into account trying to leverage on such a complex environment composed of a multitude of distributed nodes. With this in mind, some recent solutions consider the possibility of implementing distributed learning frameworks in T/NT environment where the several nodes around vehicular users can be efficiently exploited for implementing machine learning algorithms [17].

V. SUSTAINABILITY AS A DRIVER OF USE CASES AND PRELIMINARY ARCHITECTURE DEFINITION

a) Use Cases Suitable for the Automotive Sector

The ITA project will put special attention to the "wise" integration of T and NT networks towards a more sustainable future. In fact, it has to be pointed out, that according to Our World in Data, the transportation of people and goods is responsible for around one fifth of all global CO2 emissions, with 75% from road transport alone. Passenger transport accounts for 45.1%, and road freight to 29.4%. Aviation (11.6%), shipping (10.6%), rail (1%) and other (2.3%) make up the rest. Moreover, the number of road vehicles is expected to double by 2050. Therefore, the development of technology that enables an evolution toward optimal vehicle energy consumption is crucial. Connected cars show promising potential in optimized energy consumption and enable viable, attractive, more eco-friendly multi-modal transportation options.

For such reasons, ITA-NTN will focus on use cases that enable e reduction of CO2 emissions and more in general pollution. In this framework, an "improved" connectivity of cars and transport systems, will have a strong impact on the reduction of the greenhouse gas emissions. Several studies have shown the significant potential for the environmental benefits of connected cars. On the other hand, ITA-NTN also focuses on improving the sustainability on Earth without further "polluting" the space and hence, any architecture, within the 3D multilayered architecture, which will be selected for providing specific services, will also consider other types of requirements such as, for instance, the maximum number of satellites, the capability to reuse space or terrestrial infrastructure as much as possible. Therefore, ITA-NTN will focus on use cases that on one hand are the enabler of autonomous driving, and on the other hand, contribute to the reduction of CO2 emissions. Table 1 shows some of the use cases, with the relative communication requirements such as [18]: High-Definition Maps, communication with an intelligent road infrastructure, and platooning. All these three use cases are strictly related to the concept of autonomous driving, but even with a lower level of autonomy significant benefits are expected in terms of reduction of greenhouse gas emissions.

High-definition maps (HD maps) of the terrain are a key technology-enabler for autonomous driving. As it is linked to safety, the availability of the service is a key requirement, so levels of 99.9% or higher are required. Moreover, it requires continuous connection, using broadband connectivity (4 Mbps in uplink and 16 Mbps in downlink). LEO constellations could cover such needs, delivering the required bandwidth and latency plus the global coverage achieved with support from satellite communications. The communication with an intelligent road infrastructure (V2I) such as traffic lights, crossings, streetlights, as well as communication between vehicles for speed coordination and common start/stop could enable the achievement of a continuous traffic flow, which has been proved as the most effective way to reduce fuel consumption and CO2 emissions. By enabling shorter distances between cars while maintaining required safety levels, road infrastructure usage can be optimized thanks to such communications. In general, low data rates, in the order of a few kbps, are needed. Moreover, being an optimization and not a safety-critical application, moderate service availability levels of 95% could be considered adequate and in rural areas could be provided by LEO constellations. Platooning is a special case of continuous traffic flow where groups of vehicles move together in a coordinated manner, with the same speed, and keeping at very close distance. This method also leads to improved fuel consumption by reducing aerodynamic drag and keeping vehicles at a constant speed and it will be a key enabler of autonomous driving. Again, satellites could play a key role in remote areas in delivering connectivity without the need for time consuming roll-out of terrestrial infrastructure across borders and without roaming costs.

Use case	Downlink	Uplink	Availability	Latency
HD-maps	4Mbps	16Mbps	99,9%	<100ms
V2I for continuous flow	50kbps	50kbps	95%	100ms
platooning	50kbps	50kbps	95%	Not sensitive

Table 1: communication requirements of some connected cars applications

b) Preliminary investigation of reference architectures

In line with the high-level overview reported in Figure 1, the integrated T/NT architecture can be divided into three main parts: users, ground/ocean, and space/air segments. The user segment includes users with a wide range of QoS/QoE needs. As a result, it is important to broaden the scope of the offered service to a larger and more varied user base of the automotive scenario, by allowing users in areas without coverage to access the services provided by the terrestrial network [19]. Furthermore, the ground/ocean segment contains existing terrestrial and ocean networks that must be connected via ground facilities (i.e., T/NT gateways) with the space/air segment. In this context, the ITA-NTN project aims at investigating the performance of different types of T/NT architectures. In particular, as shown in Figure 2, there are distinct types of architecture, depending on the roles allocated to the space/air section (e.g., UAVs, HAPs, or satellite), such as relay, gNB-Distributed Unit (DU)/Central Unit (CU), gNB, or gNB and Core Network (CN) mode [20].

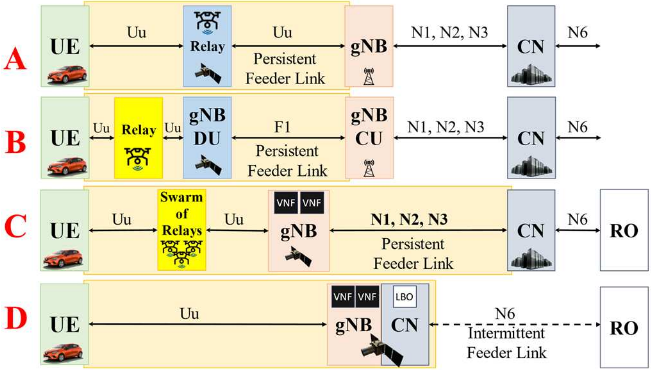

Figure 2 – Possible T/NT architectures of interest in the ITA NTN project.

In the first configuration (case A), the space/air segment acts as a relay between the user segment and the CN on the ground, without offering any processing functionalities. Relay nodes can be UAVs or HAPs deployed in the air segment, or a satellite in the space segment. The relay functionality can be implemented through Transparent or Regenerative mechanisms. In the latter case, the implementation can be supported by recent Integrated Access and Backhaul (IAB) specifications [21].

In the gNB-DU/CU mode (case B), the RAN can be split into two separate parts, with the DU hosted onboard and the CU being placed on the ground. In this configuration, the UAV (or the HAP) would act as a relay node between the user and space segments that are able to avoid possible challenges for autonomous driving in environments where the impairments limit the satellite signal penetration (e.g., tall buildings). Additionally, only the NR-Uu lower layers are directly processed onboard the satellite, enabling, for example, easier resource management procedures suitable for the Intelligent Transportation System (ITS).

On the contrary, the gNB mode (case C) provides direct access to all base station functions for the user segments. This configuration enables the onboard loading of the entire gNB, which can minimize signaling toward the ground. However, ground-based functions are still necessary. Indeed, it requires a swarm of UAVs to interface directly with the user segment, by using the satellite as a traditional gNB. Nevertheless, the information must be processed in the CN, which will continue to be hosted on the ground.

In the final configuration (case D), both gNB and CN can be accommodated onboard, enabling network functionalities without the need for a persistent feeder link to the ground. By enabling Local Break-Out (LBO) of data plane traffic, this configuration facilitates direct delivery of IP services at the network’s edge, which is represented by the satellite platform. It is especially beneficial in locations where there is no terrestrial coverage and the feeder link is intermittent, making it impractical to use additional structures that require human maintenance, such as UAV recharge stations. This feature can introduce the opportunity to operate autonomous rescue and emergency vehicles in remote locations without any telecommunications infrastructure. Additionally, not using UAVs and introducing higher intelligence and autonomy into the satellite may reduce delays that can occur during the relaying process. Nonetheless, this setup also leads to an increase in the payload design's complexity.

In conclusion, considering one of the most challenging open issues in the automotive scenario is related to the high delays, it becomes essential to bring a portion of the intelligence contained within the CN one hop away from the users. In this context, the advanced solutions presented in cases C and D allow for the effective management of dynamic and diverse resources within the T/NT architecture, resulting in reduced costs, enhanced flexibility, and the ability to support multi-tenancy and QoS/QoE for individual users and applications in the context of 6G. For instance, thanks to the Resource Orchestrator (RO), it will be possible to deploy innovative in-network processing functions through Virtual Network Functions (VNFs) by implementing smart traffic, smart collision management, and security services among autonomous vehicles. These services can be directly provisioned onboard the first available satellite, thereby minimizing the communication delay and the service outage. To achieve this, it is important to configure a RO capable of coordinating all the flying resources and optimizing the deployment of services in an optimal manner, which can be hosted on the ground [22].

VI. CONCLUSIONS

The ITA NTN project will contribute to the design and analysis of future 6G integrated Terrestrial and Non-Terrestrial networks. The research activities performed to this aim will have a strong impact for the advancement of knowledge of wireless networks, ensuring seamless connectivity, network resilience, reliable connections of mobile users and increasing the throughput under difficult propagation conditions. Strong partnerships are expected to be established with relevant industries, global telecommunications players, and standardization bodies. ITA NTN will also pursue scientific excellence in Italy and Europe by disseminating scientific results through academic venues (international conferences, journals of high profile, publications in journals dedicated to multidisciplinary discussions). Moreover, the use of an integrated system between Terrestrial and Non-Terrestrial networks will allow access to greater connectivity in areas where terrestrial networks are not available or have limited capacity, so it will have an impact on the digital divide and on digital transition, and will contribute to a more digital, green, sustainable, and resilient future.

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