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5G Smart Connectivity Platform for Ubiquitous and Automated Innovative Services

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Abstract—**Offering seamless connectivity for Next-Generation Internet (NGI) services has become a widespread concern to achieve global sustainability goals. In this position paper, we focus on the design of a smart connectivity platform that can extend its capabilities beyond the boundaries of what today's 5G architecture can support. The proposed platform encompasses and integrates a wide range of technologies, spanning from Non-Terrestrial Networks, NTNs (GEO/LEO satellites, and airborne) to terrestrial cellular 5G and long-range low-power Internet of Things (IoT) networks. We enhance 5G technology with novel network architectures and network intelligence to meet coverage and capacity requirements; and by strengthening infrastructure management and control components with autonomous capabilities to decouple operational costs from growth in network traffic, cloud computing, and IoT. Finally, we discuss the technical, commercial and market challenges that need to be overcome before the commercial deployment of the designed platform becomes reality.**

Index Terms—**Beyond 5G (B5G), Non-Terrestrial Networks (NTN), Satellites, UAVs, Internet of Things (IoT), Seamless Connectivity, Extended Coverage, Autonomous Networks.**

I. INTRODUCTION

The 2030 Agenda for Sustainable Development [1], adopted in 2015 by all United Nations (UN) member states, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. This global action plan included UN targets for internet access in the least-developed countries to ensure that connectivity is *"universal and affordable... by 2020."* Unfortunately, those targets were not met. At the end of December 2020, the global internet penetration was 63.2%, with a growth rate of 1200% over the last 20 years [2]. However, while that growth is impressive, it means that close to 40% of the world's population remains unconnected. Penetration rates are as low as 47.1% in Africa, 55% in Asia, and 70% or lower in the Middle East, Oceania, and Latin America. Europe, at 87.7% penetration rate, is "well connected" but the unconnected 13.3% is still significant with Bulgaria, Romania, Poland, and Portugal lagging behind the other countries. During the COVID-19 pandemic, it became more evident that internet access is a basic necessity for economic and human development in both developed and developing countries. Expanding connectivity to combat COVID-19 became an imperative [3]. Governments recognized the importance of having internet access to control the spread of the virus, save lives, and allow for the exercise of several rights. It is also clear that without connecting everyone to the Internet with universal, affordable, open, secure, and high-quality connectivity, there is a high risk of failing to meet all of the other sustainable development goals by 2030. The challenge to overcome is how to expand connectivity and internet access to more (and ultimately all) of humanity at a faster pace, but with a sustainable economic and environmental cost profile. The Digital Transformation market size was estimated at US$998 billion in 2020 and is expected to expand at a compound annual growth rate of 18.5% from 2021 to 2026 [4].

Digital technologies, specifically 5G and technologies beyond connectivity such as cloud computing, and Internet of Things (IoT) are becoming essential for enterprises to innovate, compete, and ultimately survive. These technologies improve efficiency and customer experience, and help the development of new products and services, and new business models. 5G has enabled new types of networking [5]. By design, it provides extended capacity to enable next-generation user experiences, empower new deployment models and deliver new services. 5G is intended to adapt to different application use cases, and deliver higher multi-Gbps peak data speeds, ultra-low latency, more reliability, massive network capacity, higher availability, and more uniform user experience to more users. Higher performance and improved efficiency empower new user experiences and connect new industries. 5G brings wider bandwidths by expanding the usage of spectrum resources, from sub-3 GHz used in 4G to 100 GHz and beyond. Network slicing will enable the creation of virtual networks on top of a single set of physical infrastructure, thereby enabling greater resource utilization, and isolation between different traffic profiles with completely different workloads (and therefore operating costs). Finally, and importantly: 5G has been designed for forward-compatibility - the ability to flexibly support future services that are unknown today [6].

Despite all the capabilities that 5G has already provided, industry and society require more - this brings the need of "beyond 5G" (B5G). More and/or better technologies are necessary for low-cost and affordable network solutions, ultra-dense networks, networking convergence with cloud and IT, and backhauling to remote areas. In particular, the integration of terrestrial networks (cellular, Wi-Fi, etc.), with NTN, e.g. satellites and high altitude platforms (HAP), must be seamless to enable consistent and robust service delivery [7]. In this position paper, we focus on the approaches to support the smooth integration of NTN and heterogeneous terrestrial networks, which will coexist in upcoming (beyond) 5G systems.

We address the aforementioned challenges by enhancing 5G technology with novel network architectures and network intelligence to meet the coverage and capacity demands while fortifying infrastructure management and control components with artificial intelligence (AI), machine learning (ML) and autonomous capabilities to decouple operational costs from growth in network traffic, cloud computing, and IoT.

The rest of the paper is organized as follows. Sec. II describes the ubiquitous connectivity platform, with its main functional blocks, and its 10 stacks (components). Sec. III overviews some of the innovative services supported by such platform. In Sec. IV the automation concept and the principles of the autonomous network framework are presented. Sec. V compares the proposed platform with existing 5G PPP platforms, highlighting its innovative aspects, and the challenges toward its real deployment. Finally, Sec. VI concludes the paper.

II. SMART CONNECTIVITY PLATFORM

Extending capabilities beyond the boundaries of what today's 5G architecture supports, implies the need to extend 5G concepts, such as *embracing and integrating a broader range of technologies*. In this work, we exploit the combination of Geostationary Orbit (GEO) and Low Earth Orbit (LEO) satellites, existing 5G infrastructure, flexibly established Unmanned Aerial Vehicle (UAV) networks, and long-range low power IoT networks to provide pervasive wireless connectivity. This will result in an enhanced 5G wireless network with higher capacity, more reliability, improved coverage, and lower latency than current combined 5G and GEO/MEO satellite networks. Figure 1 provides a high-level visual representation of the main features supported by the proposed smart connectivity platform:

- *Smart Infrastructure*
- *Efficiency*
- *Control*
- *Security and Trust*

For further detail, Table I describes the main features supported by the platform.

A. Network Architecture

The network architecture of the proposed ubiquitous connectivity platform is shown on Figure 2. It comprises three different segments: terrestrial, and both NTN space and aerial. In particular, it integrates NTN (satellites and UAVs) with terrestrial 5G, cellular and non-cellular IoT, where resources become available dynamically according to the evolution of technologies and services. The figure also highlights the main 10 *"stacks"* or *"separated network components"* (described in Sec. II-B) that are integrated, managed and coordinated by the platform. A distributed 5G/4G core network is used, comprising a central core network located in the centralized data center, and edge core functions located nearer points of consumption by both humans and devices. The core network connects to the rest of the network over IP. The business operations center is co-located with the centralized part of the core network. The "engine room" for the business operations center is the Command Control and Coordination (CCC) center, which is in the same location. CCC serves as a common data collection and storage, and information exchange platform. Finally, business-centric operations dashboards integrates the CCC.

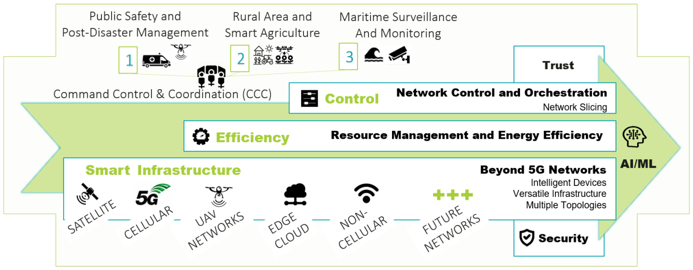

Fig. 1. Smart Connectivity Platform.

B. Network Components (Stacks)

The 10 main network components of the system can be classified according to their main segment of operation. Tables II, III, and IV summarize the characteristics of the components belonging to space, aerial and ground segments, respectively. Hereafter we describe the interaction among the different stacks within each segment.

Integration in the Space Segment: inter-satellite links (ISLs) between LEO satellites ("stack 2" and "stack 3") will be fundamental to relay data from remote service areas to the gateway. ISL between LEO satellites of the same constellation operationally achieved via CubeSats, are capable of performing ISL transmission of hyperspectral imaging or data. Future LEO Very High Throughput Satellites (VHTS) might be also used if higher throughput is needed. GEO-LEO ISL, between "stack 1" and "stack 2", allows transmission of visual imagery/data faster to the backbone (if the satellite gateway "stack 7" is not within the range of LEO constellations). "Stack 3" includes also LEO satellites integrating in-Space LoRa gateways for extended connectivity to terrestrial IoT devices.

Integration in the Aerial Segment: Three types of aerial stacks will be integrated into the others segments: a) Airborne

TABLE I
5G SMART CONNECTIVITY PLATFORM FEATURES

Features	Description
Network **Control** and orchestration	Dynamic control and orchestration of NTN (satellites, UAVs) integrated with IoT and cellular 5G. Network configuration and management are based on real-time monitoring of its state and usage.
Resource management and Energy **Efficiency**	Dynamic radio, computing and caching resource allocation based on different QoS requirements. Application scenario-specific and business-specific QoS requirements. Energy efficiency improvements based on optimized solutions (e.g. energy harvesting and energy-based users association).
Smart Infrastructure (5G, satellites, UAVs, IoT, edge, cloud)	High, long and wide-area coverage via integrated satellite networks. Quick, on-demand, and service access in remote areas via UAVs. Network slicing and integration with 5G technologies and edge-cloud intelligence.
E2E **Security and Trust**	End-to-end features to protect identity, privacy, security, and trust. Strong authentication, device security and network security.

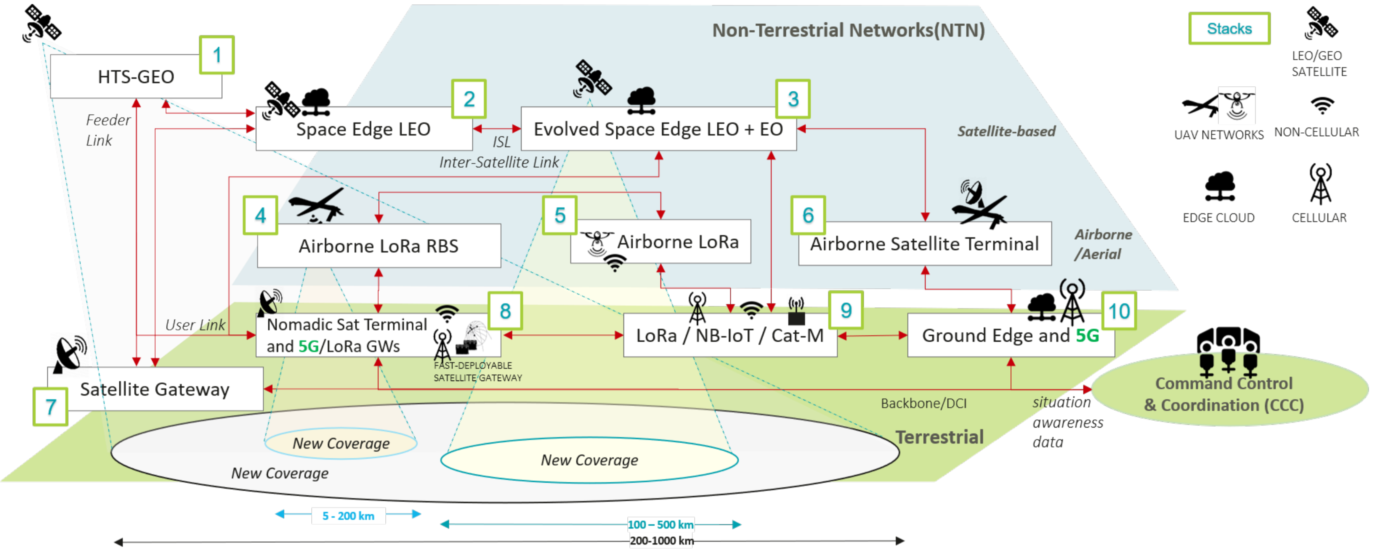

Fig. 2. Network Architecture of the proposed 5G Smart Connectivity Platform, including an overview of its 10 separated network components (stacks). The platform provides extended coverage to underserved areas by means of satellite and aerial vehicles capable of generating coverage beams over a given area - reducing the need of deploying terrestrial networks.

TABLE II
STACKS IN THE SPACE SEGMENT

#	Stacks (Separated Network Components)	Description	Feature
1	HTS-GEO	A High Throughput Satellite operating in GEO space	New Connectivity Storage
2	Space Edge LEO	ISL between HTS-LEO and HTS-GEO satellites	New Connectivity Compute & Storage
3	Evolved Space Edge LEO + EO	An HTS constellation of LEO satellites supporting: (i) low-cost services, using miniaturized technology; (ii) service with low latency; (iii) visual imagery; (iv) IoT traffic optimizations	New Connectivity Compute & Storage

UAVs "stack 4" (fixed wings) integrating LoRa Radio Base Station (RBS) with localization capabilities b) Airborne UAVs "stack 5" (hexakopter) connected by means of LoRa for visual imagery and c) Airborne UAVs integrating a satellite terminal and 4G/5G connectivity "stack 6" will be capable of transmitting visual imagery and data of a disaster area via LEO satellites and/or cellular terrestrial infrastructure.

Integration in the Ground Segment: On the ground segment, emergency trucks will be able to deploy nomadic satellite terminals "stack 8" that will integrate cellular and non-cellular gateways to provide additional connectivity in remote disaster sites. The nomadic terminal will either integrate a powerful edge serving as CCC or reach the CCC via the HTS GEO satellite. The nomadic terminal will centralize a fast deployment of different networks allowing to rely visual imagery/data from the aerial segment of the platform "stacks 4-5", from the terrestrial IoT "stack 9" as well as from smartphones and other end-user equipment with broadband or voice demands. IoT sensors "stack 9" can also be connected to the core 5G network (or other cellular networks) via NB-IoT and Cat-M. Further, IoT data might also exploit LEO connectivity "stack 3" to extend coverage in rural, remote, and disaster areas.

TABLE III

STACKS IN THE AERIAL SEGMENT

#	Stacks (Separated Network Components)	Description	Feature
4	Airborne LoRa RBS	Base station functions on board the airborne vehicle	Service/transport Optimization, localization strategies
5	Airborne LoRa	UAV/UE for visual imagery	New Connectivity, smart ad-hoc strategies
6	Airborne Satellite Terminal	Satellite terminal on board of an Airborne UAV with 4G/5G connectivity	New Connectivity, Security, Network Control, Service/transport Optimization

TABLE IV

STACKS IN THE GROUND SEGMENT

#	Stacks (Separated Network Components)	Description	Feature
7	Satellite gateway	Access to backbone for GEO/LEO satellite networks	Network Control
8	Nomadic Sat Terminal 5G/LoRa GWs	Nomadic Satellite Terminal integrating LoRaWAN Base station + 5G-ng eNB	Security Network Control
9	LoRa / NB-IoT / Cat-M	IoT sensors with cellular or non-cellular connectivity	New Connectivity
10	Ground Edge & 5G Network	Access to 4G/5G core and Backbone	New Connectivity

III. INNOVATIVE SERVICES

A vision of enhanced coverage for currently unserved areas (sea, air, rural and remote areas) is attractive for many applications. Among them, we have identified three: (i) public safety and post-disaster management; (ii) rural area and smart agriculture; and (iii) maritime surveillance and monitoring, as those that may benefit more from the proposed platform.

A. Public Safety and Post-Disaster Management

A key factor for successful emergency operations is reliable communication and real-time access to critical information [9]. Our ubiquitous connectivity platform, with its key features (seamless connectivity, resilient and reliable infrastructure, data sharing from multiple sources - IoT, UAVs, EO) can support public safety communication and contribute to saving lives in emergency situations. Furthermore, a step forward in Disaster Management (DM) services could be taken, making use of valuable data provided by distributed IoT sensors that are deployed during the disaster response (e.g. earthquake sensors, flooding sensors) and drones controlled in real-time via heterogeneous 5G networks. The integration of EO data, sensors and data coming from drones into a common operational picture will allow the commander in chief to have a better situational awareness and a more efficient management of disaster recovery. Integrating AI for decision support will further improve the decision-making process and allow a faster response to changing situations. All together, these new services will make disaster recovery more efficient, help to save lives and reduce the impact of disasters on civilians.

B. Rural Area and Smart Agriculture

Current agriculture and rural communication solutions rely typically on cellular coverage in those areas where available, or in local dedicated solutions. However, with the rise in adoption of wide-area IoT technologies such as LoRa, NB-IoT and Cat-M, which ensure better coverage and service than standard 4G cellular technologies to rural areas, connectivity is starting to improve and smart solutions are starting to flourish [10]. With our smart platform, integrating IoT technologies and satellite technologies, connectivity will be extended allowing for a massive deployment of new IoT devices and reliable remote control of certain applications while keeping the battery efficiency of the devices. Further, by enhancing monitoring and actuation in end-to-end decision-making systems, our platform can help in optimising the production, maximize the profit and minimize the costs. This will enable better data extraction, communication exchange and management, with environmental and socio-economic impacts for many actors of the IoT agriculture value chain, from farmers to IoT and satellite service providers.

C. Maritime Surveillance and Monitoring

With two-thirds of Earth's surface being covered by water, the sea is considered as a key component for sustainable development. As a result, human activities at sea have increased exponentially over the last decades, and with them, also the risk of accidents. Some of these activities (pollution from accidents such as oil spills, illegal fishing, etc.) have severe consequences on the environment and on people's lives. Thus, maritime surveillance and monitoring are of foremost importance, and sharing data is the key to make it cheaper and more effective. While the most common source of data and communication solutions for the maritime domain relies respectively on satellite images and satellite links [11]. Other data sources are becoming more and more available, spanning from IoT devices to UAVs. And several new radio technologies (5G and beyond) are emerging and offering dedicated alternative communication links.

IV. AUTOMATION: 4TH DIMENSION OF B5G

The promise and potential value of 5G has been widely publicized with the so-called "5G triangle", depicted in the left side of Figure 3. The main narrative around this triangle is the different types of networks, and therefore service requirements that can be created using a single set of telecom and IT infrastructure.

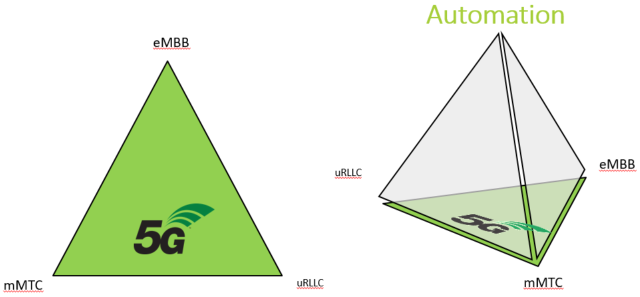

Fig. 3. Automation: the 4th dimension of B5G systems.

5G networks have to handle an exponential increase of connected devices and flexibly serve the needs of a broad range of business verticals while providing ubiquitous communication. The cost of this flexibility is a significantly increased complexity. This complexity is necessary, but it should not, in any way, detract from the adoption and consumption of 5G. To address this complexity, we propose to add a fourth dimension: *automation*, as shown on the right side of Figure 3.

This new dimension, like the others, needs to be actively managed. Autonomous networking will bring a step-change in how humans and machines (AI) work together to manage networks and services, and as responsibilities gradually shift from human to machine there will be a need for increased observability on the automation to validate its utility, correctness, and cost benefits. We incorporate in our connectivity platform significant automation improvements to enable autonomous capabilities, such as autonomy, deployability, and adaptability.

A. TM Forum Autonomous Network Framework

To drive significant efficiency gains and enable new revenue growth opportunities for Telcos and current future ecosystem partners, TM Forum has developed a business-driven user-centric framework for autonomous networks [12]. The framework consists of a "3-layer, 4-closed-loop" stack enabling automation across and within business, network operations, and network resource layers. To fulfil the aforementioned closed loops, the key mechanisms are (i) simplified network architecture to reduce the complexity, (ii) autonomous domains for resource closed loops, (iii) cross-domain collaboration for network operations closed loop, and (iv) business ecosystem enablement for the outer loop. Six autonomous levels are defined, aligned with the automotive sector SAE J3016 [13] standards, enabling operators to measure and assess the autonomy of their operations with the view to improving them over time. Levels 0 through 3 are lower autonomy, where humans are doing all or some of the operational tasks, while levels 3-5 are where the network stack is doing more. L5 is the ultimate "zero-touch" scenario where the network is doing all operations. Realistically, in the first instance, the levels will apply at feature or use case level rather than at the entire network operation, e.g. monitoring and troubleshooting of mobile broadband could be L4.

Similar to the TM Forum autonomous networks framework, our proposed smart platform employs a 3-layer approach to connect the network infrastructure in a domain- and technology-agnostic manner and expose the required connectivity and cloud computing services to the partner and business ecosystem. This is illustrated in Figure 4. Our platform is driven from the use case requirements to deliver specific capabilities for the end-user applications, specified using intent primitives. An intent specifies what is needed, but not how it is delivered, enabling decoupling between the architectural layers. An intent is typically specified at customer and business layer, and is translated into lower level intents at service, and then technology domain layers. As they progress down the stack the intents become more additive - e.g. a customer will not expressly demand all the correct and required security requirements for a service - these are added to an intent "payload" as it is translated and understood at lower layers. Situational awareness represents awareness around the business application, leveraging sensor data such as video, picture, sensor information, localization, etc. Context awareness represents service specific and cross-service contextual information that are relevant to control and orchestration decisions at the connectivity platform layer. The autonomous technology domains, shown as access, transport, core, and DC/cloud are self-configuring, self optimising, and self-healing technology domains implementing closed control loops driven by intent. Using one example (access network): when issuing an intent the service operations layer does not specify its requirements in terms of cellular, non-cellular, or terrestrial. The network intent is instead expressed in a technology agnostic way, requesting access service with nominated performance criteria, for a given set of connected clients with given device capabilities, in a nominated geographic area. The access controller will translate this intent and issue the resource allocation request towards the most appropriate technology (5G, SatCom, or LoRa). If the service has specific resiliency criteria, a hybrid resource allocation may be made, towards both 5G and SatCom simultaneously, for example.

AI will play a large role in implementing the desired autonomy and self-governance that is characteristic in new autonomous networks. We envision that AI/ML is employed to realize the following:

- Intent-based networking, monitoring and reacting in real-time to changing network conditions, and consequently adapting to different network topologies.
- Closed-loop AI/ML mechanisms based on context-aware and metadata-driven policies to make automatically actionable decisions.

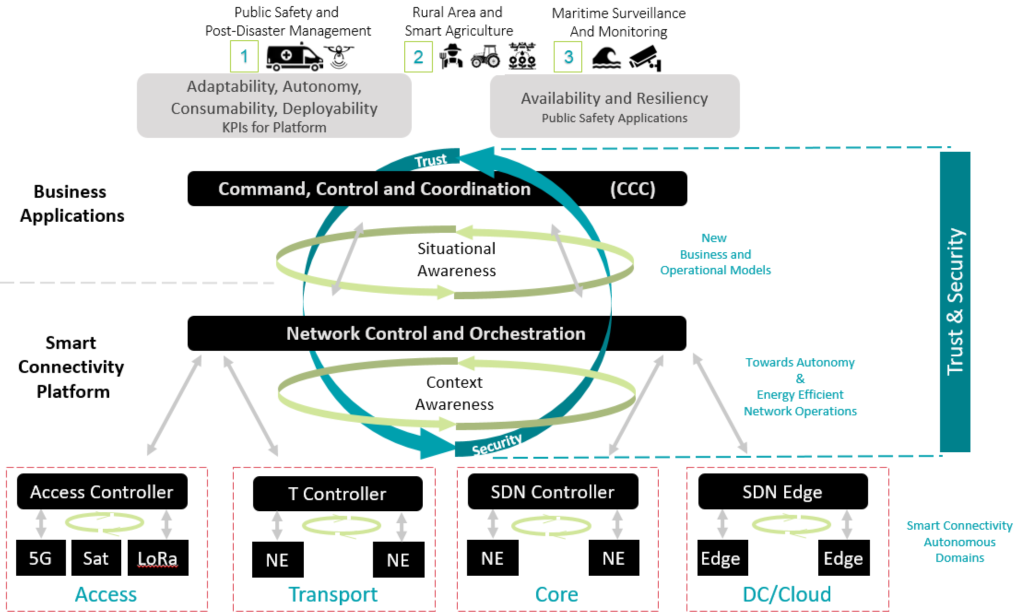

Fig. 4. TM Forum Autonomous Network Framework applied to the Smart Connectivity Platform architecture.

- Proactive resource allocation decisions based on heuristics (rather than reactive approaches).
- Decision modules as software control elements realizing an adaptive control over the network resources and terminals in an end-to-end approach.
- Taking into account both network and individual terminal perspectives in the design, enabling cognitive functionalities at an application level.

V. 5G PPP PLATFORMS

A. *Existing 5G PPP Platforms*

The 5G Infrastructure PPP platforms projects [14] – 5G-EVE, 5GENESIS and 5G-VINNI – aim to interconnect several European 5G sites to create unique 5G end-to-end facilities. These facilities will provide a large-scale end-to-end 5G validation network infrastructure, in order for vertical industries to execute and test their 5G-ready applications and business cases. The 5G-EVE platform (4 facility sites) for instance will be used to test a large panel of use cases related to Industry 4.0, Smart Cities, Smart Transport and on-site live events. Each site has already deployed the required 5G capabilities (up to Rel-15), validation tools and systems, and the secure connectivity for enabling the initial experimentation of use cases on them. 5G-EVE facilities rely on many 5G specific technologies and tools and provide to verticals several 5G capabilities: 5G Radio Access Network (RAN), Core, and Multi-access Edge Computing (MEC) platforms on each site. In the same context, the main objective of 5GENESIS platform (5 sites) is to validate 5G performances for various 5G use cases, like delivering low latency applications in large public events, providing smart connectivity for massive IoT or ensuring mission-critical services. For the latter, the facility in Limassol combines terrestrial and satellite networks with the ultimate aim of efficiently extending 5G coverage to underserved areas. Finally, the 5G-VINNI project (4 main sites and 4 experimentation sites) also include satellite in the proposed network architecture. In particular, the 5G-VINNI moving experimentation facility site is enabled by a satellite connected vehicle, GEO/MEO satellite backhauling and a virtualized satellite gateway which allows to address new categories of use-cases like public safety or disaster recovery, when compared to 5G-EVE and 5GENESIS.

B. *Advancement Beyond 5G PPP Platforms*

The proposed smart connectivity platform makes use of a new HTS constellation of LEO satellites, when compared to the three already existing 5G Infrastructure PPP platforms. Such constellations can offer higher throughput, with shorter latency, compared to HTS GEO/MEO. Some of those constellations of LEO low-cost CubeSats (like the one provided by Lacuna Space) integrate LoRa gateways, enhancing the integration of IoT devices. This extends the sphere of operation of IoT devices and improves the speed of network deployment, for instance in the case of post-disaster rescue operations. In addition to these new capabilities for IoT, the proposed platform also relies on drones for surveillance and for coverage extension. In the former case, drones are no more than 5G/satellite end-users while in the latter, they serve as relays between on-the-ground end-users and another network, as terrestrial 5G or satellite networks. To enable very large coverage extension, the platform considers multi-hop relaying through autonomous ad-hoc networks of drones. On the top of these new radio and relaying capabilities, the platform offers to Telco/SatCom operators the possibility to operate end-to-end slices over multiple heterogeneous networks. To this end, the platform includes an orchestration framework that allows the users to instantiate, modify, remove, or simply monitor end-to-end slices during runtime. The proposed platform employs autonomous network principles to implement full lifecycle operations automation across business operations, network operations, and network infrastructure layers. Autonomous domains (e.g. 5G NR, 5G Core, SatCom) are self-managed according to clear business or service requirements and policies, and will self-configure, self-optimise, self-heal, and self-protect according to the state and operating conditions it finds itself in. Feedback loops exist within domains, and between layers to enable appropriate resource, service, and business orchestration.

C. Challenges Toward Commercial Deployment

While the vision that we outline in this paper sounds appealing and promising, there are several technical, commercial, and market challenges to be addressed to realise it.

1) LEO satellite constellation deployment status: while the industry has made progress more is needed. Lowering satellite launch costs is one aspect, but perhaps more critical is the need to continue to reduce the cost of manufacturing (i) satellites, (ii) ground equipment, and (iii) user equipment.

2) ISL market readiness: ISL throughput and latency benefits, along with savings in backhaul costs, are indeed strong; however more work is needed to industrialise the technology and adequately counter the potential downsides. Specifically the complexity associated with antenna settings between satellites must be managed effectively, as does the power (fuel) consumption, and thus the lifetime expectancy. Note that this applies to LEO-to-LEO and LEO-to-GEO for GEO relay case.

3) LPWAN connectivity for Satellite IoT: LEO satellite suppliers must deliver fully featured LoRaWAN gateways for their LEO satellite products. Today the support is limited to uplink data transmission only.

4) Autonomous networking standards maturity: The standards for autonomous networking are still in development, and several standards development organisations are involved: TM Forum, 3GPP, ETSI, ITU, IETF, GSMA, etc. It is critical these groups continue to work together to realise full market acceptance and adoption of the technology. Common terminology, interfaces, and measurements are essential to ensure network autonomy becomes the norm.

5) Trust in autonomy: It is not enough that autonomous networking products and services are available, they must also engender trust in those that use and rely on them. To gain trust two key items require more elaboration, particularly in the area of additional telemetry in order to generate new metrics: (i) *consistency* and (ii) *explainability*. In other words, given the same starting state and set of inputs an autonomous system must demonstrate it consistently produces the same outcome. Decisions made by autonomous systems must be explainable in terms that make sense for humans who interact with them, and must also be free from any form of bias. Enhancements in human-machine interfaces may be required to fully enable the above features.

VI. CONCLUSION

In this paper, we focus on the challenges and approaches to provide seamless connectivity everywhere and to everyone. To this aim, we propose a 5G smart connectivity platform. The platform enables (a) service lifecycle management over heterogeneous connectivity media that are (b) made ubiquitous by the platform. To achieve (a) and (b) at reasonable cost a very high level of automation is introduced within the platform. Satellites, UAVs, long-range low-power IoT network technologies - all play a key role in delivering this seamless experience, extending cellular 5G networks to air, sea, and other remote areas. The platform explores and addresses several of the most critical success factors of future B5G systems, specifically: (i) user experience, (ii) cost and efficiency of network operations, (iii) agility and adaptability of network operations, (iv) resource efficiency and utilization. Innovative aspects of the platform, and challenges to overcome toward its actual implementation are also discussed.

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