

# *SliceNet: Enabling 5G use cases for vertical businesses*

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**Abstract**—Under the keyword 5G, the future network infrastructure targets to removal of limitations to current networks by addressing the challenges in managing, controlling and orchestrating a fully softwarized network and services running on the infrastructure. The use cases motivating 5G are so diverse and challenging that 5G networks must be customizable for a very broad range of individual scenarios. The Project SliceNet, part of the European 5G infrastructure PPP, is set to implement end-to-end multi-domain network slicing that provides a management plane for slices, as well as facilitating vertical business added value, coupled with optimized Quality of Experience (QoE) for the end users. This paper analyses the requirements derived from a set of use cases from different vertical industries including: Smart Grid Self-Healing, e-Health Smart/Connected Ambulance and Smart City, which collectively guide the development of the SliceNet architecture meeting the relevant Key Performance Indicators (KPIs) for these use cases.

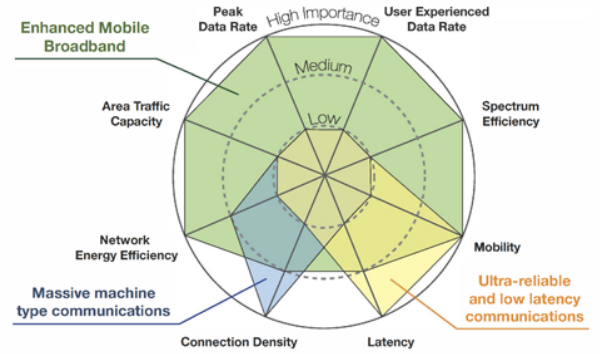
**Keywords**— *Network slicing; e-Health, smart grids, smart city*

## I. INTRODUCTION (Heading 1)

5G focuses on providing high Quality of Experience (QoE) not only for consumers, but also for industrial stakeholders with specific requirements for wide area wireless communications. The 5G communication infrastructure will be designed with native support for mission-critical services with high-demanding needs such as, among others, ultra-high reliability, ultra-low latency, enhanced mobile broadband, and/or global coverage. Cybersecurity issues will be thoroughly addressed by the 5G infrastructure, which aims to guarantee system integrity and to assure operational security. Fig. 1, originating in ITU-R Working Party WP 5D [1], approaches the level of importance for the 5G high-level requirements of 5G use case scenarios.

5G network providers are keen to offer networks as a service where “network slices” are created and allocated flexibly and efficiently to use cases, to provision logically isolated end-to-end networks for 5G users in multi-domain/operator environments. The role of a 5G operator is to deliver a tailored communication system to its customers (end users, enterprises or verticals) and, even more challenging, of enabling its customers (enterprises or verticals in this case) to customize, manage and control that communication system [2].

It is therefore required to provision a perceived integrated infrastructure that meets the requirements of verticals and utilizes the mobile and fixed infrastructure as well as digital assets that are owned by multiple stakeholders including the verticals. The term “perceived” refers to the ability of 5G to hide from the end users, enterprises and vertical businesses the actual complexity and heterogeneity in terms of technology and administrative (ownership) domains of the physical and virtual infrastructures over which the tailored communication systems are deployed and operated.



**Figure 1 Importance of the key capabilities for different usage scenarios of IMT beyond 2020 [1]**

In this paper, we describe and analyze the diverse use cases for verticals in the EU 5G-PPP SliceNet project. In particular, Section II introduces the project, Section III details three representative verticals use cases in line with the view of 3GPP 5G use case classification, whilst the requirements analysis of the use cases is described in Section IV. Finally, Section V concludes the paper.

## II. USE CASES OVERVIEW

H2020 5G-PPP SliceNet (<https://slicenet.eu>) designs, prototypes and demonstrates a verticals-oriented, QoE-driven network slicing framework that focuses on cognitive network management and control for end-to-end network slicing operation and slice-based/enabled services in 5G networks, based on Software-Defined Networking (SDN) and Network Function Virtualization (NFV) technologies. It tackles a

number of outstanding issues in 5G network slicing, in terms of tightly integrated end-to-end management and control, QoE analysis and management, customizable slice control exposed to customers (i.e. verticals), slicing scalability, cross-plane coordination and orchestration, security, and interoperability across multiple domains. It worth to note that the slice concept of SliceNet is compliant with that of NGMN, that is, a Network Slice Instance (NSI) comprises a set of run-time Network Functions (NFs), and resources to run these NFs, and an NSI can include zero, one or more Network Slice Sub-network Instances (NSSIs), following a recursive composition fashion. An NSI forms a complete instantiated logical network to meet certain network characteristics (e.g., ultra-low-latency, ultra-reliability) required by a service. Primary NSI examples include enhanced Mobile Broadband (eMBB), massive Internet of Things (mIoT), and Ultra-Reliable Low-Latency Communication (URLLC), as defined by 3GPP.

The integrated framework will be demonstrated through three representative vertical use cases: (i) Smart Grid Self-Healing, that demonstrates enhanced automation in energy distribution with self-healing capabilities; (ii) e-Health Smart/Connected Ambulance to show how to improve the emergency ambulance services using the ambulance as a mobile edge; and (iii) Smart City to demonstrate an Intelligent Public Lighting system in the city Alba Iulia in Romania.

### III. VERTICAL USE CASES IN SLICENET

In general, the three use cases present specializations of the 5G use cases, as described in the scope of the 5G-PPP and available in the vertical white papers [3]. The brochure “5G empowering vertical industries” [4] reviews the target performance parameters for 5G, currently being assessed globally and discusses the key performance parameters derived from a comprehensive analysis of them. The following subsections describe the details of the use cases in the scope of SliceNet.

#### A. Smart Grid Self-Healing

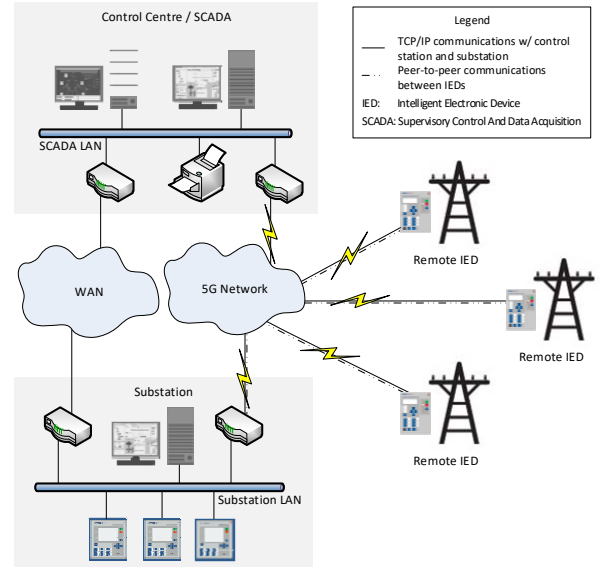
As depicted in the Smart Grid Architecture Model [5] (SGAM, proposed by the Smart Grid Coordination Group), interoperability at communication and information layers is key to drive the development of next generation smart grids. 5G technologies are a promising solution to drive new intelligent solutions for grid applications, particularly in the Distribution Automation (DA) domain. The effective implementation of Smart DA relies on the continuous investment in communication and automation technologies that allow the remote operation of the power network in nearly real time. Improving the level of monitoring and controllability of the power network ensures the possibility of implementing preventive actions that reinforce resilience according to the predicted evolution of the operating state, and deal with possible incoming contingencies, such as faults that could result in power outages.

Within the Smart Grid, advanced automation and protection schemes such as Self-Healing were designed to immediately detect and isolate faults and proceed with the automatic reconfiguration of the power network for service restoration.

In order to ensure the supply of maximum load within a certain distribution grid area affected by a fault, the Fault Detection, Isolation and Restoration (FDIR) procedures must be as agile and selective as possible, thus reducing both recovery time and affected customers to minimum. Immediately after a fault, Intelligent Electronic Devices (IEDs) that control the power switchgear equipment must rapidly re-coordinate, relying on high-speed communications to ensure critical selectivity during fault detection and isolation.

Regardless of the functional architecture adopted, the high-end protection, automation and control solutions used for implementing the advanced self-healing schemes may benefit from the URLLC provided by a 5G network slicing framework. Depending on the functional architecture, different high-level requirements may be requested from the Information and Communication Technologies (ICT) infrastructure.

The Smart Grid Self-Healing use case focuses on an IEC 61850-compliant communication-based decentralized solution. The use case comprises three scenarios which rely on IEC 61850 Generic Object Oriented Substation Events (GOOSE) and IEC 61850 Sampled Values (SV) for peer-to-peer communications for protection coordination, automatic power grid topology reconfiguration, and synchrophasor-based differential protection.



**Figure 2: 5G communications for Smart Grid Self-Healing**

Fig. 2 presents the 5G network-based communication architecture for the smart grid applications in the use case.

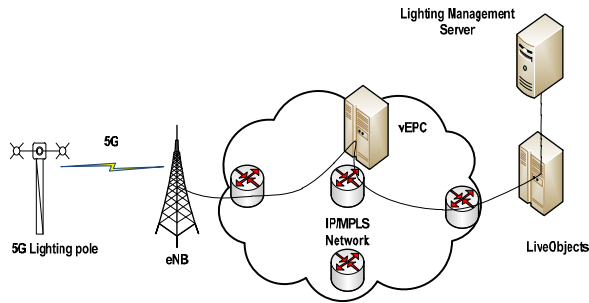
5G-PPP states that 5G will be focused on providing high QoE not only for consumers, but also for industrial stakeholders with specific needs regarding wide area wireless communications. The 5G communication infrastructure will be designed with native support for mission-critical services with high-demanding needs such as very high reliability, very low latency, or global coverage.

Communication-based applications for Smart Grid Self-Healing require an ultra-reliable communication infrastructure with ambitious specifications that, at present, cannot be fully implemented in public wireless networks. Bringing power system communications outside the substation isolated Local Area Networks (LANs) and extending them to Wide Area Networks (WANs) will increase the attack surface and potentially increase the vulnerability of such critical assets to cyber-attacks. Cybersecurity issues will be thoroughly addressed by the 5G infrastructure, which aims to guarantee system integrity and to assure operational security.

### B. Smart City

Over the last decade, the evolution of information technologies and communications networks, sensors, actuators, cloud infrastructure, big data and products/services based on these enablers has changed the way people live in cities. Access to information, services and communication is now provided anywhere and anytime by smartphones, and modern people have adapted to this new way of living.

In this use case, we observe how Alba Iulia, a small to middle size city in Romania with about 70k inhabitants, is moving forwards as a smart city by adopting the latest ICT technologies including LoRaWAN, LTE-M and finally 5G enablers. Alba Iulia has been selected by Orange to demonstrate the capabilities of the targeted smart city high level architecture in dealing with critical smart lighting infrastructure under the SmaLi-5G SliceNet use case. It is planned to build a live testing infrastructure of at least 100 smart controllers (actuators) in Alba Iulia that will be deployed on the main roads of the city.



**Figure 3: 5G general architecture for Smart City use case**

The SmaLi-5G use case to be demonstrated in the Alba Iulia pilot will consider the following high-level building blocks illustrated in Fig. 3.

- The network of connected actuators/controllers that will be deployed one per each public lighting pole and poles aggregation node from the selected area.
- The competing connectivity networks that will include: LoRaWAN, LTE-M and 5G technologies, each with its own access layer, transport layer, security layer, management layer and core layer network components.
- The open IoT middleware.

- The street lighting and energy management layer that integrates the connected actuators/controllers with web-based management applications, including a remote street lighting poles and energy management tool for the city to measure, manage and monitor connected public street lights by using a real-time, map-based view, and a street's lighting poles asset management application which helps maintenance planning and operations management.

This use case will implement a smart lighting service in a Smart City, over a 5G infrastructure, with slicing support, from IoT devices to the smart lighting cloud application. Two steps of implementation are depicted: (1) transition from existing LoRaWAN infrastructure to a LTE-M enabled network with KPIs and functionalities preservation, using the existing 4G network infrastructure, on RAN and Core physical infrastructure, with extension of implementation (1) to a virtualized EPC Core; (2) SliceNet 5G architecture and components within the open Smart City framework.

The SmaLi-5G use case will be considered in the scope of the 5G mMTC/mIoT category, where the challenge is to accommodate the massive number of connected actuators and controllers, without impacting QoS and QoE [6]. The case could be deployed to a real city, within a millions of lighting poles scenario, which will be connected to the network, as a massive IoT service. A further service requirement is to assure ultra-high network reliability and availability, while maintaining low-power, context awareness and location awareness requirements for managing the connected actuators/controllers over the access and transport layers, which will further improve this innovation's cost efficiency. This requirement will be especially important during daytime hours, when the smart streets lighting poles infrastructure is supposed to remain powered to facilitate other city services (e.g. public safety surveillance, air quality monitoring, public Wi-Fi hotspots, and advertising [6]).

The main goals of the SliceNet SmaLi-5G use case are: integration and testing of the Smart City SmaLi-5G vertical use case within the project's 5G communication framework; prototype demonstration of the SmaLi-5G targeting the requirements identified for this specific use case; demonstration of the openness of 5G to different radio access technologies; enhanced network management and network control and, prototype the network slicing model for the targeted use-case, based on SmaLi-5G requirements.

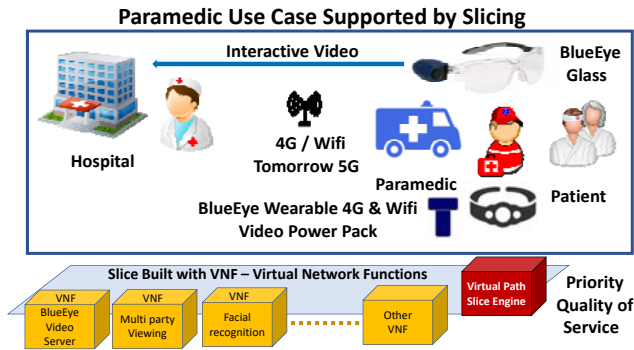
### C. eHealth

The aim of the SliceNet e-Health use case is to demonstrate how the rapid provision of dedicated end-to-end enhanced mobile broadband 5G slices can support first responder eHealth scenarios. E-Health is defined as the use of information and communication technologies (ICT) for health. It provides better decision making, enhanced diagnosis and more efficient, convenient and potentially cost-effective delivery of care [7]. 5G has the potential to enable new emergency prehospital services, built on Mobile Edge Computing (MEC), SDN and NFV [8]. Ultra-High Definition Video (UHDV) [9] can be used to track vital signs, motion, speech, pallor and demeanour, so

as to provide real-time prehospital diagnosis [10] and studies have indicated that demand for such services are growing [11], [12]. Cloud computing and machine learning are emerging as enabling technologies for healthcare, while slicing can be leveraged to meet the requirements for prehospital care.

eHealth approaches can support real-time treatment by first responders by wireless devices and video technology [7]. An “ambulance-to-hospital” based eHealth system is a good example of how 5G technology improves patient treatment pathways, as it enables remote diagnosis, provides on-scene care and reduces response time [13]. In SliceNet, we pilot a connected ambulance that will act as a connection hub for the emergency medical equipment and wearables, enabling storing and real-time streaming of video and scanned data to the awaiting diagnostic team at the destination hospital. It will leverage 5G eMBB [14], requiring both extremely high data rates and low-latency communication and reliable broadband access over large coverage areas.

The continuous collection and streaming of patient data will begin when the emergency ambulance paramedics arrive at the incident scene right up to the delivery of the patient at the emergency at the destination hospital. Video sensors will enable the provision of enhanced patient insights and the goal is for all paramedics to have wearable clothing that can provide real-time high-definition video feeds as well as other scanned or sensor related data pertaining to the immediate environment. Real-time streaming video will enable the awaiting emergency department professionals to remotely monitor the patient for conditions that are not easily sensed, such as skin pallor and patient demeanour. In other scenarios, medical scanning devices and sensor equipment could be 5G enabled to report health status to clinical and incident control staff.



**Figure 4: Scenarios that can potentially benefit from 5G SliceNet technology**

To achieve acceptable QoE and QoS in a 5G eHealth scenario, the Ultra-high reliability, Ultra-low latency data rates and KPIs shown in Table 1 are recommended [15], [8]. In addition, attention must be given to patient privacy and the end-to-end solution must meet the General Data Protection Regulation (GDPR) (Regulation (EU) 2016/679).

A variety of scenarios can benefit from SliceNet 5G technologies. Single patient events that could most benefit include ischemic stroke and cardiac arrest. Rapid diagnosis by

a proficient clinician using the NIH Stroke Scale (NIHSS) is critical to effective treatment and cannot always be determined by an onsite paramedic. In multi-patient scenarios, 5G technology could add significant benefits by providing real-time scene assessment using the METHANE protocol [12], which is used by emergency services to report major incidents. A mast or drone mounted 5G camera deployed from a connected ambulance could provide emergency service controllers with a valuable platform for real-time METHANE driven assessment and provide for both physical and virtual sensors and actuators. In such scenarios, an ambulance-to-hospital system is a good example of how MEC based machine learning technology can assist first responders [13].

#### IV. USE CASE REQUIREMENTS

5G will play a decisive role in the implementation of solutions for new visions and future services. The need of global coverage combined with ultra-low latency, as well as ultra-high reliability and security levels, combined with new networking experiences and services, creates a demanding environment. Network slicing could be the ideal solution for such an environment, offering scalability as well as flexibility in managing a giant and heterogeneous network. Network slicing in SliceNet enables creating multiple customized, logically isolated networks from the same, commonly shared 5G network infrastructure to provide cost-efficient, optimized and speedy solutions for these different use cases that are featured with diverging and demanding QoS/QoE requirements in terms of functionality, performance, flexibility, security and isolation etc., which otherwise would be too difficult, too slow or too expensive to be addressed in today's best-effort based monolithic networking paradigm.

Furthermore, the 5G vision is integrating wireless and fixed services by focusing on virtualized elements so that users can enjoy the same services regardless of how they are interconnected. Virtualization can play an important role in scalability too. The advantages of scalability and unification could unlock the ability to add new services, creating new experiences for users. Uninterrupted interconnection is another important requirement to consider for future services, such as self-driving public transport vehicles or in the crucial case of remote healthcare provision. In this complex and heterogeneous scenario, highly dynamic, flexible and coupled end-to-end slice management and control is required to take full benefit of 5G technologies and offer customized and verticals-oriented services. At 5G design level, several requirements are needed:

*A. Low latency* - The combination of low delays with the predicted increase of data traffic, makes low latency necessary.

*B. Availability* - 5G ensures uninterrupted interconnection, promising new services and new customer experience, including maximum geographical coverage so that user connectivity is continuous as he moves from place to place.

*C. High traffic needs* - As even more users would be interconnected with multiple devices, the rapid increase of data traffic needs to be considered in the network design, to avoid high latency or even interruption of a service.

*D. Low cost* - The extended network that 5G brings, coupled with increased services and new equipment, would increase the total operating cost of the network. It is important to keep that cost as low as possible.

*E. Energy efficiency* - 5G technologies will have to implement a large number of small base stations on traditional topologies in order to sustain both data volumes and capacity demands. Improving energy efficiency becomes an important target for the implementation of 5G networks.

*F. Scalability* - The architecture of 5G should be scalable in order to adapt to the diverse needs of users and services.

*G. Flexibility* - The heterogeneous resources of the infrastructure shall be managed, provisioned and controlled in support of customized and isolated network slices.

*H. Coverage* - The coverage of the small base stations is expected to be improved at the cell edges in order for the networks to sustain high bit rates especially at the edges.

*I. Security* - Strong and consistent Authentication, Authorization and Accounting (AAA) mechanisms across all parties of the 5G infrastructure is required.

Table 1 presents a summarized comparison of the most relevant 5G requirements from the three SliceNet use case.

**Table 1: Summary of SliceNet Use Case 5G Requirements**

Requirements	Smart Grid	eHealth	Smart City
Availability/reliability	99.999 %	99.999 %	99.999 %
Wide-area coverage	Yes	Yes	City area
Connection density	< 0.5 device/km <sup>2</sup>	Low	200000 users/km <sup>2</sup>
Traffic volume density	Very low	Low	700 Gbps/km <sup>2</sup>
Multi-domain slicing	Yes	Yes	Yes
Mobility	-	Yes	-
Security	Yes	Yes	Yes
End-to-end latency	≤ 10 ms (GOOSE); ≤ 5 ms (SV)	30-100 ms	Seconds to hours
Data rate, per device	≤ 20 Mbps (GOOSE); ≤ 2 Mbps (SV)	60 to 150 Mbps	Very low

## V. CONCLUSIONS

A diverging range of challenging use cases need to be supported in 5G networks for various vertical businesses with

high QoS/QoE assurance and in a cost-efficient fashion. The EU 5G-PPP SliceNet project addresses this challenge by systematically exploring and developing network slicing as the key enabler to achieve this vision by delivering varied end-to-end services across multiple domains to meet the strict performance requirements in terms of latency, availability, traffic, cost, energy efficiency, scalability, flexibility, coverage, security and so on. Three diverse vertical use cases have been selected and presented to represent three major 5G use case categories as defined by 3GPP. These use cases include Smart Grid Self-Healing, Smart City Smart Lighting, and e-Health Smart/Connected Ambulance, which correspond to the 3GPP 5G URLLC, mMTC and eMBB use case categories respectively and thus can leverage these three standardized slice types. SliceNet is applying the identified requirements from these representative vertical use cases to the definition and development of a novel 5G network slicing and slice management framework, following a vertical-informed and “verticals in the loop” approach.

## ACKNOWLEDGMENT

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