5G European Validation platform for Extensive trials

Deliverable D1.1
Requirements Definition & Analysis from Participant Vertical-Industries

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Editor(s):	Velissarios Gezerlis, Tilemachos Doukoglou, George Agapiou (OTE)
Author(s):	S. Canale, M. Tognaccini, L. de Pedro, J. Jesus Ruiz Alonso, K. Trichias, D. Meridou, P. Vlacheas, V. Stavroulaki, A. Georgakopoulos, v. Foteinos, I. Maistros, G. Loukas, V. Audebert, V. Gezerlis, T. Doukoglou, V.Gezerlis, I. Stefanakis, M. Kitra, A. Tzoulis, E. Tzifa, R. Legouable, Roberto Gavazzi, Paolo Scalambro, I.Benito Frontelo.
Reviewer(s):	Claudio Casetti, Jaime Garcia-Reinoso
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List of Acronyms and Abbreviations

Acronym	Description
3GPP	Third Generation Partnership Project
5G PPP	5G Public Private Partnership
aaS	as a Service
AGC	Automatic Generation Control
AGV	Automated Guided Vehicle
AP	Access Point
BER	Bit Error Rate
BPON	Broadband Passive Optical Network
BS	Base Station
CAPEX	Capital Expenditure
OPEX	Operative Expenditure
CDN	Content Delivery Network
CPRI	Common Public Radio Interface
CRM	Customer Relationship Management
CSA	Coordination and support Action
CSC	Communication Service Customer
CSP	Communication Service Provider
C-V2X	Cellular Vehicle-to-Everything (C-V2X)
DCSP	Data Centre Service Provider
DetNet	Deterministic Networking (IETF)
DMS	Distribution Management System
E2E	End-to-end
HER	Electronic Health Record
EPC	Evolved Packet Core
ETP	European Technology Platform
ETSI	European Telecommunications Standards Institute
eMBB	enhanced Mobile Broadband
FLISR	Fault Location Isolation and Service Restoration
HMI	Human Machine Interface
ICT	Information and Communication Technology
IEEE	Institute of Electronics and Electrical Engineering
IETF	Internet Engineering Task Force
IMT	International Mobile Telecommunications
IoT	Internet of Things
IP	Internet Protocol
IPR	Intellectual Property Rights
IRTF	Internet Research Task Force
ISG	Industry Specification Group (ETSI)
IT	Information Technology
ITU-T	International Telecommunications Union – Telecommunications standardization sector
GMS	Game Management System
GTT	Gruppo Torinese Trasporti (Transport Group of Turin, the local company of public bus)
KPI	Key Performance Indicator
LMR	Land Mobile Radio
LTE / -A	Long Term Evolution / -Advanced (3GPP)
MANO	Management and Organization
MCPTT	Mission Critical Push To Talk
MEC	Multi-Access Edge Computing
MME	Mobility Management Entity
mMTC	massive Machine Type Communications
MNO	Mobile Network Operator
MTP	Mobile Transport and Computing Platform
MVNA	Mobile Virtual Network Aggregator
MVNE	Mobile Virtual Network Enabler
MVNO	Mobile Virtual Network Operator
NaaS	Network as a Service
NE	Network Element
NEP	Network Equipment Provider (NEP)
NFV	Network Functions Virtualization
NFVRG	NFV Research Group (IRTF)

NGMN	Next Generation Mobile Networks
NOP	Network Operator
NSO	Network Service Orchestration
OBSAI	Open Base Station Architecture Initiative
ODL	OpenDayLight
OEM	Original Equipment Manufacturer
OF	Open-Flow (ONF)
ONF	Open Networking Foundation
OPNFV	Open Platform for NFV
OTT	One Trip Time
PCRF	Policy and Charging Rules Function
PMC	Probability of Missing Command
PoP	Points of Presence
PTP	Precision Time Protocol
PUC	Probability of Unwanted Command
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RHB	Right Holder Broadcasters
RO	Resource Orchestration
SCF	Small Cells Forum
SDN	Software Defined Networks
SDNRG	SDN Research Group (IRTF)
SDO	Standard Development Organization
SO	Service Orchestrator
S-/P-GW	Serving / Packet Gateway
SLA	Service Level Agreement
SME	Small Medium Enterprise
Sync-E	Synchronous Ethernet
TDM	Time Division Multiplexing
TLC	Telecommunication
URLLC	Ultra-Reliable Low-Latency Communications
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything
VAS	value-added services
vEPC	virtual EPC
VISP	Virtualization Infrastructure Service Provider
VNF	Virtual Network Function
VR	Virtual Reality
VRU	Vulnerable Road User
VS	Vertical Slicer
WG	Working Group
WPF	Wind Power Farm

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Executive Summary

This deliverable reports on the set of identified use cases and the initial requirements coming from vertical industries that are considered relevant for the project. It also analyses key project performance indicators and how they relate to the ones identified by 5G-PPP. The scope of this deliverable, which is the first document of WP1, is to describe the following Vertical industries:

- Use case 1 - Smart Transport: Intelligent railway for smart mobility
- Use case 2 - Smart Tourism: Augmented Fair experience
- Use case 3 - Industry 4.0: Autonomous vehicles in manufacturing environments
- Use case 4 - Utilities (Smart Energy): Fault management for distributed electricity generation in smart grids
- Use case 5 - Smart cities: Safety and Environment - Smart Turin
- Use case 6 - Media & Entertainment: UHF Media, On-site Live Event Experience and Immersive and Integrated Media)

The peculiarities and the main characteristics of each use case, from different verticals, are highlighted and analysed.

The main outcome of this deliverable consists in detecting/extracting/collecting a set of requirements from the use-cases defined by the internal vertical-industries participating in the 5G-EVE project. For each use case two types of requirements are used, general requirements and more specific requirements.

Each of the participating partner presents a detailed description of all Verticals Use Cases. Also, definitions of all requirements are given (both general and specific) and an introduction to the methodology of information gathering and analysis is described. The analysis compares the capabilities of existing 4G/LTE networks as well as those promised by 5G network technologies with the requirements for proper operation for each of the Use Cases above and each sub-Use Case (also referred to and as scenario). The analysis is also presented in graphical forma with extensive use of radar charts. Moreover, the results of the requirements definition for each Use Case and Sub-Use Case (12 in total) is listed. The tables with the requirement values are given and in some cases, explanation is also provided.

The most universally demanded requirement from the verticals is the increased Reliability and Availability of the Networks and Services offered to end-customers. There is a tendency to migrate and/or develop all new services to the upcoming 5G networks even if the requirements do not need the enhanced capabilities of 5G. Finally, after Reliability and Availability, the most important parameters are Latency and Capacity of the Network.

The requirements given per UC in this deliverable, can be used as an input for the subsequent work-packages of 5G EVE.

1 Introduction

This deliverable lists the requirements from vertical industries participating in 5G-EVE. It identifies the main requirements taking contributions from previous projects, standards bodies and 5G-EVE vertical industries partners. These requirements will be used as a reference to build the 5G-EVE end to end facility subsystems integration and capabilities.

This first deliverable initially focus on the first part of WP1 activities i.e. on requirements definition and analysis by project vertical industries partners, starting with the analysis of the six main use cases presented in Chapter 3. Every vertical industry identifies the high-level use cases and requirements.

In a second step all these high-level requirements will be translated into 5G-EVE end to end facility requirements. The high-level requirements have to be common across the Use Case since all of the Applications will have to use the same 5G infrastructure. Special requirement for certain Use Cases do exist but we focus on the more general that are common for all the scenarios.

The WP will later address external vertical industries not participating in this project, including: those participating in ICT-19-2019 call, systems interoperability of core applications as defined in ICT-22-2018, or other vertical industries not connected to the H2020 programme. The aim is to cover new areas in order to strengthen requirements lists and identify opportunities for standardization. The output of this later activity will be presented in Deliverable D1.2, including the requirements from all potential vertical industries as defined in ICT-19-2019 as well as systems interoperability of core applications as defined in ICT-22-2018.

Finally having the requirements from a grand total of 12 UCs and Sub-UCs in total will help us to identify some trends in terms of the more desired characteristics or capabilities that have to be implemented / built in the end-to-end facilities of the 5G EVE project.

More specifically, in Chapter 3 a detailed description of all Verticals Use Cases and sub UCs is presented gathering inputs from each of the participating partner.

In Chapter 4, the definition of all requirements is given (both general and specific) and there is an introduction to the methodology of information gathering and analysis that is performed in the next Chapter.

In Chapter 5, the results of the requirements definition for each User Case and Sub-Use Case (12 in total) are listed. The tables with the requirement values are given, with the specific analysis and explanation.

Beyond the requirements compilation (per UC), a radar chart (the concept of which is being introduced in Chapter 2), that visualizes the general requirements per UC using as a backdrop the capabilities of 4G/LTE and 5G networks is created and presented. From each radar chart, and the corresponding tables, information with respect to the adequacy (or sufficiency) of the existing 4G/LTE networks, as well as the urgency (or need) for 5G network capabilities (per Use Case) are being drawn.

Finally, even though not scientifically accurate (since the sample size is small – only 12 Use Cases) due to the lack of time and data, the 5G requirements are being prioritized in terms of the demand it was observed for the participating UCs.

2 Purpose of User Requirement Analysis

Requirements analysis is critical to the success or failure of a system or software project. The requirements should be documented, actionable, measurable, testable, traceable, related to identified business and customer needs (top-down analysis) or opportunities, and defined to a level of detail sufficient for system design and/or service deployment.

As technology evolves (4G to 5G), new services are offered, and more sophisticated networks are needed. The increasing number of Internet users leads to a redesign of network architecture (core, access and radio), forcing designers to take into account new parameters such as the need of global coverage combined with low latency, as well as a high reliability and security level. Requirement analysis encompasses those tasks that go into determining the needs or conditions to meet for a new or altered service or product, taking account of the possibly conflicting requirements of the various stakeholders.

2.1 Expectations

As specified in the ISO 9241-210 standard (ISO, 2010, Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems[1]), user-centred design begins with a thorough understanding of the needs and requirements of the users. The requirements should be documented, actionable, measurable, testable, traceable, related to identified business needs or opportunities, and defined to a level of detail sufficient for implementation. The benefits can include increased productivity, enhanced quality of work, reductions in support and training costs and improved user satisfaction. With the advent of 5G technologies new networking experiences are added such as Internet-of-Things (IoT), virtual and augmented reality (VR and AR), mission critical applications, massive machine-type communication, Gigabit mobile (on the go) connectivity and others which promise to offer new services and facilities to people's daily lives by creating "smart" homes and "smart" cities as well as vertical synergies between different markets. 5G services promise to implement new visions and deliver novel solutions within the framework of this demanding and competitive environment

A major innovation introduced by 5G technology is scalability. 5G architectures take into account the possible need of extending the capabilities of the network, both at the level of user traffic growth and at the level of new service offerings from providers. There is a steady upward trend of wireless connectivity, which is projected to be continued in the future with an exponentially increasing rate. This phenomenon poses a challenge for network designers: the integration of wireless and fixed services so that users can enjoy the same services regardless of how they are interconnected. The vision of 5G technology regarding ubiquitous access is to deal with this challenge by focusing on virtualized elements, which could be shared between wireless and fixed networks. The advantages of scalability and unification would unlock the ability to add new services that will create new experiences for users. 5G will ensure the uninterrupted interconnection of a user when, for example, he is steaming during his trip to work. This ability of uninterrupted interconnection could also be very important in services such as self-driving public transport vehicles or in the crucial case of remote healthcare provision.

[1] ISO 9241-210:2010 provides requirements and recommendations for human-centred design principles and activities throughout the life cycle of computer-based interactive systems. It is intended to be used by those managing design processes, and is concerned with ways in which both hardware and software components of interactive systems can enhance human–system interaction. It is published by the Technical Committee ISO/TC 159/SC 4

2.2 Main 5G Requirements (eMBB, URLLC, mMTC)

One may consider **Enhanced Mobile Broadband** (eMBB) characteristics for data-driven use cases requiring high data rates across a wide coverage area. eMBB will enable, among other applications, real-time AR and VR and will make the mobile internet experience faster and more seamless. eMBB can be seen as the first phase of 5G, which will be encompassed in the **3GPP Release 15** standards update (due for completion in the third quarter of 2018). Taking connected cars as an example, the first phase of eMBB services will involve enhanced in-vehicle infotainment, like real-time traffic alerts, high-speed internet access, streaming real-time video or playing games involving 3D 4K video.

5G Phase 2 will go beyond eMBB services to more transformational URLLC and mMTC applications and will be included in **Release 16**, which is due to be completed at the end of 2019 (future requirements). The second phase would be autonomous vehicles on a mass scale able to connect to and interact with other vehicles and the surrounding road infrastructure. **Ultra Reliable Low Latency Communications** (URLLC) poses strict requirements on latency and reliability for mission critical communications, such as remote surgery, autonomous vehicles or the Tactile Internet whereas **Massive Machine Type Communications** (mMTC) requires support of a very large number of devices in a small area, which may only send data sporadically, such as Internet of Things (IoT) use cases.

In Figure 1, usage scenarios correlated with the three main 5G requirements are presented.

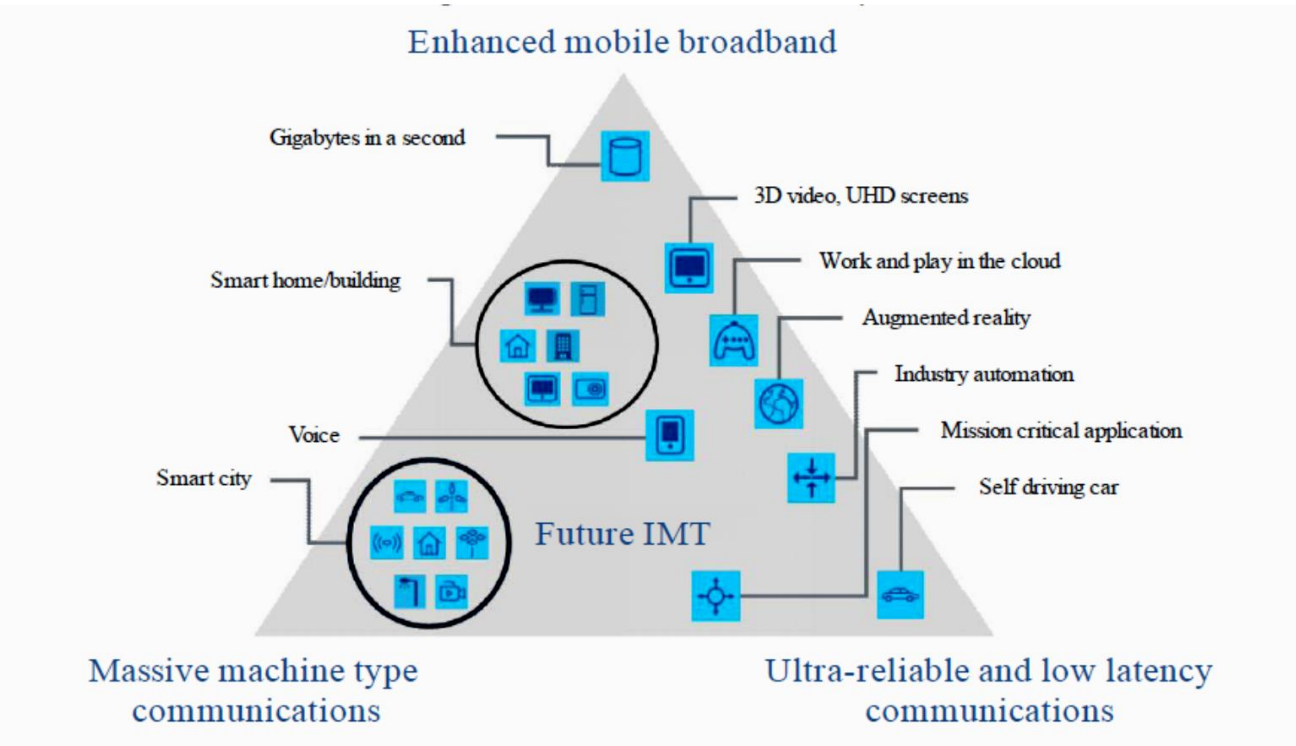


Figure 1: Usage scenarios for eMBB, mMTC and URLLC

In 5G-EVE project six main different Use Cases will be implemented during the three years interval. The Use Cases are the following and will be described in detail in chapter 3:

a) Smart Transport: Intelligent railway for smart mobility

b) Smart Tourism: Augmented Fair experience
c) Industry 4.0: Autonomous vehicles in manufacturing environments
d) Utilities (Smart Energy): Fault management for distributed electricity generation in smart grids
e) Smart cities: Safety and Environment - Smart Turin
f) Media & Entertainment: UHF Media, On-site Live Event Experience and Immersive and Integrated Media)

In Table 1, a mapping of each use case to the corresponding 5G requirements is presented.

Table 1: Mapping of 5G EVE verticals to the 5G requirements

Requirements	Smart transport	Smart tourism	Industry 4.0	Utilities (Smart Energy)	Smart cities	Media & Enter-tainment
URLLC (Ultra Reliable Low Latency Communica-tions)	✓	✓	✓	✓	✓	✓
eMBB (Enhanced Mobile Broadband)		✓				✓
mMTC (Massive Machine Type Communica-tions)	✓			✓	✓	✓

2.3 Methods for user requirements analysis

There are a lot of methods for an effective user requirements gathering and analysis [1], [2]. In our case, where six different main UCs has to be implemented for the needs of 5G-EVE, the following method is used:

- General capabilities of 4G and 5G has to be considered and illustrated with the differences between them.
- General 4G/5G requirements for each use case has to be gathered and illustrated into tables
- Special 4G/5G requirements for each use case has to be gathered and illustrated into tables
- General gathered requirements for each use case has to be illustrated into graphs in correlation with the general 4G/5G capabilities
- Final analysis for each use case requirements can be extracted from the tables and graphs

The above methodology will be followed during this project and is describes in detail in chapter 4 and 5.

2.3.1 Effectiveness of user requirements analysis

Judging the worth and impact of vertical implementations is a complex task involving subtle analysis. Qualitative methods to explore the effectiveness of vertical implementations include user interviews, observations and open-ended questionnaires targeting all stakeholders in the process. Quantitative measurements of such quantities as data-rate, link capacity, availability, latency and others can be used for evaluation and comparison. To this direction, **generic and specific user requirements** that will result as ad hoc measurements per vertical, shall be evaluate against specific criteria. In Table 2 the most common general and specific 4G/5G vertical requirements are presented. These requirements will be used for the final analysis based on Radar Chart (see Figure 2).

Table 2: Generic and specific user requirements used for evaluating verticals

General Vertical/Use Case Requirement	
	Latency (in miliseconds) - Min/MAX
	Speed (in Mbps) - Min/MAX - bitrate
	Reliability (%) - Min/MAX
	Availability (%) - Min/MAX
	Mobility (in m/sec or Km/h) - Min/MAX
	Broadband Connectivity (peak demand)
	Network Slicing (Y/N)
	Security (Y/N)
	Capacity (Mbps/m^2 or Km^2)
	Device Density
Specific Vertical/Use Case Requirement	
for Network	Number of End Points
	Number (Range) of End Devices per End Point
	Density of End Devices (per sq. Kmeter)
	Bitrate needs per end point Uplink UL (Mbps)
	Bitrate needs per end point Downlink DL (Mbps)
	End -to-end Latency (msecs)
	Highest Acceptable jitter (msec)
	Number of Class of Service (1-8, more)
for End Devices	Type of Device (i.e. Smartphone, TV, VR)
	Bitrate required Uplink (Mbps)
	Bitrate required Downlink (Mbps)
	Max Latency Allowable (in msecs)
	Max Moving Speed (km/h, 0 if stationary)
	IPv4 & IPv6 support (or both)
	Connection of Device to End Point (Wired/Wireless)
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)
	Authenication method (i.e. SIM, eSIM, Key..)

A **radar chart** is a graphical method of displaying multivariate data in the form of a two-dimensional **chart** of three or more quantitative variables (zones) represented on axes starting from the same point. It is a flexible graph format because one can combine a number of attributes, metrics, and other report objects. Its minimum requirements are that one attribute and one metric be present on the report grid. They are known with such alternative names as *Spider Charts*, *Web Charts*, *Polar Charts*, *Star Plots*. The relative position and angle of the axes is typically uninformative. A typical example of a radar chart is illustrated in Figure 2. The larger the area defined by the radar chart, the better the implementation of a 5G service. Radar Charts are also useful for seeing which variables are scoring high or low within a dataset, making them ideal for displaying performance. Grid lines that connect from axis-to-axis are often used as a guide. Each variable value is plotted along its individual axis and all the variables in a dataset and connected together to form a polygon. However, there are some major flaws with Radar Charts. Having multiple polygons in one Radar Chart makes it hard to read, confusing and too cluttered. Especially if the polygons are filled in, as the top polygon covers all the other polygons underneath it. Having too many variables creates too many axes and can also make the chart hard to read and complicated. So it's good practice to keep Radar Charts simple and limit the number of variables used.

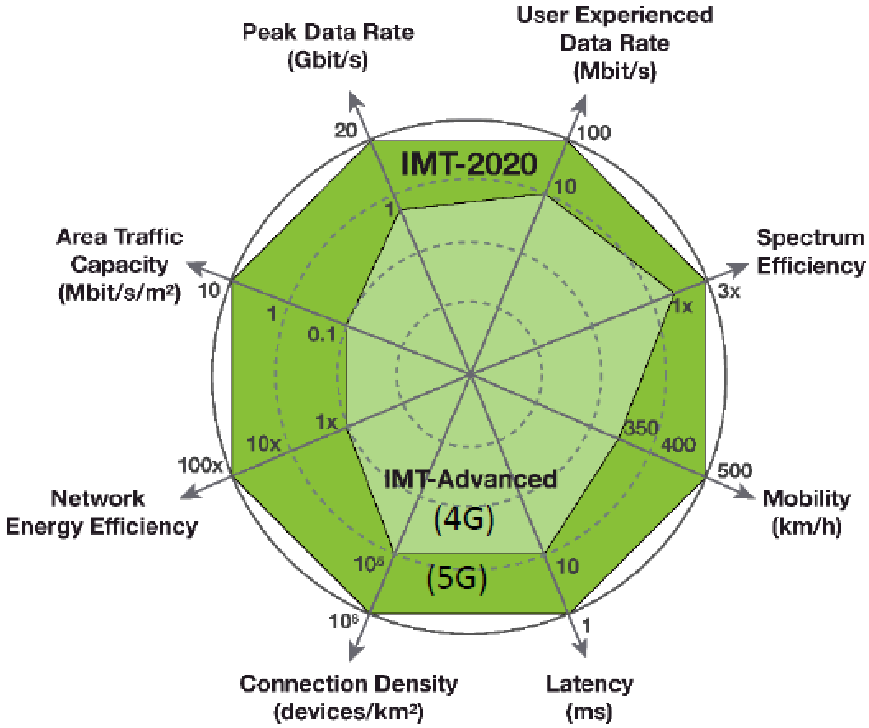


Figure 2: Example of Radar Graph of the design targets for IMT-2020 [3]

3 High-level definition of the internal use-cases proposed in 5G-EVE

5G PPP has put forth relevant 5G scenarios, service perspectives, requirements and KPIs that allow for a well-rounded evaluation of the 5G technologies. The resulting use case families are mapped to corresponding business cases identified by vertical industries [4] and can all fit under three main 5G umbrella scenarios, namely enhanced Mobile Broadband (eMBB), massive Machine Type Communications (mMTC), and Ultra-Reliable Low-Latency Communications (URLLC). The combination of a well-defined use case with the appropriate evaluation metrics [6][7], allows for the quantification of the effect of certain technical solutions on the users Quality of Experience (QoE) as well as the 5G system's performance under realistic, measurable, and verifiable conditions.

5G-EVE will cover a very broad spectrum of scenarios, addressing a multitude of 5G PPP use case families [4] and 5G PPP defined KPIs. Exemplary use cases from the most important vertical fields have been selected to showcase the suitability of 5G to successfully handle the main requirements of each field, as defined by 5G PPP. Through the complementarity of the selected use cases, the versatility and universality of 5G connectivity will be demonstrated since the same technology (5G) will handle (among others) the "worst case" ultra-fast, ultra-reliable requirements of the energy sector [13], the increase of several orders of magnitude in number of assets, volume and variety of info and decreased reaction times of industry 4.0 [15] and the "any-device, anywhere" connectivity demands for user-generated, immersive and interactive media content [14] of the media & entertainment sector. Six exemplary use cases (5G-EVE will not be restricted to only these use cases) to be tested in the 5G-EVE end to end facility, covering the most important requirements from multiple vertical industries, are defined in detail in this section.

The 5G-EVE consortium includes a number of vertical industries that represent the main segments of the 5G umbrella scenarios mentioned above. Having these vertical industries as partners in the projects, allows 5G-EVE to receive direct specific requirements that the 5G end to end facilities must address in order for them to successfully validate such a facility (achieved by participation in Task 1.1).

In the following in this chapter, all the 5G-EVE proposed use-cases and sub use cases are defined and described. For each use case the following information is given:

- in which **scenario of 5G PPP** belongs (e.g. URLLC, eMBB, mMTC)
- a **general requirements definition** for the use case
- which **site facilities** are participating to the use case
- **a high-level architecture and description** of the use case
- what are the **targeted KPIs** for the specific use case
- some information about the **demo environment**, where the use case will be implemented
- if there are specific **integration needs**

This structure is followed for each subsection that describes a proposed use case.

3.1 Use case 1 - Smart Transport: Intelligent railway for smart mobility

Intelligent transportation paradigms are one of the main vertical industries targeted by 5G, since the wide applicability of the sector as well as the stringent requirements on latency, reliability, mobility and BW, provide a challenging use case. Trenitalia (TRIT) will lead the experimentation in this area using the following example use case:

5G PPP scenario: *URLLC and mMTC.*

General requirements definition: TRENITALIA is interested in the improvement of its internal Big Data processing capacity as well as in Network Energy Efficiency Management in order to be able to customize and enhance the quality of the provision of proximity services (i.e., proximity marketing) for the Mobile End User. To this end, massive IoT connectivity and Mobile Edge Computing (MEC) facilities are required for railway transportation to be able to handle the ultra-low latency, high reliability and mobile broadband connectivity needs of this use case.

Use case Description*:* On the road towards Intelligent Transportation Systems (ITS) the integration of the railway network with other collective transportation services is essential. To that end, traffic and train management (optimization and control) enhanced by automatic identification of passenger mobility patterns, are necessary. Identification of enriched mobility patterns will improve overall traveller experience by (i) estimating aggregated mobility flows leading to optimization of real-time traffic management and congestion avoidance, (ii) identifying multi-modal transportation demands and performing spatial planning, leading to enhanced, personalized ancillary services and (iii) preventing congestion at exchange nodes leading to improved logistics efficiency as well as security. On top of that, the deployment of 5G MEC solutions will be utilized to improve network efficiency management for high speed trains, both in terms of energy consumption as well as data volume for "Entertainment at high-speed" (video streaming services).

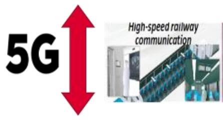
Participating site facilities: Site facility 4 – Italy

3.1.1 High level architecture and use case description

The vertical Smart Transport presents two main scenarios of practical interest from the transport operator's point of view: 1) 5G On Board Media content streaming and 2) Urban mobility 5G data flows analysis. The former mainly concerns On Board train services for passengers that 5G connectivity and mobility data will enable. The latter concerns integration of 5G data and mobility data from different transport operators to enhance distributed computing and pattern recognition to support urban multimodality between railway network and other collective transportation services (both public and private) and to realize more accurate and reliable Intelligent Transportation System (ITS).

Scenario 1 - 5G On Board Media content streaming

Train transport operators need of Ultra Reliable Low Latency Communications (URLLC) Connectivity performance answered by 5G Networks adoption can act as an incentive for the development of High quality 5G based services regarding different fields as On-Board Security and passengers' comfort.



One of these services is the innovative streaming of On-Board Heavy Media contents for entertainment and infotainment for train passengers segment of the daily High Speed services. The streaming data came from outside the train sources like video servers or other streaming sources.

Streaming of Media contents concerns the provisioning of movies, TV Shows and Music with 5G URLLC useful to interact with new generation of 5G mobile connections of trains' passengers.

Regarding the delivery of Heavy Media content on the High Speed Train, will be hampered by frequent handovers, a relevant barrier for the delivery of a high quality streaming media content.

Consequently, the most important requirements for the 5G Streaming services provision are related to:

- **Continuity of the services Media Streaming On Board**

  5G network application need to guarantee the physical broadband spectrum coverage (also considering critical communication) and reduce the negative effect of handovers in order to provide the passengers with a high quality of On-Board Streaming services in terms of continuity.

- **On Board Throughput of 5G Streaming provision**

Considering an initial average value of network density of 300-device connections on each daily service of High Speed Train, it is necessary to provide an average value of 5G Network throughput between 5 and 20 Mbps, as identified below in the 5G Throughput target KPIs, in order to deliver for each connected passengers an On Board high quality streaming service.

Scenario 2 - Urban mobility 5G data flows analysis

As mentioned, 5G Mobile Networks feature the Ultra Reliable Low Latency communications (URLLC) and massive Machine Type Communications (mMTC) scenarios, as well as distributed data storage and processing resources, applied on local public train transport (and also on other collective and private transport modalities). They can enhance Trenitalia's capability to develop real time analysis, on two distinct geographical areas (e.g., two railway stations like Torino Porta Nuova and Torino Porta Susa in city of Turin), and provide mobile data related services for commuters target considering:

- Development of tools for monitoring real time mobility passengers flows with the aim to improve railway traffic management in stressful or anomalous situations in rail transport and prevent situation of mobility traffic peak and bottlenecks in public transport for the On-Board services' management. For example, traffic flow heatmap and matrix of traffic of geo referred mobility;
- Provisioning of personalized and geo referred information services that can improve the passenger's customer experience both in the face of specific events that can alter the travel experience (interruptions of the train path or change of train times) and the provision of commercial info for the proximity marketing.

Data acquisition could be performed considering 5G Mobile Data via SIM and GNSS-supported 5G Communications with no direct involvement of user side specific applications running on personal devices, differently from current technology ((B. Sas, 2014), (Hsu, 2013)). In fact, through **5G Mobile Communications** it will be possible to elaborate the Data Set by Analytics software solutions and provide information for the definition of a Real time Innovative Dashboard able to support decision making in relation with traffic congestion management activities and provisioning of E2E of On Board and Off Board customized info-mobility services. In 5G network equipped with massive IoT connectivity and MEC facilities, collection of mobility data as well as specific mobility traffic pattern recognition are made possible as local applications hosted and running in distributed way on the core network side, so to allow local exploitation of data analytics based insight and information for Intelligent Transportation Systems.

Therefore, 5G network application is poised to improve the definition of safe, reliable and accessible local public train transport.

Perimeter of the analysis
Mobility flows among different modalities between Italian:

- Provinces
- Municipalities
- Cities
- Aggregation of districts

Basic Scenario needs
Acquisition of real time information with 5G Mobile Data via SIM and GNSS-supported 5G Communications regarding two specific geographical areas that entail Regions, Provinces, Aggregates of Municipalities, Districts. The aim is to develop with these data real time heatmap and matrix of static and dynamic traffic flow

density related to local public train transport (and also on other collective and private transport modalities). Heatmap/ Matrix of traffic flow will allow a quick understanding of:

- Number of trips for each travel segment with different transport modalities in a given period of time;
- Distribution by daily time slot;
- Distribution of traffic flow frequencies;
- Distinction of the Italian and foreigner users per each country, considering each train segment

Additional Scenario needs

The tools listed above will support the further acquisition of qualitative elements of transport demand on:

- Hypothesis of distribution of traffic flow per transport modality (it will be needed to understand the method of detection used by the mobile analytics to understand the type of transport modality used)
- Personal data (gender, age groups)

Comparing what has been detailed in terms of needs will be useful to analyze the feasibility/possibility in terms of time and cost to perform a drilldown. This will be accomplished by accurately specifying the municipalities or areas within the municipality where the mobility analysis within metropolitan areas will be carried out.

This could be performed as follows:

- Province: Understand areas of origin (neighboring municipalities) of commuters that daily move to the urban areas.
- Cities: Understand areas of origin (suburban neighborhoods) of citizens towards business areas (with offices) and Traffic flow differentials data set considering specific stressful events for traffic management
- Tourism: Distribution of tourist flows in places of interest considering a drill down on per time zone (i.e., weekly/monthly/yearly).

3.1.2 Targeted KPIs (Requirements)

The considered use of intelligent railway mobility will be set in an on-board demo environment framed on two main general requirements related to (Table 3):

- Number of devices: potential number of devices of On board 5G related services is set up to 300 per each daily train transport offering
- Mobility: an achievable value for a mobility of up to 300 km/h is considered in order to guarantee 5G collecting end-user position and contextual data

Table 3: General Requirements- Smart Transport: Intelligent railway for smart mobility

General Requirements	Value	Unit of Measure
Number of Devices	Up to 300	Devices per daily train service
Mobility	Up to 300	Km/h

From these demo framework requirements a set of target KPIs (Table 4) has been suggested regarding the URLLC and mMTC aspects in order to ensure Service continuity related to the On Board connectivity and high level of throughput provisioning level per passenger for the experimentation of the 5G End to End services of the Use Case.

Table 4: Target KPIs- Smart Transport: Intelligent railway for smart mobility

General Requirements	Value	Unit of Measure
Service Continuity	Up to 90%	Connection coverage continuity consid-

		ering 100 tests
5G Throughput Min/Max	5 to 20	Mbps per passenger (It depends from Quality Video Definition of Streaming Services)

3.1.3 Demo environment

3.1.3.1 Demo Environment Scenario1-5G On Board Media content streaming

The considered use case of Train On Board Streaming could be hypothetically tested considering a testing environment based on one train equipped with a Mobile Router Multimodem 5G, adjusted Antennas on the roof of the train (almost one per coach), and almost of an Access Point per coach, in order to offer to a target of 300 users per day a High Quality of On board Streaming.

The advantage of the installation of a Mobile Router Multimodem is the opportunity of the band aggregation in 5G considering many Mobile Operators. The number of antennas could be derived from the number of the Mobile Operator, the number of Modems installed into the Mobile Router, and the MIMO vs SISO technology. Part of the test could be also realized considering the opportunity of the carrier aggregation per single Mobile Operator.

The demo environment (Figure 3) will be based on a high quality 5G coverage provided by the network infrastructure of the Italian Mobile Operators, eNodeB along the line, considering a target rail segment in which the testing train commonly travels at a speed of 260-280 Km/h, and peak of 300Km/h, in almost 30 minutes[2].

In this way the testing environment could evaluate the performance of 4K/Full HD 5G On Board streaming at the peak of the train speed considering the complexity of the delivery of Heavy-Media Data due to the Handover effect experienced in the tested high-speed train segment.

[2] It is the max time in which the train crosses the target rail segment maintain a speed rate over 260 K/h

The overall testing electronic equipment needs to be installed considering:

- Non-invasive approach of installation of the Electronic equipment that can alter the rolling stock used for the testing activity
- Compliance of the equipment installation in the demo environment with CEI EN Standard regarding Railway applications —Electronic equipment used on rolling stocks

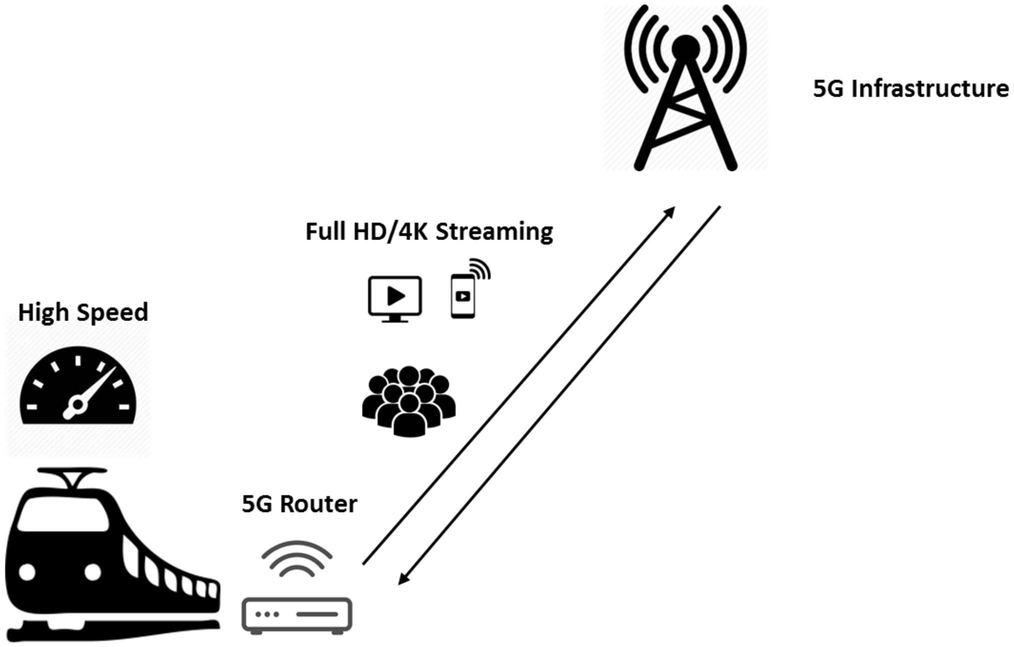


Figure 3: Architecture overview of Scenario 1- 5G On Board Media content streaming- Demo Environment

3.1.3.2 Demo Environment Scenario 2- Urban Mobility 5G data flows analysis and monitoring for traffic management for public transport

The considered scenario will target as first step of a potential small scale testing for the Development of Heatmap and matrix Origin / destination of the traffic flow with the various additional information required for monitoring the flow of daily traffic within the identified perimeter.

At the end of the small scale trial it should be possible to obtain the mobility flows related to the single type of transport used for the intermodal journey of the passengers considering the 5G Mobile Data and in relation to the type of commuter (e.g., local / tourist) and personal characteristics (e.g., age, type of traveller as a business / residential, gender, nationality, etc.) and related behaviours (frequency of travel to understand if they are commuters or not), distribution by time slot of travel and distribution of travel frequency, traffic flow differentials at events / events / conferences etc.

Consequently, it will be possible to develop a geo-referenced dashboard that highlights bottlenecks, traffic congestion of mobility streams and provides personalized and geo-referred info mobility notification services for the passengers.

The demo environment (Figure 4) should be on the basis of the previously detailed scenario considering the following architecture. According to scenario specific needs, 5G network should support high connectivity density (up to 100x number of devices per squared kilometer supported by current technology) to guarantee suitable coverage of devices for mobility data provisioning; ultra-reliable and low latency (from 1 to 5ms) connectivity to guarantee precise and reliable device positioning data in mobility; scalable data storage and processing units on RAN edge supporting MEC for analytics enabling close and accurate pattern analysis, in terms of both predictive and descriptive mobility flow analysis.

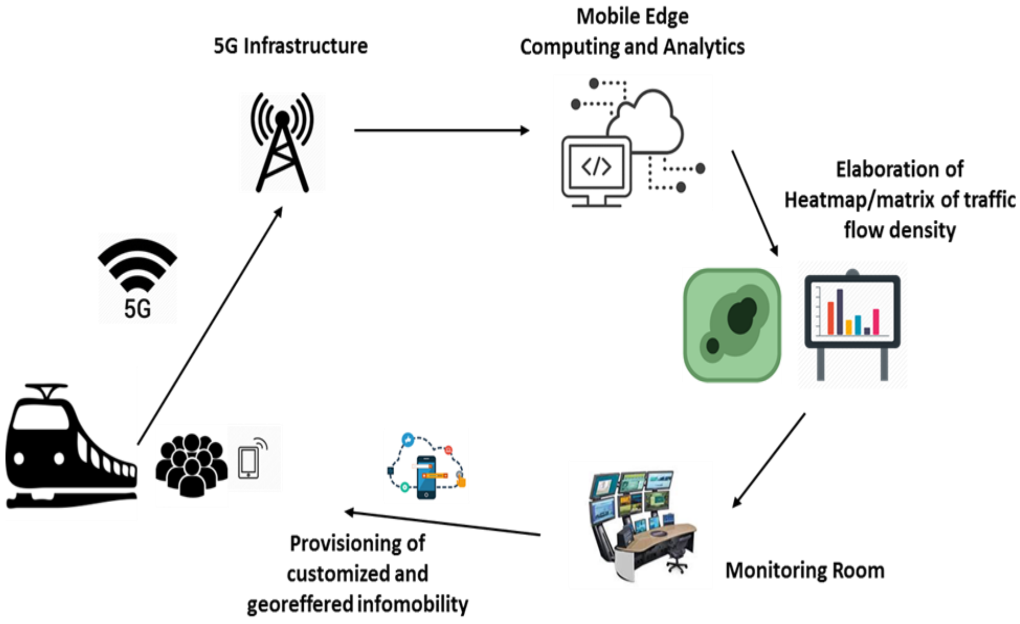


Figure 4: Architecture overview of Scenario 2-Urban Mobility 5G data flows Analysis and monitoring for traffic management for public transport- Demo Environment

3.1.4 Integration Needs

An overall integration of Communication technologies and infrastructure is needed, and specifically:

- Infrastructure elements integration and configuration
- 5G network availability
- Multimodem 5G Routers
- RAN/MEC servers availability
- Mobile Data Analytics solutions
- 5G Mobile testers
- Drive test equipment for basic performance testing activities on the achievement of target functional/technical KPIs of 5G connectivity
- Drive test equipment for the On Board 5G Video streaming customer experience in 4K/Full HD
  - Software simulation of the capability of the End users of the coach that be directly connected to a Video Streaming Service in 4K/Full HD passing from the Access Point bottlenecks of connectivity before achieving a 5G Mobile Router Multimodem
  - iPerf Test Equipment (Software simulation connecting 300 users directly with a 5G Mobile router to a Video Streaming passing over the Access Point in order to avoid connectivity bottlenecks to realize an active measurements of the maximum achievable bandwidth on the IP networks)

3.2 Use case 2 - Smart Tourism: Augmented Fair experience

Tourism activity must be considered a vast transversal industry involving a wide range of multiple providers and users which configure and determine its unique idiosyncrasies. This diversity obliges to conscientiously concrete the potential use cases participating in 5G-EVE projects so as to obtain real validation resulting from access to early state-of-the-art 5G features that can transform and improve the tourism sector globally.

5G PPP scenario: URLLC and eMBB

General requirements definition: SEGITTUR efforts are concentrated in trade fair centres niche, which host large industry events worldwide and is expected to provide means for an optimal interaction of users and exhibitors, before, during and after the event. In order to do so, uses cases selected should guarantee F2F experience of both exhibitors and visitors by incorporating more and more virtual and digital elements over time, relying on AR and Mobile technologies which in turn demand connectivity services of very high bandwidth, and fast connections and network response.

Use case Description*:* Augmented Fair aims at transforming the experience of Trade Fair events' users (exhibitors and visitors), with the objective of improving their interactions (information sharing, discussion, networking, negotiations and transactions) by leveraging VR/AR and 5G technologies. The main features encompassed in the Augmented Fair service are interaction with holographic maps, augmented booth and interactive holographic communications. Exhibitors may design virtual booths, with a variety of contents and experiences for interacting with their various types and profiles of visitors over a mixed reality layer, also able to incorporate, whenever needed, 3D volumetric presence of remotely located third persons and objects, as well as real-time translation services for making voice communications more effective between speakers of a variety of languages. All interactions and info exchanged through this platform shall also be available through digital means after the event to both exhibitor and visitor (see Figure 5).

SEGITTUR will collaborate with IFEMA (Trade Fair Institution of Madrid) enabling high-impact showcasing of 5G-EVE innovation outcomes in relevant Trade Events organized by IFEMA.

Considering the variety of events and multiple sectors that IFEMA hosts and organizes throughout the year, the possibilities for innovation enabled by digitization are diverse, but at the same time, they may be based on common core elements such as personalized planning of the visit, the combination of AR and Mobile technologies for both content exposure and online multi-band interaction, intelligent visitor guidance in real time throughout the trade fair center, constant business intelligence information on the success of ongoing activities, and, of course, guarantying the greatest security in IFEMA premises.

Therefore, the preliminary analysis makes the user, the very focus of our efforts in order to:

- Transform the experience of IFEMA clients (visitor and exhibitors), before, during and after the events they attend.
- Guarantee simple, personalized and effective interaction of IFEMA clients (participating firms and visitors), with the trade fair environment.
- Provide augmented experience for F2F attendants, enriched with virtual elements that optimize their tasks and goals: information access, discussion, networking, deal making and transactions.

Business oriented smart tourism is a large vertical industry which can be greatly enhanced using the 5G capabilities to reduce OPEX and to increase revenue through innovative services. The following four sub-uses cases, which will be described accordingly in next paragraphs, have been identified:

- Sub-use case 1: AR Interaction
- Sub-use case 2: Business Augmented Booth

Participating site facilities: Site facility 2 – Spain (5TONIC)

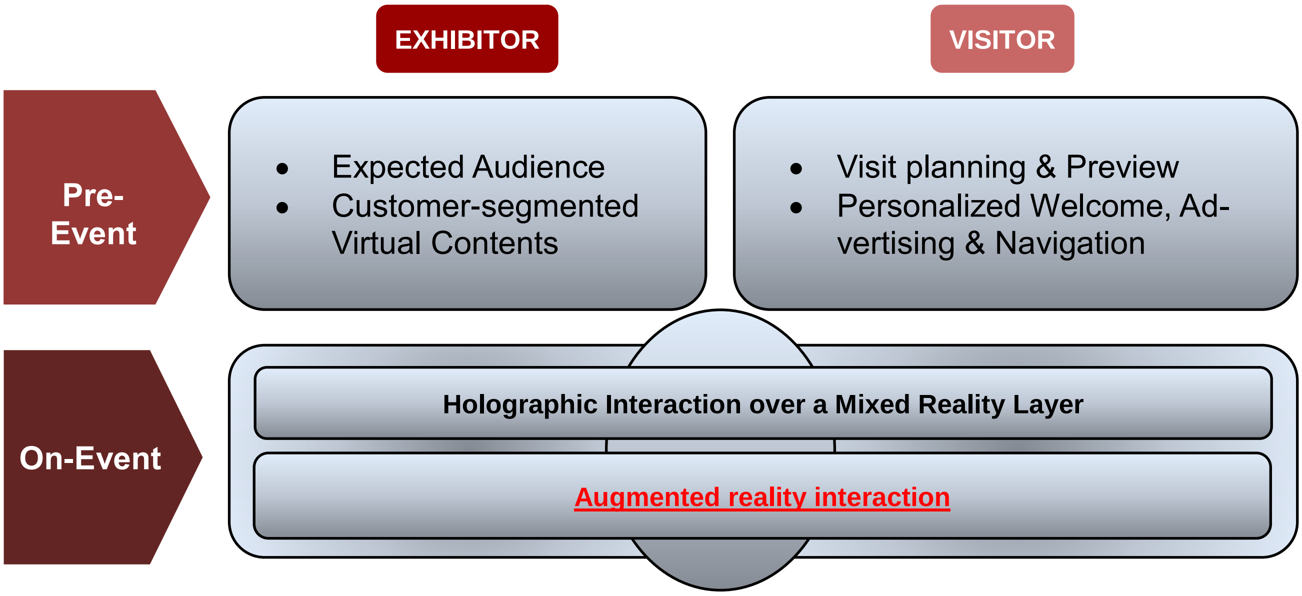


Figure 5: Smart Tourism Use Case Analysis.

3.2.1 High level architecture and use case description

Augmented Fair aims at transforming the experience of Trade Fair events' users (exhibitors and visitors), with the objective of improving their interactions (information sharing, discussion, networking, negotiations and transactions) by leveraging AR, Mobile and 5G technologies. The main features encompassed in the Augmented Fair service are interaction with holographic maps, augmented booth and interactive holographic communications. Exhibitors may design virtual booths, with a variety of content and experiences for interacting with their various types and profiles of visitors over a mixed reality layer, also able to incorporate, whenever needed

Regarding the Smart Tourism Vertical the following sub-use cases can be distinguished:

3.2.1.1 AR Interaction

The implementation of AR technologies, both in holographic devices and mobile devices, allows a wide range of possibilities in the exhibition sector, such as interaction with virtual elements in pavilions and stands, new models of augmented advertising, interactive map service with guided assistance, etc.

Thanks to 5G technologies, the flow of data and information, both generated and collected, can be managed quickly and efficiently.

3.2.1.2 Business Augmented Booth

The implementation of an Augmented Fair Service with AR Interaction will allow enhancing physical experience of both exhibitors and visitors by taking business interaction possibilities to the next level, complementing the physical experience with mixed reality and tools of the attendants to fair events (see Figure 6:

Figure 6: Enhancing the physical experience with Mixed Reality layers and tools

On the one hand, exhibitors need reliable, simple and fast access to a wide range of information regarding their products and services so as to efficiently coordinate internal operating, seamlessly respond to clients' demands and communications, provide personalized customer service and identify potential customers and differentiate their products in the marketplace. On the other side, visitors aim to compile relevant information for their organizations, define a fruitful and detailed contact agenda prior to the event, profit the chance to make key contacts in the market and organize the information gathered during the event.

These on-event needs can be met by enabling a brand new way to experience any fair through mixed, augmented layer and RT assistive and communication tools, using mixed reality as a common working and interactive space addressing the abovementioned requirements.

3.2.2 Targeted KPIs (Requirements)

Targeted KPIs*:* AR streaming requires a sustained bit rate > 50 Mbps in specific locations and on-demand. Should 4K VR headsets be used for tests, the bandwidth needed should increase to 500 Mbps. E2E latency < 10 ms for supporting the synchronization needs of AR interaction with remote facilities (see Figure 7).

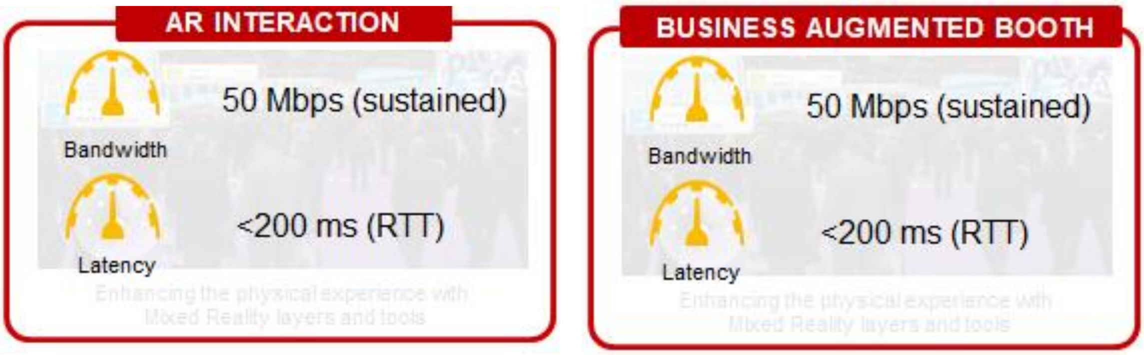


Figure 7: Requirements for AR Interaction and Business Augmented Booth

3.2.3 Demo environment

The high-level architecture for the demo environment can be seen in the following Figure 8:

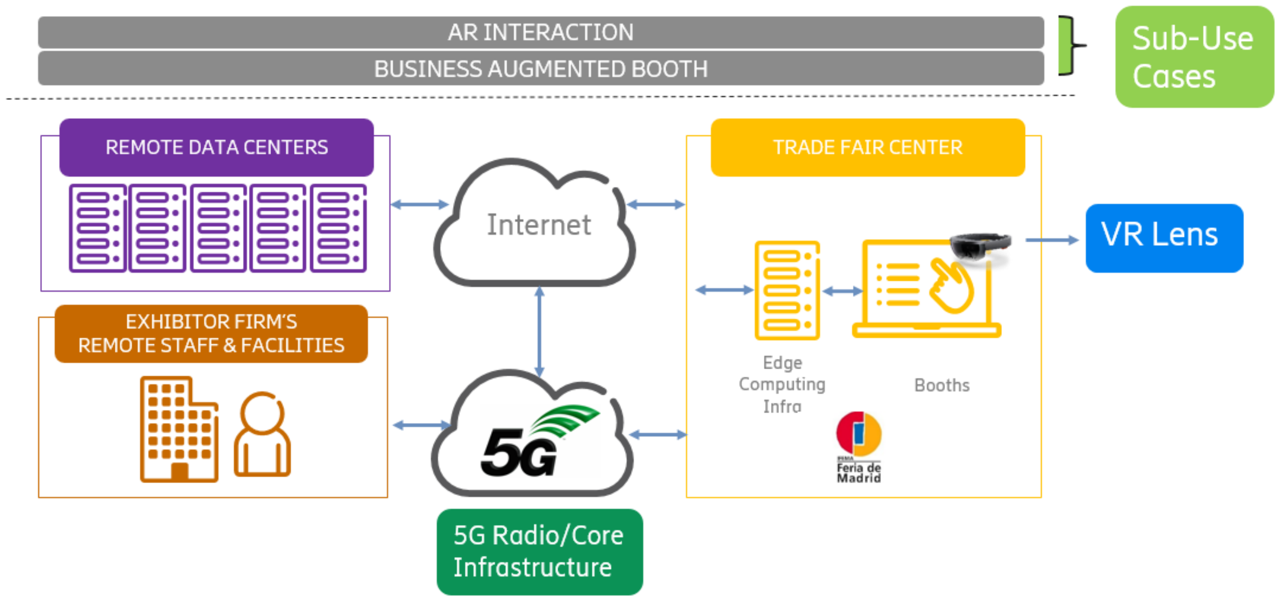


Figure 8: Demo Environment Architecture

The 5G Radio/Core infrastructure connected to Internet will be the basis for the connectivity in the demo, being the enabler for the 4 sub use-cases (see Figure 9) and providing required bandwidth and latency to each one of them.

Remote data centres will store relevant data and content to be used before, during and after the Fair.

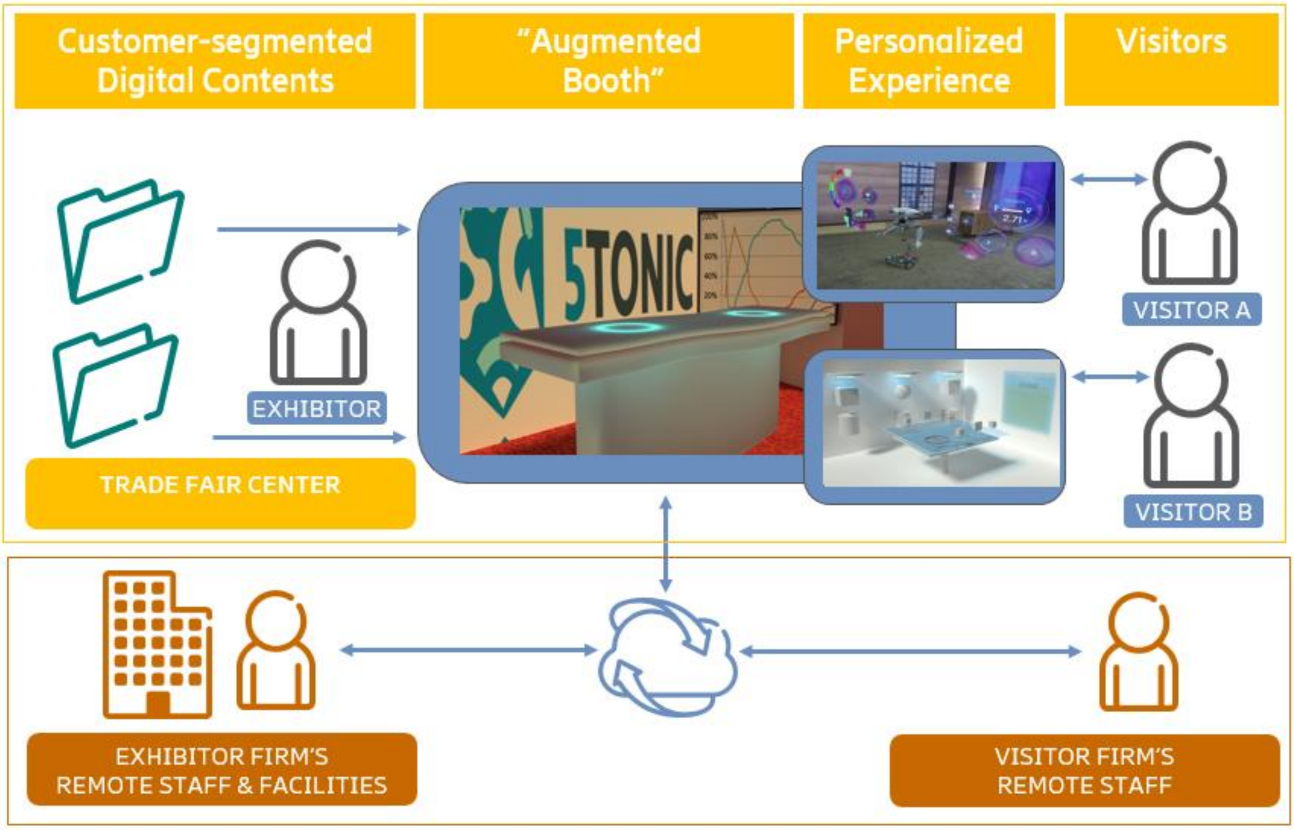


Figure 9: Exhibitor-User Interaction

The Trade Fair Centre will arrange Augmented Booths to be used by visitors and exhibitor, transforming and personalizing their experience with the objective of improving their interactions.

3.3 Use case 3 - Industry 4.0: Autonomous vehicles in manufacturing environments

The automotive industry is currently undergoing key technological transformations, as more and more vehicles are connected to the Internet and to each other, and advance toward higher automation levels. In order to deal with increasingly complex road situations, automated vehicles will have to rely not only on their own sensors, but also on those of other vehicles, and will need to cooperate with each other, rather than make decisions on their own. These trends pose significant challenges to the underlying communication system, as information must reach its destination reliably within an exceedingly short time frame – beyond what current wireless technologies can provide. 5G, the next generation of mobile communication technology, holds promise of improved performance in terms of reduced latency, increased reliability and higher throughput under higher mobility and connectivity density.

The significant effect of 5G connectivity on industrial and manufacturing environments is expected to, lower OPEX and reduce manufacturing times, while increasing safety and efficiency. Ericson and ASTI will lead the experimentation in this area using the following example use case.

5G PPP scenario: URLLC

General requirements definition: The manufacturing sector's main requirement is the reliability, that should be comparable to the wired mechanisms that constitute the state of the art.

Use case Description: The use case intends to demonstrate the feasibility of centralizing the control of automated guided vehicles (AGVs) operating in complex manufacturing environments and relying on wireless connections between the vehicles and a centralized control unit close to the network edge. This centralization (in contrast with the distributed approach used today) allows for more intelligent decisions to be taken (e.g., taking advantage of artificial intelligence) and may also enable a more flexible and reconfigurable factory. It is also expected to provide a significant advantage in terms of cost, both capital and operational. The use case requires some functionalities that are better provided or only supported by 5G, like reduced latency, network slicing to support different processes that may present different requirements, and high bit rate to support the use of inputs to the guidance process like high definition video and/or LIDAR sensors.

Participating site facilities: Site facility 1 – Greece, site facility 2 – Spain (5TONIC) & site facility 3 **-** France

3.3.1 5G EVE Cloud robotics use case: AGVs for warehouse logistics – Greece Site facility

In this Use case AVGs for warehouse logistics will be implemented in Greece site facility with the following main characteristics.

Mobile Cloud Robotics (MCR) in a Smart Wireless Logistic (SWL) facility has been identified as an exciting 5G opportunity [8] that will be exploited by Ericsson and development partners.

Mobile robots will be used to transport goods between various stations in a process or to and from depots. Deploying mobile robots in logistics improves productivity and supports the implementation of effective lean manufacturing. As long as there are no constraints imposed in their movement capabilities caused by unexpected obstacles or dirt, robots can carry out any sequence of events to ensure that materials arrive at the right place just in time.

We are enabling realistic MCR scenarios where traditional robots will be replaced by new ones connected to the cloud. These new robots only include low level controls, sensors and actuators and having their intelligence in the cloud means they have access to almost unlimited computing power. Altogether, they are more flexible, more usable and more affordable to own and operate.

The connection between MCR robots and the cloud is provided through the mobile network and will benefit from the expected 4G and 5G extremely low latency connections.

3.3.1.1 High level architecture and use case description

Test area – OTE Warehouse:

- The AGV shuttles materials between working areas. Each AGV includes mainly its own sensors, whose data are collected and sent to the AGV management system, actuators and low level control logic. The AGV is connected to the AGVs management system in cloud controlling the AGV and coordinating the operations. RAN indoor dedicated coverage, overlap and coordination for resiliency can be considered (see Figure 10).

Cosmote – Local IT area:

- The local IT area includes baseband unit and v-EPC for radio infrastructure, the local cloud server, where AGV real time management system is executed.

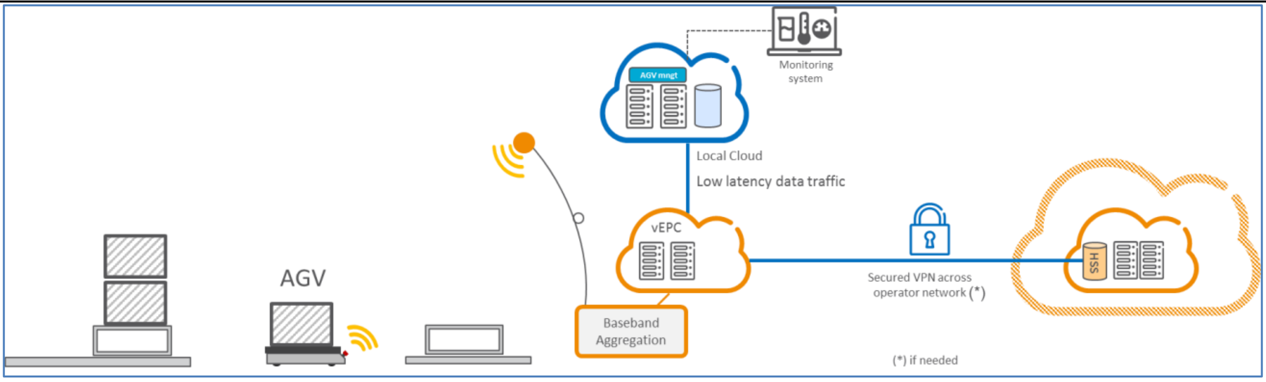


Figure 10: Overall mobile network architecture for an industrial enterprise URLLC application

- AGV with an autonomous remote control is used for shuttling goods between working areas in the warehouse on request.
- The AGV moves freely using vision and Light Detection and Ranging (LIDAR) to understand its positioning and avoid unexpected obstacles in real time.
- AGVs are connected via mobile network to a central control running in a local cloud where all the intensive control processing is performed.
- The AGV management systems include several functions from tasks management to trajectory planning, visual navigation and real-time high-level control for the AGVs.
- The human operator interacts with the control system and the AGVs by using an app on a smartphone, tablet or similar device.
- The AVG model to be used is COMAU AGILE1500 (see Figure 11 and Figure 12)

Figure 11: Multipurpose vehicle COMAU Agile 1500

Technical specifications

SIZE AND WEIGHT	
External dimensions (LxWxH) [mm]	1404 x 680 x 330
Weight [Kg]	350
SPEED AND PERFORMANCE	
Maximum payload [Kg]	1500
Maximum speed [m/s]	1.7
Positioning repeatability [mm]	+/-10
Maximun grade [%]	1
Motion	Forward at max. speed, Backward as an option at safe speed
Operating environment	Indoor

BATTERY AND POWER SYSTEM	
Battery type	Maintenance free Lead (or Litium as an option)
Battery characteristics [V] - [Ah]	24 - 205
Battery autonomy	1 shift for average applications, charging time depends on battery type
IMPLEMENTS INTERFACING AND COMMUNICATION	
Power supply	24 Vdc Power, 24 Vdc Auxiliary
Communication	CANopen

Figure 12: Technical Specification of COMAU Agile 1500

3.3.1.2 Targeted KPIs (Requirements)

A high performance mobile network connecting the robotic vehicles to the cloud-based control system is required. For example, an UL speed of 80 Mbps or higher, maximum acceptable jitter of less than 5 ms, no data buffering and end-to-end latency of less than 10 msec is required to ensure seamless and safe operation.

- Latency <10 ms
- Speed (Data rate in Mbps) >80 Mbps/AGV
- Reliability 99,999%
- Mobility 6.2 km/h speed[3]
- Broadband Connectivity yes
- Security yes
- Capacity (Mbps/m2 or Km2) 400 Mbps UL/ 100Mbps DL
- Bandwidth Each camera uses between 3 and 15 Mbps for video streaming

3.3.1.3 Demo environment

The AGV use case solution architecture is depicted in Figure 13.

[3] The speed is low since the AVG is moving in a Warehouse and has also sensor to avoid collisions

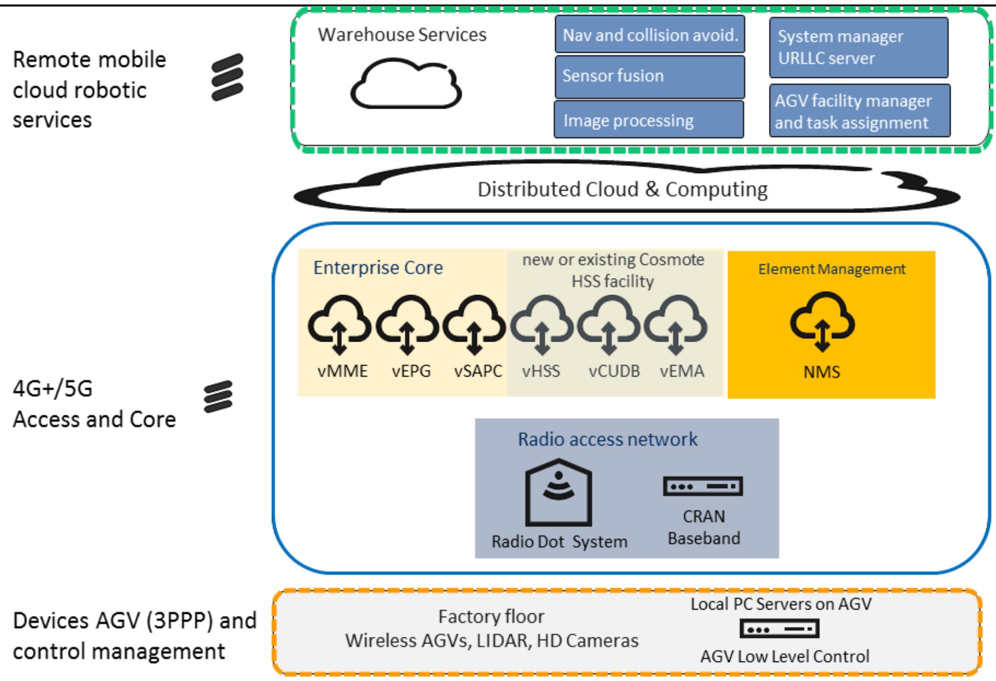


Figure 13: Architecture overview of MCR end-to-end system

AGV Related Hardware: Server pack for AGVs control and facility management (Mobile Cloud Processing)

- Server 1: Sensor fusion and LIDAR Scanning
- Server 2/3: HD navigation camera & Image processing
- Server 4: System Manager URLLC Server
- Server 5: AGV Fleet Management

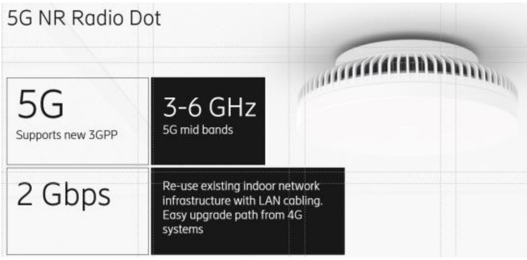
Robotic & Automatic Guided Vehicle (AGVs)

Object	Description
HDR cameras	(4 on the AGV to cover 360 degrees), 2 in the area
miniPCs	Hosted on AGV
DC Computers	remote datacenter for control and image recognition
Computers	For development and COMAU SW
Tablets	for Remote GUI
Other materials	Cables, switches, routers, etc.

Core network (to be further aligned for the Greek facility): vEPC, virtual EPC in a box solution with MME and EPG functionality

Radio Access Network (4G+/5G)

- 4G/5G Radio Dot System for indoor converage
- 4G/5G Baseband
- Dongles/SIMs to connect AGVs control to 4G+/5G network



In addition, a room space for implementing AVG warehouse logistics been selected into the Greek site facility (Figure 14).

Figure 14: Greek site facility for AVG warehouse logistics

3.3.1.4 Integration Needs

The following integration needs are identified:

- Infrastructure elements integration and configuration.
- Remote mobile cloud services
- 4G/5G Access and Core.
- AGVs Devices
- Server pack for AGVs control and facility management (Mobile Cloud Processing)
- AGV Warehouse logistics

3.3.2 5G EVE Cloud robotics use case: Spain Site facility

3.3.2.1 High level architecture and use case description

The aim of this use case is the virtualization of the control algorithms of AGVs. In the current state of the art the AGVs have a Programmable Logic Controller (PLC) in charge of governing the internal control loop, what is collecting the information of the guiding sensors, taking the appropriate control decisions and generating the necessary signals to regulate the speed of the motors. Currently the relocation of this internal control loop out of the AGV is inconceivable considering the current communication technologies.

Thanks to the 5G communication capabilities, these internal control algorithms will be able to moved out of the AGV and they will be able to be reallocated in a virtual machine. This way, the well-known benefits of the software virtualization will be also exploited in this application field. The Figure 15 presents the overall architecture needed to achieve to execute this use case. The AGV will have a Slave PLC on board. This PLC will collect the information from the sensors and physical inputs, this will be sent to the Virtual PLC. The Virtual PLC will process all this information, then it will take the appropriate control decisions and it will generate the right signals to control the motors of the AGV. This control signals will be sent by 5G communication to the Slave PLC, which will process them translating to real physical signals to command the motors.

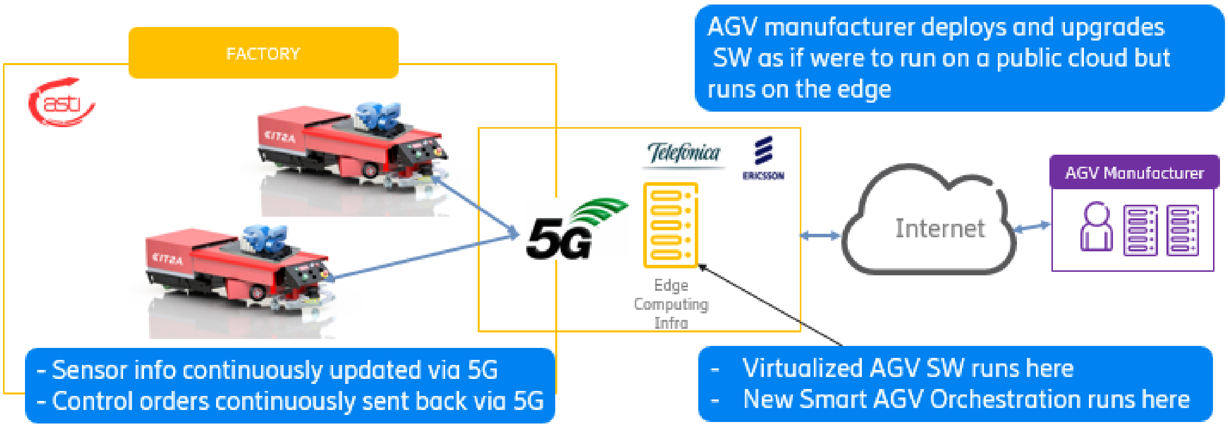


Figure 15: AGVs Use Case High Level Architecture

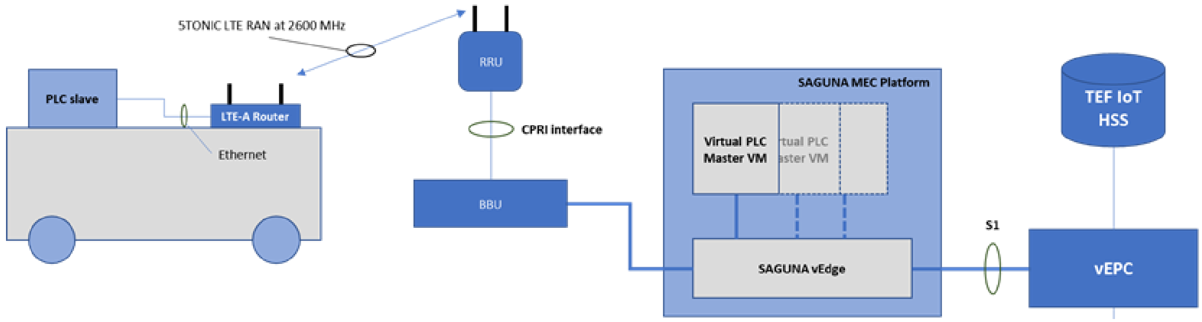


Figure 16: Overall mobile network architecture for the AGV control loop virtualization

During the execution of this use case one or two Easybot AGVs (see Figure 17) of the company ASTI Mobile Robotics (Figure 16) will be used. Also, a charger station and a traffic control box will be used in the demonstration.

Figure 17: Easybot AGV

The charging station will enable the AGVs to work continuously without human intervention. The traffic control box will coordinate the traffic in the crossing points. Figure 18 represents one possible layout to be used in the use case.

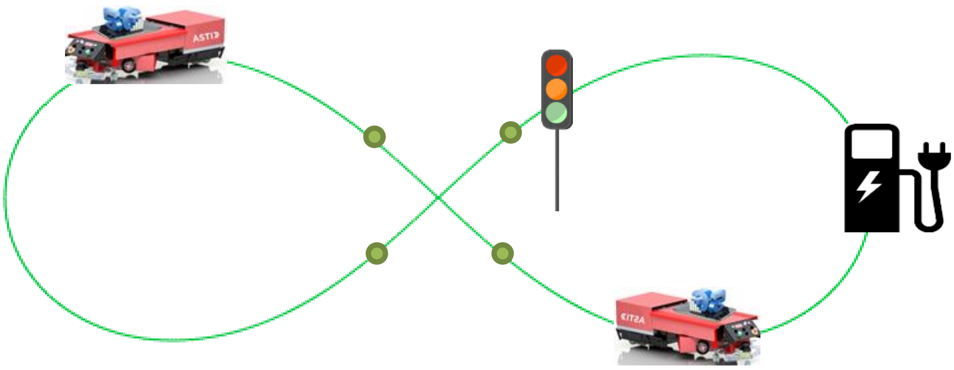


Figure 18: Example of layout

3.3.2.2 Targeted KPIs (Requirements)

A high performance and reliable mobile network connecting the AGVs to platform with the virtual machines is required. The most challenging requirements to ensure the deployment of the solution in the future factories is the high reliability and the low latency and jitter.

- Latency <10ms
- Jitter < 5ms
- Bandwidth:
  - Low bandwidth → Control =400 Kbps
  - Medium bandwidth → Control + 2 Lidar = 1.5Mbps
  - High bandwidth → Control + 2 3D sensor + 2 lidar = 54Mbps
- Reliability 99.9%[4]

3.3.2.3 Demo environment

The Demo environment (Figure 19) is composed by elements provided by 5TONIC members and collaborators:

- **Ericsson** provides the **virtual EPC and the RAN.**
- **Saguna** provides the **vEdge MEC software platform.**
- **ASTI** the **AGVs** and the **virtual P**LC implemented as a Windows VM.
- **Telefónica** provides **spectrum, HSS and SIMs.**

[4] The requested reliability is rather low since the AVG has sensor to avoid collisions and move independently in the Warehouse.

Figure 19: AGVs Use Case 5TONIC Demo Environment

More HW components details can be found in [5].

3.3.2.4 Integration Needs

The following integration needs are identified:

- Infrastructure elements integration and configuration (virtual EPC and RAN, vEdge MEC).
- Remote mobile cloud services
- 4G/5G Access and Core.
- AGVs Devices and the PLC
- Server pack for AGVs control and facility management (Mobile Cloud Processing)
- AGV Warehouse logistics
- spectrum, HSS and SIMs

3.4 Use case 4 - Utilities (Smart Energy): Fault management for distributed electricity generation in smart grids

The utilities sector comprises multiple society-critical industries such as water, electricity and gas, making the impact of 5G connectivity on their distribution networks as well as the resulting increased safety, efficiency, reliability and reduced CAPEX and OPEX, of extreme societal importance.

5G PPP scenario: URLLC and (critical) mMTC

General requirements definition: The integration of an ever-increasing number of distributed generators (renewable energy, farms, households, etc.) into the electricity grid also introduces greater unpredictability of energy production and an increased risk of failures and section isolations (i.e., islanding). To mitigate these effects, ultra-reliable and ultra-fast fault detection and management is necessary to increase network stability and provide system protection.

Use case Description: Currently, fault detection and management in energy grids, takes place through fibre connectivity among the centralized electricity generation points (e.g., power plants). The move towards Distributed Generators (DG) offers great potential but also makes a fibre-communication monitoring solution prohibitive due to its deployment cost. 5G can enable ultra-fast and ultra-reliable fault detection and management among an extensive number of DGs, with decreased CAPEX and OPEX. Such a fault management system is essential for modern smart grids, enabling immediate reaction to changes in the network thus avoiding unwanted islanding, providing dynamic stability and protection to the network and eventually allowing for the integration of an even greater number of DGs. The use of smart metering and fault detection mechanisms in combination with MEC functionality for ultra-fast processing, could even lead towards a centralized grid protection system, elevating the level of control over the energy grid.

Participating site facilities: Site facility 1 – Greece & site facility 3 – France

3.4.1 Utilities (Smart Energy): Fault management for distributed electricity generation in smart grids - Greek site facility

3.4.1.1 High level architecture and use case description

The use case considers the small/medium scale representation of distributed electricity generation in smart grids. For that purpose, the use case will target as a first step a demonstration maquette (small scale representation) with actual distributed energy generation and consumption points as well as smart meters, and potentially at a second stage a scaled-up demonstration taking place in a specially equiped room (towards medium scale representation).

The use case comprises the following elements, which represent the high level architecture of the use case.

- A network of distributed energy sources can be batteries but also panels combined with sensors to measure the energy level. Panels represent the prosumers.
- A network of distributed energy consumers can be actuators, like lamps, fans etc. combined with sensors to measure the energy consumption.
- The distribution network, connecting sources with consumers.

The use case comprises the following steps/phases, representing different conditions in the network.

1. At the beginning, there exists a specific configuration (NORMAL phase).
2. A fault situation occurs (ALERT/ALARM phase).
3. The topology of the grid is restructured so that power restoration can happen as fast as possible (RESTORATION phase).

The problems that the use case targets to solve relate to:

- Longevity of technology, deploy once and operate “forever”.
- Worst case latency, thus deliver a single message within its guaranteed delivery time.
- Ongoing evolution of the power grid into a grid supporting a much more distributed generation and storage of power, being a dynamic and unpredictable environment where intermittent and variable power sources are replacing dispatchable and controllable base load generation.
- Predictive maintenance and prompt reaction.

The use case definition and contemplated requirements have been based on the actual needs of energy providers (e.g., EDF) and the analysis presented by the 5G PPP white paper on the needs of the Energy vertical sector and the potential added value of 5G connectivity [9].

3.4.1.2 Targeted KPIs (Requirements)

Targeted KPIs: Fault detection (one-way latency) ≤ 5 ms with a 99.999% network availability and 99.999% network reliability. In case of message delivery failure, a notification should be issued to lead to the deployment of a fall-back solution / configuration. Device density and data rate requirements are low (< 2000 devices/km2 & < 50 Mbps).

- Power efficiency – Battery lifetime in all equipment at least 10-15 years, if possible 20 years
- Ubiquitous coverage and better penetration – 99.999% network availability
- Low device unit cost – radio modules at few euros
- High reliability - 99.999% network reliability
- Strong security – 100% secure
- Guaranteed (worst case) latency in fault detection ≤ 5 ms
- Restoration time incl. remote computing < 30 sec
- Number of connections < 2000 devices/km^2

3.4.1.3 Demo environment and scenario

As discussed in the previous subsection, the use case will target as first step a demonstration maquette (small scale representation) and potentially at second step a demonstration area, i.e., specially equipped room (towards medium scale representation). In both cases, the demo environment will comprise the elements described in the high level architecture, namely:

- Network of distributed energy sources combined with sensors to measure the energy level.
- Network of distributed energy consumers combined with sensors to measure the energy consumption.
- Distribution network.

In the following Figure 20, a schematic of an indicative demo set-up is depicted.

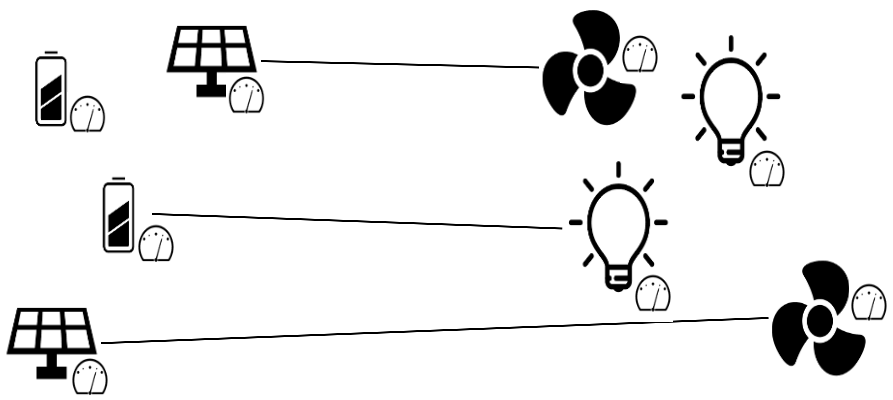


Figure 20: Indicative demo set-up for fault management for distributed electricity generation in smart grids

Scenario

The scenario will implement the three steps/phases of the use case (NORMAL – ALERT/ALARM - RESTORATION).

- At the beginning, there exists a specific configuration, specific sources are feeding the consumers.

- A fault situation occurs, e.g.,
    - Shortage of energy level in some sources (need proactive action).
    - Problem in the network (can be emulated by removing the connection in the energy network, need reactive action).
    - Increase in energy demand (e.g., more fans that actually need more energy supply in the area, like with air conditions in the summer, need proactive action).
- The network is restored in a guaranteed latency, which will be demonstrated in an instant reconfiguration, i.e., lamps and fans continue to work.
    - In case of fault situation, protective functions can communicate with each other with very short and guaranteed (worst case) latencies.
    - In the case of network problem, all connected distributed generation sources to the problematic network should be disconnected so that they do not feed fault current.
    - More distant distribution generation units should be forced to remain connected in the grid and become active if they do not belong to the area that needs to be disconnected, so that the network is restored.
    - The decision on the network restoration will be driven either by a rules-based logic or intelligence based on demand-supply matching, given that we have sensors to measure energy levels at both sources and consumers, potentially at the network edge (MEC platform).

During the demo different connectivity options and wireless technologies will be utilized for the messages transmission / reception to and from the smart meters/sensors and actuators, ranging from GPRS to NB-IoT and 4G+/5G depending on the availability of the respective technology on the Greek site facility, during the different stages of development. Though this demonstration, the added value of 5G connectivity will become evident (compared to the current state of the art, or well-established incumbent technologies), and the ultra-reliable and ultra-fast fault detection and restoration in the energy grids will be showcased.

3.4.1.4 Integration Needs

The following integration needs are identified at first instance:

- Infrastructure elements integration and configuration.
- 5G network availability.
- Provision of radio equipment/module to be integrated at device level.
- MEC availability, if we consider that decision on the network restoration will take place at MEC platform.
- For medium scale demonstration (area or room), test area availability (can be provided by WINGS and/or in collaboration with other Greek partners e.g., in OTE premises).

3.4.1.5 Other issues

No other major issues are considered. As far as concerns the advantages of 5G compared to legacy technologies, the use case will consider appropriate ways so that these advantages are feasible to be demonstrated.

3.4.2 Utilities (Smart Energy): Fault management for distributed electricity generation in smart grids - France site facility (EDF)

3.4.2.1 High level architecture and use case description

The use case, remote decoupling protections for DGs in electric grid, considers two electric feeders in a primary substation and all the Distributed Generation (DGs) connected to these feeders. In Figure 21 you have the schema of the existing solution for protection of distributed electricity generation in smart grids. For that purpose, the use case will target a demonstration mock-up (small scale representation) with actual distributed energy generation protection and feeder protections.

The use case comprises the following elements, which represent the high-level architecture of the use case.

- A schema network of distributed energy sources can be PV panels or wind generation equipped with their protections.
- A schema of a two feeders primary substation equipped with protections.
- The schema of a distribution network, connecting sources and primary substation.

The use case comprises the following steps/phases, representing different conditions in the network.

- At the beginning, there exists a specific configuration (NORMAL phase).
- A fault situation occurs (PRIMARY FEEDER 1 OPEN phase).
- The information is immediately relayed to the DG1, DG3 & DG4 of the grid (DGs FEEDER 1 OFF phase).

The problems that the use case targets to solve relate to:

- More robust electric grid due to hierarchical coordinated protection
- Worst case latency, thus delivering a single message within its guaranteed delivery time.

Ongoing evolution of the power grid into a grid supporting a much greater amount of distributed generation without any risk of unwanted islanding.

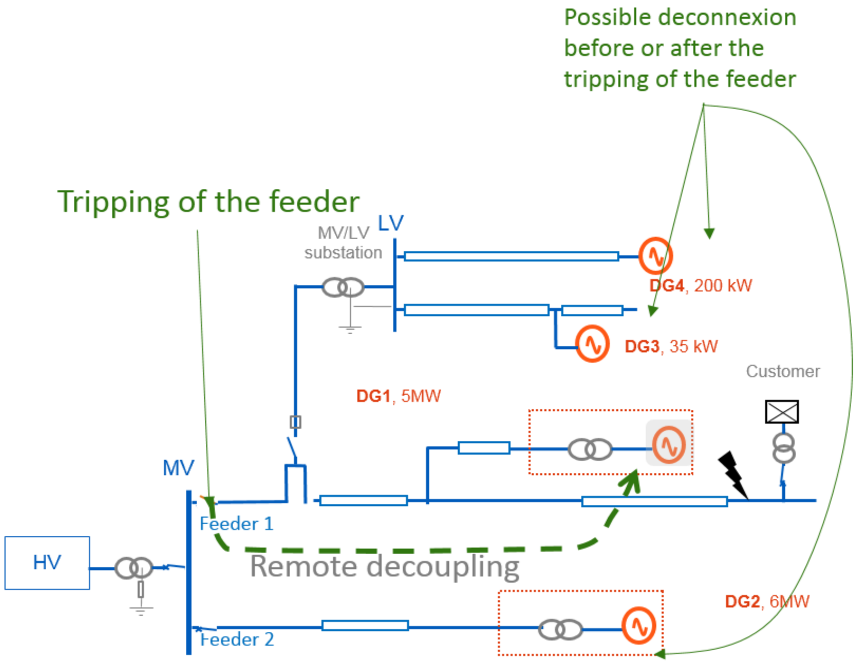


Figure 21: Decoupling protections in France

3.4.2.2 Targeted KPIs (Requirements)

Targeted KPIs: Fault detection (one-way latency) ≤ 30 ms with a 99.999% network availability and 99.999% network reliability. In case of the latency cannot be obtained, a notification should be issued to switch to the deployment of a fall-back configuration of the DGs protections. Device density and data rate requirements are low (< 2000 devices/km2 & < 1 Mbps).

- Power efficiency – Battery lifetime in all equipment at least 10-15 years, if possible 20 years
- Ubiquitous coverage and better penetration – 99.999% network availability
- Low device unit cost – radio modules at few euros
- High reliability - 99.999% network reliability
- Strong security – 100% secure
- Guaranteed (worst case) latency in fault detection ≤ 30 ms
- Number of connections < 2000 devices/km^2

3.4.2.3 Demo environment and scenario

As discussed in the previous subsection, the use case will target a demonstration mockup (small scale representation):

- Network of distributed energy sources combined with sensors to measure the energy level.
- A schema network of distributed energy sources, can be PV panels or wind generation equipped with their protections.
- A schema of a two-feeder primary substation equipped with their lines protections.
- The schema of a distribution network, connecting sources and primary substation.
- A 5G network to allow the coordination between the protections

Figure 22 is a schematic of an indicative demo set-up.

Demo Scenario

The scenario will implement the three steps/phases of the use case (NORMAL – PRIMARY FEEDER 1 OPEN - DGs FEEDER 1 OFF).

- At the beginning, all the grid is connected to the secondary substation
- A fault situation occurs, e.g, leeding feeder 1 to open the protection
    - Default on feeder 1
    - Overload of the protection of feeder 1
    - Remote action to open feeder 1
- The unwanted islanding is avoided through signaling to the DGs being feeder 1.
    - DG1, DG3 & DG4 will switch off.
    - DG4 keep connected..

During the demo 5G connectivity will be used on the French site facility. Though this demonstration, the added value of 5G connectivity will become evident due to the ultra-reliable and ultra-fast fault detection in the energy grids will be showcased.

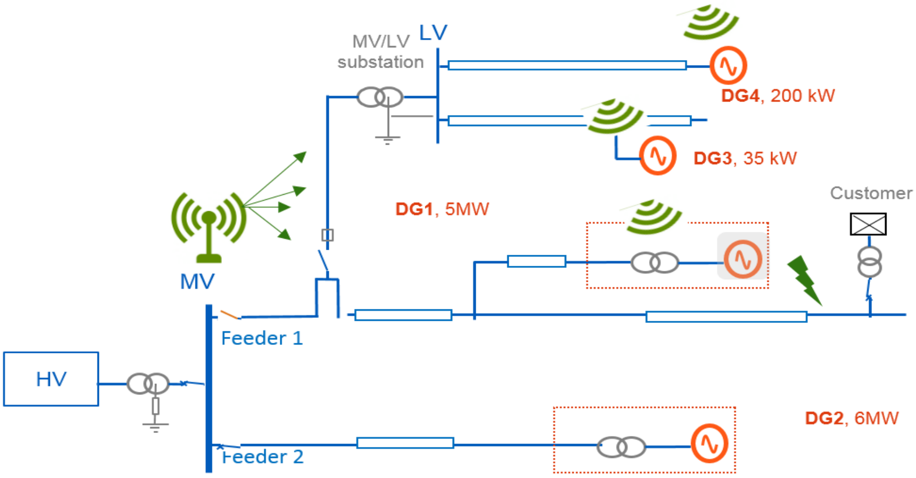


Figure 22: Remote decoupling using 5G

3.4.2.4 Integration Needs

The following integration needs are identified at first instance:

- Infrastructure elements integration and configuration.
- 5G network availability.
- URLL slice.
- Provision of radio equipment/module to be integrated at device level

3.5 Use case 5 - Smart cities: Safety and Environment

A **smart city** is an urban area that uses different types of electronic data collection sensors to supply information that is used to manage assets and resources efficiently. This includes data collected from citizens, devices, and assets that is processed and analysed to monitor and manage traffic and transportation systems, power plants, water supply networks, waste management, law enforcement, information systems, schools, libraries, hospitals, and other community services. The smart city concept integrates information and communication technology (ICT), and various physical devices connected to the network (the Internet of things or IoT) to optimize the efficiency of city operations and services and connect to citizens. Smart city technology allows city officials to interact directly with both community and city infrastructure and to monitor what is happening in the city and how the city is evolving.

ICT is used to enhance quality, performance and interactivity of urban services, to reduce costs and resource consumption and to increase contact between citizens and government. Smart city applications are developed to manage urban flows and allow for real-time responses. A smart city may therefore be more prepared to respond to challenges than one with a simple "transactional" relationship with its citizens.

5G PPP scenario: URLLC and mMT

General requirements definition: The requirements of the network that will support the management of the envisaged services are mainly related to a set of “machine type” communications (sensors in the city) and those for low latency communications (low latency response to events).

Targeted KPIs: Taking into account the 5G requirements (Rel.16) and the foreseen technology availability in the project timeframe: number of connected sensors/device with target of about 60K/km2 (evaluated analytically per extrapolation or by simulation); radio one-way latency with a target of <5ms. From a more usage scenario point of view: increased efficiency, reduction of critical situations. The KPIs will be updated and revised during the project lifetime accordingly to the evolution of the standardization process and corresponding technology availability and actual implementation.

Participating site facilities: Site facility 1 – Greece & Site facility 4 – Italy

3.5.1 Smart cities: Safety and Environment – Smart Turin, Italy Site Facility

3.5.1.1 High level architecture and description

- Management of critical issues related to urban mobility in the corridor between Politecnico and the Porta Susa railway station.
- Monitoring the flow of people to or from the University and Station, identifying the type of mobility used (pedestrian, bus, bike etc.). Introducing sensors that allow communication with the users (e.g., beacons) and putting them in communication with the users in the train, at the station, in the Politecnico and in the outdoor.

Use case Description: Within the framework of the collaboration between TIM and Comune di Torino for the 5G deployment in the city of Turin, managed under the "5G Memorandum of Understanding" signed on May 2017, the partners involved in this "Safety and Environment - Smart Turin" testbed will work towards the implementation of the well-known set of 5G services under the areas of URLLC and mMTC. A set of significant number of sensors will be deployed and connected to the Italian 5G site, acquiring ultra-low latencies in the overall communication. In particular, the object of the experimental activities will be focused on the "Urban Safety" scenario, with ad-hoc use cases for the every-day life experience improvement of the Turin inhabitants, as well as the tourists' safety in selected areas of the city. Moreover, the collection in a smart and effective way of the environmental data is also in the context of the experimental activities to be implemented during 5G-EVE lifetime.

Situations and metrics to monitor:

- security and safety of passengers with respect to anomalies that can occur indoors (e.g., delays at the station) and outdoor (e.g., events) in order to monitor the mobility situation and to manage critical situations;
- counting of people in the area, i.e., by sensorizing entrances and exits of Politecnico and of the train station (e.g., using sensors that detect the wi-fi signal of mobile phones), or by sensorising at least 1 or more public transportation vehicle along the route with on-board sensors (e.g., tram no. 10, where overcrowding could be monitored);
- density, queues and abnormal presence of people inside the train station (Telecommunication (TLC) for counting and / or other systems).

Data collected by sensors will be integrated by mobility data from the city transportation company, GTT[5], and by the city mobility service provider, 5T (i.e., through the MaTO portal, www.muoversiatorino.it). Users will be given the possibility to download a tool to interact with beacons and receive useful information and track them.

[5] Gruppo Torinese Trasporti (Transport Group of Turin, the local company of public bus)

Furthermore, a cloud platform will be made available in the City that can exchange data with other partners, including:

- social analytics
- analytics with heatmap of density, queues through TLC
- analytics using people counting sensors
- 5T and GTT data on urban mobility.

Thanks to analytics history, it will be possible to provide predictive analysis on the use of public space and on mobility policies (Figure 23).

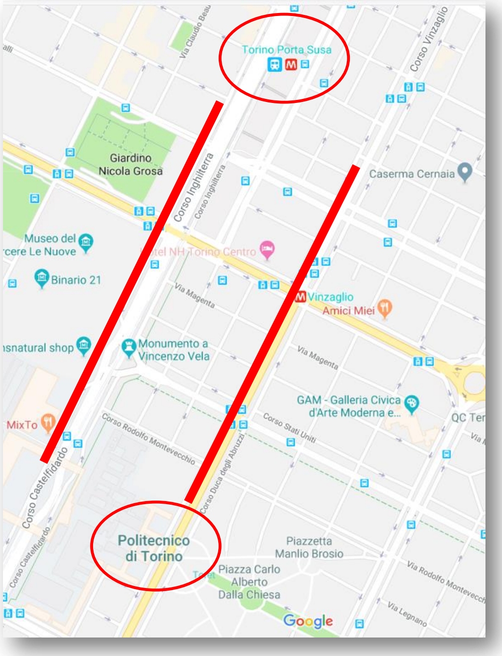


Figure 23: Map of the monitored Torino area

Figure 24 below describes a high-level architecture of the scenario considered.

Based on detection of Beacon and WiFi/Bluetooth signals, data are collected via 5G/NBIoT network and stored on the oneM2M platform (http://www.onem2m.org). This data will be available on the oneM2M platform via REST APIs, allowing cloud platforms to process data collected in order to monitor the traffic and evaluate parameters and performance.

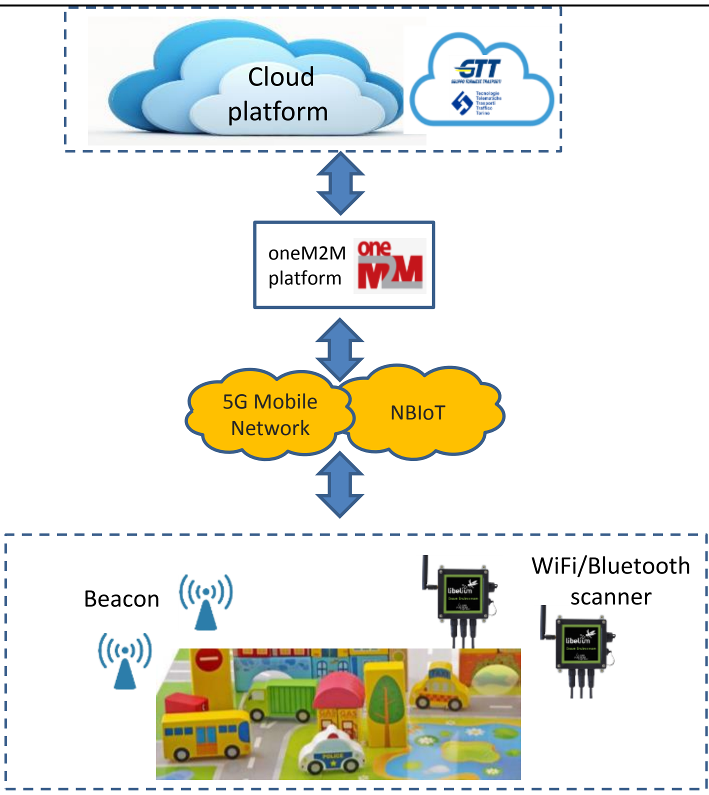


Figure 24: **High level architecture**

3.5.1.2 Targeted KPIs (Requirements)

For monitoring people and vehicles the main general requirements (see Table 5) are related to:

- Number of people per time unit in/out of Politecnico gates.
- Number of people and vehicles (car, bikes, motorbikes) per time unit in the corridor(s) Politecnico/Porta Susa railway station.
- Vehicle data (e.g., position, velocity, direction, fuel consumption, etc.) from a monitored public bus/tram

Figure 25 and Figure 26 describe a possible method of analysing the traffic (pedestrian and vehicles).

By measuring the time to move between WiFi scanners it is possible to monitor the traffic and estimate the type of vehicle (car, bikes, and motorbikes) depending on the speed, possibly using machine learning algorithms.

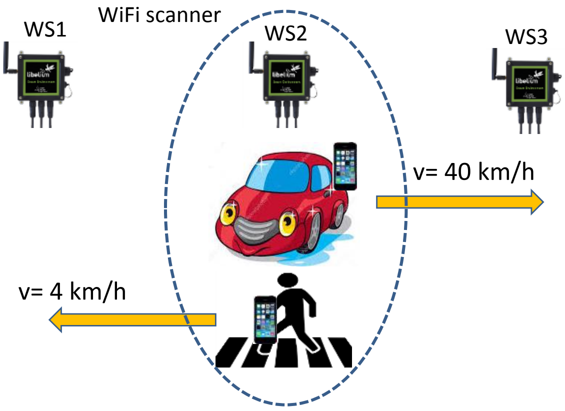


Figure 25: **Car/pedestrian in WS2 area**

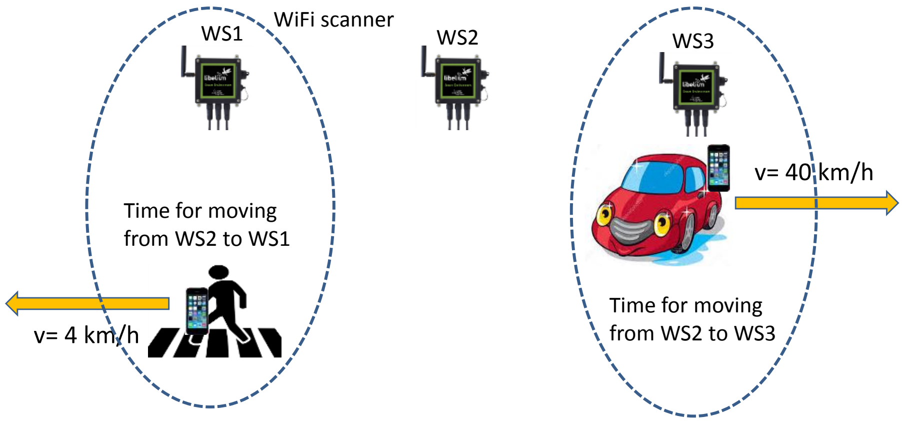


Figure 26: **Car/pedestrian moved to WS1 and WS3 area**

Table 5: Target KPIs form point of view of end-user - Smart Cities

Target KPIs	Value	Unit of Measures
End to End Latency	Number	ms (milliseconds)
Number of people per time unit in/out of Politecnico gates	Number	Number per Min
Number of people and vehicles (car, bikes, motorbikes) per time unit in the corridor(s) Politecnico/Porta Susa railway station	Number	Number per Min
Vehicle data (e.g., position, velocity, direction, fuel consumption, etc.) from a monitored public bus/tram	Numbers	Lat X, Long Y, Km/Hours, L/Km
Number of people measured compared with real people	From 1/3 to 1/5	Number

3.5.1.3 Demo environment

The environment considered is the area monitored by means of Beacon and WiFi/Bluetooth scanners: therefore scanners (and Beacons) have to be installed along the road and clodse to the main entrances of Politecnico/Porta Susa station.

3.5.1.4 Integration Needs

Main components and elements that have to be integrated are:

- Infrastructure elements
- 5G NB-IoT network devices
- WiFi/Bluetooth scanner and Beacon
- RAN/MEC servers
- Data Analytics solutions
- OneM2M provided as PaaS.

3.5.2 Smart cities: Safety and Environment – Connected Ambulance Greek Site Facility

The 5G **"Connected Ambulance"** concept will advance the emergency ambulance services with their healthcare stakeholders to help create improved experiences and outcomes for patients in their care. The vision of the Connected Ambulance combines many advanced technologies that come together to enable the delivery of better life enhancing outcomes for patients. Communications capabilities that can deliver challenging performance requirements in 5G will be fundamental, as the Connected Ambulance will act as a connection hub (or mobile edge) for the emergency medical equipment and wearables, enabling storing and potential real-time streaming of patient data to the awaiting emergency department team at the destination hospital. The continuous collection and streaming of patient data will begin when the emergency ambulance paramedics arrive at the incident scene right up until the delivery of the patient to the emergency department at the destination hospital.

Wearables will enable the provision of enhanced patient insights and the goal is for all paramedics to have wearable clothing that can provide real-time video feeds as well as other sensor related data pertaining to the immediate environment. 567 million wearable devices will be employed in Europe in 2030, a 66-fold increase from the 8.5 million in 2015 according to EC research forecasts. The availability of patient related real-time video stream to the awaiting emergency department will enable more intelligent decision support for the paramedics attending the patient. 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 a more ambitious scenario, life-saving remote assistance might be required on the ambulance, supervised by a specialist located elsewhere and connected to the same platform. Clearly, some of these events will require high-resolution video capabilities, e.g., the remote assistance will require ultra-high-definition video streaming from the ambulance to the remote site where the specialist is located. This enhanced and interactive communication between the medical professional teams and the remote paramedics attending to the patient will lead to fundamental improvements in emergency medical care and improve the probability of better patient outcomes.

The 5G "Connected Ambulance" use case offers the following benefits:

- Capacity essential for video streaming
- Coverage
- Reliability
- Mobility

- Virtualization
- Security

3.5.2.1 High level architecture and use case description

Emergency care platform whereby the patient's vital signs, health stats as well as audio/video data will be wirelessly transmitted real time whilst on the accident scene and/or on the ambulance, enabling teleconsultation to paramedics, treatment during transport and timely informing of healthcare professionals in next point of definitive care (hospital or other health units) as shown in Figure 27.

- Improved emergency handling
- Better preparation for the patient at the hospital
- Onsite instructions for healthcare treatment

Figure 27: 5G Connected ambulance use case architecture (Phase 1)

PHASE 1: STATIC data measurements

- Phase 1 will be implemented in ***phase 1a*** and ***phase 1b*** (Figure 28) and will include the lab verification of the use case using the existing LTE network and NB IoT connectivity. Reconstruction of on-site emergency vital data and audio/video transmission.

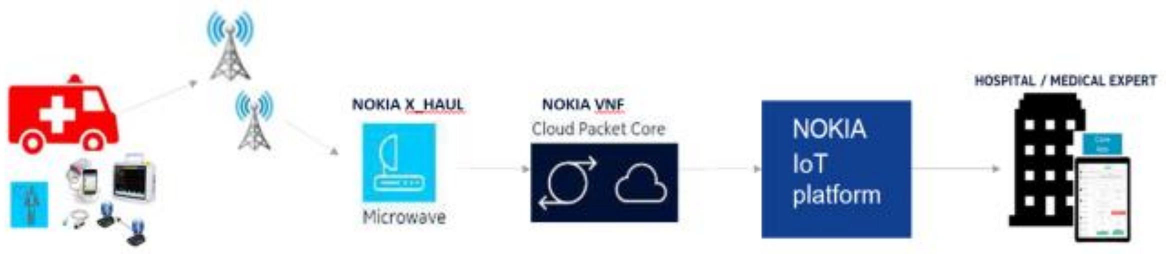


Figure 28: Phase 1 deployment of the connected ambulance use case

PHASE 2: MOBILITY data measurements (Figure 29)

- Phase 2 will include the 5G implementation of the use case using the 5G network. Introduction of mobility testing in the area of Marousi.
- Reconstruction of en route emergency vital data and audio/video transmission.
- Introduction of augmented reality showcase.
- Comparison between LTE and 5G KPIs and impact on use case Replication in OTEs commercial network can be possible.

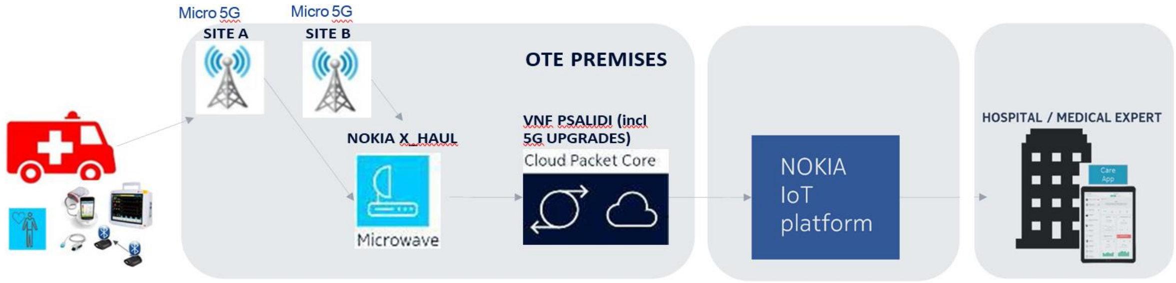


Figure 29: **Phase 2 mobility data measurements architecture**

3.5.2.2 Targeted KPIs (Requirements)

The required data rates for the use case are not so high, but the reliability requirement is the issue on the vital measurement. The reliability here refers both to vital data security and privacy and to connection reliability i.e., outage and failure rates (e.g., for remote operation those requirements could be as demanding as few seconds per year and failure rate even below 10^{-7} respectively, but here we are not assuming such tight requirements).

On the other hand if the diagnosis is based also on the visual inspections by camera views then the data rate requirements are much higher e.g., 200 Mbps for uncompressed high quality video and in the order of few Gbps in case of VR.

5G technology provides the reliability features with massive capacity for 3D high definition picture or video, virtual reality/presence to doctor and patient, data collection and analysis and makes it easier for the healthcare professional to make a judgement.

To get view on the data rate requirement in Table 6 there are list some of the typical measurement rates of vital sensors:

Table 6: Typical measurement rates of vital sensors

Measurement	Sampling rate (Hz)	Sample size (bits)	Packet rate [p/s]	Packet size [B]	Traffic load [kbps]
ECG	200	12	2	150	2.4
EEG	200	12	2	150	2.4
Blood pressure	200	12	2	150	2.4
Glucose	50	16	1	50	0.8
EMG	1000	16	4	500	16
Oxygen saturation	50	16	1	50	0.8
Temperature	5	8	1/4	20	0.04
Respiration rate	5	8	1/4	20	0.04
Physical activity	50	16	1	50	0.8

3.5.2.3 Demo environment

During the initial stage of the use case verification, there will be a simulation of vital data transmission from the accident scene (no mobility). This can take place indoors at OTE premises. During the second step, there will be transmission of data from a moving vehicle, to introduce the factor of mobility and demonstrate the 5G benefits

3.5.2.4 Integration Needs

- For ***phase 1a*** and ***phase 1b*** the following elements are needed:

- NB IoT sensors
- LTE Camera
- Nokia X-Haul related HW
- VNF Playground ePC availability
- NOKIA IoT platform
- E-Health application SW

- For ***phase 2*** the following elements are needed:
  - Sensors
  - Camera
  - 5G NR
  - Nokia X-Haul related HW
  - VNF Playground SW updates for 5G
  - NOKIA IoT platform
  - E-Health application SW

3.5.2.5 Other issues

When using wearables and/or embedded devices to collect sensor data it should be taken into account there are several different technologies used for the short range wireless communication and the most of the technologies are using unlicensed bands, which might come crowded in the future so more efficient (in the interference control sense) communication technologies are needed.

1. Network slicing to be flexible enough and guarantee the proper quality for creating an instance of an entire network virtually, which is, a customized network for each diverse use case. Different customized virtual networks will exist simultaneously and without interfering with each other.
2. MEC / caching to be considered: MEC / caching to move the gateway and application server closer to the radio in order to significantly reduce latency even further. This offers the shortest and best path for routing traffic that needs low latency while at the same time ensuring continuity and seamless mobility.

3.5.3 Smart cities: Safety and Environment – Health Monitoring and Forecasting, Smart Mobility and Smart Home - Greek Site Facility

Western world population is ageing fast [10], which leads to a huge cost for social security and healthcare. Ageing well is a key target; this also applies to facilitating people with disabilities. Hence, AAL systems are needed leveraging among others robust IoT connectivity and health and city condition monitoring. This is of paramount importance so as to improve the livability of the city, which can spur economic growth. The scenarios featured in this use case will demonstrate how 5G capabilities can contribute to the domains of home automation and assisted living. To this end, three scenarios are leveraged:

- **Scenario #1: automated indoor environment adaptation** with functionality for learning user patterns to forecast the preferences of the user regarding indoor environment/home appliances configuration and proactively take actions/offer recommendations (Figure 30).
- **Scenario #2: remote health monitoring and forecasting** comprising functionality for learning patterns in the user's physical status so as to be able to identify abnormalities. Family members and/or professional caretakers can be informed, and appropriate alarms may be raised if necessary (Figure 31).
- **Scenario #3: smart mobility** providing navigation instructions, information on dangerous locations in the proximity, public transportation help considering user preferences and health/wellbeing status (Figure 32).

3.5.3.1 High level architecture and description

Scenario #1: automated indoor environment adaptation:

This scenario showcases the application of learning mechanisms for estimating the preferences of the user with respect to the configuration of their indoor environment (e.g., in terms of temperature and luminosity). The acquired sensor-based data will be turned into knowledge that will be then exploited for the purpose of indoor environment automation by offering recommendations or even proactively taking actions. Air quality, temperature, humidity and luminosity are examples of measurements that can guide the automated adaptation of the user's home environment. Besides the obvious goal of facilitating the everyday activities of the user, this scenario also contributes to the energy efficiency of the home environment of the user (e.g., by automatically adjusting luminosity and temperature levels also on the basis of the corresponding outdoors levels).

This scenario will require massive machine type communications so as to timely aggregate all information coming from sensors deployed within the smart home environment and, consequently, adjust the latter by modifying the status of various sensors and actuators deployed therein.

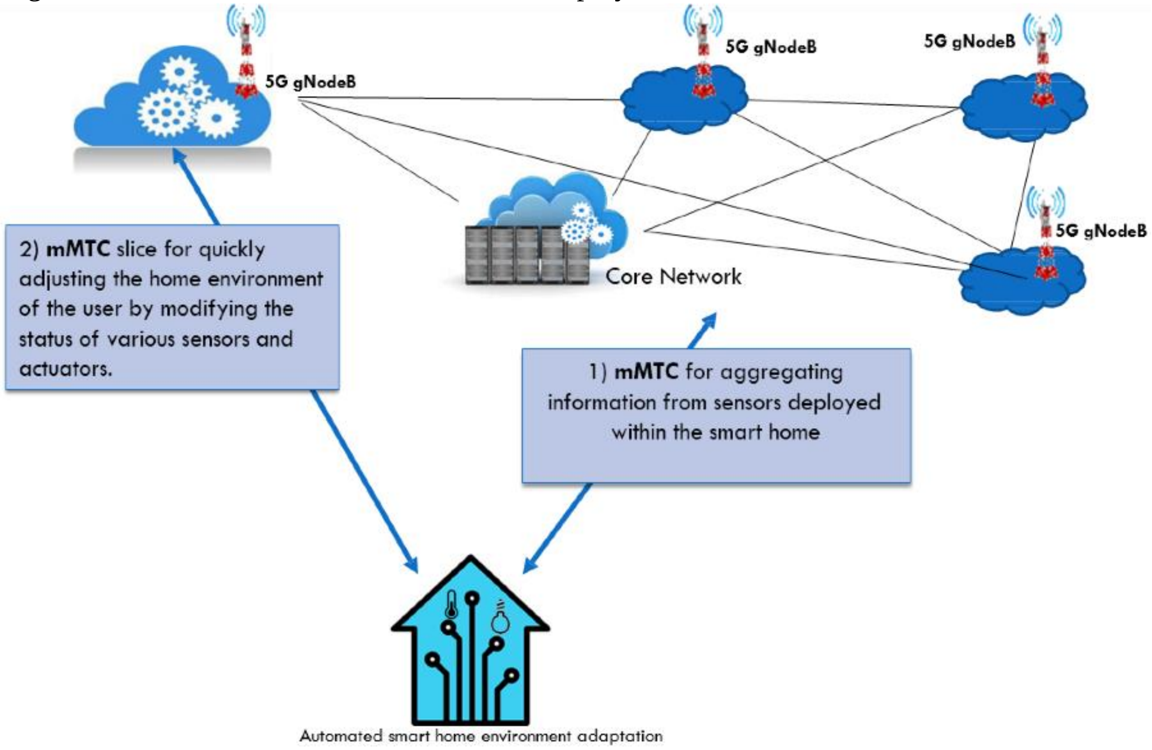


Figure 30: **Automated indoor environment adaptation architecture**

Scenario #2: Remote health monitoring and forecasting:

This scenario addresses the monitoring and assessment of vital signs, such as blood pressure and perspiration, for inferring the physical condition of an individual. The aim is to acquire knowledge on the user health status and, potentially, their behaviour and identify possible irregularities that may call for medical treatment. Notifications/alarms can be raised even in case something is not yet abnormal, but the recorded values show a trend towards a potential problematic situation. For instance, increasing blood pressure, which has still not reached a certain threshold, may still be worrying and alarms or suggestions could be offered so as to avoid reaching the aforementioned threshold. The acquired knowledge may also be exploited for automated decision-making considering the user's health status. Advanced ML algorithms will be exploited for the prediction of future vital signs, also considering other contextual factors, such as air quality. Notifications are issued to an application running on the user's smartphone, informing them about possible upcoming health situations.

Leveraging 5G, the goal of this scenario is to establish a corridor from incident to hospital, i.e., notify all stakeholders (medical personnel, family members, etc.) as soon as an abnormality has been identified, allowing at the same time for the optimal scheduling of caretakers and medical resources. Towards the above, extensive continuous monitoring of the user and the surrounding environment will be achieved through an mMTC slice, while URLLC (for quick and reliable notification) and eMMB (for potential video streaming of the patient condition while on route) slices will be required in case of an emergency or so that an emergency is avoided.

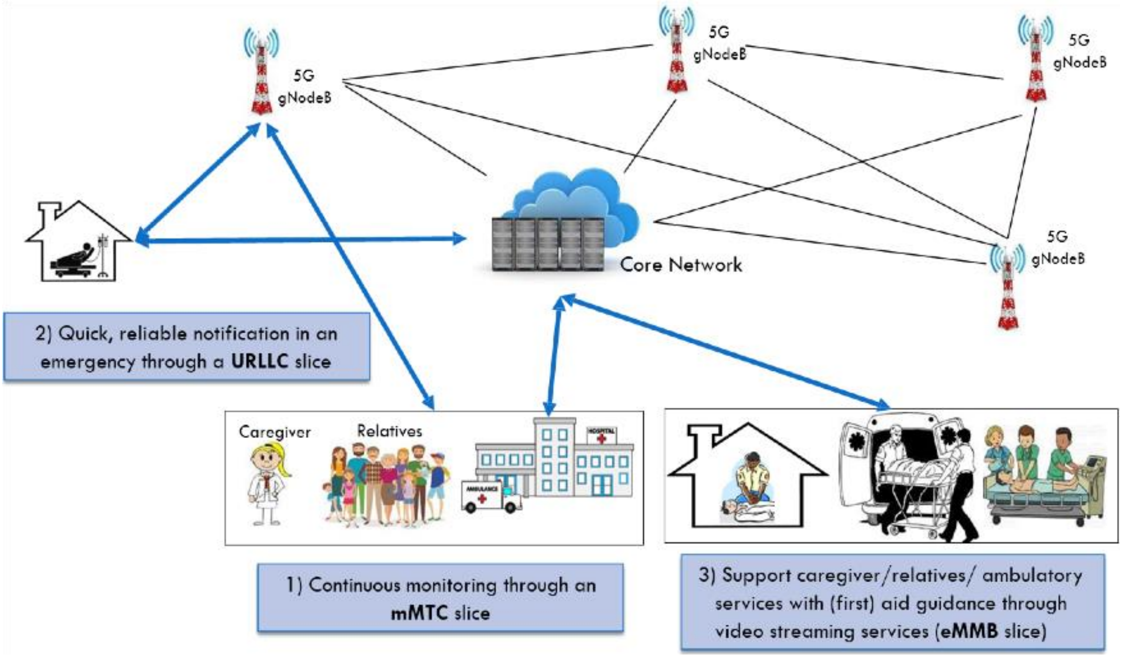


Figure 31: **Remote health monitoring and forecasting architecture**

Scenario #3: smart mobility:

This scenario showcases the exploitation of knowledge on user health status, user preferences, public transportation means, city scheduled and unexpected events, weather, pollution, etc. so as to provide personalised recommendations on the optimal route from a given starting point to a destination. The calculated set of potential routes leverages diverse means of transportation (i.e., public and private transportation, walking, etc.), taking user-defined limitations (such as preference for taxis over buses) into consideration. A distinguishing aspect of this scenario is that the route calculation process is performed also on the basis of potential health conditions the user suffers from. In this course, areas with high pollution or pollen count can be avoided in case of respiratory problems, uphill routes or non-accessible roads can be excluded for users with mobility restrictions, etc. At the same time, real-time re-routing will be made available so as to go through from nearby POIs or to avoid closed road due to demonstrations. Potential data sources involve air quality, pollution, pollen, humidity, temperature and traffic sensors, as well as weather and city events APIs and user data (e.g., from a wearable device).

Apart from mMTC slices so as to communicate the aggregated sensor data, URLLC slices will be required in this case for the purpose of instant recalculation of the user's route and their consequent notification.

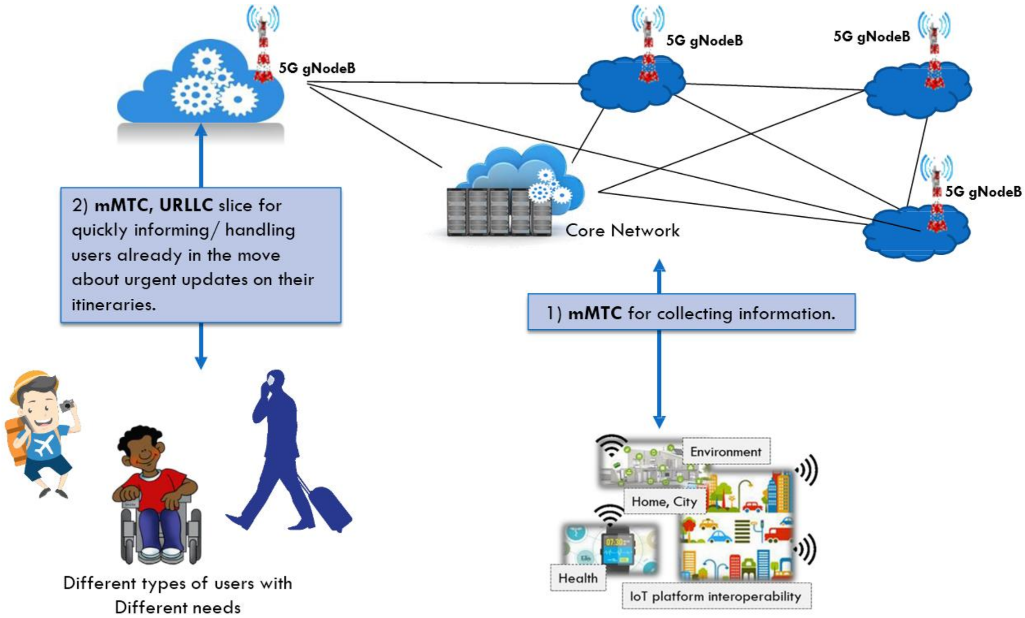


Figure 32: Smart Mobility architecture

3.5.3.2 Targeted KPIs (Requirements)

The network requirements of the services envisaged in this use case are shaped as follows:

- **mMTC** slices for aggregating various kinds of information as described above in the context of continuously monitoring the users and the city.
  KPIs: latency ~20 ms; mobility spanning 0-200 km/sec; device density around 60K devices/km^2.
- **uRLLC** slice for disseminating critical information, such as in the case of re-routing due to urgent city incidents.
  KPIs: latency <5 ms; speed up to 1Mbps; reliability ~99,99%; availability ~99,99%; mobility spanning 0-200 km/sec; broadband connectivity ~25Mbps; capacity up to 0,2Mbps/m^2.
- **eMBB** slice for providing support to caregivers through live streaming of the user's status while on route to the hospital.
  KPIs: latency ~ 20 ms; speed spanning 25Mbps-400Mbps; mobility up to 200km/h; broadband connectivity at 400Mbps.

3.5.3.3 Demo environment

The previously described use cases will be realized with the support of STARLIT (**s**mar**t** living pl**a**tform powered by a**r**tificia**l** **i**ntelligence and robus**t** IoT connectivity) [11][12], which is WINGS's end-to-end solution offering a combination of services for smart home, smart health and smart navigation and comprises functions for learning, forecasting and system self-management. The rich set of (enhanced city and smart home) services offered by STARLIT includes dynamic creation of smart city dashboard applications; visualisation of real-time and historical data, as well as predictions on information of interest about city; proactive customised recommendations for city life improvement; self-healing/repairing of the system. The above are realised through (a) our proprietary algorithms, which are based on advanced artificial intelligence (AI) mechanisms, i.e., machine learning algorithms and predictive analytics (supervised, unsupervised, reinforcement, deep learning); (b) cloud and IoT technologies, exploiting various sensors and actuators, e.g., temperature, humidity, luminosity, lighting, motion and several programmable IoT boards (Raspberry Pi, Arduino); end-user applications for family member monitoring, home environment automation and smart mobility.

While a very large part of existing smart home and health products are tied to devices made available from specific vendors, STARLIT is independent of devices and technologies. In this respect, STARLIT aims at supporting a comprehensive set of sensors and data sources, in general, as well as various types of connectivity technologies enhancing, this way, the value and effectiveness of the solution and easing integration with third-party systems, respectively. Figure 33 below gives an overview of the system architecture and supported protocols and technologies of the STARLIT smart city platform.

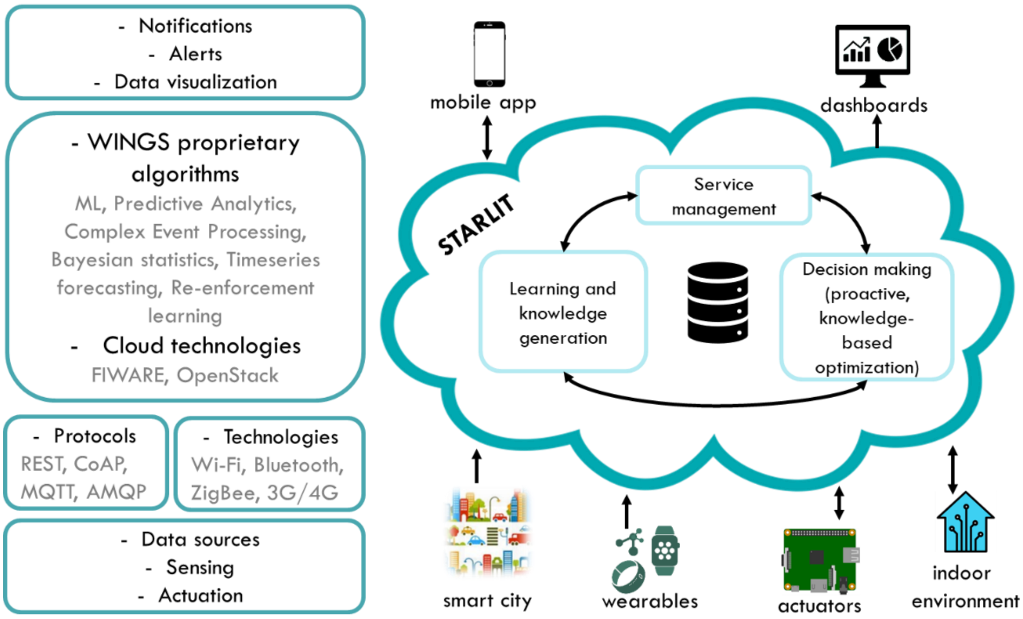


Figure 33: WINGS smart city STARLIT platform overview

Following the above, the three afore-described scenarios will be demonstrated both in indoors (in the home environment adaptation scenario) and outdoors (in the smart mobility scenario) test areas. Apart from 5G connectivity, this would require a number of sensors performing various measurements, such as temperature, humidity, luminosity, air quality, but also traffic and city status information. Information coming from several in-house developed sensors and open APIs will be leveraged as well. The results of each scenario will be presented to the user via smartphone applications and appropriately designed informative dashboards.

The storyline to be followed in the scope of a demonstration will be as depicted in Figure 33 above. Finally, the use case will target a small-scale demonstration at first and pursue a broader one (towards medium scale) as a second step.

3.5.3.4 Integration Needs

The following integration needs are identified:

- 5G network availability;
- indoors and outdoors test areas;
- integration and configuration of in-house developed WINGS smart city platform;
- integration and configuration of in-house developed hardware supporting 5G connectivity and integration of COTS sensors (as described above).

3.6 Use case 6 - Media & Entertainment: UHF Media, On-site Live Event Experience, Immersive and Integrated and Virtual visit over 5G

Multimedia and Entertainment services demand ever increasing network capacity. To optimise the use of the network capacity, it is necessary that the on-demand resource parameters (latency, bandwidth, security, connectivity, etc.) are allocated and configurable as required by the service. Telefonica (TID) will lead the experimentation in this area using the following example use case:

5G PPP scenario: eMBB, mMTC and URLLC

General requirements definition: Media will play a critical role in the future communications in a myriad of new 5G vertical applications, we have selected the most critical use cases including Ultra High-Fidelity (UHF), On-site Live Event and Immersive media in order to be able to customize and enhance the quality of the Vertical user's experience. To this end, eMBB scenario will be covered to guarantee maximum coverage, mMTC for machine media creation and URLLC to guarantee live events coverage will be supported.

Use case Description: This use case includes four (adaptable) multimedia scenarios. *Ultra High-Fidelity* Media experience with highly immersive viewing experience and ultra-crisp, wide-view pictures will be made possible through the use of both linear (e.g. live programming, streaming) and non-linear (e.g. on-demand) content. To guarantee this high quality of experience, the future 5G network should be able to support efficient network management high speed transport capabilities and strategies, e.g. by means of local and network caching of content. *On-site Live Event Experience* will be made possible in large scale event sites, such as cinemas, stadiums and hall parks leading to enhanced viewing experience (replay, choose a specific camera, etc). *Immersive and Integrated Media* will provide ambient media consumption at home but also on the move, with content capable of following the users and adapt to his / hers ambient for viewing (e.g. in the car, at home etc.) *Virtual visit over 5G* will enable 360 immersive video experiences such as immersive video conferencing simulating the face to face experience that present videoconferencing systems do not allow.

Participating site facilities: Site facility 2 – Spain (5TONIC) & Site facility X – France (ORANGE)

3.6.1 High Level architecture and Description:

This use case includes four (adaptable) multimedia scenarios:

- ***Scenario A: Ultra High-Fidelity* Media** experience with highly immersive viewing experience and ultra-crisp, wide-view pictures will be made possible through the use of both linear (e.g., live programming, streaming) and non-linear (e.g., on-demand) content. To guarantee this high quality of experience, the future 5G network should be able to support efficient network management high speed transport capabilities and strategies, e.g., by means of local and network caching of content.
- ***Scenario B: On-site Live Event Experience*** will be made possible in large scale event sites, such as cinemas, stadiums and hall parks leading to enhanced viewing experience (replay, choose a specific camera, etc).
- ***Scenario C: Immersive and Integrated Media*** will provide ambient media consumption at home but also on the move, with content capable of following the users and adapt to his / hers ambient for viewing (e.g., in the car, at home etc.) New 5G capabilities will enable 360 immersive video experiences such as immersive video conferencing simulating the face to face experience that present videoconferencing systems do not allow.
- ***Scenario D: Immersive Virtual Visitors*** should benefit from 360° media delivery in a quality that may allow replacing a physical visit with a virtual one, therefore one general requirement is to support the streaming of 360° video matching the highest quality supported by high-end head mounted displays

3.6.1.1 Scenario A, B and C – Multimedia over 5G

Scenarios evolutions in two phases:

- First phase for initial deployments
- Second phase for massive deployments

Scenario A: Ultra High-Fidelity Media (Phase1 and Phase 2)

- Telefonica Movistar + is an IPTV Multicast platform including live and on-demand channels for high quality TV (up to 4K video service)
- Telefonica wants to deliver the same video quality, not other qualities (smaller bandwidth qualities), to mobile users, including mobility scenarios (Figure 34)

Figure 34: Scenario A, Ultra High-Fidelity Media

Ultra High-Fidelity Media – Phase 1

- 2019 scenarios for initial deployments
- Urban scenarios
- Up to 100-200 Mbps TV delivery per mobile cell with allocated bandwidth of 55 MHz
- Reusing part of available spectrum currently owned by Telefonica for LTE, so Carrier aggregation on separate bands must be supported
- Configuration must support a mix of SD 60%, HD 25% and 4K 15% live channels distribution to mobile users
- Some users may be connected to 3.5 GHz band
- 90% live TV, 10% VOD

Ultra High-Fidelity Media – Phase 2

- 2020 scenarios for massive deployments
- Urban scenarios
- Up to 150-250 Mbps TV delivery per mobile cell with allocated bandwidth of 50 MHz in the 3.5 GHz band
- Configuration must support a mix of SD 40%, HD 35% and 4K 25% live channels distribution to mobile users
- Some users may be connected to 3.5 GHz band
- 70% Live TV, 30% VOD

Scenario B: On-site Live Event Experience (Phase1 and Phase 2)

- Telefonica Movistar + is producing and distributing many TV events in Stadiums, car Racing, Sport Events, etc
- Telefonica wants to deliver some TV events in on-site places, on limited coverage areas
- Open air, wide area event– e.g., Race Track, County Fair , parade, etc. (Figure 35)

Figure 35: Scenario B: On-site Live Event Experience

On-site Live Event Experience – Phase 1

- 2019 scenarios for initial deployments
- Urban scenarios: Downtown areas
- Up to 40-80 Mbps TV delivery per mobile cell with allocated bandwidth of 20 MHz
- Realtime video Uplink from connected cameras (encoded video sources) of up to 4 cameras @10 Mbps - @2 Mbps (20-40 Mbps total uplink)
- Configuration must support a mix of SD 60%, HD 25% and 4K 15% live channels distribution to mobile users
- Some users may be connected to 3.5 GHz band

On-site Live Event Experience – Phase 2

- 2020 scenarios for massive deployments
- Urban scenarios: Stadiums, Race places, Downtown open areas
- Up to 60-120 Mbps TV delivery per mobile cell with allocated bandwidth of 20 MHz in the 3.5 GHz band
- Realtime video Uplink from connected cameras (encoded video sources) of 4 cameras @15 Mbps - @3 Mbps (30-60 Mbps total uplink)
- Configuration must support a mix of SD 40%, HD 35% and 4K 25% live channels distribution to mobile users
- Some users may be connected to 3.5 GHz band

Scenario C: Immersive and Integrated Media (Phase 1 and Phase 2)

- Telefonica Movistar + is an IPTV Multicast platform including live and on-demand channels for high quality TV (up to 4K video service)
- Telefonica wants to deliver immersive and Integrated Media in massive scenarios. This is a new video delivery format, so must be introduced in the massive delivery networks like natural evolution of digital video.
- The new formats may be applied in many different configurations, including some for low latency (Figure 36).

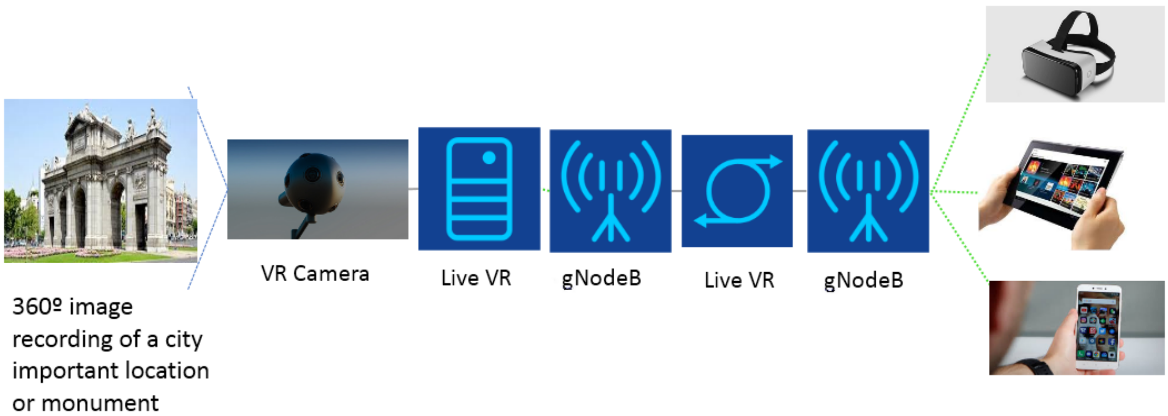


Figure 36: Scenario C - Immersive and Integrated Media

Immersive and Integrated Media - Phase 1

- 2019 scenarios for initial deployments
- Urban scenarios, very scalable, MEC required
- Up to 40-80 Mbps TV delivery per mobile cell with allocated bandwidth of 20 MHz
- Realtime video Uplink from connected cameras (encoded video sources) of up to 4 cameras @10 Mbps - @2 Mbps (20-40 Mbps total uplink)
- Configuration must support a mix of HD 75% and 4K 25% live channels distribution to mobile users
- Some users may be connected to 3.5 GHz band

Immersive and Integrated Media - Phase 2

- 2020 scenarios for massive deployments
- Urban scenarios, MEC required
- Up to 60-120 Mbps TV delivery per mobile cell with allocated bandwidth of 20 MHz in the 3.5 GHz band, but other bandwidth can be explored
- Real-time video Uplink from connected cameras (encoded video sources) of 4 cameras @15 Mbps - @3 Mbps (30-60 Mbps total uplink)
- Configuration must support 4K 100% live channels and VOD distribution to mobile users
- Some users may be connected to 3.5 GHz band

3.6.1.2 Targeted KPIs (Requirements)

For the eMBB aspects of multimedia, up to 50 Mbps of a single video source will be generated, but many concurrent video sources will be tested including up to 20 channels at 1 Gbps total bandwidth. For mMTC and URLLC a camera car for remote driving using and control will require low latency (< 10ms) and ultra-reliable capacity. The KPIs will be updated and revised during the project lifetime accordingly to the evolution of the standardization process and corresponding technology availability and actual implementation.

3.6.1.3 Demo environment

The demo environment will be initially Non-standalone, so we can focus first in what will be first available in the market: 5G new radio in Spain, with 3.5 GHz focus first. Later we will evolve the demo environment to the new frequencies, new devices and new mobile network components as soon as are available for market early prototyping (Figure 37, Figure 38, Figure 39 and Figure 40).

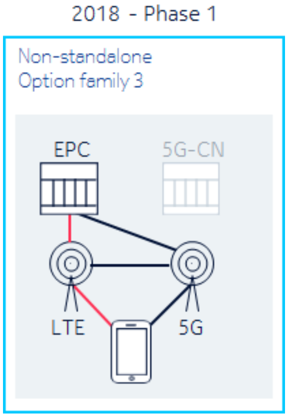


Figure 37: **5G 2018 – Phase 1**

Basically, the following scheme present the main components required for the Use Case deployment in the 5G network.

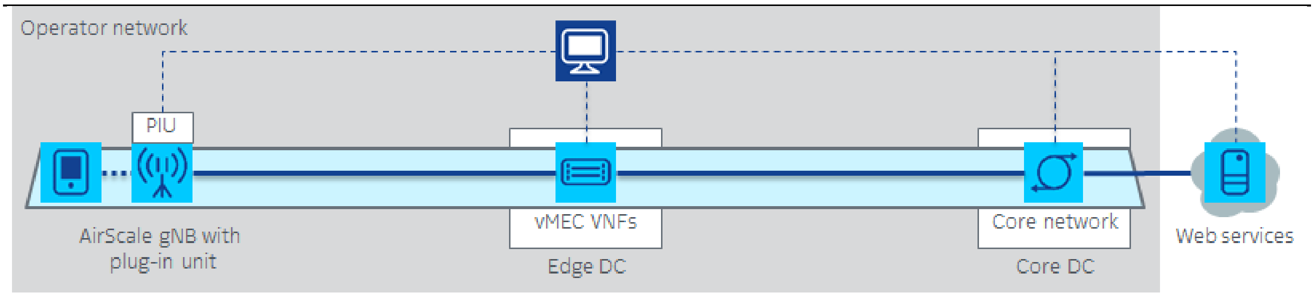


Figure 38: **NOKIA 5G EVE main deployed network components**

The demo environment will include different end devices, like 4K STB, mobile devices with immersive video support, immersive cameras, encoders, a Multi-Edge Compute Node, one EPC, the Nokia AirScale with support of two different 4G frequencies and one or more new 5G frequencies.

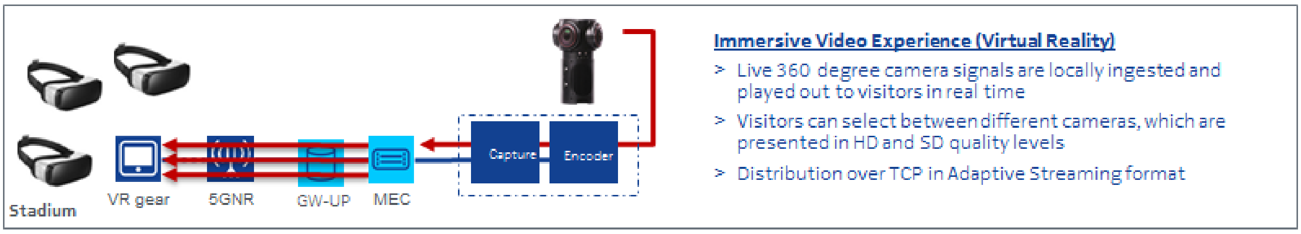


Figure 39: **NOKIA UC6 Immersive Video Experience Components**

The demo will include one AirScale Base Station, it is compact, and it delivers huge capacity and connectivity to support future traffic growth as the network evolves to 5G and IoT. A key part of AirScale Radio Access, the base station is easy to install and gives the flexibility to run all radio technologies, including 5G, and support all network topologies, including Cloud RAN.

AirScale Base Stations enabled by the new Nokia ReefShark chipsets deliver market leading throughput, up to 84 Gbps per system module. AirScale baseband module chaining supports base station throughputs of up to 6 terabits per second, which will allow operators to meet the huge growing densification demands and support the massive enhanced mobile broadband needs of people and devices in megacities.

Figure 40: **Nokia AirScale Base Station**

Even more capacity can be added from the cloud. AirScale Base Station also includes single band and multiband radio heads, including the world's first triple band radio. Thanks to their compact size, energy efficiency, high output power and multiband capabilities, the radios help to reduce the site space requirement and allow faster roll out while lowering the total cost of ownership (TCO). These can support carrier aggregation, massive MIMO and Beamforming solutions to maximize the cell throughput and capacity for an enhanced overall user-experience. Depending on how the lab requires new components or capacity, this could be provided by this Base Station.

3.6.1.4 Integration Needs

For each of the demos we will integrate in the demo lab one Multi-Edge Compute node with two reference VNFs, one for all the video services and a second VNF for KPIs.

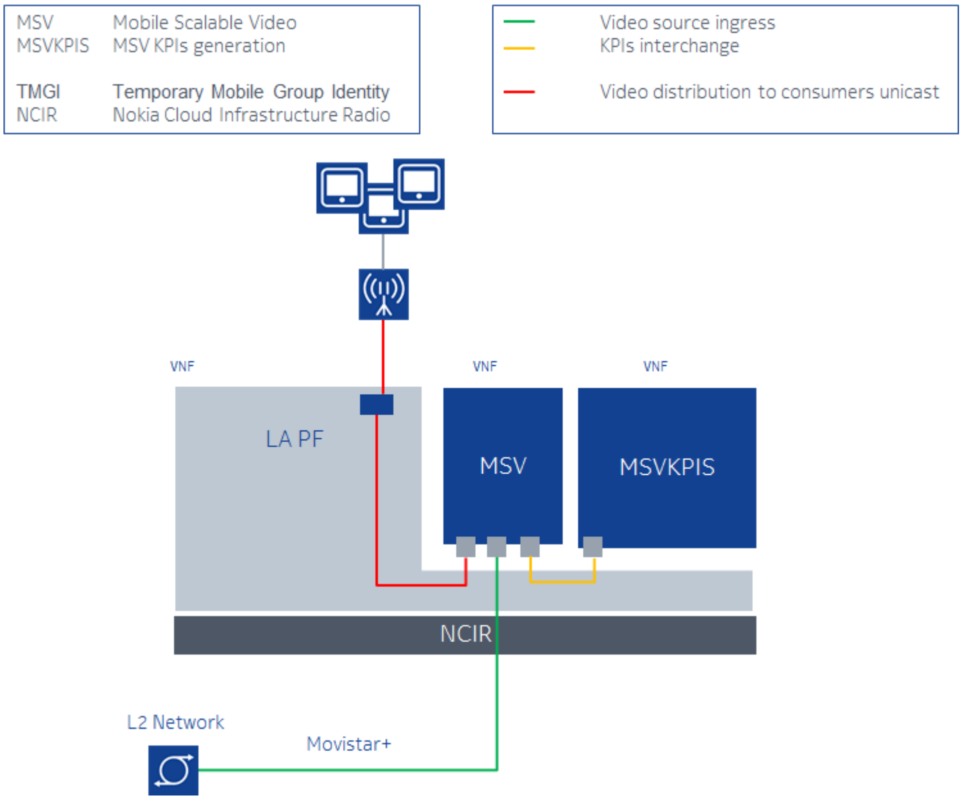


Figure 41: **NOKIA Multi-Edge Computing configuration for Media & Entertainment Use Case**

Nokia MEC provides the following networks for the connectivity to the applications as shown in the figure below

- OAM Network – Managing the application. Ex: SSH Login, Upgrade and EMS interfacing
- Offload Network – Offloading UE traffic. Ex: LTE, WIFI
- Application Backend Network – Connecting to External Server. Ex: Internet
- Using Application Backend Network, two applications can connect to each other and the same two applications can connect to a single external server

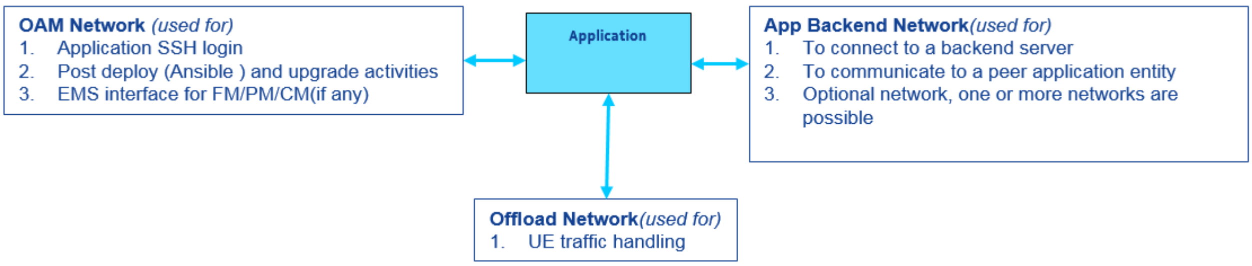


Figure 42: **NOKIA Multi-Edge Computing networks connectivity**

For the complete deployment of the services many network flows must be implemented and supported, in the following image we can see one example of network flows that must be properly integrated to support this use case.

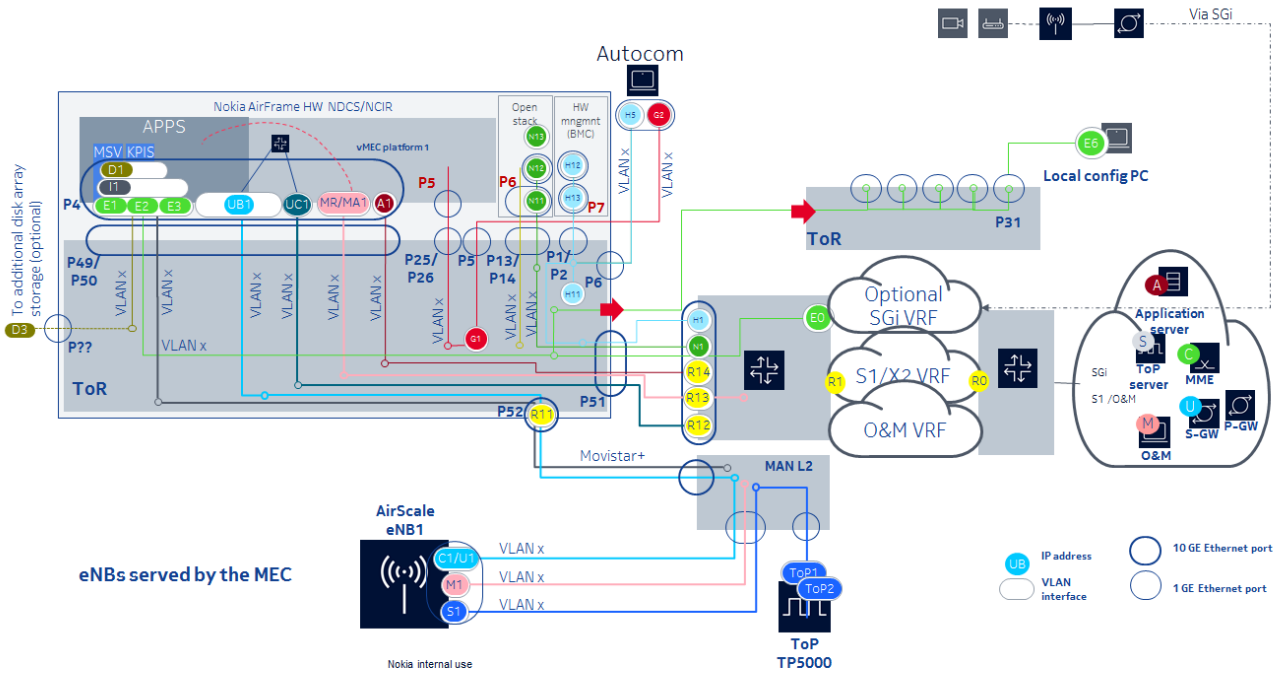


Figure 43: **Example of Networks configuration for Multi-Edge Computing deployments**

3.6.1.5 Other Issues

Instrumentation equipment will play a key role in the performance demo lab to demonstrate the network capacities at various levels of one lab configuration, so some radio and video performance additional equipment will be installed to provide additional measurements.

The different scenarios will be emulated with tools that will generate traffic and the required performance measures that must be integrated in the KPI platforms.

3.6.1.6 Scenario D - Virtual visit over 5G

Some physical places, such as houses and popular touristic places provide limited access to potential visitors. In this scenario a virtual visit is proposed to relax this limitation.

Buying or renting houses or apartment is not immediate and visiting many of them is sometimes required before finding the lovely one. This is really time-consuming for the buyers but also for the real estate agency. It also has a cost for going to the location (fuel, train, etc.) Some agencies propose to view some goods with many pictures and sometimes with simple 360° views. But this experience is currently very limited and does not really help the visitor to see all what she likes, with the many details she is interested at. A very good experience of 360° video with a virtual reality headset could be the starting point for deploying this service at large scale.

Moreover, virtual visitors (i.e., potential buyers) do not have time to waste waiting for the download of large 360° video content to finish. Therefore we advocate the use of video streaming to quickly start a virtual visit and to quickly swap from one virtual visit to another. This use-case, showing this service, should then rely on a very high performing physical network.

This use-case is described above with a real estate agencies example, but we can imagine wider examples. For instance, the virtual visit of touristic places allows relieving the frequentation by directing interested tourists to a virtual visit either before or instead of a physical one (Figure 44).

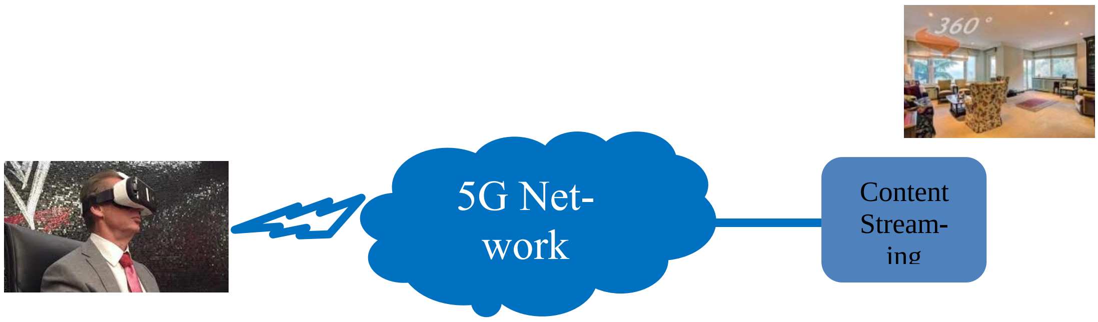


Figure 44: 5G PPP scenario: eMBB and URLLC.

General requirements definition: Virtual visits should benefit from 360° media delivery in a quality that may allow replacing a physical visit with a virtual one, therefore one general requirement is to support the streaming of 360° video matching the highest quality supported by high-end head mounted displays. It mainly means a physical network with a good throughput and a very low latency and offer a very reliable performing connectivity for such high quality content. In one variant the content should be both accessible to the widest viewer population and to the widest content provider population thus the service should be supported over eMBB. In a more specialized variant, the viewing terminals are provided by the real estate agency or the smart tourism agency which requires more controlled performances from its network provider. For this variant the service is supported over URLLC.

Participating site facility: France

3.6.1.7 High level architecture and description:

For this use-case, we need high quality 360° video content, compatible with the VR headset. Ideally, it would be a video related to the visit of one house, but if not available, we can get another one.

The end-user will have a Head Mounted Displays (which could be a standalone one or attached to a PC, depending of the market availability) with 5G connectivity capable of streaming 360° video from content servers located in a separate place. The content will be hosted on a dedicated content server, which would have the streaming capability, at the speed and latency required by the use-case.

Finally, the architecture is completed by the delivery network itself, which will allow the end-users to receive the 360° video content. We might add network appliances to alter or modify the network conditions for tests purposes and identify the impacts of a degraded network connectivity.

To implement this use-case, there are some risks. The first one is the content itself, if only generic 360° content are available, not suited for the device or not adapted for the requirements of this use-case. The second one is the 5G network connectivity, with the given requirements. Finally, having a content server, being able to stream the content, encoded to the specific format compatible with the headset is the last risk.

3.6.1.8 Targeted KPIs (Requirements):

Latency: the RTT from the Head Mounted Display (HMD) to video server.

Speed: Bandwidth between the HMD and the video server on downlink

What is displayed to the HMD is only a fraction of the full 360 degree frame called the viewport. To prevent simulator sickness and provide good Quality of experience (QoE), the multimedia system should react to the head movements as fast as the HMD refresh rate. For a HTC vive HMD, the refresh rate is 90hz. Therefore, the latency should be less than 10 ms.

In First option for 360 degree video delivery system, the server sends the full 360-degree stream, from which the Head Mounted Displays (HMD) extracts the viewport in real time, according to the head movements. Therefore, the majority of delivered video stream data are note used. In this case, there is no latency requirement, but the bandwidth requirement is high (80 Mbps with compression).

In the second option, the server sends only the viewport according to the head movements. In this case the latency requirement is high (around 10 ms) but the requirement on bandwidth on downlink is less (40 mbps).

3.6.1.9 Demo environment:

The end-user will have a Head Mounted Displays (HMD) attached to a PC with 5G connectivity capable of streaming 360° video from content servers located in a separate place. The 360-degree video content will be hosted on a dedicated content server, which would have the streaming capability, at the speed and latency required by the use-case.

3.6.1.10 Integration Needs:

The following integration needs are identified at first instance:

- Infrastructure elements integration and configuration.
- 5G network availability.
- eMBB and URLL slices.
- Provision of radio equipment/module to be integrated at device level

4 The Use-Cases 'Top Level Requirements'

In this section, the general requirements for each vertical domain are defined. The final goal is to illustrate how 5G, and more specifically 5G-EVE, will be able to address significantly different requirements over the same 5G infrastructure. The overall requirements are organized in three main groups:

- General Vertical/Use Case Requirements
- Specific Vertical/Use Case Requirements
- 5G-EVE Site Services user requirements

A "top-down" approach requires that business analysts should focus on business processes, end user requirements, and desired results. The data required to support end user applications and customer experiences is in turn determined and sourced with the help of the information technology department and engineering teams (according to Figure 45).

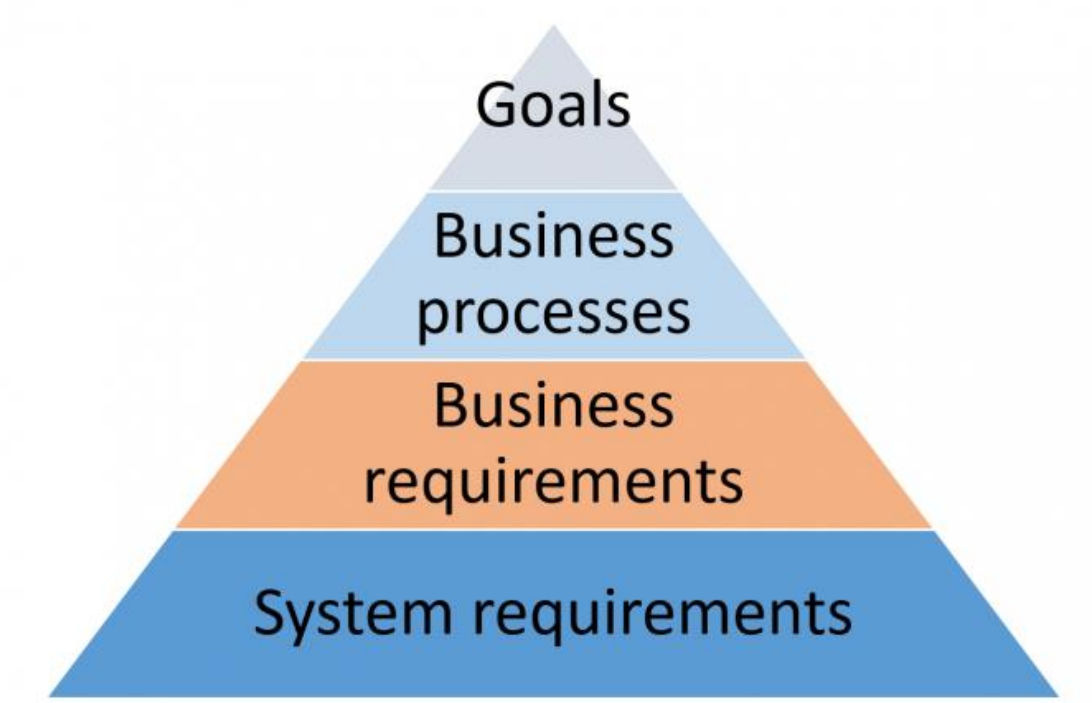


Figure 45: Schematic of the top-down pyramid in requirement analysis

4.1 Use Case Requirements description

Drawing from experience a list of general Vertical/Use Case Requirements is compiled. These are the most common requirements among the different Use Cases proposed, and the ones that will dictate what basic Network requirement should be materialized (if not in the initial phase but definitely in the final stage) in the 3 Project Sites. The full list of requirements (General and Specific ones) are found in Table 7, below. The table is given to all Use Case participants in the form of a spreadsheet file. Each Participant for each Use Case and for Each Scenario is asked to fill-out the corresponding table. The file contains separate workbooks for each scenario. The explanation of what each general and specific requirement is also given and it is show in sections 4.1.1 and 4.1.2 respectively.

Beyond the General and Specific Requirements there are Use Case specific requirements that are also mentioned in the spreadsheet file but not been included in the analysis of Chapter 5. These might be Battery Life expectancy, Energy Efficiency and other more specific for the particular UC and scenario.

Table 7: Questionnaire table for collecting general and specific 5G requirements for each use case

		Units	Use Case description			Priority	Range	
			URLLC	mMTC	eMMB[10]		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in miliseconds) - Min/MAX	msec						
2	Speed (in Mbps) - Min/MAX - sustained demand	Mbps						
3	Reliability (%) - Min/MAX	%						
4	Availability (%) - Min/MAX	%						
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/s						
6	Broadband Connectivity (peak demand)	Y/N or Mbps						
7	Network Slicing (Y/N)	Y/N						
8	Security (Y/N)	Y/N						
9	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2						
10	Device Density	Dev/Km2						
Specific Vertical/Use Case Requirements								
Network	Number of End Points							
	Number (Range) of End Devices per End Point							
	Density of End Devices (per sq. meter)							
	Bitrate needs per end point (Kbps,Mbps, Gbps)							
	End -to-end Latency (msecs)							
	Highest Acceptable jitter (msec)							
	Number of Class of Service (1-8, more)							
End Devices	Type of Device (i.e. Smartphone, TV, VR)							
	Bitrate required (Kbps / Mbps / Gbps)							
	Max Latency Allowable (in msecs)							
	Max Moving Speed (km/h, 0 if stationary)							
	IPv4 & IPv6 support (or both)							
	Connnection of Device to End Point (Wired/Wireless)							
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)							
	Authenication method (i.e. SIM, eSIM, Key..)							
Other Vertical Specific (non-Network related Requirements)								
	i.e Battery life requirement							

4.1.1 General Use Case Requirements description

The explanation and definition of all General Requirements included in Table 7 are provided next. Although a general definition is given, a more specific interpretation is also possible.

For example, Latency for one UC can be the time it takes for the data to travel from a Smartphone to the Server that runs a particular Application (in the Cloud) and the time for the answer to be received back (on the Smartphone).

For another UC, Latency might be the time for a location-information of a vehicle to be send to the Application Sever and the time for the acknowledgement (that the operation is successfully completed) to be received back.

In the order that they appear on the table the definitions are shown below.

Latency (also end-to-end or E2E Latency):

> Measures the duration between the transmission of a small data packet from the application layer at the source node and the successful reception at the application layer at the destination node plus the equivalent time needed to carry the response back.

Speed:

> Speed (data rate): It is set as the minimum user experienced data rate required for the user to get a quality experience of the targeted application/use case (it is also the required sustainable date rate).

Reliability:

The amount of sent packets successfully delivered to the destination within the time constraint required by the targeted service, divided by the total number of sent packets. NOTE: the reliability rate is evaluated only when the network is available.

Availability:

The network availability is characterized by its availability rate X, defined as follows: the network is available for the targeted communication in X% of the locations where the network is deployed and X% of the time (see Table 8 below for different levels of availability).

Table 8: Different levels (%) of Availability

Availability %	Downtime per year	Downtime per month*	Downtime per week
90%	36.5 days	72 hours	16.8 hours
95%	18.25 days	36 hours	8.4 hours
98%	7.30 days	14.4 hours	3.36 hours
99%	3.65 days	7.20 hours	1.68 hours
99.5%	1.83 days	3.60 hours	50.4 minutes
99.8%	17.52 hours	86.23 minutes	20.16 minutes
99.9% (“three nines”)	8.76 hours	43.2 minutes	10.1 minutes
99.95%	4.38 hours	21.56 minutes	5.04 minutes
99.99% (“four nines”)	52.6 minutes	4.32 minutes	1.01 minutes
99.999% (“five nines”)	5.26 minutes	25.9 seconds	6.05 seconds
99.9999% (“six nines”)	31.5 seconds	2.59 seconds	0.605 seconds

*month = 30 days

Mobility:

Mobility refers to the system’s ability to provide seamless service experience to users that are moving. In addition to mobile users, the identified 5G use cases show that 5G networks will have to support an increasingly large segment of static and nomadic users/devices.

Broadband connectivity:

High data rate provision during high traffic demand periods (It is also a measure of the peak data rate required).

Network Slicing:

A network slice, namely “5G slice”, supports the communication service of a particular connection type with a specific way of handling the Control- and User- plane for this service. To this end, a 5G slice is composed of a collection of 5G network functions and specific Radio Access Technology (RAT i.e., WiFi, LTE, etc.) settings that are combined together for the specific use case or business model.

Security:

Network resilience against signaling based threads which could cause malicious or unexpected overload. Provision of basic security functions in emergency situations, when part of the infrastructure maybe destroyed or inaccessibly. Protection against malicious attacks that may intend to disrupt the network operation

Capacity:

Capacity is measured in bit/s/m2 is defined as the total amount of traffic exchanged by all devices over the considered area. The KPI requirement on the minimum Traffic Volume Density / Areal Capacity for a given use case is given by the product: [required user experienced data rate] x [required connection density].

Device Density:

Up to several hundred thousand simultaneous active connections per square kilometer shall be supported for massive sensor deployments. Here, active means the devices are exchanging data with the network.

4.1.2 Specific Vertical/Use Case Requirements (Network and End-Device Related)

The explanation and definition of all Specific Requirements included in Table 7 (Second section) are provided next in the order that they appear in the table.

Network oriented requirements:

- **Number of End Points**.
  The total number of Network End-Points. This is the last or closest NE or PoP to the end-device or end-user. This can be a mobile BS or WiFi AP.
- **Number (Range) of End Devices per End Point.**
  The total number of End-Devices (i.e IoT sensors, Smartphones, Se that can potentially be connected to the End-Point as this is defined above (i.e., the total number of Smart Phones that can use simultaneously or register themselves to a particular BS).
- **Density of End Devices (per sq. meter).**
  The number of the End-Devices (as defined above) that can be collocated (or share) a particular space (3D volume or 2D surface area). I.e., the maximum number of IoT Devices that can be found in an area of 1 m^2. Alternatively, if the network is sparse, the Density can be defined for an area of 1 Km^2.
- **Bitrate needs per End Point (Kbps, Mbps, Gbps).**
  The peak traffic capacity which each end point can service its associated end-devices. For example, if a BS can provide a total of 400 Mbps this can be throttled down to a single end-user device or it can be shared among all the end-devices associated (connected) to this end-point.
- **End-to-end Latency (msec).**
  The total time or delay it takes for a data-packet to travel from an end-device to the destination end-device (server, other end-user etc.). This is a stochastic quantity and can vary depending on network conditions (i.e., congestion state). The desirable value beyond which the service is not acceptable should be provided.
- **Highest Acceptable Jitter (msec)**.
  The highest deviation in the latency metric above, that can be acceptable without disrupting the offered service and making it unacceptable. For example, a jitter value of 5 msec is acceptable if an information packet can arrive -/+ 5 msec (earlier of later) than its expected arrival time. This requirement is more important in real-time control or synchronous transmission systems. The value for jitter should be much smaller than the value for E2E latency.
- **Number of Class of Service (1-8, more)**
  Class of Service is a way of managing traffic in a network by grouping similar types of traffic (for example, e-mail, streaming video, voice, control signals etc.) together and treating each type as a class with its own level of service priority. The number of different Classes / Priorities required will dictate the Data Queues and other Network Element Capabilities (i.e., memory/buffering etc.).

End devices oriented requirements:

- **Type of Device (i.e., Smartphone, TV, VR)**
  The type of end-devices that need to be connected to the network. Video-Source/Camera, Smartphone, Proximity Sensor, Virtual Reality Head-Set etc.

- **Bitrate required (Kbps / Mbps / Gbps)**
  The amount of data traffic that the device will produce or accept.

- **Max Latency Allowable (in msec)**
  The delay in delivery the data packets to and from the end device to the traffic destination. It is more important for real time services (like navigation, voice/video conference, real-time-control) and less important for non-real-time services like SMS, e-mail, or Temp / Power consumption monitoring (without the need for actions based on these values) etc.

- **Max Moving Speed (km/h, 0 if stationary)**
  The moving speed of the end-device. I.e., a walking customer with a smart phone (5-8 Km/h), a moving car (up to 180 Km/h), a moving train (up to 400 Km/h) etc.

- **IPv4 & IPv6 support (or both)**
  Currently most devices (apart from special purpose ones) utilize and connect via IP. The support of IPv4 and/or IPv6 (or both) will allow for proper network configuration.

- **Connection of Device to End Point (Wired/Wireless)**
  Type of interface and connection of the Devices to the Network End-Point (i.e., wireless or cable)

- **Type of Connection (i.e., Ethernet, WLAN, Zigbee)**
  The type of connection the end-device is using to connect to the Network End-Point (i.e., WLAN 802.11n at 5 GHz, 4G mobile, NB-IoT etc.)

- **Authentication method (i.e., SIM, eSIM, Key)**
  Method by which the end device is authenticated (if any required) in order to be allowed to access and use the Network resources (i.e., SIM / eSIM, WPS key, Username/Password etc.)

Other Vertical Specific (non-Network related Requirements)

- Battery life requirement (usually in years)

- Outdoor environment resiliency (i.e., IP67 or IP68) etc.

The analysis presented in the next Chapter focuses on the General Use Case Requirements for all the Use Case presented in Chapter 3.

4.1.3 5G-EVE Site Services user requirements

Finally, some information regarding each particular site/demo environment (for logistics, identification and security purposes) are also requested. Since these requirements are not relevant to the scope of the Project most participants failed to provide them. These might be deemed necessary in the case of a commercial deployment.

- **City:**
  The city that the particular Use Case will be demonstrated.
- **Address & End Tel. Number:**
  - Complete the postal address with the postal code (eg Doirani 58, Kallithea, 17672).
- **Competent, Tel. Number, FAX:**

Site Manager/Network Administrator for Site.

- **Type of Service:**
    - The service type is selected from the following and defined per end: Fixed, Broadband, Wireless, Dial up.
- **Speed/Capacity:**
    - Access speed for Fixed, Broadband, Dial up, and Wireless service capacity is completed as per the offer.
- **Access Protection:**
    - Selection from (if technical feasibility) 1: Single Entry / Single Drive 2. Single Entry / Dual Driving 3. Dual Input / Dual Driving.
- **PRIMARY / BACK UP:**
    - Primary or Back up.
- **EXTRANET:**
    - Enter the Customer's VAT ID to which the IP VPN will connect the end as an Extranet. If the VAT number has more than one IP VPN, the VRF is also filled in.
- **Broadband Access Line:**
    - Enter the phone number on which Broadband access already exists or will be built.
- **Existing Access:**
    - Complete YES if Broadband access already exists, NO if it will be constructed under the request of the project.
- **Minimum Duration of Service:**
    - The amount of time (and the period) during which the required service/connection should be available.
- **Class of Service (Silver/Gold/Premium):**
    - The desired COS capacity is filled in. All COS must be integer multiples of 8 Kbps. The service is only available in Fixed-type connections.

4.2 Difference between Current and Future Requirements

The release timing for 5G distinguishes between Phase 1 and Phase 2 as indicated in the following roadmap. Standardization will take place in Release 15 and 16 respectively based on the outcome of the Release 14 Figure 46.

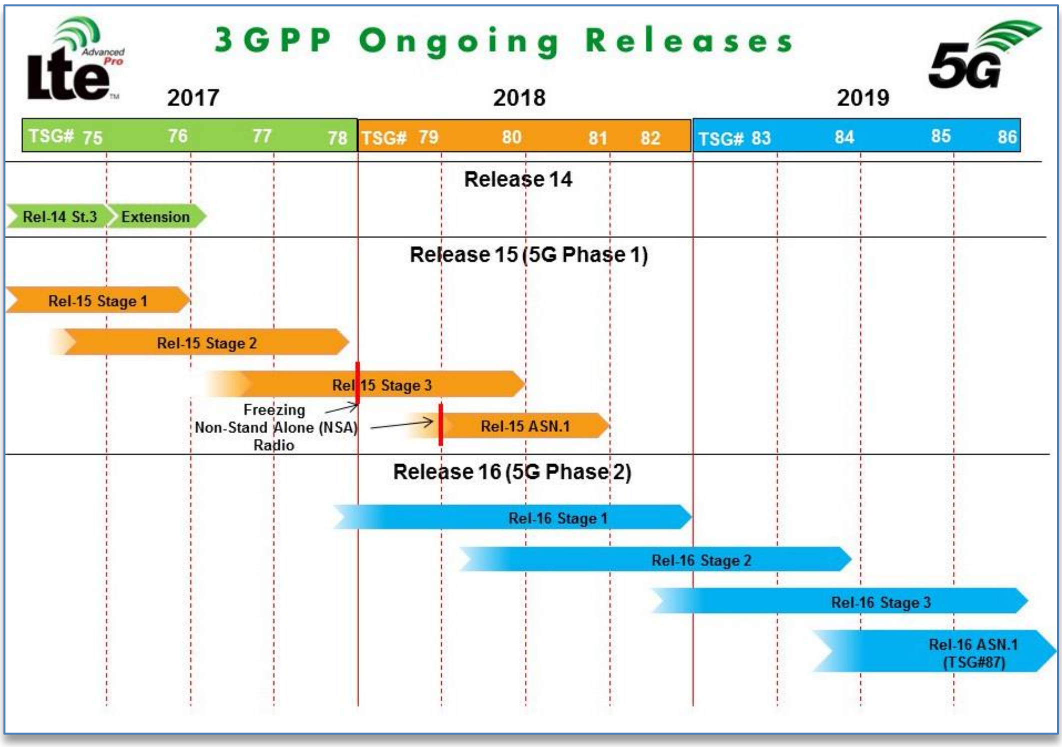


Figure 46: 3GPP Releases schedule [18]

End of 2017 the non-standalone 5G access is completed. The new 5G access scheme is using dual connectivity with LTE as the master eNB and does not need a specification of a full 5G radio resource control. The standalone 5G radio access network that will be connected to the 5G core is be completed in Release 15 (mid of 2018). Phase 1 includes:

- Network Slicing support
- QoS framework
- UE/Mobility Management
- Data Session Continuity
- Efficient User Plane path
- Network Function Interaction
- Policy/Charging Control, Security
- Interworking & Migration from 4G
- Support for IMS in providing voice,
- Network discovery/selection 3GPP
- Network Capability Exposure.

Whereas subsequent phases include:

- Broadcast/Multicast Capabilities
- Proximity Services
- Communications via Relays
- Off-Network communications
- Network discovery/selection non3GPP
- Traffic steering/switching between non3GPP accesses
- Extremely rural deployments and others.

It is suggested to use NB-IoT and eMTC as baseline for 5G submission of an mMTC component. RAN standardization bodies have been discussing work items that will enhance NB-IoT and eMTC in order to fulfill the 5G requirements (one may see [16] for NB-IoT and [17] for eMTC). 5G can stand as standalone (Option 2 in

3GPP). There are deployment options that use both LTE and NR at the same time using dual connectivity technology (so called non-standalone deployments).

4.2.1 Scenario functional and non-functional requirements

A **functional requirement** defines a function of a system or its component, where a function is described as a specification of behaviour between outputs and inputs.

Functional requirements may involve calculations, technical details, data manipulation and processing, and other specific functionality that define what a system is supposed to accomplish. Behavioural requirements describing all the cases where the system uses the functional requirements are captured in use cases. Functional requirements are supported by non-functional requirements (also known as "quality requirements"), which impose constraints on the design or implementation (such as performance requirements, security, or reliability). Generally, functional requirements are expressed in the form "system must do <requirement>," while non-functional requirements take the form "system shall be <requirement>" [7]. The plan for implementing functional requirements is detailed in the system design, whereas *non-functional* requirements are detailed in the system architecture.

As defined in requirements engineering, functional requirements specify particular results of a system. This should be contrasted with non-functional requirements, which specify overall characteristics such as cost and reliability. Functional requirements drive the application architecture of a system, while non-functional requirements drive the technical architecture of a system.

In some cases a requirements analyst generates use cases after gathering and validating a set of functional requirements. The hierarchy of functional requirements collection and change, broadly speaking, is: user/stakeholder request → analyse → use case → incorporate. Stakeholders make a request; systems engineers attempt to discuss, observe, and understand the aspects of the requirement; use cases, entity relationship diagrams, and other models are built to validate the requirement; and, if documented and approved, the requirement is implemented/incorporated. Each use case illustrates behavioral scenarios through one or more functional requirements. Often, though, an analyst will begin by eliciting a set of use cases, from which the analyst can derive the functional requirements that must be implemented to allow a user to perform each use case.

4.2.2 'Questionnaires' for collecting the general and specific requirements of the six main Use Cases of 5G-EVE

All the partners of the 5G-EVE that have in their responsibility the implementation of one of the six main Use Case and the sub-Use Cases, have been asked to fill-in the corresponding values and ranges for each 5G requirement that appears into the following questionnaire Table 9 (shown also here for convenience):

Table 9: Questionnaire table for collecting general and specific 5G requirements for each use case

		Units	Use Case description			Priority	Range	
			URLLC	mMTC	eMMB[10]		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in miliseconds) - Min/MAX	msec						
2	Speed (in Mbps) - Min/MAX - sustained demand	Mbps						
3	Reliability (%) - Min/MAX	%						
4	Availability (%) - Min/MAX	%						
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/s						
6	Broadband Connectivity (peak demand)	Y/N or Mbps						
7	Network Slicing (Y/N)	Y/N						
8	Security (Y/N)	Y/N						
9	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2						
10	Device Density	Dev/Km2						
Specific Vertical/Use Case Requirements								
Network	Number of End Points							
	Number (Range) of End Devices per End Point							
	Density of End Devices (per sq. meter)							
	Bitrate needs per end point (Kbps,Mbps, Gbps)							
	End -to-end Latency (msecs)							
	Highest Acceptable jitter (msec)							
	Number of Class of Service (1-8, more)							
End Devices	Type of Device (i.e. Smartphone, TV, VR)							
	Bitrate required (Kbps / Mbps / Gbps)							
	Max Latency Allowable (in msecs)							
	Max Moving Speed (km/h, 0 if stationary)							
	IPv4 & IPv6 support (or both)							
	Connnection of Device to End Point (Wired/Wireless)							
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)							
	Authenication method (i.e. SIM, eSIM, Key..)							
Other Vertical Specific (non-Network related Requirements)								
	i.e Battery life requirement							
5G-EVE Site Services USER REQUIREMENTS								
	City							
	Address & End Tel. Number[1]							
	Competent, Tel. Number, FAX							
	Type of Service[2]							
	Speed/Capacity[3]							
	Access Protection[4]							
	PRIMARY / BACK UP[5]							
	EXTRANET[6]							
	Broadband Access Line[7]							
	Existing Access[8]							
	Number of DIAL-UP Users							
	Minimum Duration of Service							
	Class of Service[9] (Silver/Gold/Premium)							

All the requirements of the table have been described in the first workbook of the spreadsheet file and also included in Section 4.1 above. The questionnaire table was filled-in from each one of the following list of Use-Cases and Sub-Use-Cases (also mentioned as scenario) of the Table 10 below:

Table 10: List of use-case and sub-use-case and description

a/a	Use Case	Description
1	Use Case 1	Smart Transport – Intelligent Railway for smart mobility - TRENITALIA
2	Use Case 2	Smart Tourism - Augmented Fair experience - SEGITTUR - Spain
3	Use Case 3a	Industry 4.0 – Autonomous vehicles in manufacturing environments – ASTI Spain
4	Use Case 3b	Industry 4.0 – Autonomous vehicles in manufacturing environments – Ericsson GR
5	Use Case 4	Utilities - Smart Energy - Fault management for distributed electricity generation in smart grids – WINGS GR / EDF FR
6	Use Case 5a	Smart cities - Safety and Environment - Smart Turin – COMUNE DI TORINO Italy
7	Use Case 5b	Smart cities - Safety and Environment – eHealth/eAmbulance – NOKIA GR
8	Use Case 5c	Smart cities - Safety and Environment – Health Monitoring and Forecasting, Smart Mobility, Smart Home – WINGS GR
9	Use Case 6a	Media & Entertainment – UHF Media – TELEFONICA Spain
10	Use Case 6b	Media & Entertainment – On-Site Live Event Experience – TELEFONICA Spain
11	Use Case 6c	Media & Entertainment – Immersive and Integrated Media – TELEFONICA Spain
12	Use Case 6d	Virtual Visit – Virtual 360° Visit for real estate or tourism – ORANGE FR

- The Completed Tables of each Use Case and each Sub-Use-Case/Scenario are shown in the next chapter (Chapter 5) of this deliverable.
- All the tables for each Use-Case are collected into the following spreadsheet file. (**5G-EVE Use Cases Specific Requirements.xlsx**) into the 5G EVE Workspace (BSCW) - available upon request.

5 The Use-Cases' Requirements Analysis

A **radar chart or graph** (also referred to as spider graph) is a graphical method of displaying multivariate data in the form of a two-dimensional chart of three or more quantitative variables represented on axes starting from the same point (the middle of the chart). The relative position and angle of the axes is typically uninformative. Radar graphs with multiple axis and different scales (linear or logarithmic) are used in order to better represent to comparison of two or more set of values.

In our analysis a radar chart of 8 axes is used. Even though we could have used a 10 axis graph (since this is the number of general requirements presented in 4.1.1) an 8 axis chart is both cleaner and more informative. Therefore the need of Slicing and the Security requirement are not included in the charts and the subsequent analysis.

As a reference for the analysis a 4G vs. 5G capabilities Radar Graph is first created. The Radar Graph is based on Table 11 (below) that presents the values for each metric with respect to the 4G and 5G network capabilities. Each one of metrics/capability (i.e., Latency, Reliability, Slicing, etc.) correspond to a different axis with its own scale.

In the first Radar Graph of this Deliverable, the inner area (see Figure 47: Radar graph for 4G/5G capabilities-shown below) shaded light blue and delimited by the red-dots, is the "domain" of existing 4G networks. If the requirements of a particular Use Case fall inside this are then there is no need for a 5G network in order to materialize this Use Case.

The area that is bounded by the blue-dots is the "domain" of the upcoming 5G networks (shaded turquoise). If the requirement of a particular Use-Case falls inside this area, but outside the area of the 4G network capabilities then this Use Case needs a 5G network to function properly. If the requirement of a particular Use Case falls outside even this area (defined by the blue dots) then this Application/Use Case has to wait for the 5G networks to evolve further or try to reduce this particular requirement.

Table 11: 4G/5G capabilities for mapping the Vertical's Use Cases Requirements

General 4G/5G capabilities		Units	4G	5G
1	Latency (in miliseconds)	msec	10	1
2	Speed (in Mbps) - bitrate	Mbps	400	1000
3	Reliability (%)	%	99,9%	99,999%
4	Availability (%)	%	99,9%	99,999%
5	Mobility (in m/sec or Km/h)	Km/s	300	500
6	Broadband Connectivity (peak demand)	Gbps	1	20
7	Network Slicing (Y/N)	Y/N	N	Y
8	Security (Y/N)	Y/N	Y	Y
9	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	0,1	10
10	Device Density	Dev/Km^2	100K	1000K

The first radar chart which corresponds to Table 11 (above), is equivalent to the one shown in Figure 2) and will be subsequently use as a reference since all the Use Case Requirements will be mapped on this one to access their existing and future needs.

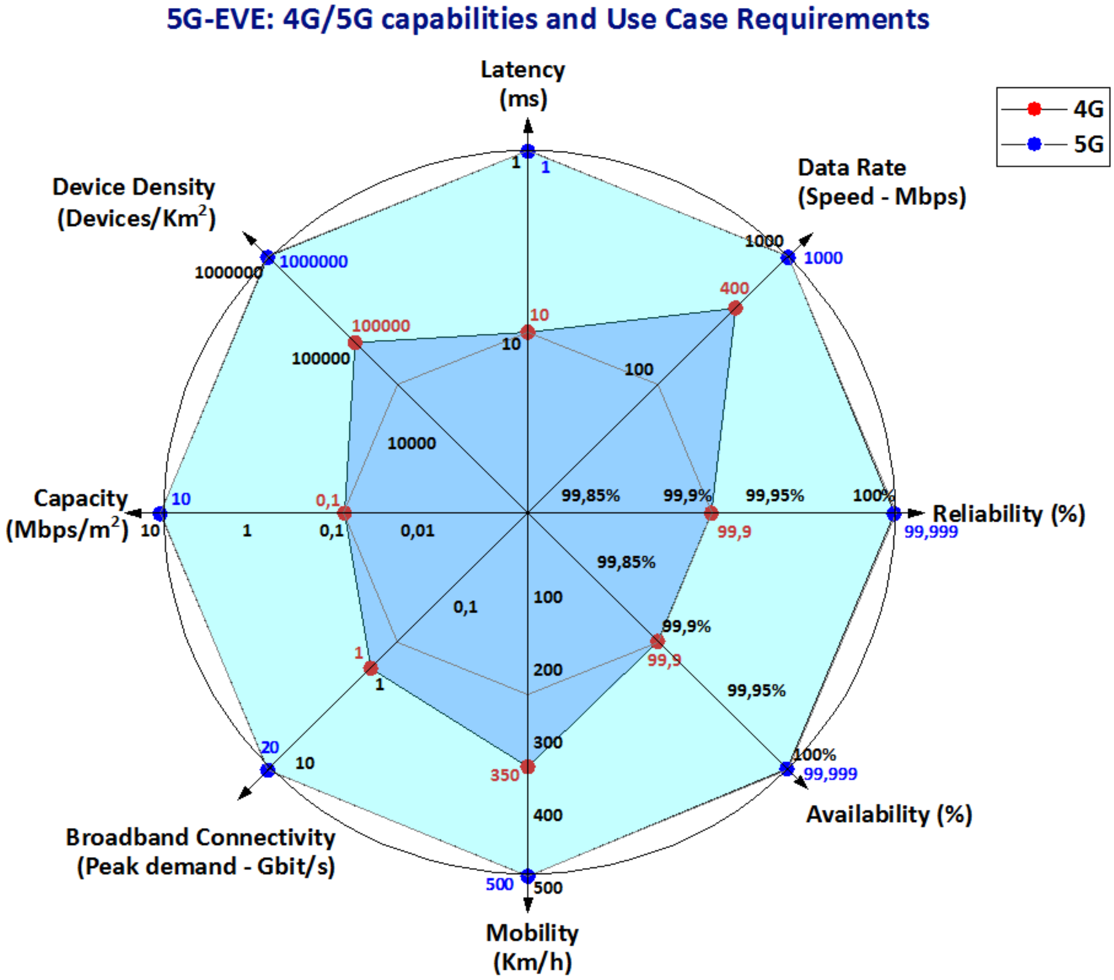


Figure 47: Radar graph for 4G/5G capabilities

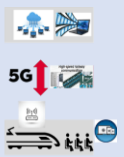
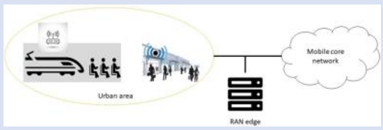
The radar chart above will serve as backdrop where the general requirements of all Use Case included in Table 10 will be presented. With this graphical representation will become easily apparent if the requirements fall inside the capabilities of 4G/LTE networks, or need the enhanced capabilities of the 5G technologies or even need something better than that (we did encounter one of these instances but a remedy is also proposed).

Next, the compiled requirement tables and a basic analysis of the 12 use cases and sub-use cases is presented.

5.1 Use case 1 Requirements - Smart Transport: Intelligent railway for smart mobility

The requirements of the Smart Transport Use Case values are shown in Table 12 bellow. The values are given by Trenitalia and the formula by which some of the requirements are estimated (i.e., Capacity) is also given. The values of the requirements are mapped in our reference radar chart and the results are shown in Figure 48.

Table 12: Use case 1 – Smart Transport – Intelligent Railway for smart mobility - TRENITALIA

5G-EVE - Use Cases: direct specific requirements		Units	Use Case 1: Smart Transport (IT-TRENITALIA) Intelligent railway for smart mobility		Priority	Range	
			URLLC[10]	mMTC[11]		Min	Max
General Vertical/Use Case Requirement							
1	Latency (in miliseconds) - Min/MAX	msec	1			0	5
2	Speed (in Mbps) - Min/MAX - sustained demand	Mbps	100			40	100
3	Reliability (%) - Min/MAX	%	>99,95%			99,95%	99,999%
4	Availability (%) - Min/MAX	%	99,9			90,00%	99,99%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/h	300	300		260	300
6	Broadband Connectivity (peak demand) - whole train, per each MO (band aggregation oriented)	Y/N or Mbps	5000			1600	10000
7	Network Slicing (Y/N)	Y/N	Y			Y	Y
8	Security (Y/N)	Y/N	Y			Y	Y
9	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	3,56*			1	5
10	Device Density	Dev/Km2		100000		100000	1000000
Specific Vertical/Use Case Requirements-5G On Board Media content streaming (End Point=End Devices)							
Network	Number of End Points		300			100	400
	Number (Range) of End Devices per End Point		300			100	400
	Density of End Devices (per sq. meter)	nsity per Sq met	Not appliable				
	Bitrate needs per end point (Mbps)	Mbs	100			40	100
	End -to-end Latency (msecs)	msecs	1			0	5
	Highest Acceptable jitter (msec)	msecs	Not appliable				
	Number of Class of Service (1-8, more)		Not appliable				
End Devices	Type of Device (i.e. Smartphone, TV, VR)		Smartphone, laptop				
	Bitrate required (Mbps)	Mbs	100			40	100
	Max Latency Allowable (in msecs)	msecs	1			0	5
	Max Moving Speed (km/h)	km/h	300			260	300
	IPv4 & IPv6 support (or both)		Both			Both	Both
	Connnection of Device to End Point (Wired/Wireless)		Wireless			Wireless	Wireless
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)						
	Authenication method (i.e. SIM, eSIM, Key..)		SIM			SIM	SIM
Other Vertical Specific (non-Network related Requirements)							
	Advanced Multimodem/multisim MR, with band aggregation						
Specific Vertical/Use Case Requirements- Urban Mobility 5G data flows Analysis and monitoring for traffic management for public transport							
Network	Number of End Points		140			100	140
	Number (Range) of End Devices per End Point		1400			1000	1400
	Density of End Devices (per sq. meter)	sq meter	2			1	2
	Bitrate needs per end point (Mbps)	Mbps	14000			10000	14000
	End -to-end Latency (msecs)	mcsecs	100			200	100
	Highest Acceptable jitter (msec)	mcsec	20,00			100,00	20,00
	Number of Class of Service (1-8, more)						
End Devices	Type of Device (i.e. Smartphone, TV, VR)		Smartphone, laptop, Smartwatch, Tablet VR				
	Bitrate required (Mbps)	Mbps	100			50	100
	Max Latency Allowable (in msecs)	msecs	5			5	1
	Max Moving Speed (km/h)	km/h	300			260	300
	IPv4 & IPv6 support (or both)		Both				
	Connnection of Device to End Point (Wired/Wireless)		Wireless			Wireless	Wireless
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)						
	Authenication method (i.e. SIM, eSIM, Key..)		SIM			SIM	SIM
Other Vertical Specific (non-Network related Requirements)							
	i.e Battery life requirement	Data storage and processing resources at RAN edge					

***** (38 passengers/wagon x 30Mbps/passenger x 10% overbooking) ÷ $32m^2$ wagon area

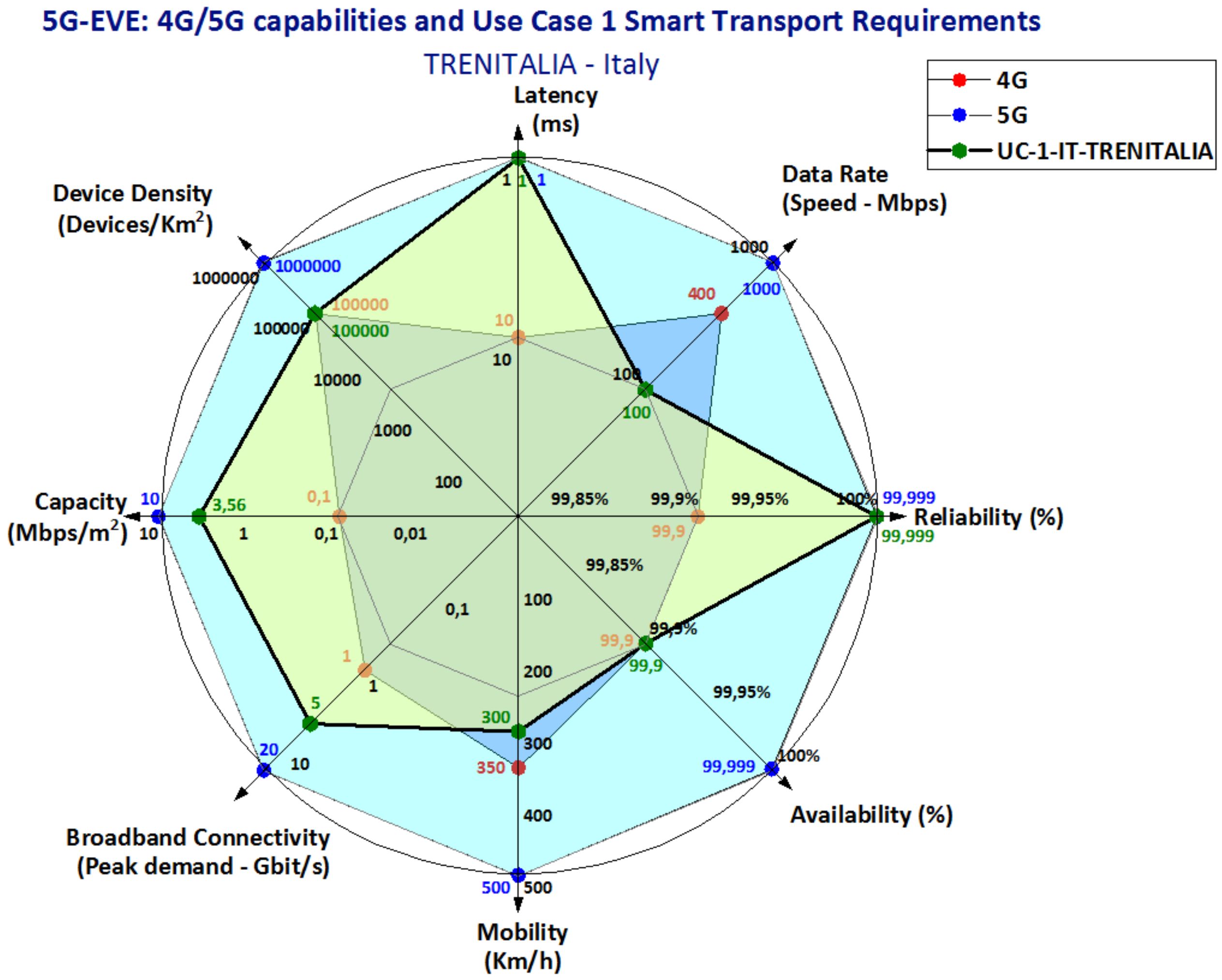


Figure 48: 4G/5G capabilities and Use Case 1 Smart Transport Requirements by TRENITALIA

From the Table 12 of general requirement values and most prominently from the radar chart above it can be concluded that for Smart Transport Use Case existing 4G/LTE networks are not adequate.

4G/LTE network(s) does not offer the required

a) Latency

b) Capacity in terms of Mbps/m^2

c) Broadband Connectivity and

d) Reliability

Therefore, TRENITALIA (and its customers) will greatly benefit by the introduction of the 5G network and its enhanced capabilities.

5.2 Use case 2 Requirements - Smart Tourism - Augmented Fair experience - SEGITTUR Spain

The General and Specific requirements for the smart-tourism Use-Case are shown in Table 13, shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 49.

Table 13: Use Case 2 - Smart Tourism - Augmented Fair experience - SEGITTUR - Spain

5G-EVE - Use Cases: direct specific requirements		Units	Use Case 2: Smart Tourism (SP - SEGITTUR) Augmented Fair experience	Priority	Range	
			eMMB[12]		Min	Max
General Vertical/Use Case Requirement						
1	Latency (in miliseconds) - Min/MAX	msec	100		200	100
2	Speed (in Mbps) - Min/MAX - sustained demand	Mbps	100		1	100
3	Reliability (%) - Min/MAX	%	99%		99%	99%
4	Availability (%) - Min/MAX	%	99%		99%	99%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/hour	10		10	10
6	Broadband Connectivity (peak demand)	Mbps	30000		500	30000
7	Network Slicing (Y/N)	Y/N	Y		N	Y
8	Security (Y/N)	Y/N	N		N	N
9	Capacity (Mbps/m^2 or Km^2)	$Mbps/m^2$	18,75		0,3125	18,75
10	Device Density	Dev/Km2	187500		187500	187500
Specific Vertical/Use Case Requirements						
Network	Number of End Points		1		1	50
	Number (Range) of End Devices per End Point		300		6	300
	Density of End Devices (per sq. meter)		0,1875		0,1875	0
	Bitrate needs per end point Uplink UL (Mbps)		30000			
	Bitrate needs per end point Downlink DL (Mbps)		30000			
	End -to-end Latency (msecs)		100		200	100
	Highest Acceptable jitter (msec)		20		100	20
	Number of Class of Service (1-8, more)					
End Devices	Type of Device (i.e. Smartphone, TV, VR)		SMP,TV,VR		SMP	SMP,TV,VR
	Bitrate required Uplink (Mbps)		100		50	100
	Bitrate required Downlink (Mbps)		100		100	100
	Max Latency Allowable (in msecs)		100		200	100
	Max Moving Speed (km/h, 0 if stationary)		10		0	10
	IPv4 & IPv6 support (or both)		N		N	N
	Connnection of Device to End Point (Wired/Wireless)					
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)					
	Authenication method (i.e. SIM, eSIM, Key..)		SIM		SIM	SIM
Other Vertical Specific (non-Network related Requirements)						
	i.e Battery life requirement					
5G-EVE Site Services User Requirements						
	City		Madrid, Spain			
	Address & End Tel. Number[1]		Av. Partenón, 5, 28042 Madrid			
	Competent, Tel. Number, FAX		"+34 917 22 30 00"			
	Type of Service[2]					
	Speed/Capacity[3]					
	Access Protection[4]					
	PRIMARY / BACK UP[5]					
	EXTRANET[6]		http://www.ifema.es/Institucional_06/			
	Broadband Access Line[7]					
	Existing Access[8]					
	Number of DIAL-UP Users					
	Minimum Duration of Service					
	Class of Service[9] (Silver/Gold/Premium)					

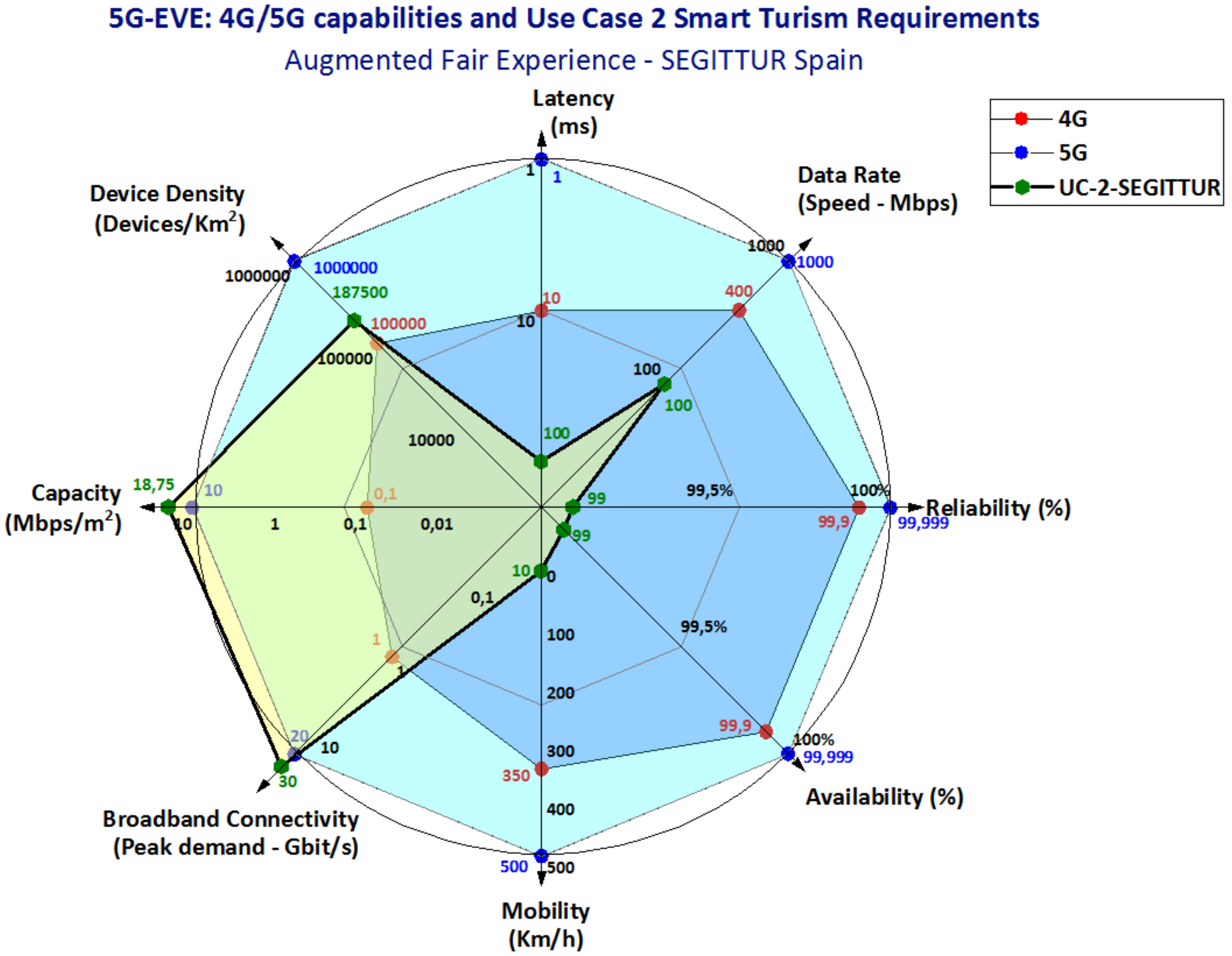

5G-EVE: 4G/5G capabilities and Use Case 2 Smart Turism Requirements
Augmented Fair Experience - SEGITTUR Spain
Latency (ms)
Data Rate (Speed - Mbps)
Reliability (%)
Availability (%)
Mobility (Km/h)
Broadband Connectivity (Peak demand - Gbit/s)
Capacity (Mbps/m2)
Device Density (Devices/Km2)
4G
5G
UC-2-SEGITTUR
1000000
187500
100000
10000
1000
400
100
99,5%
100%
99,9
99,999
350
500
18,75
30
20

Figure 49: 4G/5G capabilities and Use Case 2 Smart Tourism - Augmented Fair experience by SEGITTUR Spain

It becomes obvious that from values given for the general requirement, and especially be a simple observation of the radar chart above it can be concluded that for Smart Tourism Use Case existing 4G/LTE networks are lacking in terms of

a) Device Density,

b) Capacity in terms of Mbps/m^2 and

c) Broadband Connectivity.

Another, outcome that can be observed is that the suggested requirements of i) Capacity and ii) Broadband Connectivity (Peak Demand) exceeds even the capabilities of even the 5G Networks.

This indicates that two alternative approaches can be followed. Either the launch of this Service has to wait until the available network technologies evolve and surpass the required values, or there should be spatial separation of the area where this services will be provided. That is more Base Station (BS) with adequate backhauling (10 Gbps) should be installed covering the area of interest. Furthermore (since the latency value is not that demanding) no Edge Cloud architecture is needed. Great care should be taken though, in order for customers / users (although they will be able to associated with more than one BS), to be distributed carefully among BSs so as to be able to offer the increased Peak Bitrate of 30 Gbps (overall) and allow for 18,75 Mbps/m^2 area capacity.

5.3 Use Case 3a Requirements: Industry 4.0 - Autonomous vehicles in manufacturing environments - ASTI Spain

The genaral and specific requirements for Use Case 3 and Scenario a (UC3a) are shown Table 14 below. The generated radar chart from these values with the 4G and 5G network capabilities as a backdrop is shown in Figure 50in the subsequent page.

Table 14: Use Case 3a - Industry 4.0 – Autonomous vehicles in manufacturing environments – ASTI Spain

5G-EVE - Use Cases: direct specific requirements		Units	Use Case 3: Industry 4.0 (SP - ASTI) Autonomous vehicles in manufacturing environments	Priority	Range	
			URLLC		Min	Max
General Vertical/Use Case Requirement						
1	Latency (in miliseconds) - Min/MAX	msec	10		100	10
2	Speed (in Mbps) - Min/MAX - sustained demand	Mbps	54		54	54
3	Reliability (%) - Min/MAX	%	99,90%		99,00%	99,90%
4	Availability (%) - Min/MAX	%	99,90%		99,00%	99,90%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/hour	20		10	20
6	Broadband Connectivity (peak demand)	Mbps	6480		108	6480
7	Network Slicing (Y/N)	Y/N	Y		N	Y
8	Security (Y/N)	Y/N	N		N	N
9	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	2,16		2,16	2,16
10	Device Density	Dev/Km2	40000		40000	40000
Specific Vertical/Use Case Requirement						
Network	Number of End Points		1		1	1
	Number (Range) of End Devices per End Point		120		2	120
	Density of End Devices (per sq. meter)		0,04		0,04	0
	Bitrate needs per end point Uplink UL (Mbps)		6480		108	6480
	Bitrate needs per end point Downlink DL (Mbps)		240		4	240
	End -to-end Latency (msecs)		10		100	10
	Highest Acceptable jitter (msec)		5		100	5
	Number of Class of Service (1-8, more)					
End Devices	Type of Device (i.e. Smartphone, TV, VR)		SIM Modem		SIM Moden	SIM Modem
	Bitrate required Uplink (Mbps)		54		54	54
	Bitrate required Downlink (Mbps)		2		2	2
	Max Latency Allowable (in msecs)		10		100	10
	Max Moving Speed (km/h, 0 if stationary)		20		0	10
	IPv4 & IPv6 support (or both)		N		N	N
	Connnection of Device to End Point (Wired/Wireless)					
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)					
	Authenication method (i.e. SIM, eSIM, Key..)		SIM		SIM	SIM
Other Vertical Specific (non-Network related Requirements)						
	i.e Battery life requirement					
5G-EVE Site Services User Requirements						
	City		Leganés. Madrid. Spain			
	Address & End Tel. Number[1]		Avenida del Mar Mediterráneo 22			
	Competent, Tel. Number, FAX		"+34 91 481 62 10"			
	Type of Service[2]					
	Speed/Capacity[3]					
	Access Protection[4]					
	PRIMARY / BACK UP[5]					
	EXTRANET[6]		https://www.5tonic.org/			
	Broadband Access Line[7]					
	Existing Access[8]					
	Number of DIAL-UP Users					
	Minimum Duration of Service					
	Class of Service[9] (Silver/Gold/Premium)					

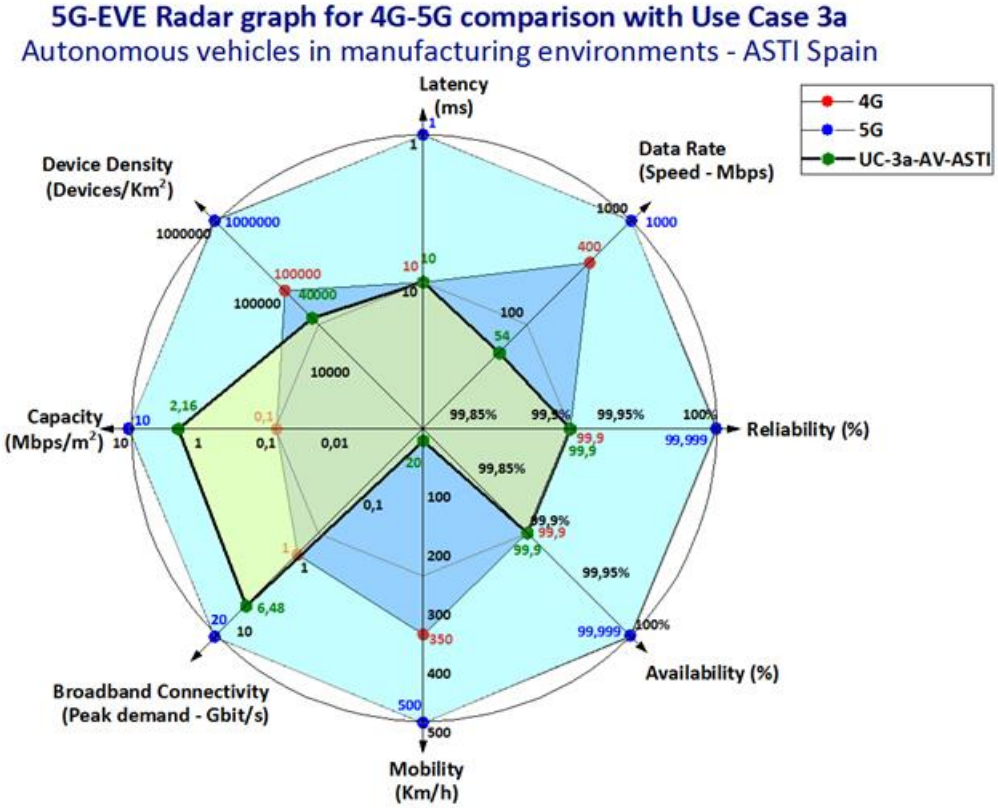


Figure 50: 4G/5G capabilities and Use Case 3 – Industry 4.0

The Industry 4.0 – Autonomous Vehicle Guidance Use Case can be considered a classic Application where 5G is needed. From the radar chard above it can be concluded that 5G networks capabilities are needed for the

a) Capacity and
b) Broadband Connectivity or Peak Demand.

Contrary to the previous (Smart Tourism Use Case) the required values can be satisfied by the 5G network capabilities. Therefore, it appears that this Service is one of the first to benefit or even be launched as soon as the 5G Networks become commercially available.

5.4 Use Case 3b Requirements: Industry 4.0 - Autonomous vehicles in manufacturing environments – Ericsson GR

The requirements for Use Case 3 and Scenario b) (UC3b) are included in

Table 15. In addition, a table with assumptions for phase 1 can also be found in Table 16. The corresponding radar graphs can be be found in the subsequent page in Figure 51.

Table 15: Use Case 3b - Industry 4.0 – Autonomous vehicles in manufacturing environments – Ericsson GR

5G-EVE - Use Cases: direct specific requirements		Units	Use Case 3: Industry 4.0 (GR-Ericsson) Autonomous vehicles in manufacturing environments	Priority	Range	
			URLLC		Min	Max
General Vertical/Use Case Requirement						
1	Latency (in miliseconds) - Min/MAX	msec	10		100	10
2	Speed (in Mbps) - Min/MAX - sustained demand	Mbps	80		80	80
3	Reliability (%) - Min/MAX	%	99,999%		99%	99,999%
4	Availability (%) - Min/MAX	%	99,999%		99%	99,999%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/hour	0		0	0
6	Broadband Connectivity (peak demand)	Mbps	400		160	400
7	Network Slicing (Y/N)	Y/N	Y		N	Y
8	Security (Y/N)	Y/N	N		N	N
9	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	3,2		1,28	3,2
10	Device Density	Dev/Km2	40000		16000	40000
Specific Vertical/Use Case Requirement						
Network	Number of End Points		1		1	1
	Number (Range) of End Devices per End Point		5		2	5
	Density of End Devices (per sq. meter)		0,04		0,016	0,04
	Bitrate needs per end point Uplink UL (Mbps)		400		160	400
	Bitrate needs per end point Downlink DL (Mbps)		20		20	20
	End -to-end Latency (msecs)		10		100	10
	Highest Acceptable jitter (msec)		5		100	5
	Number of Class of Service (1-8, more)					
End Devices	Type of Device (i.e. Smartphone, TV, VR)		SIM Modem		SIM Modem	SIM Modem
	Bitrate required Uplink (Mbps)		#ΔIAIP./0!		80	80
	Bitrate required Downlink (Mbps)		0		0	0
	Max Latency Allowable (in msecs)		10		100	10
	Max Moving Speed (km/h, 0 if stationary)		0		0	10
	IPv4 & IPv6 support (or both)		N		N	N
	Connnection of Device to End Point (Wired/Wireless)					
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)					
	Authenication method (i.e. SIM, eSIM, Key..)		SIM		SIM	SIM
Other Vertical Specific (non-Network related Requirements)						
	i.e Battery life requirement					
5G-EVE Site Services User Requirements						
	City		Greece			
	Address & End Tel. Number[1]		Greece - Cosmote warehouse			
	Competent, Tel. Number, FAX		"+30 697 10 138 18"			
	Type of Service[2]					
	Speed/Capacity[3]					
	Access Protection[4]					
	PRIMARY / BACK UP[5]					
	EXTRANET[6]	www.cosmote.gr/fixed/en/corporate/company/who-we-are/network				
	Broadband Access Line[7]					
	Existing Access[8]					
	Number of DIAL-UP Users					
	Minimum Duration of Service					
	Class of Service[9] (Silver/Gold/Premium)					

Table 16: Assumptions for Phase 1 – Ericsson GR

Assumptions	Phase 1	Units
One AGV per 25 square meters (5m x 5m)	25	square meters
Factory size of 125 square meters (100m x 30m)	125	square meters
Factory with up to 5 AGVs	5	AGVs
Minimum case with 2 AGVs	2	AGVs
Minimum speed Km/hour	6	Km/hour
Maximun speed Km/hour	10	Km/hour
Downlink per AGV Mbps	20	Mbps
Minimum scenarios latency (ms)	100	

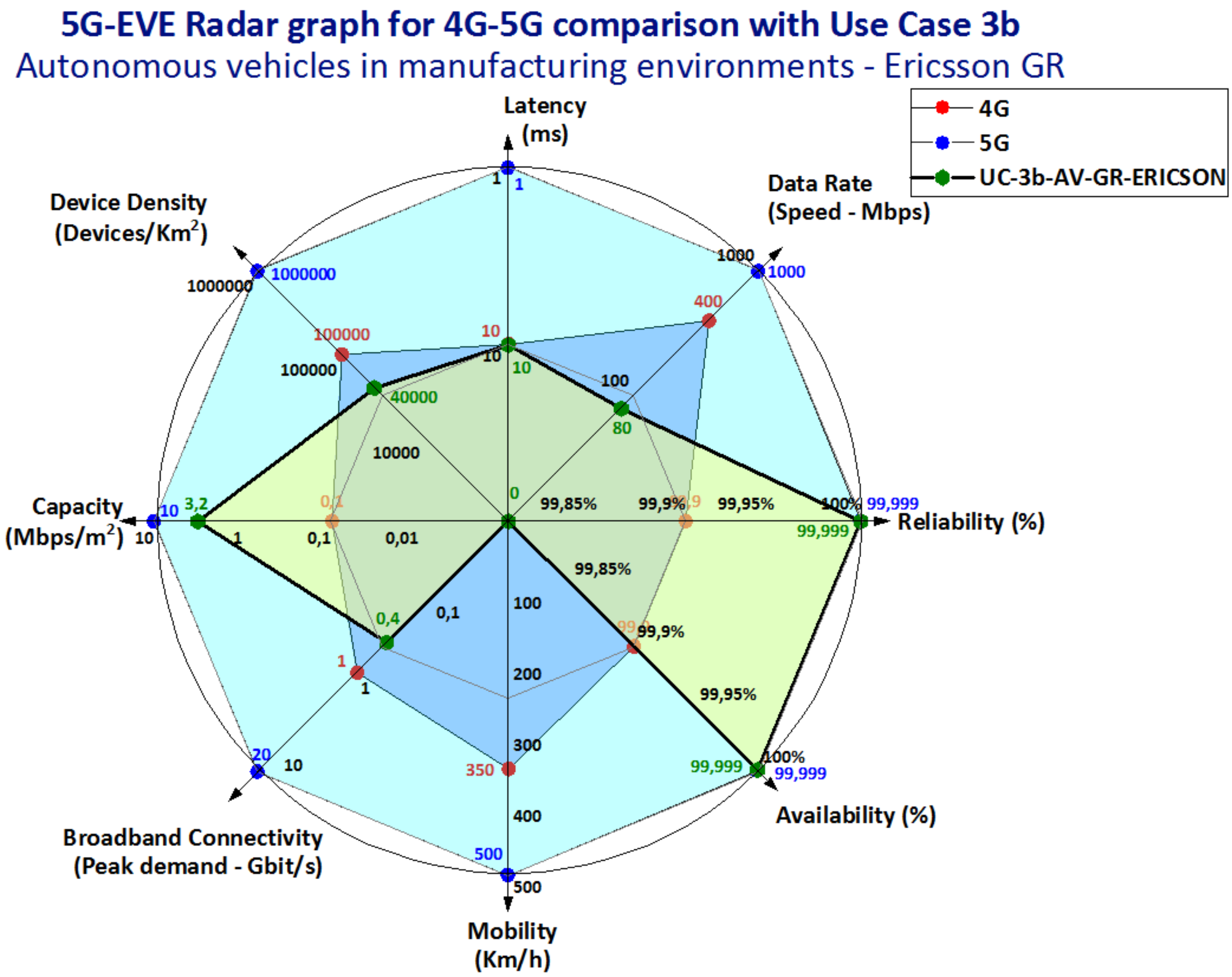


Figure 51: 4G/5G capabilities and Use Case 3 – Industry 4.0
Autonomous vehicles in manufacturing environments by Ericsson GR

From the Table 15 and radar chart of UC3b can be easily be concluded that the suggested Service cannot be provided over the existing 4G/LTE networks mainly due to the

a) Capacity
b) Availability and
c) Reliability

requirements.

Like the previous Use Case, this application, is also one of the first to benefit or even be launched as soon as the 5G Networks become commercially available. It appears that this application can even start being offered using existing 4G/LTE network as long as the number of AVGs in a particular space is limited (so as not to exceed the Capacity requirement) and there are lower Reliability and Availability requirements. This might deem the commercial viability of this UC more difficult.

Furthermore, if the 5-nines (99.999%) Availability and Reliability requirements cannot be provided in the initial phase of the 5G network will potentially hinder further the commercial introduction of the service.

5.5 Use Case 4 Requirements: Utilities - Smart Energy - Fault management for distributed electricity generation in smart grids - WINGS GR-WINGS/EDF FR

The requirements for Use Case 4 that deals with Energy and more specifically the implementation of Smart Grids can be found in Table 17. The corresponding radar graph is in page that follows (see Figure 52).

Table 17: Use Case 4: Utilities - Smart Energy - Fault management for distributed electricity generation in smart grids – WINGS GR / EDF FR

5G-EVE - Use CaA3:G49ses: direct specific requirements		Units	Use Case 4: Utilities (Smart Energy) (GR-WINGS/FR-EDF) Fault management for distributed electricity generation in smart grids	Priority	Range	
			URLLC		Min	Max
General Vertical/Use Case Requirement						
1	Latency (in miliseconds) - Min/MAX	msec	< 5 ms	High	5	30
2	Speed (in Mbps) - Min/MAX - sustained demand	Mbps	<1Mbps	low		
3	Reliability (%) - Min/MAX	%	99,999%	High	99,999%	
4	Availability (%) - Min/MAX	%	99,999%	High	99,999%	
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/s	0			
6	Broadband Connectivity (peak demand)	Y/N or Mbps	10 Mbit/s			
7	Network Slicing (Y/N)	Y/N	Y	High		
8	Security (Y/N)	Y/N	Y	High		
9	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	0,1			
10	Device Density	Dev/Km2	<2000	medium		
Specific Vertical/Use Case Requirements						
Network	Number of End Points		1			
	Number (Range) of End Devices per End Point		<30			
	Density of End Devices (per sq. meter)		<30			
	Bitrate needs per end point (Kbps,Mbps, Gbps)		< 15 Mbps			
	End -to-end Latency (msecs)		10 ms			
	Highest Acceptable jitter (msec)		2 ms			
	Number of Class of Service (1-8, more)		2 *			
End Devices	Type of Device (i.e. Smartphone, TV, VR)		Sensors, Actuators			
	Bitrate required (Kbps / Mbps / Gbps)		250-500 kbps **			
	Max Latency Allowable (in msecs)		10 ms			
	Max Moving Speed (km/h, 0 if stationary)		0			
	IPv4 & IPv6 support (or both)		Both			
	Connnection of Device to End Point (Wired/Wireless)		Wireless			
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)					
	Authenication method (i.e. SIM, eSIM, Key..)		SIM			
Other Vertical Specific (non-Network related Requirements)						
	i.e Battery life requirement		10-15 years			
5G-EVE Site Services USER REQUIREMENTS						
	City					
	Address & End Tel. Number[1]					
	Competent, Tel. Number, FAX					
	Type of Service[2]					
	Speed/Capacity[3]					
	Access Protection[4]					
	PRIMARY / BACK UP[5]					
	EXTRANET[6]					
	Broadband Access Line[7]					
	Existing Access[8]					
	Number of DIAL-UP Users					
	Minimum Duration of Service					
	Class of Service[9] (Silver/Gold/Premium)					

*1 for periodic and 1 for urgent communications
**Higher bit rates required for remote SW upgrades

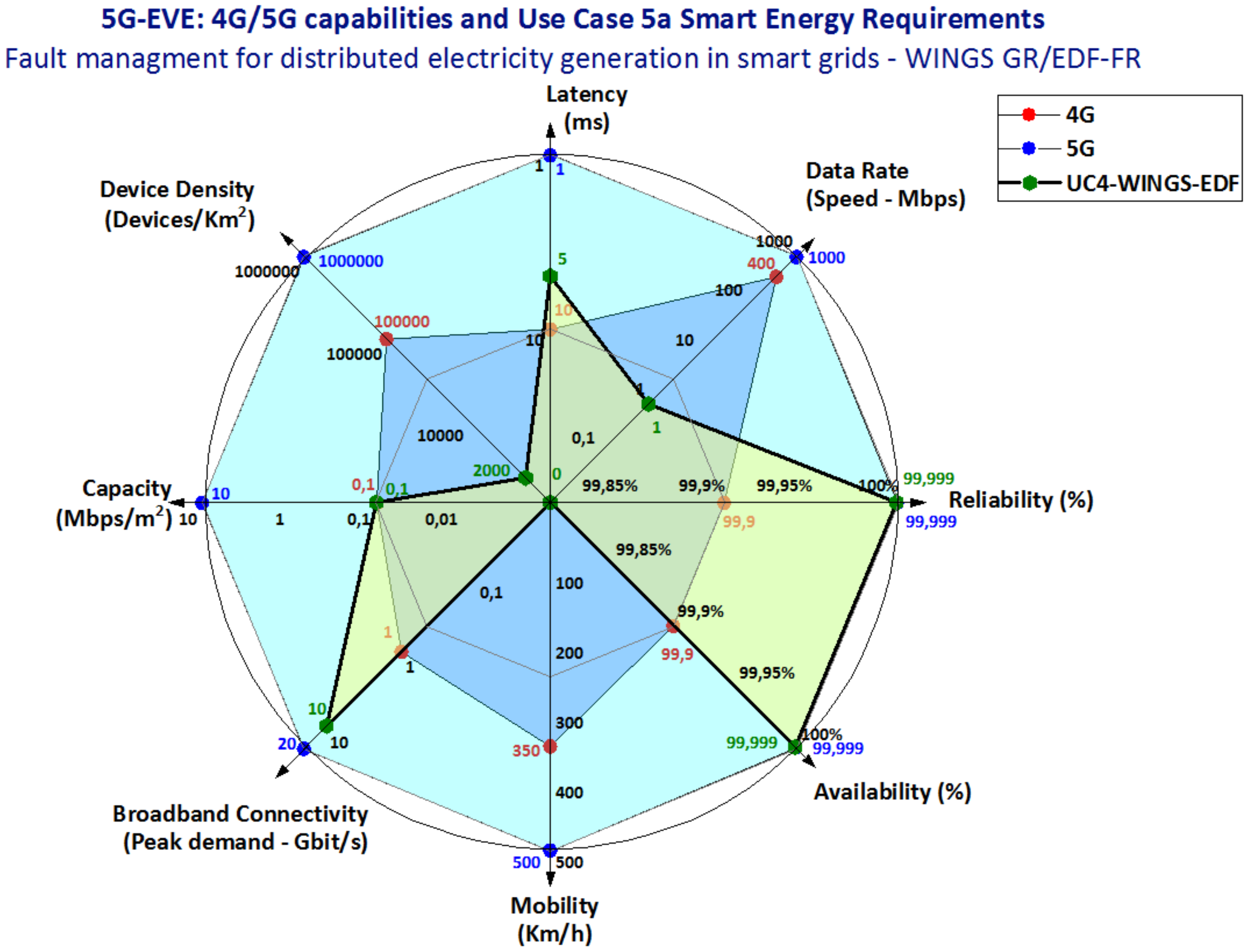


Figure 52: 4G/5G capabilities and Use Case 4 Utilities - Smart Energy - Fault management for distributed electricity generation in smart grids by GR-WINGS/FR-EDF

From the Smart Energy UC requirements Table 17 and the radar graph above it can be seen that only half of the basic/general requirement are being fulfilled by existing 4G/LTE network technologies. Enhanced performance in terms of

a) Latency

b) Broadband Connectivity or Peak Demand

c) Reliability and

d) Availability

are required and can only be materialized via the upcoming 5G technology.

Energy and Smart Grids are fields in continuous evolution, from monolithic Point to Multi Point unidirectional, distribution networks to Multi Point bidirectional (in terms of energy flow) networks (due to introduction of renewable sources and distributed storage). Response time, i.e., to identify faults and rectify and restore energy flow (provisioning) is critical. Smart Grid application are in great demand for the 5G network capabilities. The overall reliability of the Energy Network itself is also important for the 5-nines reliable operation of the 5G network that is called upon to serve the Smart Grid.

5.6 Use Case 5a Requirements: Smart cities - Safety and Environment - Smart Turin - COMUNE DI TORINO Italy

The requirements table for Smart Cities Use Case 5 and the Safety and Environment Scenario are shown in Table 18 below. The radar chart that maps the requirements values over the 4G and 5G network capabilities is found in the next page (Figure 53).

Table 18: Use Case 5a Requirements: Smart cities - Safety and Environment - Smart Turin – COMUNE DI TORINO Italy

5G-EVE - Use Cases: direct specific requirements		Units	Use Case 5a: Smart cities (IT-COMUNE DI TORINO) Safety and Environment - Smart Turin		Priority	Range	
			URLLC	mMTC		Min	Max
General Vertical/Use Case Requirement			Smart Cities				
1	Latency (in miliseconds) - Min/MAX	msec	1 to 5 msec	<5ms		1	5
2	Speed (in Mbps) - Min/MAX - sustained demand	Mbps	0,1 to 1 Mbps			0,1	1
3	Reliability (%) - Min/MAX	%	99.99% to 99.999%			99,99%	99,999%
4	Availability (%) - Min/MAX	%	99.9 % to 99.99%			99,90%	99,990%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/s	0 Km/s			0	
6	Broadband Connectivity (peak demand)	Y/N or Mbps	10 Mbps			10	
7	Network Slicing (Y/N)	Y/N	Y			N	Y
8	Security (Y/N)	Y/N	Y			N	Y
9	Capacity (Mbps/m^2 or Km^2)	$Mbps/m^2$	0,01 to 0,1 $Mbps/m^2$			0,01	0,1
10	Device Density	Dev/Km2		60K (sensors)			60K
Specific Vertical/Use Case Requirements							
Network	Number of End Points		520				
	Number (Range) of End Devices per End Point		1				
	Density of End Devices (per sq. meter)		12				
	Bitrate needs per end point (Kbps,Mbps, Gbps)		1 Kbps				
	End -to-end Latency (msecs)		200 msec				
	Highest Acceptable jitter (msec)		50 msec				
	Number of Class of Service (1-8, more)		2				
End Devices	Type of Device (i.e. Smartphone, TV, VR)		IoT device				
	Bitrate required (Kbps / Mbps / Gbps)		1 Kbps				
	Max Latency Allowable (in msecs)		200 msec				
	Max Moving Speed (km/h, 0 if stationary)		0				
	IPv4 & IPv6 support (or both)		IPv6				
	Connnection of Device to End Point (Wired/Wireless)		Wireless				
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)		NB IoT (4G+)				
	Authenication method (i.e. SIM, eSIM, Key..)		eSIM				
Other Vertical Specific (non-Network related Requirements)							
	i.e Battery life requirement						
5G-EVE Site Services USER REQUIREMENTS							
	City						
	Address & End Tel. Number[1]						
	Competent, Tel. Number, FAX						
	Type of Service[2]						
	Speed/Capacity[3]						
	Access Protection[4]						
	PRIMARY / BACK UP[5]						
	EXTRANET[6]						
	Broadband Access Line[7]						
	Existing Access[8]						
	Number of DIAL-UP Users						
	Minimum Duration of Service						
	Class of Service[9] (Silver/Gold/Premium)						

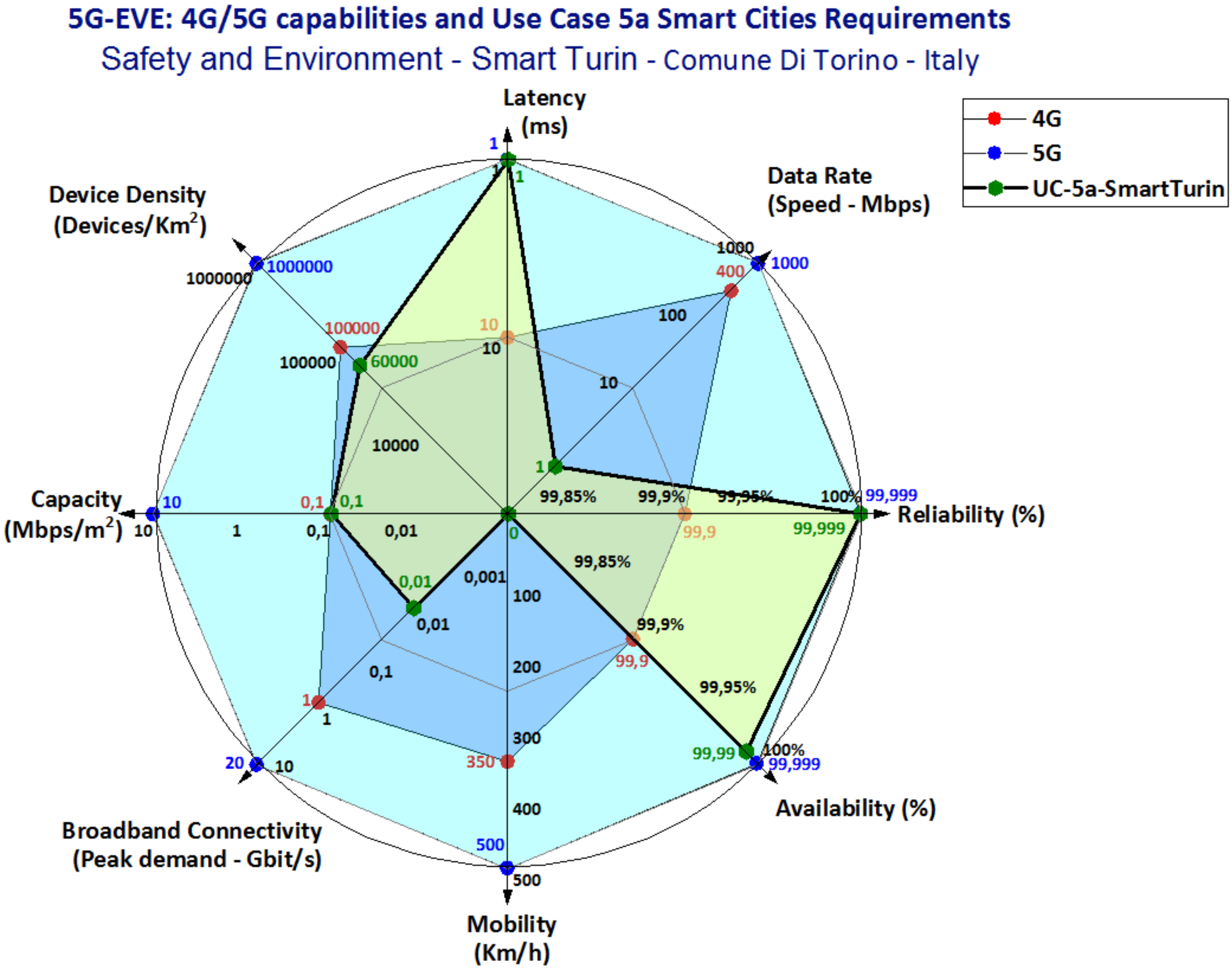


Figure 53: 4G/5G capabilities and Use Case 5a Smart cities - Safety and Environment - Smart Turin – by COMUNE DI TORINO Italy

There are 3 requirements that existing 4G/LTE networks cannot deliver and 5G network is called upon to fulfil for this Use Case. Namely:

a) Latency
b) Reliability and
c) Availability.

The Smart Torino Use case will benefit from the introduction of 5G network in their municipality. Furthermore, since there is an emphasis on people, their wellbeing and safety for citizens, the requirement for 5-nines in terms of reliability and availability of the service is more than justified.

5.7 Use Case 5b Requirements: Smart cities - Safety and Environment – eHealth/eAmbulance – NOKIA GR

The requirements for the sub-Use Case of e-Health/e-Ambulance are shown in the Table 19. The radar chart that maps all these values against the 5G & 4G/LTE network capabilities can be found in the chart of Figure 54.

Table 19: Use Case 5b Requirements: Smart cities - Safety and Environment – eHealth/eAmbulance – NOKIA GR

5G-EVE - Use Cases: direct specific requirements		Units	Use Case 5b: Smart cities (GR-NOKIA) Safety and Environment - eHealth-eAmbulance			Priority	Range	
			URLLC	mMTC	eMMB		Min	Max
General Vertical/Use Case Requirement			Smart Cities					
1	Latency (in miliseconds) - Min/MAX	msec	5	<20 ms	<20 ms		5	20
2	Speed (in Mbps) - Min/MAX - sustained demand	Mbps	0,1 to 1 Mbps		up to 400		25	400
3	Reliability (%) - Min/MAX	%	99.99% to 99.999%				99,99%	99,999%
4	Availability (%) - Min/MAX	%	99.9 % to 99.99%				99,90%	99,990%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/s	0km/h-200km/h	0km/h-200km/h	0km/h-200km/h		0	
6	Broadband Connectivity (peak demand)	Y/N or Mbps	25 Mbps		200Mbps		10	
7	Network Slicing (Y/N)	Y/N	Y	Y	Y		N	Y
8	Security (Y/N)	Y/N	Y	Y	Y		N	Y
9	Capacity (Mbps/m^2 or Km^2)	$Mbps/m^2$	0,01 to 0,2 $Mbps/m^2$				0,01	0,2
10	Device Density	Dev/Km2		60K (sensors)				60K
Specific Vertical/Use Case Requirements								
Network	Number of End Points		520					
	Number (Range) of End Devices per End Point		10		1			
	Density of End Devices (per sq. meter)		12		1			
	Bitrate needs per end point (Kbps,Mbps, Gbps)		25 Kbps		0,5Mbps			
	End -to-end Latency (msecs)		150 msec					
	Highest Acceptable jitter (msec)		50 msec					
	Number of Class of Service (1-8, more)		2 *					
End Devices	Type of Device (i.e. Smartphone, TV, VR)		IoT device, camera, VR					
	Bitrate required (Kbps / Mbps / Gbps)		16 Kbps **					
	Max Latency Allowable (in msecs)		150 msec					
	Max Moving Speed (km/h, 0 if stationary)		0					
	IPv4 & IPv6 support (or both)		IPv6					
	Connnection of Device to End Point (Wired/Wireless)		Wireless					
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)		NB IoT (4G+)					
	Authenication method (i.e. SIM, eSIM, Key..)		eSIM					
Other Vertical Specific (non-Network related Requirements)								
	i.e Battery life requirement							
5G-EVE Site Services USER REQUIREMENTS								
	City							
	Address & End Tel. Number[1]							
	Competent, Tel. Number, FAX							
	Type of Service[2]							
	Speed/Capacity[3]							
	Access Protection[4]							
	PRIMARY / BACK UP[5]							
	EXTRANET[6]							
	Broadband Access Line[7]							
	Existing Access[8]							
	Number of DIAL-UP Users							
	Minimum Duration of Service							
	Class of Service[9] (Silver/Gold/Premium)							

*1 for periodic and 1 for urgent communications

**Higher bit rates required for remote SW upgrades

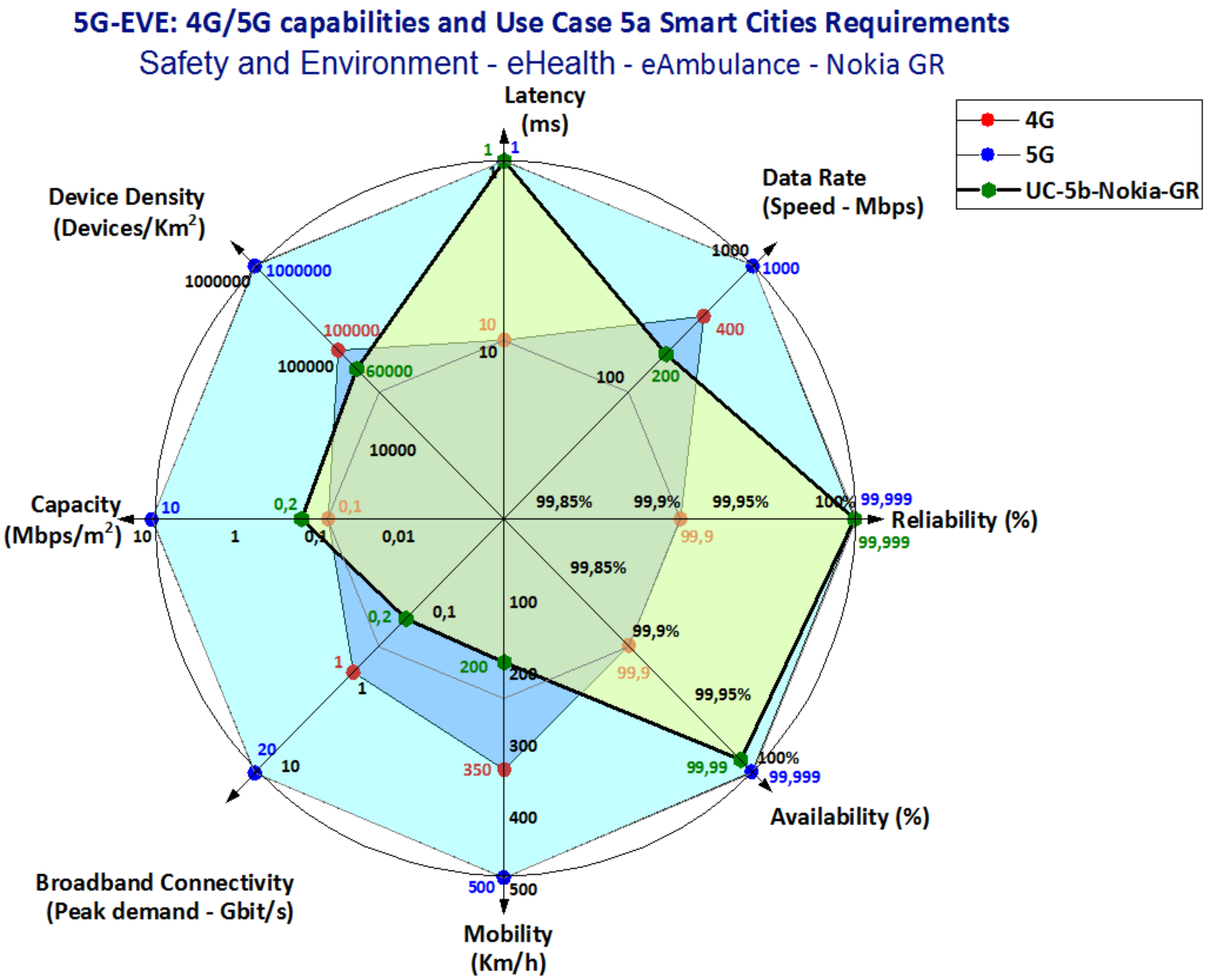


Figure 54: 4G/5G capabilities and Use Case 5b Smart cities - Safety and Environment – eHealth/eAmbulance – by NOKIA GR

It becomes easily apparent that the eHealth/eAmbulance Use case requires the extra capabilities offered by 5G network in terms of the

a) Capacity
b) Latency
c) Reliability and
d) Availability

The relation of the Use Case with the Health Industry is more than justifies the required Availability and Reliability. Furthermore since we have to deal with real time transmission of data a low latency is also needed. The materialization of such a service like eAmbulance is subject to the capabilities that the 5G networks will offer.

5.8 Use Case 5c Requirements: Smart cities - Safety and Environment – Health Monitoring and Forecasting, Smart Mobility, Smart Home – WINGS GR

The requirements for the sub-Use Case of Health Monitoring and Forecasting, are shown in the Table 20.

The radar chart that maps all these values against the 5G & 4G/LTE network capabilities can be found in the chart of Figure 55.

Table 20: Use Case 5c Requirements: Smart cities - Safety and Environment – Health Monitoring and Forecasting, Smart Mobility, Smart Home – WINGS GR

5G-EVE - UA3:G49s+A3:I49e Cases: direct specific requirements		Units	Use Case 5c: Smart cities (GR-WINGS) Health Monitoring and Forecasting , Smart Mobility, Smart Home			Priority	Range	
			URLLC	mMTC	eMMB[10]		Min	Max
General Vertical/Use Case Requirement			Smart Cities					
1	Latency (in miliseconds) - Min/MAX	msec	5	<20 ms	<20 ms		5	20
2	Speed (in Mbps) - Min/MAX - sustained demand	Mbps	0,1 to 1 Mbps		up to 400		25	400
3	Reliability (%) - Min/MAX	%	99.99% to 99.999%				99,99%	99,999%
4	Availability (%) - Min/MAX	%	99.9 % to 99.99%				99,90%	99,990%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/s	0km/h-200km/h	0km/h-200km/h	0km/h-200km/h		0	
6	Broadband Connectivity (peak demand)	Y/N or Mbps	25 Mbps		200Mbps		10	
7	Network Slicing (Y/N)	Y/N	Y	Y	Y		N	Y
8	Security (Y/N)	Y/N	Y	Y	Y		N	Y
9	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	0,01 to 0,2 Mbps/m^2				0,01	0,2
10	Device Density	Dev/Km2		60K (sensors)				60K
Specific Vertical/Use Case Requirements								
Network	Number of End Points		520					
	Number (Range) of End Devices per End Point		10		1			
	Density of End Devices (per sq. meter)		12		1			
	Bitrate needs per end point (Kbps,Mbps, Gbps)		25 Kbps		0,5Mbps			
	End -to-end Latency (msecs)		150 msec					
	Highest Acceptable jitter (msec)		50 msec					
	Number of Class of Service (1-8, more)		2 *					
End Devices	Type of Device (i.e. Smartphone, TV, VR)		IoT device, camera, VR					
	Bitrate required (Kbps / Mbps / Gbps)		16 Kbps **					
	Max Latency Allowable (in msecs)		150 msec					
	Max Moving Speed (km/h, 0 if stationary)		0					
	IPv4 & IPv6 support (or both)		IPv6					
	Connnection of Device to End Point (Wired/Wireless)		Wireless					
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)		NB IoT (4G+)					
	Authenication method (i.e. SIM, eSIM, Key..)		eSIM					
Other Vertical Specific (non-Network related Requirements)								
	i.e Battery life requirement							
5G-EVE Site Services USER REQUIREMENTS								
	City							
	Address & End Tel. Number[1]							
	Competent, Tel. Number, FAX							
	Type of Service[2]							
	Speed/Capacity[3]							
	Access Protection[4]							
	PRIMARY / BACK UP[5]							
	EXTRANET[6]							
	Broadband Access Line[7]							
	Existing Access[8]							
	Number of DIAL-UP Users							
	Minimum Duration of Service							
	Class of Service[9] (Silver/Gold/Premium)							

*1 for periodic and 1 for urgent communications

**Higher bit rates required for remote SW upgrades

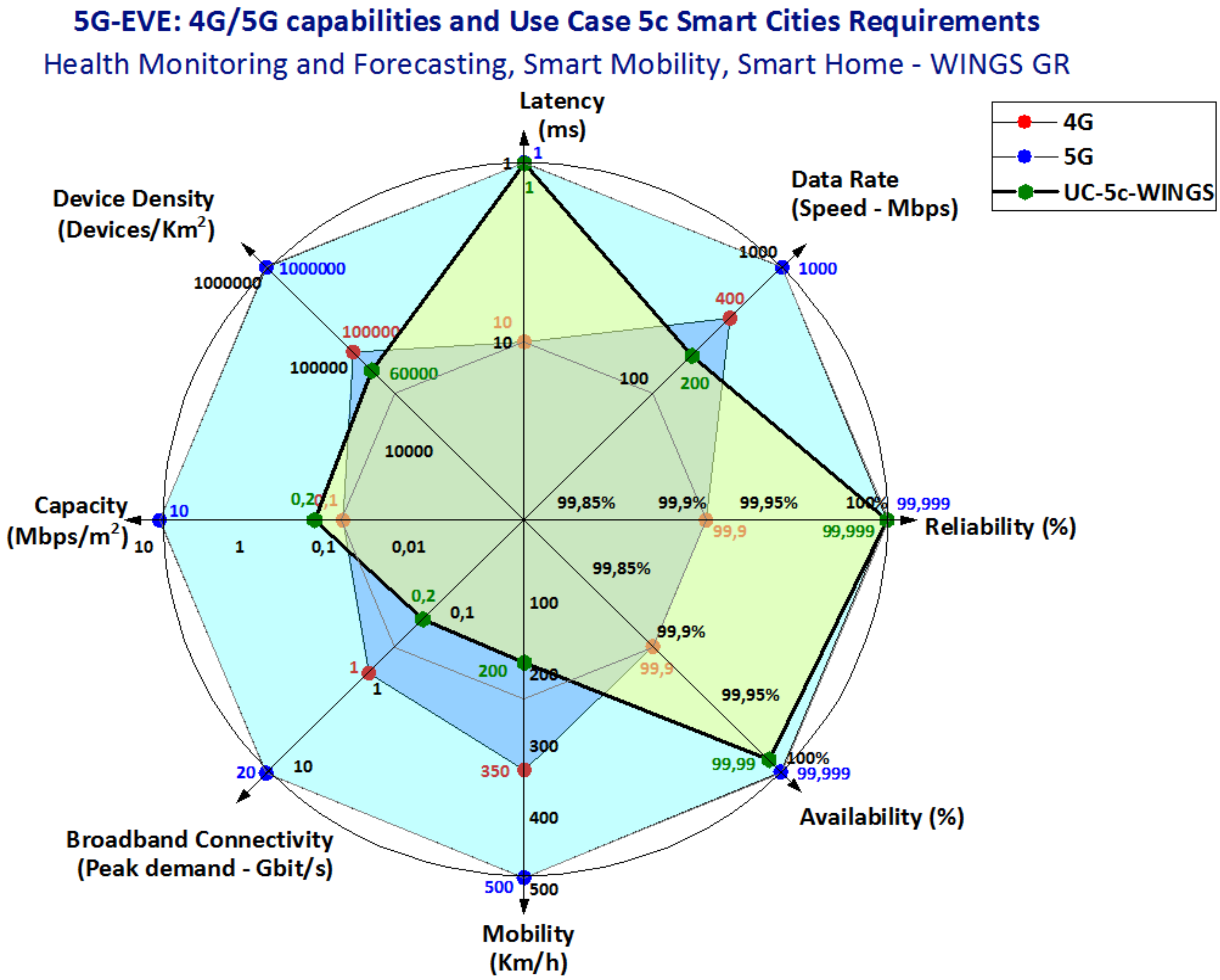


Figure 55: 4G/5G capabilities and Use Case 5c Smart cities - Safety and Environment - Health Monitoring and Forecasting, Smart Mobility, Smart Home - by WINGS GR

Similarly, with the two previous sub-Use Case it is easily apparent that the Application of Health Monitoring and Forecasting requires the extra capabilities offered by 5G network in terms of the

a) Capacity
b) Latency
c) Reliability and
d) Availability

Likewise, as in the previous Use Case that deal with Health, the requirements for Reliability and Availability of the Network play a key role in the proper operation of the Service/Application of Health Monitoring. After Latency, Capacity is very important, especially if Medical Video with lossless compression needs to be transmitted.

5.9 Use Case 6a Requirements: Media & Entertainment – UHF Media – TELEFONICA Spain

The requirements for the Use Case 6 sub-use case a that deals with the provisioning of Ultra High Fidelity Media can be found in Table 21. The evolution of the requirements between the Phases of the Project can also be found in Table 22. Finally, the corresponding radar graph is produced and presented in Figure 56. This particular Use Case (Ultra High Fidelity Media) for most its requirements (7 out 10) it appears to be able to be provided over today's 4G/LTE networks. Nevertheless, when it comes to Reliability and Availability a higher value is requested. Furthermore, it becomes clear that network Slicing will also be highly desirable for the provisioning of the particular service.

Table 21: Use Case 6a Requirements: Media & Entertainment – UHF Media – TELEFONICA Spain

5G-EVE - Use Cases: direct specific requirements		Units	Use Case 6a: Media & Entertainment (SP-TELEFONICA) UHF Media	Priority	Range	
			eMMB		Min	Max
General Vertical/Use Case Requirement						
1	Latency (in miliseconds) - Min/MAX	msec	100		500	100
2	Speed (in Mbps) - Min/MAX - sustained demar	Mbps	120		88	120
3	Reliability (%) - Min/MAX	%	99,990%		99%	99,990%
4	Availability (%) - Min/MAX	%	99,990%		99%	99,990%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/hour	50		0	50
6	Broadband Connectivity (peak demand)	Mbps	249		165,9706	249
7	Network Slicing (Y/N)	Y/N	Y		N	Y
8	Security (Y/N)	Y/N	N		N	N
9	Capacity (Mbps/m^2 or Km^2)	Mbps/Km^2	1,529		1,018	1,529
10	Device Density	Dev/Km2	13,804		8,282	13,804
Specific Vertical/Use Case Requirements						
Network	Number of End Points		1		1	1
	Number (Range) of End Devices per End Point		26,471		26,471	22,059
	Density of End Devices (per sq. Kmeter)		8,282		8,282	13,804
	Bitrate needs per end point Uplink UL (Mbps)		0		165,971	249
	Bitrate needs per end point Downlink DL (Mbps)		249,265		165,971	249
	End -to-end Latency (msecs)		100		500	100
	Highest Acceptable jitter (msec)		100		500	100
	Number of Class of Service (1-8, more)					
End Devices	Type of Device (i.e. Smartphone, TV, VR)		SMP		SMP	SMP
	Bitrate required Uplink (Mbps)		24,926		16,597	24,926
	Bitrate required Downlink (Mbps)		249,265		165,971	249,265
	Max Latency Allowable (in msecs)		100		500	100
	Max Moving Speed (km/h, 0 if stationary)		50		0	50
	IPv4 & IPv6 support (or both)		N		N	N
	Connnection of Device to End Point (Wired/Wireless)					
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)					
	Authenication method (i.e. SIM, eSIM, Key..)		SIM		SIM	SIM
Other Vertical Specific (non-Network related Requirements)						
	i.e Battery life requirement					
5G-EVE Site Services User Requirements						
	City		Leganés. Madrid. Spain			
	Address & End Tel. Number[1]		Avenida del Mar Mediterráneo 22			
	Competent, Tel. Number, FAX		"+34 91 481 62 10"			
	Type of Service[2]					
	Speed/Capacity[3]					
	Access Protection[4]					
	PRIMARY / BACK UP[5]					
	EXTRANET[6]		https://www.5tonic.org/			
	Broadband Access Line[7]					
	Existing Access[8]					
	Number of DIAL-UP Users					
	Minimum Duration of Service					
	Class of Service[9] (Silver/Gold/Premium)					

Table 22: Assumptions for Phase 1 and Phase 2 – UHF Media - TELEFONICA Spain

Assumptions	Phase 1	Phase 2	Units
Medium City housholds	30000	30000	houses
Average people per households	2	2	people
Total city area	163	163	Square km
Maximum speed city area	50	50	Km/hour
Total population	60000	60000	people
TV mobile subscription percentage	15%	25%	percentage
UHFM people	9000	15000	people
Nodes in medium city	17	17	nodes
Cells per node	3	6	cells per node
Total cells	51	102	cells
Concurrency factor	15%	15%	percentage
Max number of concurrent users	1350	2250	people
Max number of concurrent users per cell	26	22	people/cell
SD bitrate	2,2	2	Mbps
HD bitrate	6	6	Mbps
4K bitrate	22	20	Mbps
SD percentage	60%	40%	percentage
HD percentage	25%	35%	percentage
4K percentage	15%	25%	percentage
Average bitrate	6	11	Mbps
Total bitrate DL	166	249	Mbps/cell
Total bitrate per area	1,018	1,529	Mbps/Square Km
Total devices per area	8,282	13,804	devices/Square Km
Total bitrate UL (10% DL)	16,597	24,926	Mbps/cell
UL bitrate per device (10% DL)	2,2	2,0	Mbps
Single User Modem Max Speed (Several devices)	88	120	Mbps

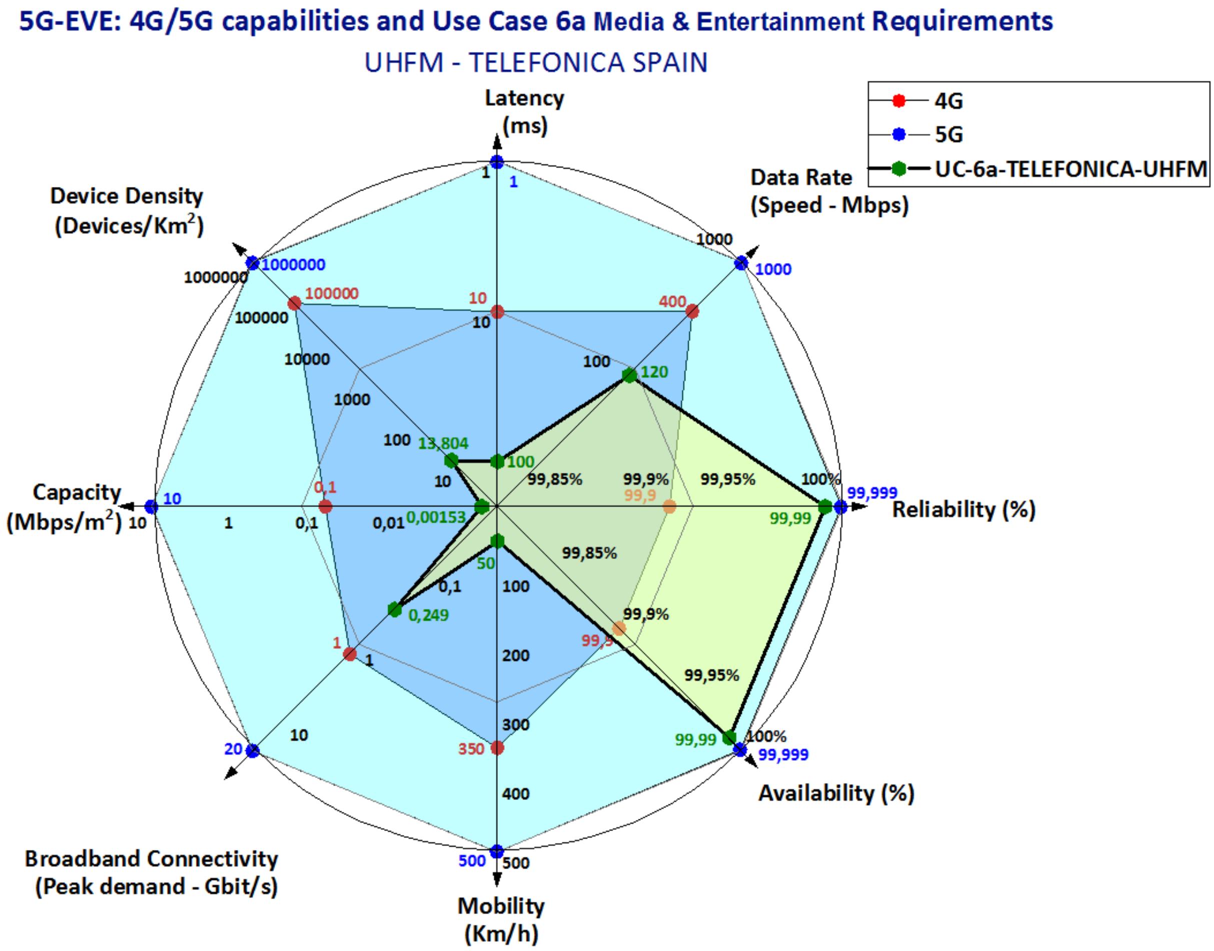


Figure 56: 4G/5G capabilities and Use Case 6a - Media & Entertainment – UHF Media by TELEFONICA Spain

5.10 Use Case 6b Requirements: Media & Entertainment – On-Site Live Event Experience – TELEFONICA Spain

The requirements for Use Case 6 sub-use case b (On-Site Live Event Experience) is shown in Table 23. There is an additional table where the requirements between the two phases of the project evolution is shown in Table 24. Finally the radar chart of the requirements when mapped on the 4G and 5G capabilities domain is shown in Figure 57. Like in the previous sub-use-case of UHF Media, this one also (Live Event Experience Application) needs enhanced capabilities in terms of a) Reliability, b) Availability and c) Slicing. The radar chart is very similar if not identical with the one of the previous Use Case (as expected).

Table 23: Use Case 6b Requirements: Media & Entertainment – On-Site Live Event Experience – TELEFONICA Spain

5G-EVE - Use Cases: direct specific requirements		Units	Use Case 6b: Media & Entertainment (SP-TELEFONICA) On-site Live Event Experience	Priority	Range	
			eMMB		Min	Max
General Vertical/Use Case Requirement						
1	Latency (in miliseconds) - Min/MAX	msec	100		500	100
2	Speed (in Mbps) - Min/MAX - sustained demar	Mbps	114		88	114
3	Reliability (%) - Min/MAX	%	99,990%		99%	99,990%
4	Availability (%) - Min/MAX	%	99,990%		99%	99,990%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/hour	0		0	0
6	Broadband Connectivity (peak demand)	Mbps	122		83,6	122
7	Network Slicing (Y/N)	Y/N	Y		N	Y
8	Security (Y/N)	Y/N	N		N	N
9	Capacity (Mbps/m^2 or Km^2)	Mbps/Km^2	12150		8360	12150
10	Device Density	Dev/Km2	4000		4000	4000
Specific Vertical/Use Case Requirement						
Network	Number of End Points		1		1	1
	Number (Range) of End Devices per End Point		13,333		13,333	13,333
	Density of End Devices (per sq. Kmeter)		4000		4000	4000
	Bitrate needs per end point Uplink UL (Mbps)		72,15		48,360	72
	Bitrate needs per end point Downlink DL (Mbps)		121,500		83,600	122
	End -to-end Latency (msecs)		100		500	100
	Highest Acceptable jitter (msec)		100		500	100
	Number of Class of Service (1-8, more)					
End Devices	Type of Device (i.e. Smartphone, TV, VR)		SMP		SMP	SMP
	Bitrate required Uplink (Mbps)		15		10	15
	Bitrate required Downlink (Mbps)		22		22	22
	Max Latency Allowable (in msecs)		100		500	100
	Max Moving Speed (km/h, 0 if stationary)		0		0	0
	IPv4 & IPv6 support (or both)		N		N	N
	Connnection of Device to End Point (Wired/Wireless)					
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)					
	Authenication method (i.e. SIM, eSIM, Key..)		SIM		SIM	SIM
Other Vertical Specific (non-Network related Requirements)						
	i.e Battery life requirement					
5G-EVE Site Services User Requirements						
	City		Leganés. Madrid. Spain			
	Address & End Tel. Number[1]		Avenida del Mar Mediterráneo 22			
	Competent, Tel. Number, FAX		"+34 91 481 62 10"			
	Type of Service[2]					
	Speed/Capacity[3]					
	Access Protection[4]					
	PRIMARY / BACK UP[5]					
	EXTRANET[6]		https://www.5tonic.org/			
	Broadband Access Line[7]					
	Existing Access[8]					
	Number of DIAL-UP Users					
	Minimum Duration of Service					
	Class of Service[9] (Silver/Gold/Premium)					

Table 24: Assumptions for Phase 1 and Phase 2 – OSLE Media - TELEFONICA Spain

Assumptions	Phase 1	Phase 2	Units
Total event area	0,010	0,010	Square km
OLEE people	400	400	people
Nodes in event	1	1	nodes
Cells per node	3	3	cells per node
Total cells	3	3	cells
Concurrency factor	10%	10%	percentage
Max number of concurrent users	40	40	people
Max number of concurrent users per cell	13	13	people/cell
SD bitrate	2,2	2,0	Mbps
HD bitrate	6	5	Mbps
4K bitrate	22	19	Mbps
SD percentage	60%	40%	percentage
HD percentage	25%	35%	percentage
4K percentage	15%	25%	percentage
Average bitrate	6,3	9,1	Mbps
Total bitrate DL	84	122	Mbps/cell
Total bitrate per area	8360	12150	Mbps/Square Km
Total devices per area	4000	4000	devices/Square Km
Total bitrate UL (10% DL) + Cameras	48,4	72,2	Mbps/cell
UL bitrate per device (cameras DL)	10,0	15,0	Mbps
Single User Modem Max Speed (Several devices)	88	114	Mbps

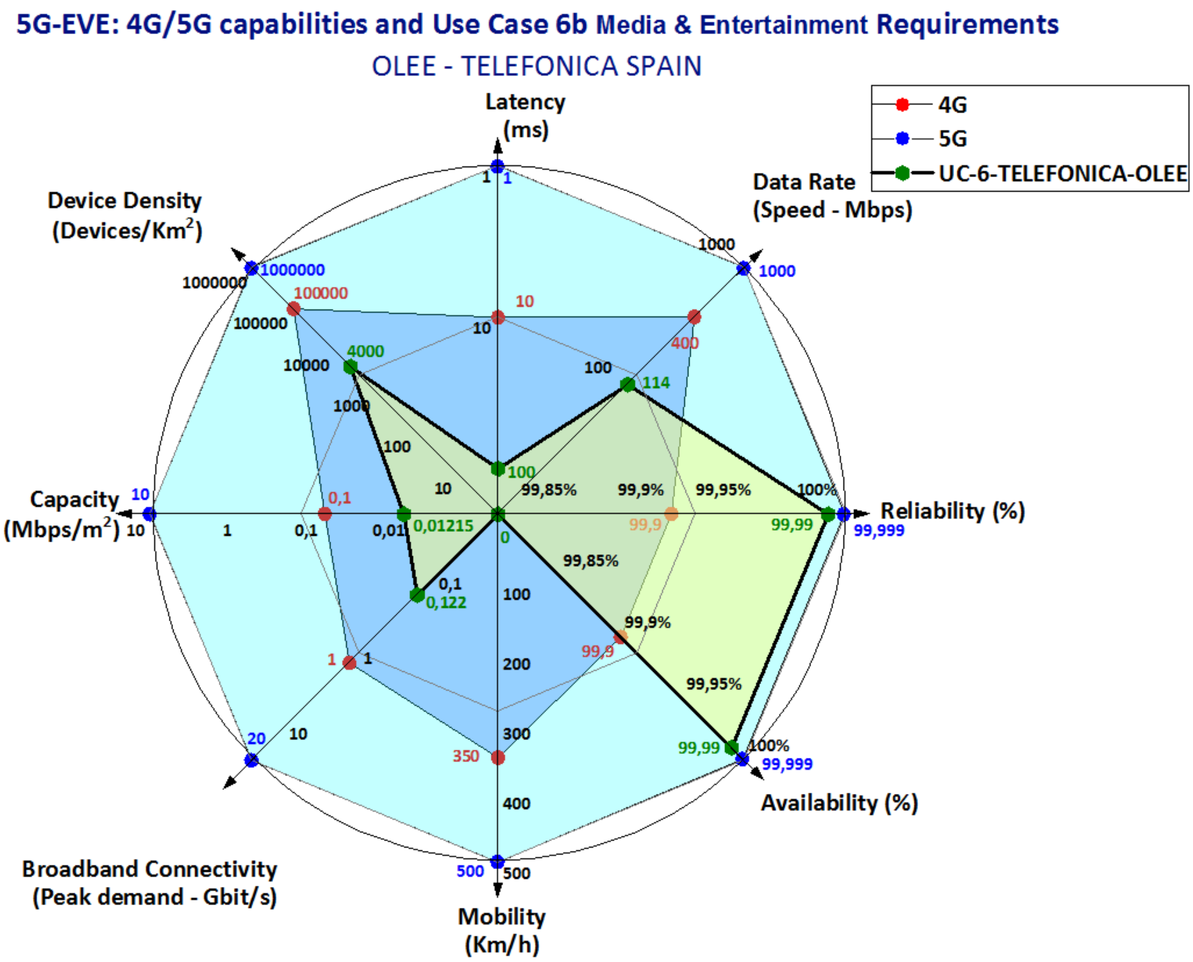


Figure 57: 4G/5G capabilities and Use Case 6b - On-Site Live Event Experience – TELEFONICA Spain

5.11 Use Case 6c Requirements: Media & Entertainment – Immersive and Integrated Media - TELEFONICA Spain

The Immersive and Integrated Media Use Case requirements are included in Table 25. The radar chart is shown in Figure 58. An additional Table 26 that indicates the evolution of the requirements between the 2 Phases of the Project can also be found below. Similarly, to the two previous sub-use-cases, this Immersive and Integrated Media Application, needs enhanced capabilities in terms of a) Reliability, b) Availability and c) Slicing.

The radar chart is very similar if not identical with the two previous ones (as expected). It should be noted that although only a few requirements dictate the use of 5G technologies, Network Operators (like Telefonica, OTE etc.) would like to move more and more of existing and future Applications and Services to the new network, allowing for a faster pay-back time and an quicker return of their investment. Therefore, we should expect this “migration” strategy to become more apparent in the future years.

The utilization of the new 5G network for even not so demanding services is also dictated by the aging 3G infrastructure. Therefore, application will be “encouraged” to skip the 4G evolution and directly be provided over the 5G infrastructure.

Table 25: Use Case 6c Requirements: Media & Entertainment – Immersive and Integrated Media – TELEFONICA Spain

5G-EVE - Use Cases: direct specific requirements		Units	Use Case 6c: Media & Entertainment (SP-TELEFONICA) Immersive and Integrated Media	Priority	Range	
			eMMB		Min	Max
General Vertical/Use Case Requirement						
1	Latency (in miliseconds) - Min/MAX	msec	100		500	100
2	Speed (in Mbps) - Min/MAX - sustained demai	Mbps	114		88	114
3	Reliability (%) - Min/MAX	%	99,990%		99%	99,990%
4	Availability (%) - Min/MAX	%	99,990%		99%	99,990%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/hour	0		0	0
6	Broadband Connectivity (peak demand)	Mbps	127		83,333	127
7	Network Slicing (Y/N)	Y/N	Y		N	Y
8	Security (Y/N)	Y/N	N		N	N
9	Capacity (Mbps/m^2 or Km^2)	Mbps/Km^2	12667		8333	12667
10	Device Density	Dev/Km2	2500		2500	2000
Specific Vertical/Use Case Requirement						
Network	Number of End Points		1		1	1
	Number (Range) of End Devices per End Point		8,333		8,333	6,667
	Density of End Devices (per sq. Kmeter)		2500		2500	2000
	Bitrate needs per end point Uplink UL (Mbps)		72,667		48,333	73
	Bitrate needs per end point Downlink DL (Mbps)		126,667		83,333	127
	End -to-end Latency (msecs)		100		500	100
	Highest Acceptable jitter (msec)		100		500	100
	Number of Class of Service (1-8, more)					
End Devices	Type of Device (i.e. Smartphone, TV, VR)		SMP		SMP	SMP
	Bitrate required Uplink (Mbps)		15		10	15
	Bitrate required Downlink (Mbps)		22		22	22
	Max Latency Allowable (in msecs)		100		500	100
	Max Moving Speed (km/h, 0 if stationary)		0		0	0
	IPv4 & IPv6 support (or both)		N		N	N
	Connnection of Device to End Point (Wired/Wireless)					
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)					
	Authenication method (i.e. SIM, eSIM, Key..)		SIM		SIM	SIM
Other Vertical Specific (non-Network related Requirements)						
	i.e Battery life requirement					
5G-EVE Site Services User Requirements						
	City		Leganés. Madrid. Spain			
	Address & End Tel. Number[1]		Avenida del Mar Mediterráneo 22			
	Competent, Tel. Number, FAX		"+34 91 481 62 10"			
	Type of Service[2]					
	Speed/Capacity[3]					
	Access Protection[4]					
	PRIMARY / BACK UP[5]					
	EXTRANET[6]		https://www.5tonic.org/			
	Broadband Access Line[7]					
	Existing Access[8]					
	Number of DIAL-UP Users					
	Minimum Duration of Service					
	Class of Service[9] (Silver/Gold/Premium)					

Table 26: Assumptions for Phase 1 and Phase 2 – IIM - TELEFONICA Spain

Assumptions	Phase 1	Phase 2	Units
Total event area	0,010	0,010	Square km
OLEE people	250	200	people
Nodes in event	1	1	nodes
Cells per node	3	3	cells per node
Total cells	3	3	cells
Concurrency factor	10%	10%	percentage
Max number of concurrent users	25	20	people
Max number of concurrent users per cell	8	7	people/cell
SD bitrate	2,2	2,0	Mbps
HD bitrate	6	5	Mbps
4K bitrate	22	19	Mbps
SD percentage	0%	0%	percentage
HD percentage	75%	0%	percentage
4K percentage	25%	100%	percentage
Average bitrate	10,0	19,0	Mbps
Total bitrate DL	83	127	Mbps/cell
Total bitrate per area	8333	12667	Mbps/Square Km
Total devices per area	2500	2000	devices/Square Km
Total bitrate UL (10% DL) + Cameras	48,3	72,7	Mbps/cell
UL bitrate per device (cameras DL)	10,0	15,0	Mbps
Single User Modem Max Speed (Several devices)	88	114	Mbps

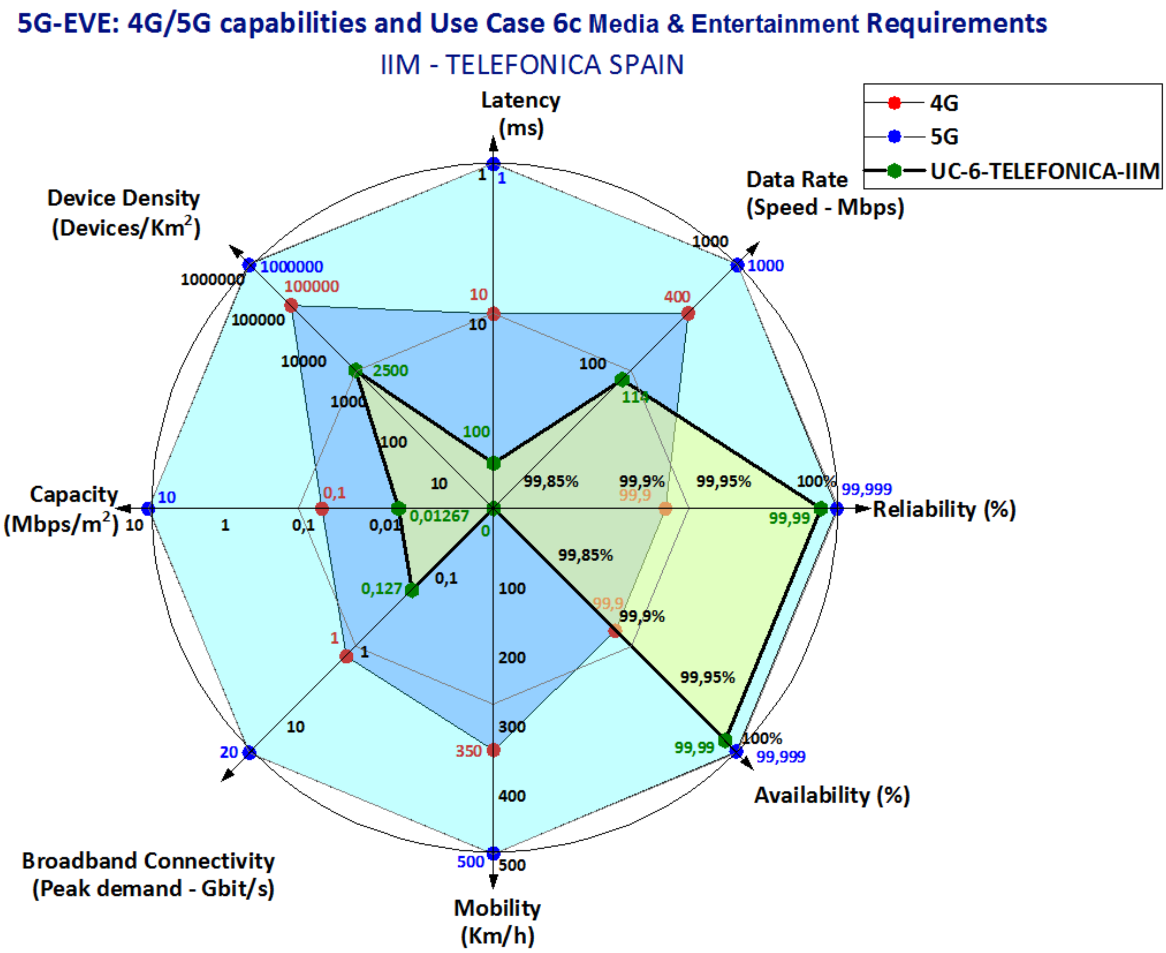


Figure 58: 4G/5G capabilities and Use Case 6c – Immersive and Integrated Media – by TELEFONICA Spain

5.12 Use Case 6d Requirements: Virtual Visit - Virtual 360° Visit for Real Estate or Tourism – ORANGE FR

The final Use Case 6, sub-use case d requirements that deal with virtual reality application(s) for the tourist industry, are found in Table 27. Like in the previous 3 sub-use cases the evolution of the requirements for the different phases of the project can be found in Table 28. The radar chart or the Virtual 360° Visit is shown in Figure 59. This Virtual 360º Visit Application as applied in the real estate industry does not need to wait for the introduction of the 5G networks. All requirements fall within the capabilities area of the 4G/LTE networks, as it is also very easily verifiable from the radar graph.

Nevertheless, as also noted in the previous sub-use case (of Immersive and Integrated Media) it is for the benefit of the operators/investor to introduce new application and services directly to the new 5G network. The payback period become shorter and there is no need for an upgrade path from 4G to 5G. Furthermore, if this strategy is successful the end users and Service Providers will also benefit from possibly better prices for more capabilities due mainly to economies of scale.

Table 27: Use Case 6d Requirements: Virtual Visit – Virtual 360º Visit for real estate or tourism – ORANGE FR

5G-EVE - Use Cases: direct specific requirements		Units	Use Case 6d: Virtual Visit (FR-ORANGE) Virtual 360° Visit for Real Estate or Tourism	Priority	Range	
			eMBB		Min	Max
General Vertical/Use Case Requirement						
1	Latency (in miliseconds) - Min/MAX	msec	10*		10	None
2	Speed (in Mbps) - Min/MAX - sustained demand	Mbps	80Mbps		40Mbps	80Mbps
3	Reliability (%) - Min/MAX	%	99,000%		99%	99,000%
4	Availability (%) - Min/MAX	%	99,000%		99%	99,000%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/s	0		0	0
6	Broadband Connectivity (peak demand)	Y/N or Mbps	80Mbps		40Mbps	80Mbps
7	Network Slicing (Y/N)	Y/N	N		N	N
8	Security (Y/N)	Y/N	N		N	N
9	Capacity (Mbps/m^2 or Km^2)	Mbps/Km^2	12150		8360	12150
10	Device Density	Dev/Km2	4000		4000	4000
Specific Vertical/Use Case Requirements						
Network	Number of End Points					
	Number (Range) of End Devices per End Point		1		1	1
	Density of End Devices (per sq. meter)		1		1	1
	Bitrate needs per end point (Kbps,Mbps, Gbps)					
	End -to-end Latency (msecs)		1		1	1
	Highest Acceptable jitter (msec)		40		40	80
	Number of Class of Service (1-8, more)		9 **		9	None
End Devices	Type of Device (i.e. Smartphone, TV, VR)		1		1	Any
	Bitrate required (Kbps / Mbps / Gbps)					
	Max Latency Allowable (in msecs)		HMD+PC		HMD+PC	HMD+PC
	Max Moving Speed (km/h, 0 if stationary)		1		1	1
	IPv4 & IPv6 support (or both)		40		40	80
	Connnection of Device to End Point (Wired/Wireless)		10*		10	None
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)		0		0	0
	Authenication method (i.e. SIM, eSIM, Key..)					
Other Vertical Specific (non-Network related Requirements)			Wireless		Wireless	Wireless
	i.e Battery life requirement					
			SIM		SIM	SIM
5G-EVE Site Services USER REQUIREMENTS						
	City					
	Address & End Tel. Number[1]					
	Competent, Tel. Number, FAX					
	Type of Service[2]		Lannion			
	Speed/Capacity[3]		2 avenue Pierre Marzin			
	Access Protection[4]		"+33 2 96 07 18 71"			
	PRIMARY / BACK UP[5]					
	EXTRANET[6]					
	Broadband Access Line[7]					
	Existing Access[8]					
	Number of DIAL-UP Users					
	Minimum Duration of Service					
	Class of Service[9] (Silver/Gold/Premium)					

*For MTU-sized packets and capacity seeking traffic

**We assume that network end-to-end latency = RTT

Table 28: UC6d, Assumptions for Phase 1 and Phase 2 – VV – ORANGE FR

Assumptions	Phase 1	Phase 2	Units
Total event area	0,010	0,010	Square km
OLEE people	400	400	people
Nodes in event	1	1	nodes
Cells per node	3	3	cells per node
Total cells	3	3	cells
Concurrency factor	10%	10%	percentage
Max number of concurrent users	40	40	people
Max number of concurrent users per cell	13	13	people/cell
SD bitrate	2,2	2,0	Mbps
HD bitrate	6	5	Mbps
4K bitrate	22	19	Mbps
SD percentage	60%	40%	percentage
HD percentage	25%	35%	percentage
4K percentage	15%	25%	percentage
Average bitrate	6,3	9,1	Mbps
Total bitrate DL	84	122	Mbps/cell
Total bitrate per area	8360	12150	Mbps/Square Km
Total devices per area	4000	4000	devices/Square Km
Total bitrate UL (10% DL) + Cameras	48,4	72,2	Mbps/cell
UL bitrate per device (cameras DL)	10,0	15,0	Mbps

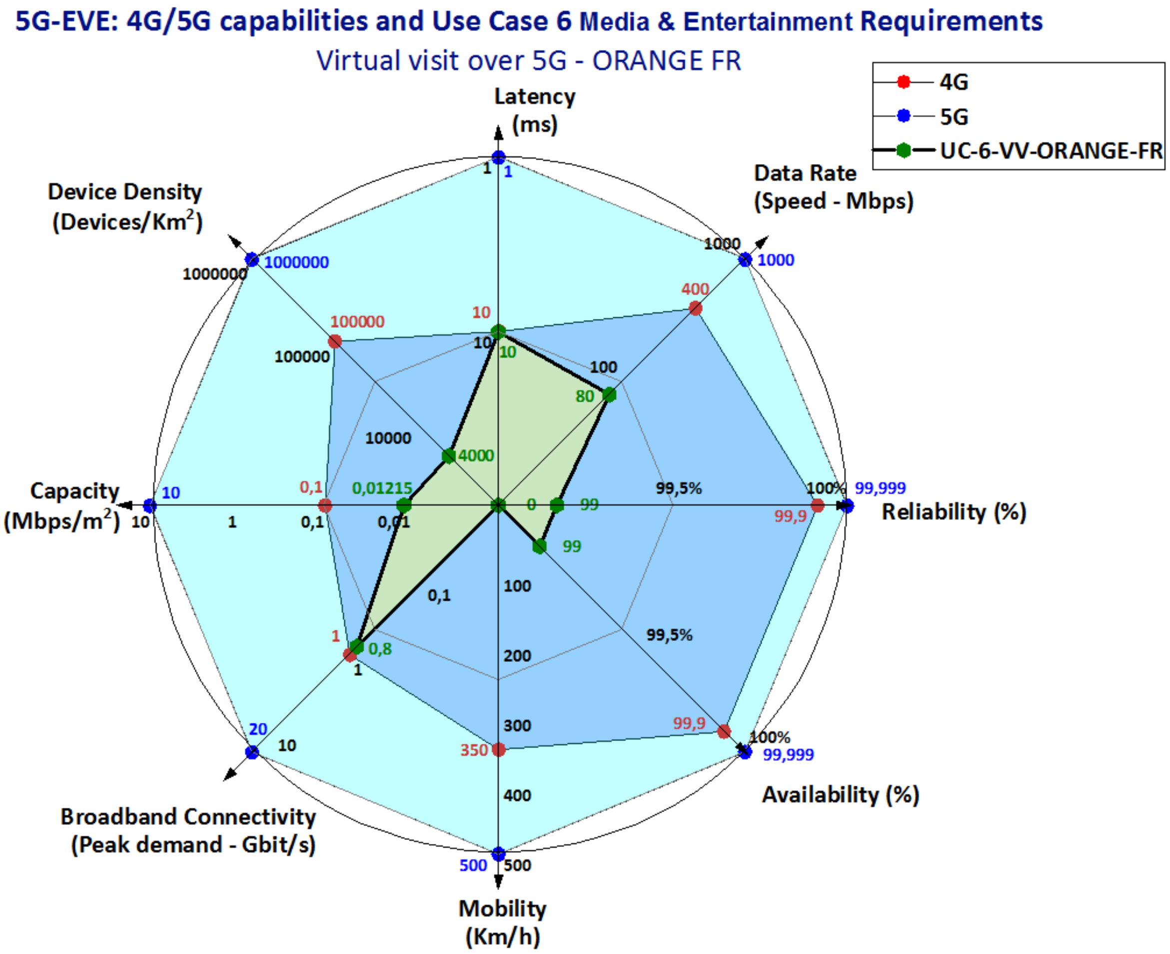


Figure 59: 4G/5G capabilities and Use Case 6d – Virtual Visit – Virtual 360º Visit for real estate or tourism by ORANGE FR

With this last radar chart the presentation and analysis of the User Requirements for 5G-Eve concludes.

If we are to prioritize the 5G network capabilities in terms of how much demand is there in the different Use Cases presented in Chapter 3 (High-level definition of the internal use-cases proposed in 5G-EVE) then the graph below can be generated:

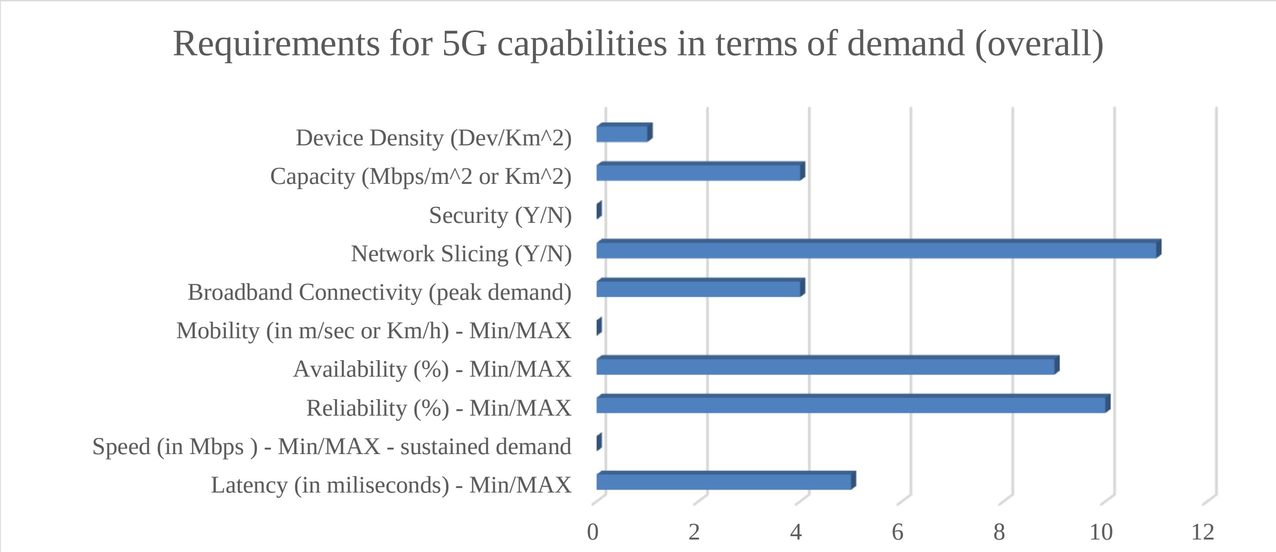


Figure 60: Prioritization of UCs' 5G Capabilities by the frequency that appears in the requirement tables.

What this chart indicates is that the most desirable capability is slicing. Although it might not be clear what this capability will offer to the end user, nevertheless it indicates that all, network operators, equipment manufacturers, service providers and end-users require a single network that will fulfil all their needs (no matter how basic and how advanced they might be).

Secondly, this indicates that the allocation of networks resources on demand in order to fulfil certain requirements is also in high demand. From the point of view of end-users, they do not want to "order" higher than needed "network capabilities" but get them only for as long as they need them. This is an indication of a desire for cost saving also. From the point of view of the operators, it shows that they want to move if not all but as much as possible services and application from the legacy 2G/3G, existing 4G/LTE networks to the newer 5G infrastructure allocating the appropriate slices for these services. There is also an important contrast both in the approaches and trends in the European and US markets.

We have a slow and smooth transitions from 4G to 5G from the operators perspective in Europe whilst it seems we will have a more abrupt change in the US market. This is probably motivated by the fact that in US the fiber infrastructure is not as important as in Europe and they are planning moving directly from cable to 5G rather than using any other technology in between.

The second most asked-for capability is Reliability. It is an indication that mobile networks should reach a much higher level of reliability (of 5-nines), feature that is now only reserved for fixed-network core-connections and very critical infrastructures (i.e., military etc.). Paired with Reliability is the Availability requirement. The importance of these two parameters, indicate that service providers and end users alike want the Service to be available "always", not only in temporal terms but also in spatial terms (everywhere). This last requirement (that directly links to network coverage) can potentially make the construction and deployment of the network more expensive. However, even though this is the case, cost may potentially be reduced by using network slicing so that the cost is not propagated to the whole infrastructure but just to the pieces involved in those extremely high availability and reliability use cases. In our case, the Availability deals only with the time domain (available 99.999% of the time, which is 5.26 minutes of downtime per year or 25.9 sec per month – on average).

Fourth requirement in priority is Latency, followed by Capacity. It appears that more and more real time applications need to be introduced in the network. Interactive applications also require shorter latency.

Even though, the above analysis is **far from a rigorous scientific one,** it nevertheless it indicates a trend that Network Equipment manufacturers and Network Operators experience lately. User and Developers require more reliable networks (i.e., interruption of even a few seconds increase the calls to the help desk) and faster response from the network and the applications (gamers are usually the ones to immediately detect increased latency in the network). Finally the appetite for more capacity is always there since more and more information migrates to online depots/storage and the Video resolution (and bandwidth for transmission) requirement also increase continually.

6 Conclusions

In this deliverable (D1.1 of 5G EVE project) each of the participating partner presented a detailed description of all Verticals Use Cases. Also, definitions of all requirements were given (both general and specific) and an introduction to the methodology of information gathering and analysis was described. Moreover, the results of the requirements definition for each User Case and Sub-Use Case (12 in total) were listed. The tables with the requirement values are given and, in some cases,, explanation is also provided.

Beyond the requirements compilation (per UC), a radar chart (the concept of which is being introduced in Chapter 2), that visualizes the general requirements per UC using as a backdrop the capabilities of 4G/LTE and 5G networks was created and presented. From each radar chart, and the corresponding tables, information with respect to the adequacy (or sufficiency) of the existing 4G/LTE networks, as well as the urgency (or need) for 5G network capabilities (per Use Case) was drawn.

Even from the preliminary analysis, some interesting trends can be identified. The most universally desired requirement is the increased Reliability and Availability of the Networks and Services offered to end-customers. There is a tendency to migrate and/or develop all new services to the upcoming 5G networks even if the requirements do not need the enhanced capabilities of 5G. Finally, after Reliability and Availability, the most important parameters are Latency and Capacity of the Network. With a larger sample of Verticals' requirements and also a more rigid analysis additional results can be extracted, nevertheless this is beyond the scope of this current deliverable.

The requirements given per UC, will serve as an input for the subsequent work-packages of 5G EVE. Specifically they can be used as a target when building the 5G EVE end-to-end facilities where the UC will be demonstrated. Lastly, the result of the work presented here will be included in Deliverable 1.2, including (but not limited to) the requirements from all potential vertical industries as defined in ICT-19-2019.

These requirements will be used as reference to build the 5G-EVE end to end facility subsystems integration and capabilities.

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