5G European Validation platform for Extensive trials

Deliverable D1.2

Requirements definition and analysis from vertical industries and core applications

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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
AIA	Athens International Airport
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

One of the main goals of 5G-EVE is to offer a complete multi-operator, distributed 5G Network Platform that participants of other EU funded projects and other Vertical Industries can use to run, test and validate their Applications and Services.

In order to access the adequacy of the 5G-EVE Platform the network requirements from other ICT-19 Projects Use Cases were collected and analysed.

This analysis will be used by the 5G-EVE project both to familiarize with what the different Vertical Industries require from a 5G Network and also prepare the different sites to host future validation trials.

In total, Network Requirements from 6 ICT-19 + 1 ICT-22 Projects and 32 different Use Cases (with sub-use cases) were collected and analysed. A standardized approach helped collect the Network requirements from wildly dissimilar use cases from a variety of Vertical Industries that induce

- Health
- Transportation
- Food Chain Safety (Aquaculture and Agriculture)
- Energy/ IoT
- Industry 4.0
- Smart Cities & Safe Living

The analysis from the 32 different Use Cases belonging to the Vertical Industries indicates that there are Services and Applications that will greatly benefit and do require the use of a 5G Network. Existing 4G/LTE networks do not suffice and fall short in their capabilities.

There were also use cases that (with careful planning and implementation) can be implemented using existing 4G/LTE technology. These services although do not require 5G are more than welcome to be hosted in the Operators' 5G networks since their revenues will help shorten the payback time of the initial investment (for rolling out 5G infrastructures).

Finally, there are Use Case, whose requirements stretch even the limits of the 5G technology capabilities. These either have to reconsider some of their requirements or dedicated and careful network planning and resource allocation should be performed. The later action will result in expensive implementation that only significant revenue stream from these Services can justify.

1 Introduction

The main objective of this document is to list the different ICT-19/22 projects that aim at integrating their vertical for test and validation in the 5G EVE facility. In order to evaluate the verticals requirements according to the 5G EVE facility features/specifications, we need to know more about the ICT-19/22 projects and their specific use-cases to implement. The network requirements from most Use Cases participating in:

- 5G-TOURS
- 5G-HEART
- 5G-VICTORI
- 5G-SOLUTION
- 5G-GROWTH
- 5G-DRONES
- 5G-DRIVE

were collected in standardized form, which is the same with the one that was used for Requirement Definition and Analysis of the 5G-EVE Use Cases (D1.1, [2]). The only difference is that 2 new Network Requirement were added in order to accommodate for the newly introduced Services/Application and also to correct for the misunderstanding that was created in the 5G-EVE Analysis.

These are:

a) Location Accuracy and
b) RAN Latency (which is different from Network Round Trip Latency).

A similar analysis [3] to the one performed in D1.1 of the 5G-EVE project was performed. In this report initially a very brief description of Use Cases from all Aforementioned Projects is presented (sections 2-8). Next the Network Requirement for each use case in tabular form together with a Radar Chart of the values, overlaid on top of the 4G and 5G network capabilities is being presented and a brief analysis and commentary of the results is included for every use case (section 9).

Finally, in conclusion, aggregated results and analysis are presented. In Table 1 a list of all ICT19/22 projects that will rely on 5G-EVE project are presented.

Table 1: ICT19-22 projects list versus use cases

Project	Website	Industry 4.0	Agriculture & Agri-food	Automotive	Transport & Logistic	Smart cities & Utilities	Public Safety	Smart (air)ports	Energy	E-Health & Wellness	Multimedia and entertainm.
5G EVE	https://www.5g-eve.eu	V		V		V			V		V
5G Drive	https://www.5G-drive.eu			V							
5G Solutions	https://www.5gsolutionsproject.eu	V				V		V	V		V
5G Tours	http://5gtours.eu									V	V
5G!Drones	https://5gdrones.eu				V		V				V
5G HEART	http://5gheart.org		V		V					V	
5GROWTH	http://5growth.eu	V			V				V		
5G VICTORI	https://www.5g-victori-project.eu				V				V		V

2 Project 5G-TOURS

[1].

2.1 Project 5G-Tours (SmarT mObility, media and e-health for toURists and citizenS)

The goal of 5G-TOURS is to get the European 5G Vision of "5G empowering vertical industries" [5GPPP16] closer to commercial deployment with highly innovative use cases involving cross-industry partnerships. 5G-TOURS aims to demonstrate the ability of 5G to support multiple vertical use cases concurrently on the same infrastructure. 5G-TOURS vision is to improve the life in the city for the citizens and tourists, making cities more attractive to visit, more efficient in terms of mobility and safer for everybody

2.2 VERTICAL: Smart City (Touristic city)

2.2.1 Use-case 1: Augmented tourism experience

The proposed solution enriches the Turin's tourism experience using technologies like immersive media content and intelligent video analysis that augment the human interaction with 3D art pieces. The solution can be further divided into the following sub-use cases:

UC1.a: Immersive and interactive virtual tour.

UC1.a is a virtual guide service that delivers a hyper-personalized and interactive experience to the museum's visitors. The virtual guide relies on XR technologies and aims to be context-aware and adaptive to the characteristics (culture, language, etc.) of the visitor. Such adaptation allows personalized interaction with the visitors, understanding their indications, gestures and commands [4].

UC1.b: 3D Immersive and Interactive Learning with Augmented Reality Games.

UC1.b concerns the implementation of Immersive and Interactive Learning with Augmented Reality Games. The UC will rely on gamification to maximize end-user's engagement and participation as well as to make the learning experience more amusing. Therefore, the solution includes game-based learning and gamification features that are accessed by interactive technologies such as augmented or virtual reality, [4].

UC1.c: Interactive Cultural walk experience.

UC1.c: Interactive Cultural walk experience will be about Smart city services that provide a new tourist experience, guaranteeing visitors "temporal and spatial continuity" when they use services provided by 5G TOURS, [4].

2.2.1.1 Equipment

For the needs of the UC1a,b,c the following sensors and actuators will be used:

[1] http://5gtours.eu/

- Sensors & Actuators
  - Short-range signalling devices such as beacons, which will be placed inside museum rooms to allow indoor localization of visitors through their smartphone.
  - At least two "Earthquake Sensing Station" for each floor of the museum, in order to monitor structural oscillations and emit early warning in case of an earthquake. Each sensing station is equipped with proper sensors (accelerometer or velocimetry) and a radio module for data transmission.
  - A least two "Air Quality Sensing Stations" deployed in the external area considered by the trial. Each sensing station is equipped with environment sensors (temperature, humidity, solar radiation), gas sensors (CO, NO2, O3, SO2) and dust sensors (PM1, PM2.5, PM10), and a radio module for data transmission.
- IoT Platform
  - The data measured and sent by the sensors will be collected on an IoT platform that will make them accessible to external applications through APIs. At the platform level, data analysis algorithms can also be defined to obtain correlations between apparently heterogeneous data and to define trigger-action rules (involving also third-party services), according to the well-known paradigm of If-This-Then-That.
- Content storage, analysis and delivery
  - System needs to be able to (temporarily) store media files and annotations. Those contents may be stored in the cloud or in the user device. In the last case the user should (at least) has 1GB of free disk.
  - Management of (live) media contents.
  - Encoding capabilities (including on the fly encoding for live performance) and adaptive streaming capabilities (e.g., dynamic adaptive streaming over HTTP). Standards such as protocols HLS or MPEG-DASH may be used to ensure video streaming adaptability to play video encoded with the H.264 or HEVC/H.265 codecs.
- Services and User Interfaces
  - Context-aware to interaction-based recommendations.
  - Enable setting and updating profile information.
  - Support of AR/VR interaction.
  - The user interaction must be device agnostic
- Network Requirements

The most important network requirements are listed below. However, the full table of the network requirements is presented in section 9 with the corresponding analysis.

  - Low-Latency is one of the most important requirements to support XR Interaction. i.e. XR to provide pleasant immersive requires stringent latency requirements typically with values < 15 ms of round-trip time including the rendering in the cloud
  - Fast Data Rate: immersive interaction requires data rates to about 200 Mbps for a VR system
  - Supports multiple wireless ad-hoc connectivity like WiFi, Bluetooth, telephone network such as 5G.
  - The user should not have to configure connectivity channels.
  - NB-IoT coverage in the areas considered by the trial (indoor and outdoor).

2.2.2 Use-case 2: Telepresence

Telepresence refers to technologies that allow a user appears to be present, feel like they are present or have some effect in a space the person does not physically inhabit. Telepresence can include video teleconferencing tools, where a picture and audio stream is conveyed to a remote location, as well as more involved robotics installations that can actually help a user to accomplish tasks from a remote location.

2.2.2.1 Equipment

A mobile connection should be available in each room of the museum the robot is required to operate. For more sophisticated single user experience (e.g. night surveillance) the robot must be enhanced using Infrared/3D Camera and tilt/pan enabler, control statit must be enhanced using VR headset and controller.

Network Requirements:

The most important network requirements are listed below. However, the full table of the network requirements is presented in section 9 with the corresponding analysis.

A bandwidth of a least 10Mbit/s (upstream) is required for successful high-quality video transmission from the robot cameras to the control room. Additional upstream bandwidth (5-10Mbit/s) might be required for additional robot sensors (robot joints data, audio stream, depth sensor and laser range finder data etc). A bandwidth of at least 10Mbit/s (downstream) is required to teleoperate the robot from the control room. A latency of ~10ms (or less) is recommended for safe robot teleoperation and control. Internet connectivity for cloud computing (e.g. to connect to software for natural language processing). In Turin the UC will start in Palazzo Madama, and progressively extended to GAM, Museo Pietro Micca and Borgo Medievale

2.2.3 Use-case 3: Robot-assisted museum guide and monitoring

The goal of this use case is to leverage robotic technology to provide an enhanced museum visit experience, improving at the same time the efficiency of safety monitoring aspects in the museum. In this case, a robot is deployed inside the museum and has a map of the environment enriched with the location of the main attractions. Visitors interact with the robot, asking information on what they can see and where. The robot can physically guide the visitors to the required attraction. Furthermore, the robot will be able to monitor the presence of people in areas that are forbidden to the public and deliver a warning if a violation of the rules takes place. Additional robot intelligence in need of high amount of computational resources is required for this task, which further motivates the use of computing power external to the robot such as computing cluster, as well as low latency and high bandwidth communication for a proper operation [4].

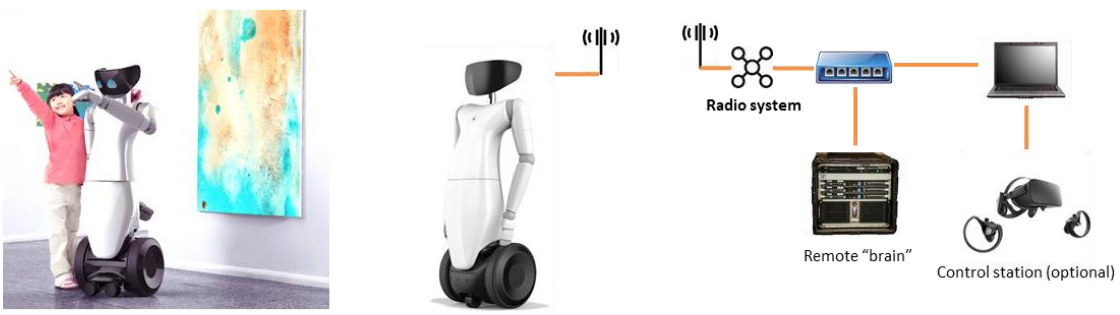


Figure 1: 5GTours Robotic guide use case (left). A schematic representation of the robot control system (right).

2.2.3.1 Equipment

This use case explores the requirement of an autonomous system which is controlled by a remote-control station. In this case high bandwidth is required upstream to transmit data acquired by the robot sensory system (RGB and depth cameras, laser range finder, audio stream, robot joints data) and make it available to the set of computers that control the robot from a remote station (the robot "brain", Figure 1). The control station processes the data received from the robot, e.g. audio analysis for speech-to-text, natural language processing and localization of the robot on the map. It then computes the commands for the robot: speech (audio format), motor velocity for the wheels on the base or the robot limbs. The control loop should be reliable with low latency to guarantee correct operation of the robot. As different streams of data have different importance for the application, QoS control may be also investigated to assign higher priority to data streams that are involved in the control of the robot. The most important network requirements are listed into the table below. However, the full table of the network requirements is presented in section 9 with the corresponding analysis.

Table 2: 5GTours Robotic use-case network requirements

Metric	Required value
Latency	≤ 10 ms (bidirectional mode)
Reliability	99.9999%
Coverage	The museum in the city of Turin in which the robot will operate (Palazzo Madama, GAM or Borgo Medievale)
Data rate per user/device	A bandwidth of 15-20Mbit/s upstream and 10Mbit/s downstream

The use case will take place in the city of Turin and will involve the museums of Palazzo Madama, GAM and Borgo Medievale.

2.2.4 Use-case 4: High quality video services distribution

This UC lies in providing the user with additional content related to the surrounding environment (i.e. pictures, video or virtual content) by using smartphones, TVs or VR/AR devices. This type of services requires the availability of computing resources in the network edge in order to support such advanced processing techniques [4] .

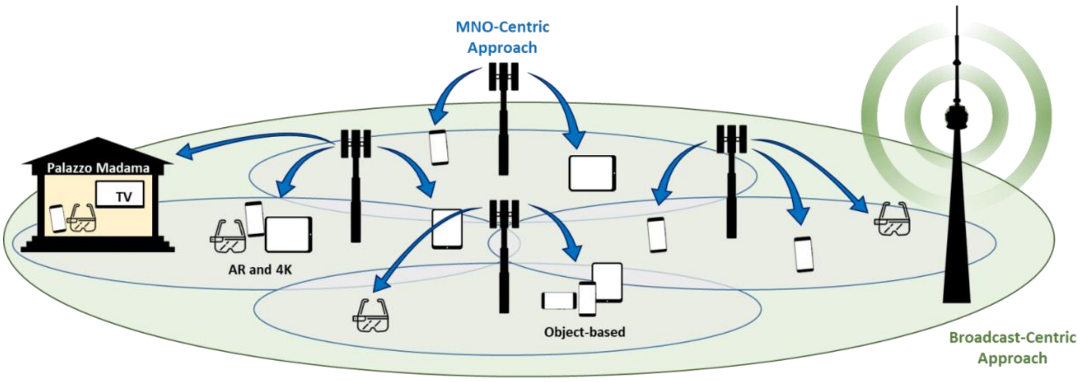


Figure 2: 5GTours High quality video services distribution with both MNO- and broadcast-centric approaches

UC4.A: Mixed unicast/broadcast services in cellular networks
The consortium will consider a MNO-centric approach. The content is transmitted via the cellular 5G network in a mixed mode where multicast/broadcast and unicast share resources. With this option, it is possible to distribute immersive contents to a large number of users, where part of the content needs to be personalized and there is also information being delivered by the user in the uplink. The trials will be divided in several stages of implementation and demonstration [4].

UC4.B: 5G Broadcast delivery to massive audiences
The second option is a broadcast-centric receive-only approach, where a broadcaster's infrastructure is used. This use case utilizes a High-Power High-Tower (HPHT) topology to transmit the content to all users at once. The trials will be divided into two stages as described in [4].

2.2.4.1 Equipment

Immersive A/V services require edge-computing equipment for fast server processing, ensuring very reduced latencies. This is especially important to keep a good user experience when transmitting AR content. This use case also requires extremely good reliability with very-high data rates to deliver the content with consistent and extremely good quality. Another requirement is the capacity to cover a high density of users. Up to several users per square meter are expected in crowded areas such as the museum or its surroundings.

The main use case components to make this use case a reality is, on the one hand, a 5G network (Core and RAN) with multicast/broadcast capabilities. On the other hand, 5G compatible receivers, which in turn can be AR devices (e.g. HoloLens) or smartphones. Smart TVs with connectivity are also needed in the museum.

The main service level objective of this use case is to provide the same high-quality content to an extremely large number of users with high reliability. Another objective is the use of innovative A/V formats such as object-based video and AR. The specific requirements are the following, however the full table of requirement is presented in section 9 with the specific analysis:

Table 3 5GTours High quality video services distribution use-case 4 metric

Metric	Required value
Latency	≤ 10 ms (bidirectional mode) N/A for PTM mode
Reliability	99.9999%
Coverage	Venue (museum, surroundings) / Turin city (~15 km) Depending on the network infrastructure
Data rate per user/device	≥ 25 Mbps

The trials of this use case will be done in the city of Turin. In particular, they will take place in Palazzo Madama, its surroundings and the other locations to be defined in the progress of the project.

The trials for the video distribution use case will be done by using the 5G NSA infrastructure of both the network provider and the mobile network operator (MNO). The first option is to develop a MNO-centric network with PTM capabilities. This network is intended to be updated to a 5G SA core network with PTM capabilities. The second option is the use of a broadcaster's infrastructure to transmit linear TV content via enTV Rel-14 and Rel-16. Each option will have a series of trials associated in order to validate and demonstrate the technologies implemented.

2.2.5 Use-case 5: High quality video services distribution

The objective of this use case is to analyse how 5G networks could support various scenarios where high quality video (e.g., in 4K, HD/HDR or Video 360°) is generated and transmitted. Video contents could be delivered from cameras located in places where an event is taking place to a TV studio in the broadcasting center or to a remote studio facility on the event location itself. Such video contents could be used both for immediate live broadcasting of the event or recorded to be further edited and used in TV programs to be broadcasted later on [4].

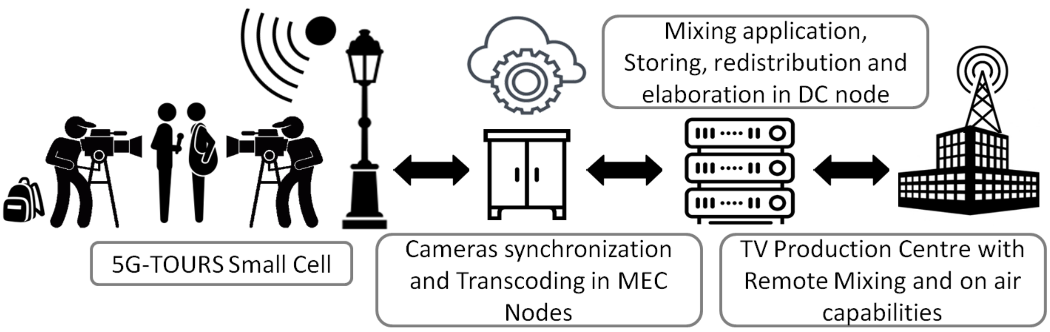


Figure 3: 5GTours Example of a remote production environment

2.2.5.1 Equipment

The itinerant orchestra use case data flow is constituted of two consecutive parts. The first portion includes transmission of high-quality video from multiple locations to a local/remote studio whereas the second includes video production and live video transmission to a number of wall LED screens as well as to spectators' devices.

The use case needs very low and stable delays, an ultra-reliable capability and a very large bandwidth capacity, we can summarize the most important network requirements as follow (the full table with the requirements is presented in section 9 with the specific analysis):

Table 4: 5GTours High quality video services distribution -2- metrics

Metric	Required value
Latency	≤ 10 ms (bidirectional mode) taking into account to use audio streams to synchronize all content
Reliability	99.9999%
Coverage	Turin city - where remote musicians are moving The auditorium where the event take place
Data rate per user/device	• ≥ 25 Mbps (for each video) It depends by the coding of videos, to avoid additional delay from the video coding phase some very low delay coding mode is needed.

The trial site will be the city of Turin, the exact locations are to be defined according to the network infrastructure, in general we have to cover areas in where remote musicians are moving and the auditorium where the event take place (e.g. the auditorium Rai "Arturo Toscanini").

2.3 VERTICAL: Smart City (Safe city)

2.3.1 Use-case 6: Remote Health Monitoring and Emergency Situation Notification

This UC is for enabling remote monitoring, especially when it comes to a person diagnosed with a disease, and consultation by their medical attendants, as well as their remote collaboration with the local medical personnel leveraging advanced technology in case of an emergency is expected to act as additional motivation for travelling. The main features offered by this use case involve (a) remote health monitoring services leveraging a variety of datasets, including, but not limited to, health signs, air quality, weather conditions, site waiting times, transportation, traffic and location, and (b) quick, reliable notifications to nearby ambulances, medical professionals and family members in case of a health incident or a health emergency prediction. The use case will leverage wearable devices and patches tracking the tourist's vital signs and having them aggregated inside an IoT-based AAL platform named STARLIT (**S**mar**t** living pl**a**tform powered by A**r**tificia**l** **i**ntelligence & robus**t** iot connectivity), where they will be processed in a combined fashion exploiting also various city sources and open APIs. STARLIT's outcome will be the identification or the prediction of a health-related emergency situation, which will be followed by the immediate notification of the dispatch centre of the Rennes University Hospital [4].

2.3.1.1 Equipment

Remote health monitoring requires some distinct component for the use case implementation as well as specific series of functions for their effective communication. A set of machine type communications is foreseen in the

context of continuous monitoring of the user's health condition, as well as of city sensors so as to offer a combined touristic yet health-aware experience.
Input devices (biosensors, wearable devices, smartphones, etc.,) are used for the data collection (biological measurements, vital signs or disease-specific indicators) and the gathered information is stored in a local repository (cloud-based infrastructure). Afterwards, the data can be transmitted to the healthcare facility through different types/forms of communication. The appropriate software/AI mechanisms will automatically examine the data and if something abnormal exists, notifications/alarms will be sent to the doctors/caregivers/emergency responders and then immediate assistance will be provided to the patient.
The fully integrated 5G communications system promises a high level of performance through the aforementioned functions with high reliability, accuracy and low latency communication for the notification of an ambulance. The device density is expected up to several devices per m^2 and an enhanced reliability of 99.99%.

Table 5: 5GTours Remote Health Monitoring and Emergency Situation Notification use-case metrics

Metric	Required value
Device density	Several devices per m^2
Reliability	99.99%

The full table of network requirements is presented in section 9, as well as the corresponding analysis. The trials for this use case will be carried out in Rennes with the Rennes University Hospital in France.

2.3.2 Use-case 7: Teleguidance for diagnostic and intervention support

The 5G connected ambulance can function as the "first room of hospital", enabling the on-the-spot, direct treatment of the patient under the guidance of a remote expert so as to prevent further, and potentially irreversible, deterioration of the condition of the patient. The hospital may be far away from the patient and the ambulance, so the patient may not survive. Alternatively, permanent damage may by incurred to the patient during transport. The key to such situations is to perform a first diagnosis as fast as possible, in order to know what to do next. In particular, the emergency responders need to deter-mine the best treatment to stabilize the patient, locate the most suitable hospital and, notify it to make all necessary preparations for the patient, e.g., prepare the OR and call all necessary medical staff. Especially in case of trauma, immediate intervention strongly impacts the outcome, e.g., for hemodynamic un-stable patients, in case of suffocation, internal bleeding, complicated fractures, critical prenatal cases, etc. The available equipment within the ambulance for monitoring, examining, and guiding interventions include ultrasound, which is rapid, non-invasive, portable, versatile and low cost, patient monitors and, 4K video. In addition, instant access to medical records is important to understand the patient's condition prior to the incident (AMA's Xperteye smartglasses: interactive HD head up display for monitoring patient's vitals, medical imagery, protocol; first person point of view live camera).

Next to the improvements for the staff in the ambulance, this use case will also evaluate whether the use of AR/VR over 5G can improve the situational awareness the medical staff in the hospital has, which positively impacts the quality of the teleguidance. AR/VR technology also brings enhanced video and spatial scanning features that further improve the immersion and richness of the presented information. These again should positively impact the quality of remote guidance and telepresence.

2.3.2.1 Equipment

In this use case, ambulance staff gets tele-guidance from an expert in the hospital. This expert can base his guidance on live video from cameras in the ambulance and the camera in the smart glasses, as well as Ultrasound image data. The expert can also control the Ultrasound acquisition parameters of the Ultrasound equipment in the ambulance directly. The received Ultrasound images can be interpreted directly by the expert in the hospital, or can be fed into clinical decision support algorithms to help the expert. Inside the ambulance, the staff gets the guidance through smart glasses. Additionally, the staff should also be able to retrieve information from the medical file of the patient through the smart glasses.

Inside the hospital, the expert will have the option to use regular displays to keep overview, of use AR/VR technology to immerse himself in the situation in the ambulance. The immersion aids in making the context and situation understandable without the need for local staff to manage information provisioning for the remote expert. In the ideal case, this creates a virtual team, consisting of the emergency responders and the hospital expert. They should be able to experience an uninterrupted workflow and dialog within the team.

This leads to the following communication-centric technical requirements:

- High dependability: the solution should work everywhere and always in the safe city
  - Bandwidth and latencies should be always sufficient for clinical use
  - Even in very crowded situations, e.g. with priority over all non-essential 5G traffic
  - It should not depend on where the ambulance is parked.
- The network capacity should be available with very little advance notice (<1 minute).
  - Keeping the bandwidth continuously reserved is a waste of resources and unnecessarily expensive, so an 'instant' slicing based solution is probably desired.
- This use case focusses on a single ambulance
  - In more advanced scenarios, e.g. a major emergency, a hundred ambulances may be involved, although probably not all of them will use tele-guidance
- While the tele-guidance is expected to happen in a stationary situation, it is desired that most functionality is still available during transport of the patient to the hospital.
- Data streams:
  - Three camera video streams from the ambulance to the hospital
    - HD / 4K
    - ~ 45Mbps
    - ~ 50ms latency end-to-end including compression
    - Two static cameras, one smart glasses
    - Per camera
  - Ultrasound data streams towards the hospital
    - ~720p resolution
    - ~ 5Mbps (compressed) / 30Mbps (uncompressed)
    - ~ 50ms latency end-to-end
  - Guidance AR video stream towards the ambulance
    - ~720p
    - 5Mbps (compressed)
    - ~ 25ms latency end-to-end
    - For display on smart glasses
  - Smart glasses position + orientation data stream towards the hospital
    - Needed to generate AR video stream
    - < 100 kbps
    - ~25ms latency end-to-end
- Location accuracy is not a critical parameter

2.3.3 Use-case 8: Wireless operating room

Figure 4: 5GTours TherA-Image platform [CHU]

5G will be deployed in a real hybrid Operating Room (OR) comprising several pieces of equipment for interventional procedures and ultrasound guided gestures, as well as videos produced by digital cameras, as documented in the TherA-Image platform [CHU] and depicted in Figure 4. A surgery enhanced with 5G connectivity improves the effectiveness of the operating room, especially in case of an unplanned procedure that needs to be performed during the operation. The quality, reliability and low latency provided by 5G makes it possible to support advanced medical applications such as, e.g., Augmented Reality Assisted Surgery and Cobotic-aided surgery. In the same network infrastructure, various types of communications can be supported (e.g., Augmented Reality Assisted Surgery, tele-mentoring using smart glasses, real-time broadcast of surgery for educational purposes, etc.) with a proper management of slices, providing the necessary degree of isolation and reliability to guarantee the quality of the critical slices and thus ensure the patient's safety. In case the patient is a tourist, the wireless operating room allows that the home doctor of the patient can provide remote assistance [4].

2.3.3.1 Equipment

The service level requirements will be:

- ≤ 150ms (end to end) from surgeon gesture to monitor display for human interaction
- 10 Gbps video flows combination (before compression)
- Reconfiguration of slice in less than 1mn for introducing a new medical imaging equipment (network configuration pre-defined), with reduction of quality on non-high-priority video flows

The most important requirements for this UC is the following (however, the full set of requirements is presented in section 9 with the corresponding analysis).

Table 6: 5GTours Wireless operating room metrics

Metric	Required value
Latency	≤ 5ms for synchronization between videos and associated metadata (AR), ≤ 15ms for video transmission (local network contribution at the overall latency)
Reliability	99.999% (to be discussed)
Density	N/A
Mobility	N/A
Coverage	100 m^2
Slice/service deployment time	≤ 90 minutes (≤ 1 minute for planned slice)
Data rate per user/device - DL	≥ 150 Mbps (compressed fullHD 3 Gbps video)
Data rate per user/device - UL	≥ 150 Mbps (compressed fullHD 3 Gbps video)

Metric	Required value
Security	“Carrier grade”
Location accuracy	N/A

Then main location will be Thera-Image OR in CHU de Rennes, with potential connection with a remote participant in Turin.

2.3.4 Use-case 9: Optimal ambulance Routing

This use case addresses real time navigation of the ambulance both to the site of the emergency, to ensure that medical help will be provided as quick as possible as well as for the ambulance to arrive at the hospital as soon as possible once the patient has been stabilized on site [4].

2.3.4.1 Equipment

The use case requires a fast and reliable network connection for real-time acquisition and communication of data from various sources (sensors, devices, APIs). Moreover, security of the connection is necessary so that no tampering with the data or the routing instructions is possible, while location accuracy is also important. Indicative relevant 5G network requirements are listed in the following table.

Table 7: 5GTours Optimal ambulance routing use case metrics

Metric	Required value
Latency	≤ 10ms
Reliability	99.999%
Mobility	Above 100Km/h
Coverage	3 km^2
Security	“Carrier grade”
Location accuracy	≤500 m

The full set of requirements is presented in section 9 with the corresponding technical analysis. The scenario/script for the trial corresponding to this use case will roughly evolve as follows (as part of the overall safe city use case):

- An ambulance needs to be dispatched to an emergency site
- Optimal ambulance routing for the specific ambulance is initiated, taking into account the site location, the available routes, traffic flow, weather conditions (if applicable), city events (e.g. road closures). Relevant data is continuously retrieved to select and update the optimal route on the go.
- Once it is decided that the patient(s) should be transferred to hospital based on the assessment of the medical experts involved optimal routing is initiated to dynamically calculate the route to the most suitable hospital and emergency department.

For the sake of showcasing the operation of the optimal ambulance routing under various conditions (traffic, weather, appropriateness of hospital) aspects of the trial may be emulated such as the ambulance on route, the traffic conditions, weather conditions, etc.

2.4 VERTICAL: Smart City (Mobility-efficient city)

For each vertical that is planned to be implemented in 5G EVE, please use as much as subsections as verticals.

2.4.1 Use-case 10: Smart Parking

The scope of this use case is to design, implement and deploy the smart parking management demo at Athens International Airport (i.e., in the Athens node). This use case will address 5G connectivity from the perspective of massive machine type communications. To this end, a large number of 5G enabled parking occupancy sensors will be deployed to one of the parking areas of AIA feeding an intelligent platform with real-time information on the parking positions status so as to enable targeted suggestions for an improved travelling experience. This task also foresees the development of the parking occupancy sensors [4].

2.4.1.1 Equipment

Network requirements

The most important network requirements are:

- **Latency**: to offer optimum driver experience, the application should be able to provide updates on parking space availability in terms of seconds
- **Reliability**: this application isn't considered critical; still, as the application will be offered via mobile network infrastructure, the same service availability KPI as generally offered by the mobile networks also apply for this use case i.e. 99,999%
- **Density**: the network infrastructure should be able to accommodate communication for few thousand MTC devices/sensors (at full deployment) and hundreds of application users
- **Mobility**: the service is expected to be offered to low/moderate speed moving vehicles, so no special mobility requirements are imposed by current use case to the mobile network
- **Coverage**: the service is targeted to a confined geographic area, so deployed radio network should be such that all designated area is given radio connection with expected quality of service (see below) with mobile radio access network
- **Data rate per user/device** -DL/UL: this highly depends on the info expected to be provided real-time to the driver by the parking assistance application. The application needs to provide at the minimum dis-tance and direction to closest available parking space or provide several parking space(s) as options for the driver to select from. Overall low to moderate data in DL direction per user is expected. In addition, the data rate per MTC device – DL/UL is expected to be low to carry update(s) on parking space availa-bility on the uplink direction. In the downlink direction, low to moderate bit rate is expected primarily during MTC device firmware upgrade/maintenance
- **Location**: location accuracy is terms of few meters is needed to ensure trust of users to the service

The full table with requirements is presented in section 9 with the corresponding technical analysis. The smart parking use case will take place on the Athens trial, particularly in the location of the Athens International Airport (Spata area of Attica). The trial will provide 5G connectivity to the airport, which covers a substantially large area (around 5 Km2).

2.4.2 Use-case 11: Video-enhanced ground-based moving vehicles

This use case covers mobility efficiency from the scope of follow-me vehicles, which lead aircrafts to parking positions, monitor and oversee the activity at the Airport Airside area, and attend incidents, emergencies and critical events. Within the context of this use case, AIA's follow-me vehicles will be enhanced with mobile units equipped with high definition cameras; the scenario will demonstrate how live video feeds sent to the Airport Operations Centres (AOCs) and other stakeholders improve both day-to-day airport operations and response activities to emergencies.

This will result to a dramatic increase of the situational awareness of the stakeholders responsible for the running of the airport operations. Moreover, in case of an emergency or a developing incident, the AOCs can have immediate overview and decide in a timely manner all required mitigation actions, regardless of the area of the airport where the incident is taking place and irrespectively of whether the AOC has direct viewing capability of the area or not. In this respect, the AOC can respond to incidents that are not predefined and are dynamically evolving to non-standard events.

Furthermore, the video feed can be propagated in real time to multiple stakeholders required for the incident resolution such as Police, Special Forces, Firefighting, Ambulance, Civil Protection etc., regardless of their proximity to the airport [4].

2.4.2.1 Equipment

Network requirements

The most important network requirements are:

- **Latency**: to offer optimum live video experience, low latency, in terms of milliseconds, is expected
- Reliability: this application may be considered critical; thus, it is expected to be associated with public safety quality of service thus given priority in terms of network congestion. Overall service availability KPI should be the same as generally offered by the mobile networks i.e. 99,999%
- **Density**: the network infrastructure should be able to accommodate communication from few tens of video sources
- **Mobility**: the service is expected to be offered to moderate or even high speed moving vehicles, so no special mobility requirements are imposed by current use case to the mobile network
- **Coverage**: the service is targeted to a confined geographic area, so deployed radio network should be such that all designated area (in this use case, the airport) is given radio connection with mobile radio access network at expected quality of service (see below)
- **Data rate per user/device** -DL/UL: this highly depends on the quality of video feed. At minimum a few Mbps in the uplink direction is needed to support adequate quality video (or tens of Mbps in case of high definition video)

The full table with requirements is presented in section 9 with the corresponding technical analysis

2.4.3 Use-case 12: Emergency Airport evacuation

Airport terminals are very large and complex public venues with a large number of travelers, visitors and employees. Daily, up to approximately fifty to sixty thousand passengers travel through Athena's airport, while during the peak traffic days this number can reach approximately one hundred thousand or even more including visitors and employees. The Airport's objective is to process this crowd in an efficient and safe manner, while at the same time have in place the relevant plans, tools and processes required to mitigate any emergency. Efficient and effective evacuation is one of the mitigation measures that are of particular importance in security incidents or even in the case of fire, gas leakage, etc. Airport evacuations in general, are currently based on pre-established plans and procedures to be executed during the emergency.

During this process the airport attendees will be notified with a message to their mobile device on the emergency situation, while from that point on, they will be receiving further notifications on regular time intervals. Guidance will be provided in a personalized manner, taking into consideration the design of the physical space, any obstacles that might exist, the current occupancy, the capacity of the evacuation routes and the travellers' individual needs and limitations, such as their age, health status and mobility capabilities, etc. The location of the travellers will be also tracked to provide more targeted guidance especially for evolving events such as a fire spreading or an evacuation route becoming unavailable. The system can also be used for early detection of passenger movement anomalies that can signify an evolving emergency and timely alarm airport response units. Enhanced location services will be made available with 5G after all [4].

2.4.3.1 Equipment

Network requirements

The most important network requirements are:

- **Latency**: low latency, in terms of milliseconds, is required to provide up-to-date evacuation assist info in personalized manner
- **Reliability**: this application is considered critical; thus, it is expected to be associated with public safety quality of service thus given priority in terms of network congestion. Overall service availability KPI should be the same as generally offered by the mobile networks i.e. 99,999%
- **Density**: the network infrastructure should be able to accommodate communication towards a few thousands users (airport attendees)

- **Mobility**: the service is expected to be offered to low/moderate speed users, so no special mobility requirements are imposed by current use case to the mobile network
- **Coverage**: the service is targeted to a confined geographic area, so deployed radio network should be such that all designated area (in this use case, the airport) is given radio connection with mobile radio access network at expected quality of service (see below)
- **Data rate per user/device** -DL/UL: this highly depends on the info provided and the rate of updates towards the end user. At minimum a few Mbps in the downlink direction, at the user plane, is needed per user. Note that the network should be able to support moderate capacity particularly for the location service
- **Location**: location accuracy is terms of few meters is needed to provide evacuation assistance info in personalized manner

The full table with requirements is presented in section 9 with the corresponding technical analysis

2.4.4 Use-case 13: Excursion on AR/VR-enhanced bus

Use case 13 aims at improving the learning and entertainment (‘infotainment’) experience of the passengers of a bus that is transporting them so that they can visit a site of interest. The improved user experience will be realized in two locations:

- On the bus while traveling to the visit destination and/or returning from it
- At the destination, while visiting the site.

Using new possibilities offered by 5G, visitors will be provided with digital content, media and applica-tions that will enhance both the experience of traveling to the visit destination, and the experience of visiting the site of interest, complementing and extending relevant conventional content and activities [4].

In particular, the use case is materialized with a focus on the example of:

- school students traveling to a site of educational interest in the context of an excursion or field visit
- the use of Extended Reality (XR) applications as the enablers of the digitally enhanced passenger and visitor experience (XR is used in this context as the umbrella term including Virtual Reality or VR, Augmented Reality or AR, and Mixed Reality or MR), i.e. involving the introduction of digital objects in the real and/or 3D virtual world.

2.4.4.1 Equipment

For the trials, a school bus with 20-25 students will be provided by EA.

Software to enable the VR and AR experiences will need to be developed. EA will provide the educational design and content for the development of the VR and AR applications, collaborating closely with the technical partners involved in the development of the applications.

The 5G-enabled hardware required includes VR and AR equipment to be used by each of the participating students. Options range from wearables such as VR headsets or possibly also haptic hands-tracking equipment to the mere use of 5G smartphones (to which VR equipment is attached, or which are used as displays of VR content in combination with a simple frame headset holding the smartphone in front of the user’s eyes, or which are used for camera-based AR on the handheld device. In addition, parts of the applications which are location-aware (e.g. the exhibit-based AR) may require equipment such as beacons, etc.

The AR/VR enhanced bus use case involves presenting AR/VR type educational/cultural content to the students while on the move. Different requirements are posed to the network depending on type of enriched content i.e. AR or VR. While VR type of content may be predefined and broadcasted by the network to the end user the AR type of content may be correlated to the bus surroundings. Thus, eMBB and URLLC requirements may be posed to both the access and core network to support the content delivery. Thus, the network shall accommodate high user data rate, primarily in the downlink direction, with low latency and location accuracy particularly for the AR type of content delivery. In addition, to support undisruptive service experience while the end user moves across mobile cells, the handover completion delay shall be kept to the minimum. Communication and user data exchange between the end users device and the Content Delivery sever is done via vEPC node (in phase 01) and via the v5GS core (in phase 02) and the corresponding RAN network i.e. 4G RAN possibly capable to provide dual connectivity to the core network and gNB-RAN, respectively.

This use case involves case involves presenting AR/VR type educational/cultural content to the students while on the move. Different requirements are posed to the network depending on type of enriched con-tent i.e. AR or VR. While VR type of content may be predefined and broadcasted by the network to the end user the AR type of content may be correlated to the bus surroundings. *Network requirements*

The most important network requirements are:

- **Latency**: Latency is particularly relevant to AR applications so that small movement (or change of direction) of the AR device is reflected as fast as possible in the augmented video. Thus, latency should be ~10-20ms end-to-end round-trip for optimum end user experience but also <100msec round trip would provide an acceptable end user experience.
- **Reliability**: this application isn't considered critical; thus, overall service availability KPI should be the same as generally offered by the mobile networks i.e. 99,999%
- **Mobility**: the service is expected to be offered to moderate/high speed users, so no special mobility requirements are imposed by current use case to the mobile network
- **Data rate per user/device** -DL/UL: At minimum a few Mbps in the downlink direction, at the user plane, is needed per user.

The full table with requirements is presented in section 9 with the corresponding technical analysis.

3 Project 5G HEART

[2]

3.1 Project description

5G-HEART (validation trials) will focus on these vital vertical use-cases of healthcare, transport and aquaculture. In the health area, 5G-HEART will validate pillcams for automatic detection in screening of colon cancer and vital-sign patches with advanced geo-localization as well as 5G AR/VR paramedic services. In the transport area, 5G-HEART will validate autonomous/assisted/remote driving and vehicle data services. Regarding food, focus will be on 5G-based transformation of aquaculture sector (worldwide importance for Norway, Greece, Ireland).

The infrastructure shared by the verticals, will host important innovations: slicing as a service; resource orchestration in access/core and cloud/edge segments with live user environments. Novel applications and devices (e.g. underwater drones, car components, healthcare devices) will be devised. Trials will run on sites of 5G-Vinni (Oslo), 5Genesis (Surrey), 5G-EVE (Athens), as well as Oulu and Groningen, which will be integrated to form a powerful and sustainable platform where slice concurrency will be validated at scale.

The consortium includes major vertical players, research/academic institutions and SMEs. Partners have proven know-how in 5G, vertical applications, standardisation, business modelling, prototyping, trials, demonstrations.

5G-HEART KPI validation ensures improved healthcare, public safety, farm management and business models in a 5G market, stimulating huge business opportunities within and beyond the project.

3.2 VERTICAL: Agri-food industry

For each vertical that is planned to be implemented in 5G EVE, please use as much as subsections as verticals.

3.2.1 Use-case: Remote monitoring of water and fish quality

In 5G-HEART, the intention is to build a cross-border aquaculture use case. The main pilot will be in Greece, supported by the 5G-EVE node in Athens. The **Skironis** aquaculture site owns and operates a fish-farming unit on floating facilities of fifty thousand (50000) m3 in the area of "Kato Aloni", Megara Bay, Megara, Western Attica, of the Region of Attica, comprising 3 sites, with an annual production capability of 1500 tonnes. The first site has an area of 20000 m3 with 15 cages, the second site has an area of 10000 m3 with 12 cages, and the third site has an area of 20000 m3 with 10 cages

Fish farming sites are usually located in an offshore area with insufficient coverage of cellular networks (3G/4G). There are currently needs for data transfer and Internet access for two main purposes:

- Security of the aquaculture sites equipped with video cameras.
- Operational management of the aquaculture sites, especially the management of the quantities for feeding the fish population, report of dead fish, management of cage transfers, time sharing and personnel management.

For this reason, one use case is addressed in the aquaculture vertical: **Remote monitoring of water and fish quality**.

[2] http://5gheart.org

3.2.1.1 Envisaged system design and requirements

Use case requirements (quantitatively), e.g. throughput, latency, reliability etc. Refer to 5G PPP KPIs

- Ubiquitous coverage
- Bandwidth for cameras (security and fish behaviour monitoring) and mobile applications (operational management)
- Power efficiency for sensors, especially since it is an offshore system
- Latency in case of automation (Remotely Operated Vehicles and/or actuation systems).
- High reliability and security are also a must, since the management affects not only the fish population but also the protection of the environment.

Use case categories; eMBB, URLLC and mMTC

The use case has features from mainly mMTC (due to sensors) and eMBB (due to cameras), but can also be relevant to URLLC (due to autonomous vehicles and autonomous functionality).

Slicing, types, number, properties etc

The network should be able to cover both Internet needs for personnel, data transfer from monitoring stations and sensors, and most importantly the video/images transfer. The last is mainly required at specific hours and/or events, thus a solution based on slicing can be promising.

The intelligent management system (data and predictive analytics, decision making for alert notification and actuation) can be hosted at MEC level, in order to enable timely actuation/automation operational decisions in the context of Phase 3 tests.

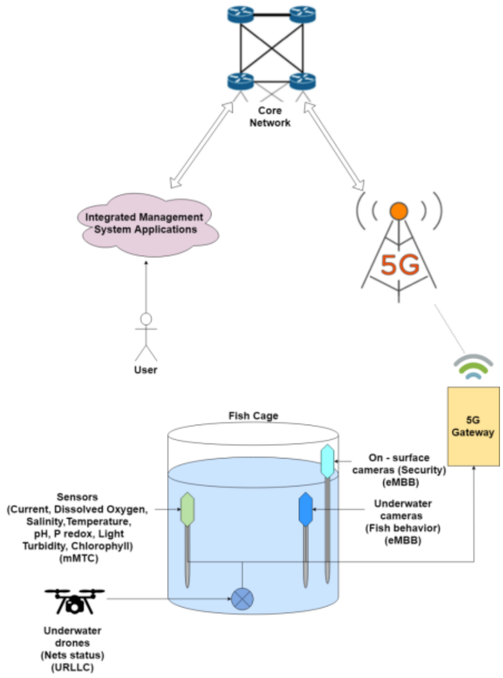


Figure 5: Aquaculture use case architecture

3.2.1.2 Test cases

The added value of 5G networks is multi-dimensional and can be demonstrated in a variety of cases. The main features that will be tested and are expected to enhance the operation and development of the aquaculture vertical are briefly described here:

1. **Multi-parameter monitoring/data collection**
   During this test case, remote monitoring of the farm using sensor data for physical/biological/chemical parameters will be applied on site, gathering data from multiple sources. The goal of the experiment is to identify the connection density that the network can support as well as the bandwidth that can support remote transferring of the payload.

2. **Security**
   Security is a very important field for aquaculture sites, for both the production as well as the welfare of the fish. Thus, in this test case, the ability of the network to transfer real-time security footage to the operator will be tested, measuring capacity and throughput.
3. **Fish monitoring**
   The welfare of the fish depends on multiple factors, such as environmental causes, predator attacks heath issues etc. By monitoring the behaviour of the fish through underwater cameras, the operator will be able to quickly identify such situations and take measures regarding their confrontation. Bandwidth and throughput will also be measured in this test case.
4. **Infrastructure monitoring**
   Monitoring and maintenance of the infrastructure is a very important aspect of the activities that occur during the operation of an aquaculture farm. In order to identify the gains that these activities have from 5G technologies, the test case will include camera (underwater, on-surface, drone) input to enhance the overview of the infrastructure for the operator. Bandwidth will be measured for this case.
5. **Autonomous functionality**
   Autonomous functionality is an obvious gain for the aquaculture farm, concerning the difficult conditions that farmers face towards the weather or other environmental factors. So, mechanisms like automatic feeding, nets or raft maintenance that require instant response from the operator are considered a big asset for the site. So, latency is a major requirement that will be evaluated through this test case.

3.2.2 Equipment

As shown in Figure 5, the equipment that will be used for the integration, testing and operation of the use case consists of the following:

- Water quality sensors
- Security cameras for site supervision
- Underwater cameras
- Underwater drones
- 5G gateways
- Network equipment (5G modems) and infrastructure

The full set of requirements is presented in section 9 with the corresponding technical analysis.

4 Project 5G-VICTORI

[3]

4.1 Project description

5G-Victori project conducts large scale trials for advanced vertical use cases, focusing on Transportation, Energy, Media and Factories of futures. The project leverages several 5G network technologies developed in 5G-PPP phase 1 and phase 2 and further exploits the ICT-17 infrastructures, as 5G-EVE. The aim of the project is to provide also enhancements of existing infrastructures through integration of several verticals and cross verticals use cases. The ICT-17 infrastructure should be transformed from a dedicated infrastructure into open environments, exposed to different resources functions and verticals industries. The request for the ICT-19 project 5G-Victori is to access on demand several functions of the ICT-17 infrastructure and to deploy services in such ecosystem. Even 5G-Victori solution is focused to enable interconnection and interworking of three main ICT-17 platforms, 5G-VINNI, 5GENESIS, 5G-EVE. The main facilities involved in 5G-VICTORI is from 5G-VINNI the Patras site in Greece, from 5GENESIS the 5G-Berlin test-bed in Berlin Germany and for 5G-EVE the Paris Saclay and Sophia Antipolis sites in France as well as the 5GUK national facility available in Bristol, UK.

The main 5G-VICTORI use cases are:

- “Enhanced Mobile broadband under high speed mobility”, Vertical: Transportation – Rail
- “Digital Mobility”, Cross-Vertical - Transportation and Media.
- “Critical services for railway systems”, Vertical: Rail.
- “Smart Energy Metering”, Cross-Vertical: Energy and Rail.
- “Digitization of Power Plants”, Vertical: Smart Factory.
- “CDN services in dense, static and mobile environments”, Vertical: Media.

5G-EVE is intended to support only part of this use cases, deployed through Orange Romania, as:

- Energy Metering
- Transportation

4.2 VERTICAL Emergency Services for Transport

4.2.1 Use case 1: On-demand network creation for emergency services

The main objective of this UC is to develop a common framework for innovative mobility applications and services, as On-demand network creation for emergency services.

A Passenger followed pop-up network on-demand able to:

- To create and deploy customized networks for a large group of passengers arriving at a station.
- To create an on-demand network that seamlessly converge with available networking technologies and devices at each station e.g. IoT, various wireless access networks, edge computing.
- To create a network that can follow passengers seamlessly in all stations.

[3] www.5g-victori-project.eu

- To provide a robust, mission-critical, interoperable public safety communication network.

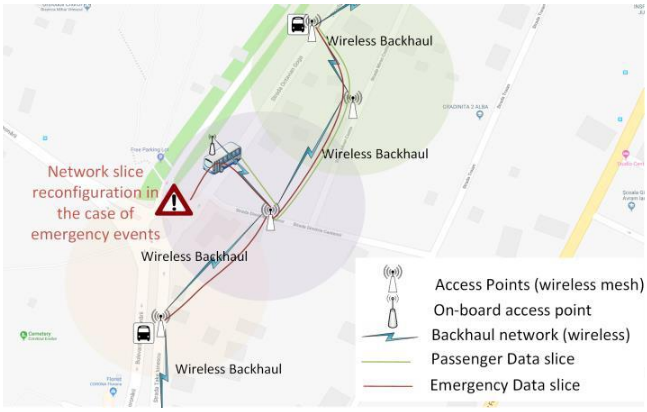


Figure 6: 5G-Victori Network pop-up for emergency services at Alba Iulia city.

- Network pop-up for emergency services at Alba Iulia city.
- Network bandwidth used for passengers' services is on the fly reconfigured and allocated for public safety applications

Orange initiative, dedicated to smart mobility in **AIM** Smart City, consists in the installation at 15 public service vehicles (buses) of an intelligent transportation system providing Secure Internet access.

Table 8: Main KPI to achieve

Vertical	RTT	UE-UE latency	One-way delay
Critical services	< 100 ms (URLLC)	8 ms	0.5 ms

- Targeted architecture: give architecture scheme. More eMBB, URLLC or mMTC oriented?
    - URLLC oriented, uRLLC Ultra high Reliability, high availability (Service interruption for mission critical traffic =0 ms, Packet loss rate: as low as 1e-04; delivered in 8 ms)
- What kind of tests should be performed?
    - This platform will be enhanced with an advanced SDN control plane solution to enable the creation of a network slice that can be allocated for provisioning of mission critical services (audio, video, data). Under emergency situations, network capacity dedicated to passengers' services will be reconfigured to create a LAN around the incident location and will connect to the backbone of the network (backhauling) where mission critical servers are hosted with guaranteed bandwidth.
- Location to integrate the use-case
    - The use case will be integrated on the Romanian testbed- Alba Iulia City, with support of Orange infrastructure and testbed located in Bucharest.
- Need to imply several distant sites for E2E transmission?
    - It will imply distant sites communication for E2E transmission, UP & CP.

4.2.2 Use case 2 description: Energy Metering for Low Voltage(LV), LV energy metering application for AIM smart city.

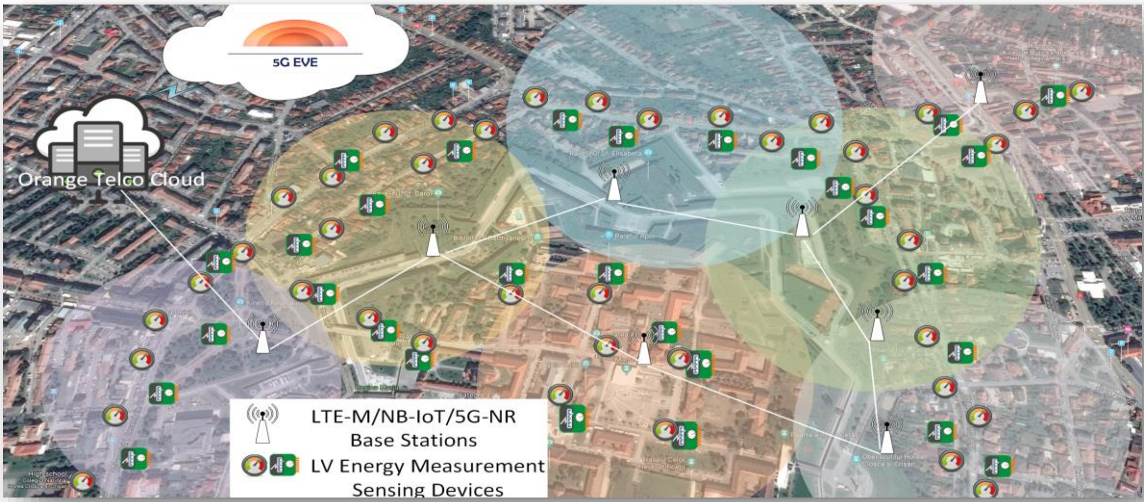


Figure 7: 5G-Victori Platform that will be used to validate LV UC

Massive energy metering application covering public buildings such as schools, high schools, cultural and administrative buildings but also street lightning will be demonstrated. The main objective of this use case is to showcase how 5G can address the requirements of mMTC application in city scale environments.

Will demonstrate an mMTC energy metering application in city scale environment at AIM, RO. A massive number of sensors/energy metering devices will be installed across public building/street lighting and will be connected to the 5G-EVE platform.

4.3 Equipment

Utilizing and extending the 5G-EVE French site at Paris and Sophia Antipolis connected with the Romanian cluster, based on the OpenAirInterface and Mosaic-5G platforms, 5G-VICTORI use-cases KPIs will be experimented and validated. The test site experiment with 3GPP technologies: 3GPP 5G NR (including RU,DU and CU node functions), 3GPP 4G LTE-A (including RU,DU-LTE and CU-LTE node functions), 3GPP 4G LTE-M, 3GPP 4G NB-IoT, 3GPP 4G LTE-Sidelink (ProSe / V2X), 3GPP Rel 15 EPC (MME,HSS,S+PGw), 3GPP Rel 15 5GCore. From the Mosaic5G community allowing to deploy agile 5G service platforms. These packages covering FlexRAN: a SW-defined RANs, JoX: an event-driven orchestrator for 5G network slicing based on Juju, LL-MEC: a low-latency multi-access edge computing, Store: a distribution repository of reusable network applications/Functions for RAN and CN domain.

What are the specific equipment requested by the vertical coming from 5G EVE?

Physical network connectivity.

- Resilient, instantaneous connectivity, which drives the need for URLLC
- Web Portal access for service deployment
- 4G/5G OAI extension capabilities to the sites.
- ONAP capabilities extension and integration into the environment.
- End-to-End Cluster integration and adaptation, prepared for different verticals and use cases
- 2x USRP N310 (or higher model) pieces with accessories requested in order to extend 5G-EVE physical network to serve the verticals in Alba Iulia.
- Wide Band Outdoor Antennas (800 - 3000MHz).

- HPE ProLiant Gen 11 (or higher) servers for computing and for MEC, servers integrating new apps and to link the existing ones, for the use case+ energy monitoring system
- Mobile/portable devices for performing calibration and testing activities, Tablets and/laptops to run tests

What are the specific features requested by the vertical coming from 5G EVE?

- Web Portal access for service deployment
- 4G/5G OAI & Mosaic5G extension capabilities to the sites.
- ONAP capabilities extension and integration into the environment.
- End-to-End Cluster integration and adaptation, prepared for different verticals and use cases

The set of network requirements of both UCs is presented in section 9 with the corresponding analysis.

5 Project 5G-SOLUTIONS

[4]

5.1 5G solutions for EU Citizens

5G solutions for EU Citizens (5G-Solutions) is a flagship 5G-PPP project supporting EC's 5G policy by implementing the last phase of the 5G-PPP roadmap. It aims to prove and validate that the 5G capabilities provide prominent industry verticals with ubiquitous access to a wide range of forward-looking services with orders of magnitude of improvement over 4G, thus bringing the 5G vision closer to realisation. This will be achieved through conducting advanced field trials of innovative use cases, directly involving end-users across five significant industry vertical domains:

- Factories of the Future
- Smart Energy
- Smart Cities
- Smart Ports
- Media & Entertainment

The field trials will be used to validate both the technological as well as the business aspects of 5G for increased resilience, coverage and continuity, higher resource efficiency with concurrent usage by multiple verticals, boosted capacity and greater reliability. 5G- Solutions is in direct support of 5G-PPP's aspiration to see new connected digital markets, and it contributes to the EC's broader industry digitisation and policy objectives in support of the Digital Single Market, maintaining Europe's leadership position in mobile telecommunications.

5.2 VERTICAL SMART ENERGY

As mentioned above, in 5G- Solutions, vertical use cases are organized in Living Labs. The one Living Lab interested in a site facility offered by 5G EVE is denominated as "Smart Energy". The Smart Energy Living Lab has been clustered with the "Smart Cities and Smart Ports" Living Lab in the so called "Smart urban Environment", since these living labs address primary mMTC use cases.

The Smart Energy Living Lab presents three use cases:

1. Industrial Demand Side Management
2. Electrical Vehicle Smart Charging
3. Electricity network frequency stability

In the following section the use cases will be briefly described as well as their main aim. Reference KPIs, being common to three use cases, will be reported

[4] www.5gsolutionsproject.eu

5.3 Use-case description

5.3.1 UC1 Industrial Demand Side Management

The aim of this use case is to demonstrate in the field that 5G technologies can be suitably adopted to support new grid services and to significantly decrease tolerance setting in smart meters circumstances of practical interest in industrial environment for large, medium and small enterprises. A distributed load monitoring and control system will be setup based on sensors, meters and in-cloud data analytics and specific control tools. Real-time load schedule and energy profile assessment for each activity/production will allow evaluating suitable actions of power reduction to be offered on the dispatching markets by the impacting electricity transmission network operator.

5.3.2 UC2 Electrical Vehicle Smart Charging

The aim of this use case the is to demonstrate that 5G network allows reliable real time scheduling of charging sessions and provide a fast reschedule in case of overload, in case of simultaneous charging sessions, or in case the electric power generated from renewables suddenly falls short of the predictions. The use case will rely on a smart charging system including charging stations up to 22kW AC equipped with 5G communication modems for testing purposes as well as e-Mobility Service Provider (EMPS)/Charge Point Operator (CPO) managing and offering charging experience to end users, namely the Fully Electric Vehicle (FEV) drivers.

5.3.3 UC3 Network frequency regulation

The aim of this use case the is to demonstrate that 5G network allows a significant decrease of frequency meters needed to provide network balancing service, with a related reduction of overall cost for the network operators, by extending the smart charging system involved in UC2 to develop a fully control based primary frequency regulation service relying on 5G capabilities.

As mentioned above, the Smart Energy Living Lab is primary mMTC oriented, though URLLC is required too. In fact, all use cases need architectural solutions ensuring latency (less than 10 ms), connection density (more than 0.01 device per square meter), reliability (more than 99.999%) and coverage (more than 99.9%). The full set of requirements is presented in section 9 with the corresponding technical analysis.

Table 9: 5G-Solutions reference KPIs

Metric	Required value
Latency (ms)	<10
Reliability	>99.999%
Coverage	>99.9% Indoor

Tests will involve residential and commercial users (UC1) and Fully Electric Vehicle (FEV) owners/drivers or FEV fleet owners/managers (UC2 and UC3). Location for single use case integration is the 5G EVE Italian site in Turin (UC1, UC2 and UC3).

6 Project 5Growth

[5]

6.1 Project description

The 5Growth vision is to empower vertical industries, such as Industry 4.0, Transportation, and Energy with an AI-driven automated and shareable 5G end-to-end solution that will allow them to simultaneously achieve their key business and performance targets. 5Growth will automate the process for supporting diverse industry verticals through:

- a vertical-oriented frontend providing a common entry point and interface and an advanced customer portal, in charge of interfacing verticals with the 5G end-to-end platforms, receiving their service requests and building the respective network slices,
- closed-loop automation and SLA control for vertical service lifecycle management,
- AI-driven end-to-end network solutions to jointly optimize resources provided across all the network and application segments (access, transport, core, cloud, edge and fog), and across multiple technologies and domains.

The main objective of 5Growth is the technical and business validation of 5G technologies from the verticals' perspective, following a field-trial-based approach in vertical sites (TRL 6-7) to increase exploitation opportunities in products, services, and vertical markets, hence economy and society at large. Multiple use cases of vertical industries will be field-trialled in four vertical-owned sites in close collaboration with the vendors and the operators of the project. 5Growth will leverage on the results of 5G-PPP Phase 2 projects where slicing, virtualization and multi-domain solutions for the creation and provisioning of vertical services are being developed and validated with specific Proofs of Concept, e.g., 5G-TRANSFORMER.

Two ICT-17-2018 5G end-to-end platforms, 5G EVE and 5G-VINNI, will be integrated with the 5Growth platform in the trials to demonstrate the 5Growth specific vertical use cases.

6.2 VERTICAL Industry 4.0 INNOVALIA

There are two pilots in 5Growth focusing on Industry 4.0 use cases, one hosted at INNOVALIA premises, and one hosted at COMAU. In this section we describe the INNOVALIA pilot and its associated use cases.

The motivation for the INNOVALIA pilot is summarized next:

- Every time the measuring machine is reconfigured (for example changes in the piece design), an expert metrologist has to go there and help defining the measuring trajectories for the optical sweep.
- High volume of data transmitted in real time needs a reliable, high-capacity connection, that nowadays is only available by a wired network. This limits the mobility of operators and may require expensive infrastructures.

6.3 INNOVALIA Use-case 1 (Connected Worker Remote Operation of Quality Equipment) description

[5] http://www.5growth.eu

The first use case is about controlling the measuring machine remotely. The objective of this use case is that an expert metrologist can configure the sweeping trajectory of the measuring machine remotely. With the help of a 4K camera, real time video must be synchronized with a virtual joystick to allow the worker to control the machine and see, in real time, how it's moving.

In this case, most of the bandwidth will be used for the 4k video transmission, while the delay is one of the most important issues to have in mind.

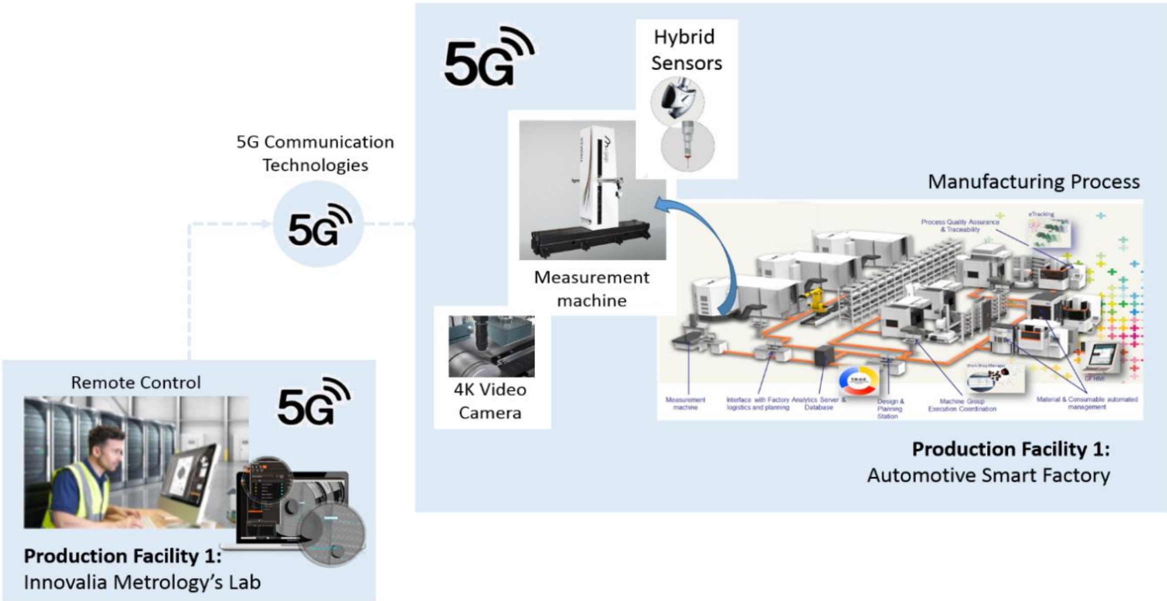


Figure 8: 5Growth Connected Worker Remote Operation of Quality Equipment

As in most industrial applications, availability is a must. Apart from the latency and the bandwidth, the other requirements are not that important, as there are not too many measuring machines in a production line, machines are static, and the worker usually also (although we've set a "walking" speed) and the area of coverage is usually the manufacturer site, which is not usually really big.

5G Service:

- eMBB for 4K video streaming.
- URLLC services for virtual joystick operation.

Technical requirements (the full set of requirements is presented in section 9 with the corresponding technical analysis):

Table 10: 5GrowthConnected Worker Remote operation requirements

Availability / Reliability	Latency	Bandwidth	Connection Density	Mobility	Wide-Area Coverage
99.9999%	< 5 ms	1 Gbps	< 1000 dev per km^2	3 km/h	5-8 km^2

The activities of this pilot will span over two nearby trial sites located in the Basque Country (Spain), within the Automotive Intelligence Center (AIC) in Amorebieta.

6.3.1 INNOVALIA Use-case 1 (Connected Worker Remote Operation of Quality Equipment) Equipment

The vertical, together with the main vendor (Ericsson) and operator (Telefonica) involved in this use case, provides the on-site equipment required for this use case. This is still being discussed within 5Growth and the involved partners, but at this stage we assume that 5G New Radio coverage will be provided, together with the edge computing and networking resources required for the specific use-case vertical application, plus the 5Growth orchestration platform.

Some of the 5G core components (e.g., part of the control part) could be located at 5G-EVE, specifically at 5TONIC site. Additionally, 5G-EVE is expected to be involved (again, the 5TONIC site) to perform early testing of the use case at Madrid, prior to the real field trial testing at INNOVALIA premises. All the above highly depends on the ongoing discussion about what interaction/integration model with 5G-EVE can be implemented.

6.3.2 INNOVALIA Use-case 2 (Connected Worker Augmented ZDM Decision Support System) description

The second use case is about being able to provide the worker with the digital twin view, and allowing him to manipulate it in real time. This way, the quality inspector will be able to move within the production plant and see in his tablet the representation of the 3D Point Cloud. The challenge, in this case, is both the amount of data transmitted (~5 GB per piece) and the delay (it's supposed to be a real time view).

Figure 9: 5Growth connected worker augmented ZDM

Again, as this is an Industry Pilot, availability is a clue parameter. In this case, mobility might also be important, as the worker might be moving in the plant with a car. Again, connection density and area coverage are not determinant factors for the pilot.

5G Service:

- eMBB for the interaction with the MEC server storing the 3D point clouds.

Technical requirements (the full set of requirements is presented in section 9 with the corresponding technical analysis):

Table 11: 5Growth connected worked use case metrics

Availability / Reliability	Latency	Bandwidth	Connection Density	Mobility	Wide-Area Coverage
99.9999%	< 5 ms	10-20 Gbps	< 1000 dev per km^2	3-50 km/h	5 km^2

The activities of this pilot will span over two nearby trial sites located in the Basque Country (Spain), within the Automotive Intelligence Center (AIC) in Amorebieta.

6.3.3 INNOVALIA Use-case 2 (Connected Worker Augmented ZDM Decision Support System) Equipment

The vertical, together with the main vendor (Ericsson) and operator (Telefonica) involved in this use case, provides the on site equipment required for this use case. This is still being discussed within 5Growth and the involved partners, but at this stage we assume that 5G New Radio coverage will be provided, together with the edge computing and networking resources required for the specific use-case vertical application, plus the 5Growth orchestration platform.

Some of the 5G core components (e.g., part of the control part) could be located at 5G-EVE, specifically at 5TONIC site. Additionally, 5G-EVE is expected to be involved (again, the 5TONIC site) to perform early testing of the use case at Madrid, prior to the real field trial testing at INNOVALIA premises.

All the above highly depends on the ongoing discussion about what interaction/integration model with 5G-EVE can be implemented.

6.4 VERTICAL Industry 4.0 COMAU

There are two pilots in 5Growth focusing on Industry 4.0 use cases, one hosted at INNOVALIA premises, and one hosted at COMAU. In this section we describe the COMAU pilot and its associated use cases.

The Industry 4.0 use cases by COMAU are related to remote support and time-critical process control in the factories. The use cases are to demonstrate the performance of a 5G communication network serving industrial applications where strict requirements of reliability and latency are mandatory to keep the connection stable and to avoid emergency stops and safety issues. Three use cases will be deployed in COMAU Plant (Grugliasco, TO - Italy) addressing Digital Twin, Telemetry & Monitoring, Digital Tutorials and Remote Support. I4.0 use cases require of enhanced Mobile Broadband (eMBB) and Ultra-Reliable Low Latency Communication (URLLC).

6.5 COMAU Use-case 1 (Digital Twin) description

Digital Twins are digital replicas of physical assets (see Figure 10), processes, and systems that also interact with the real system – with the digital replica reproducing changes as they occur in the actual physical system. The concept has been around for some time now, but it has found a limited application until recently, due to storage costs, processing power, and bandwidth performances.

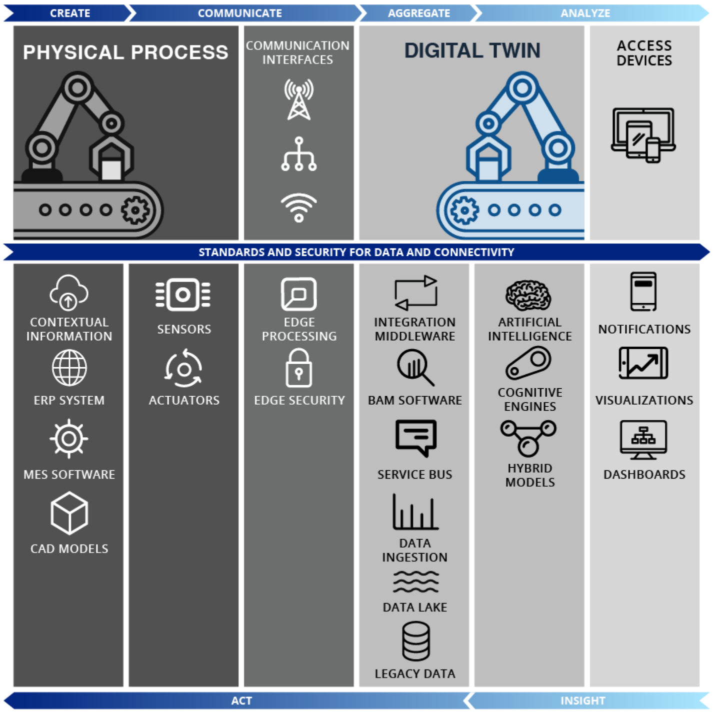


Figure 10: 5Growth Digital Twin use case

This specific use case will demonstrate 5G performance of interconnecting a real robot to its digital twin, which sharing the computing resources and the software with the real robot and will virtually replicate the same function. The robot will be controlled in real time, remotely by a virtual controller located on a powerful dedicated computer or a virtual machine, to exploit the computational power provided by the cloud. The robot will receive instructions about its pose in a stepwise manner by the controller, while sensors data will be sent back to provide a real-time feedback to the remote controller. Both control instructions and information from sensors will be used to update the virtual model in real-time. Said model can be used to highlight critical conditions inferred by sensors data and to provide alarms and preventive maintenance information to humans. In case that critical or dangerous situations are detected, the remote control could stop in real time the operations for safety reasons. Safety requires a very reliable and fast track for transmission of data and, among wireless technologies, only 5G can satisfy these tight requirements. In industrial applications, the overall end-to-end latency budget (time delay between data being generated at a sensor and the data being correctly received by the actuator) is spent for the processing time of the data received by sensors; the remaining part of the latency budget limits communication time to few milliseconds. 5G connectivity will guarantee the reliability and the low latency remote control and, at the same time, full support to the safety functions.

5G Service required: This use case requires eMBB and URLLC for the on-time delivery of the information of the sensors to the virtual twin and for the interaction with the digital model.

Output: The digital twin use case will provide a virtual replica of a robot or of a part of a production line. The 5G network coverage will be deployed to enable real-time visibility and remote insights into robot status and performance without having to directly operate on the physical equipment.

Benefit: Using a digital twin will facilitate, with respect to the real operating machines, assessing the concepts of remote control, monitoring for preventive maintenance, and safety that can be applied in a factory in large scale and with high density of devices.

This pilot will be developed in Automation Systems and Robotics floors of COMAU Grugliasco (Torino, Italy), a site in charge of production for the whole European area of Robots and Automated production lines, providing "body-in-white" solutions (i.e., car bodies production) for main OEMs such as FCA, Daimler, Jaguar/Land Rover, Volvo, Porsche etc. The COMAU facility in Italy is composed of two buildings.

6.5.1 COMAU Use-case 1 (Digital Twin) Equipment

For the scope of the pilot, the radio systems will be Ericsson products including the radio antenna, the base station, the core part of the network that could be (according to the deployment options that will be explored during the project development) on premises or located in a central office of TIM which will provide the access to its licensed spectrum in the pilot area. As for the radio antenna, it is foreseen to use an indoor small cell operating in the 5G dedicated bands (e.g. 28 GHz) according to the availability of Ericsson radio products at the time of pilot deployment, as the Ericsson 5G radio portfolio is evolving including new products. The use of 5G slicing is also an option in the radio deployment as the three use cases include in the pilot pose different requirements on the 5G network in terms of e.g. bit rate, latency, reliability performances.

Use case specific applications are expected to run on resources in the COMAU premises.

Some of the 5G core components (e.g., part of the control part) could be located at 5G-EVE. All the above highly depends on the ongoing discussion about what interaction/integration model with 5G-EVE can be implemented. Different approaches are being internally discussed. The full set of technical requirements is presented in section 9 with the corresponding technical analysis.

6.5.2 COMAU Use-case 2 (Telemetry/Monitoring & control Apps) description

The second use case aims at demonstrating the advantages of 5G communication, for mMTC, URLLC and secure communications, by means of a telemetry/monitoring application deployment. Failure detection is a challenge that exists throughout the manufacturing industry. Issues, such as vibration patterns affecting the robots, could be revealed by monitoring the process in real time. 5G will facilitate using a plethora of new wireless sensors, easy to attach on robots even in legacy plants: sensors with long lasting batteries and communicating few data in real time. Example of sensors are: pressure, temperature, vibration (IMU). Correlating data from these sensors would enhance monitoring and prevention. This data could be used to feed expert systems (located in the plant or in a centralized company location) to determine what is happening, to predict future issues, and to prevent failures. Early failure detection which brings significant savings, as costs increase when the longer failures remain undetected. In summary, the main purpose of this application is to gather real-time data from machines and sensors to continuously monitor production and machines' behavior. An analysis and mapping of the data collected will lead to a "health status" definition and, as said, allow preventive maintenance.

5G Service required: This use case requires mMTC to connect a high number of sensors (tens of sensors per robot/object to monitor) and URLLC for the quick reaction upon failure (alarm).
Output: The use case will explore the capabilities of 5G to support massive communication with sensors pinging data, in all machines on the shop floor, maintaining at the same time the same availability/reliability over wireless, compared to the one offered by conventional wired connections. Moreover, battery-powered sensors will also benefit from low power consumption for 5G connectivity.
Benefit: The use of Telemetry/Monitoring Apps over 5G, will eventually reduce network infrastructure TCO (Total Cost of Ownership) and limit factory outages thanks to a deep preventive maintenance.

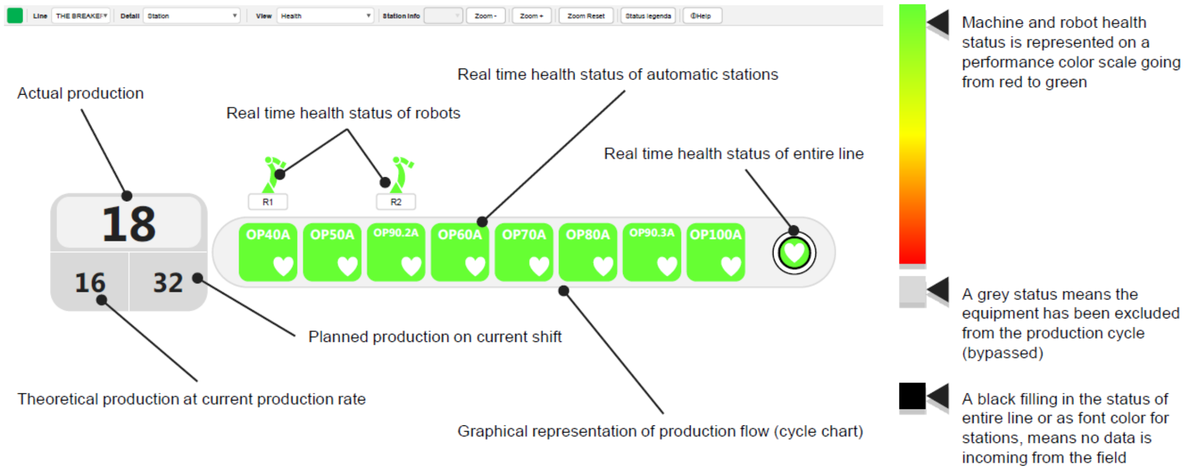


Figure 11: 5Growth Telemetry/Monitoring & control use case

This pilot will be developed in Automation Systems and Robotics floors of COMAU Grugliasco (Torino, Italy), a site in charge of production for the whole European area of Robots and Automated production lines, providing “body-in-white” solutions (i.e., car bodies production) for main OEMs such as FCA, Daimler, Jaguar/Land Rover, Volvo, Porsche etc. The COMAU facility in Italy is composed of two buildings.

6.5.3 COMAU Use-case 2 (Telemetry/Monitoring & control Apps) Equipment

For the scope of the pilot, the radio systems will be Ericsson products including the radio antenna, the base station, the core part of the network that could be (according to the deployment options that will be explored during the project development) on premises or located in a central office of TIM which will provide the access to its licensed spectrum in the pilot area. As for the radio antenna, it is foreseen to use an indoor small cell operating in the 5G dedicated bands (e.g. 28 GHz) according to the availability of Ericsson radio products at the time of pilot deployment, as the Ericsson 5G radio portfolio is evolving including new products. The use of 5G slicing is also an option in the radio deployment as the three use cases include in the pilot pose different requirements on the 5G network in terms of e.g. bit rate, latency, reliability performances.

Use case specific applications are expected to run on resources in the COMAU premises.

Some of the 5G core components (e.g., part of the control part) could be located at 5G-EVE. All the above highly depends on the ongoing discussion about what interaction/integration model with 5G-EVE can be implemented. Different approaches are being internally discussed.

The full set of technical requirements is presented in section 9 with the corresponding technical analysis.

6.5.4 COMAU Use-case 3 (Digital tutorials & remote support) description

The purpose of this use case is to provide technicians and maintenance staff with digital tutorials and remote support by means of high definition videos and live connections to remote technical offices. Experts will provide live support on field to solve faults in a shorter time, reducing the MTTR (Mean Time to Repair) and consequently the factory downtime. The use of high definition images and videos are necessary to have the possibility to zoom in on specific parts and to avoid mistakes during assembly and maintenance operations. The value of 5G here is mainly related to the possibility to stream video flows at any definition with no interruptions and with the possibility to scale up the number of active users, using the application.

5G Service required: This use case requires eMBB to deliver the un-interrupted video streaming to multiple users with high definition formats.
Output: Given the fact that 5G can support increased bandwidth demands, the use case will deploy applications that will allow users to remotely access digital tutorials and support remote technicians though live connections at high resolution (see figure below).

Benefit: Main benefits will be an increase in productivity due to the possibility to access live tutorials/instructions and video tutorials, as well as a reduction of MTTR thanks to the real-time connection with technicians in remote locations supporting maintenance and repair operations.

Figure 12: 5Growth Digital tutorials & remote support use case

This pilot will be developed in Automation Systems and Robotics floors of COMAU Grugliasco (Torino, Italy), a site in charge of production for the whole European area of Robots and Automated production lines, providing "body-in-white" solutions (i.e., car bodies production) for main OEMs such as FCA, Daimler, Jaguar/Land Rover, Volvo, Porsche etc. The COMAU facility in Italy is composed of two buildings.

6.5.5 COMAU Use-case 3 (Digital tutorials & remote support) Equipment

For the scope of the pilot, the radio systems will be Ericsson products including the radio antenna, the base station, the core part of the network that could be (according to the deployment options that will be explored during the project development) on premises or located in a central office of TIM which will provide the access to its licensed spectrum in the pilot area. As for the radio antenna, it is foreseen to use an indoor small cell operating in the 5G dedicated bands (e.g. 28 GHz) according to the availability of Ericsson radio products at the time of pilot deployment, as the Ericsson 5G radio portfolio is evolving including new products. The use of 5G slicing is also an option in the radio deployment as the three use cases include in the pilot pose different requirements on the 5G network in terms of e.g. bit rate, latency, reliability performances.

Use case specific applications are expected to run on resources in the COMAU premises.

Some of the 5G core components (e.g., part of the control part) could be located at 5G-EVE. All the above highly depends on the ongoing discussion about what interaction/integration model with 5G-EVE can be implemented. Different approaches are being internally discussed. The full set of technical requirements is presented in section 9 with the corresponding technical analysis.

7 Project 5G!DRONES

[6]

7.1 Project description

5G!Drones aim is to trial several UAV use-cases covering eMBB, URLLC, and mMTC 5G services, and to validate 5G KPIs for supporting such challenging use-cases. The project will drive the UAV verticals and 5G networks to a win-win position, on one hand by showing that 5G is able to guarantee UAV vertical KPIs, and on the other hand by demonstrating that 5G can support challenging use-cases that put pressure on network resources, such as low-latency and reliable communication, massive number of connections and high bandwidth requirements, simultaneously. 5G!Drones will build on top of the 5G facilities provided by the ICT-17 projects and a number of support sites, while identifying and developing the missing components to trial UAV use-cases.

The project will feature Network Slicing as the key component to simultaneously run the three types of UAV services on the same 5G infrastructure (including the RAN, back/fronthaul, Core), demonstrating that each UAV application runs independently and does not affect the performance of other UAV applications, while covering different 5G services. While considering verticals will be the main users of 5G!Drones, the project will build a software layer to automate the run of trials that exposes a high level API to request the execution of a trial according to the scenario defined by the vertical, while enforcing the trial's scenario using the API exposed by the 5G facility, as well as the 5G!Drones enablers API deployed at the facility. Thus, 5G!Drones will enable abstracting all the low-level details to run the trials for a vertical and aims at validating 5G KPIs to support several UAV use-cases via trials using a 5G shared infrastructure, showing that 5G supports the performance requirements of UAVs with several simultaneous UAV applications with different characteristics (eMBB, uRLLC and mMTC). Using the obtained results, 5G!Drones will allow the UAV association to make recommendations for further improvements on 5G.

7.2 VERTICAL: UAV verticals & 5G actors

The vertical industries are as follows: Alerion, Unmanned Systems Limited, hepta Airborne, CAFA Tech, INVOLI, THALES, Airbus DS SLC and Frequentis. This part describes only the use cases and scenarios, in which 5GEVE facility (EURECOM site) will be involved.

7.2.1 Use-case description

7.2.1.1 UC1: UAV Traffic Management

This use case will demonstrate a common functionality for all UAV applications, by providing the necessary safe and secure incorporation of drones into the air traffic. UTM (UAS Traffic Management) is expected to manage drone traffic in the lower altitudes of the airspace, providing a complete and comprehensive end-to-end service to accumulate real-time information of weather, airspace traffic, drone registration, and credentials of drone operators, among others.

[6] https://5gdrones.eu/

In this scenario, 5G!Drones project aims to demonstrate a UAV traffic command and control application, which will manage a high number of flying drones. It includes Beyond Visual Line of Sight (BVLoS) drone operations, and entails long-range commercial drone control, for applications such as drone delivery. The command and control application will demonstrate features such as automatic collision avoidance of drones, especially those flying in swarm, which requires sending large amounts of data in near real time to assess the potential risks in the sky and enable an enhanced flight awareness of all types of flying objects. Particular efforts will be drawn in this scenario to the security and integrity of command and control traffic. Indeed, ensuring that a malicious third party is not capable of taking control of operating drones is essential to deploying such unmanned device in urban and critical environments. In addition, one BVLoS application enables secure controlling of the drone (telepresence) using the VR/AR equipment.

In this scenario the network needs to provide i) a cross-domain network slice for UAV traffic control **– a uRLLC slice** able to **reduce delay and having a high priority**; ii) in addition to low latency and high priority, this slice should ensure the authentication of users as well as the integrity and often confidentiality of the conveyed control traffic – in particular, end to end encryption of the slice can be a solution that would protect a third party from taking control of the drone; iii) a UAV control applications hosted at the edge; and iv) the possibility to have D2D communications in licensed or unlicensed spectrum (Wi-Fi).

7.2.1.2 UC2: Public safety/saving lives

In this UC we will explore two scenarios:

- The first one is “Monitoring a wildfire*”,* where UAVs are equipped with HD cameras can be used for streaming HD video to a remote application hosted at the edge. Using AI tools, the remote application analyses the video to predict the direction of spreading of wildlife to the firefighters, so they can pay immediate attention to those areas and also avoid using the potentially dangerous routes for rescue operation. In such a case, 5G-based eMBB is needed to handle the video traffic volume efficiently. Moreover, the support of a MEC server to process the video as close as possible to the rescue operation is necessary. In this scenario, the network needs to provide i) two cross-domain network slices for UAV traffic control and drones’ data, i.e., a **uRLLC** slice able **to reduce delay** to offer the appropriate level of security and isolation and **having a high priority** for UAV traffic control and an **eMBB** slice with **high-priority for the HD video stream** sent by the drone. Given the nature of the monitoring operation, a strict isolation between these slices spreading until the radio segment should be ensured with a particular attention to be drawn to the security of this control slice; depending of the conveyed HD video traffic and its copyright requirements a controllable level of security can be added to the eMBB slice. The network also needs to provide (ii) edge cloud resources to host both the drone control application and a data analysis server. The instantiation of resources and their dynamic configuration will leverage the virtualised 5G architectures we rely on in this project.
- The second one is “Disaster recovery”, where UAVs are considered fitted with 5G small cells and can be carried close to the disaster area using a mobile ground station. UAVs can interconnect and communicate with the ground station over direct D2D links, allowing for the rapid deployment of a wireless backhaul in situations where capacity is needed on an expedited basis, as these networks allow both victims and emergency workers to communicate when it is most important. This would then allow the swarm of tethered and untethered UAVs to be used to bridge the signal for backhaul interconnect and provide ultra-reliable low latency and other types of wireless connectivity to those who severely need it with the dynamic network coverage they offer. In this scenario, the network needs to provide i) two cross-domain network slices for UAV traffic control and drones’ data, i.e. a **uRLLC** slice able to **reduce delay and having a high priority** for UAV traffic control and an **eMBB** slice with **high-priority** for the data sent by drones; ii) edge computing resources to host both the drone control application and a data analysis server; iii) enabled D2D communications in unlicensed or licensed spectrum.

7.2.2 Requirements and features per scenario

The following table provides a summary of the scenarios that are planned to be trialed using the 5G EVE facility. For each scenario, we report the main 5G-related KPIs and the 5G features and/or architectural components exploited by each scenario.

Table 12: 5G!Drones use case KPIs

Scenario	5G KPI	5G service(s)
UAV traffic management 1	• End-to-end latency of < 1ms	uRLLC
Safety 1	• End-to-end latency of < 1ms • 1000 times higher mobile data volume per geographical area.	uRLLC, eMBB (high priority)
Safety 2	• End-to-end latency of < 1ms • 1000 times higher mobile data volume per geographical area.	uRLLC, eMBB (high priority

In addition to the above 5G requirements, the following requirements related to the network service will be measured:

- Service deployment time: the time needed to deploy a UAV service using a network slice provided by the 5G facility.
- Service monitoring: full capacity to monitor all UAV service components and their underlying network slices.
- Service elasticity: capacity to increase/decrease resources used by the UAV slices.

The full set of technical requirements is presented in section 9 with the corresponding technical analysis.

7.3 Equipment

5G!Drones verticals will provide the UAV hardware (Drones), including the 5G modem, as well as a set of VNFs that need to be instantiated at the facility to control, to manage the flying drones and to gather data. A 5G infrastructure that enables Network Slicing, including: geNB, EPC (or 5G CN), MEC and computing capabilities.

- What are the specific features requested by the vertical coming from 5G EVE?
    - Support Network Slicing.

8 Project 5G-DRIVE

8.1 Project description

5G-DRIVE will trial and validate the interoperability between EU & China 5G networks operating at 3.5 GHz bands for enhanced Mobile Broadband (eMBB) and 3.5 & 5.9 GHz bands for V2X scenarios. The key objectives are to boost 5G harmonisation & R&I cooperation between EU & China through strong connected trials & research activities, with a committed mutual support from the China "5G Large-scale Trial" project led by China Mobile.

To achieve these objectives and to deliver the impact for early 5G adoption, 5G-DRIVE structures its main activities into three pillars.

- The first one will test and demonstrate the latest 5G key technologies in eMBB and V2X scenarios in pre-commercial 5G networks. 5G-DRIVE will run three extensive trials in Finland, Italy and UK. The Chinese project will run large-scale trials in five cities. These twinned trials aim to evaluate synergies and interoperability issues and provide recommendations for technology and spectrum harmonisation.
- The second one focuses on researching key innovations in network slicing, network virtualisation, 5G transport network, edge computing and New Radio features to fill gaps between standards and real-world deployment.
- The third one will push EU-China 5G collaboration at all levels thru extensive dissemination and exploitation actions.

8.2 VERTICAL: eMBB Network Slicing Evaluation

5G-DRIVE would like to utilize 5G EVE infrastructure to test the eMBB slicing performance under pre-commercial network environments. The work will focus on the evaluation of the network performance, instead of on a particular vertical service. 5G-DRIVE intends to evaluate the network slicing under the Standalone (SA) architecture. It has interests in two evaluations: one is the end-to-end slicing evaluation with service chains cross radio access network (RAN) and core network (CN); the other is service slicing performance evaluation with the focus on eMBB services at the RAN side. 5G-DRIVE is also interested in evaluating the slicing deployment, which includes the basic performance in slicing life-cycle management.

8.2.1 Use-case description

- Targeted architecture:
- eMBB oriented SA architecture.
- Main KPI to test:
    - Basic performance including throughput, latency in slicing against service level agreement (SLA) / quality of service (QoS)
    - Service isolation performance – evaluate slicing isolation and resource sharing among at RAN and CN
    - Slice deployment performance
    - Mobility support - Continuity of slices when user equipment (UE) hands over between gNBs.
- What kind of tests should be performed?
  The basic performance of the network slicing will be evaluated. No additional equipment except the normal network infrastructure is needed at 5G EVE site to do the test. The tests can have two stages.
    - In the first stage, the partners from 5G-DRIVE will conduct tests through remote access to 5G EVE platforms or visit 5G EVE sites for the tests.

  - In the second stage, the interconnection between 5G EVE and 5G-DRIVE testbed may be set up for joint evaluation. However, the feasibility of interconnection and workload for implement will be further investigated.
- Location to integrate the use-case:
  - Depend on the availability of network slicing in 5G EVE sites and the schedule of the project. Note that 5G-DRIVE will be ended in Feb 2021.
- Need to imply several distant sites for E2E transmission?
  - None

8.2.2 Equipment

5G-DRIVE may bring the test UE and test software to the 5G EVE sites. But as the tests are basic network performance tests, 5G-DRIVE would like to utilize the test facility and software available by 5G EVE sites. The full set of technical requirements is presented in section 9 with the corresponding technical analysis.

9 ICT19/22 use cases technical requirement analysis

9.1 Requirements description

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, planning 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.

There are a lot of methods for an effective user requirement gathering and analysis [1] [2]. In our case, where four different main UCs has to be implemented within the scope of 5G-Tours Project, the following method is used:

- General capabilities of 4G and 5G have to be considered and the differences between them are illustrated.
- General 4G/5G requirements for each use case has to be gathered and compiled into tables
- General gathered requirements for each use case have 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 corresponding graphs

For the analysis of the technical requirements Radar charts will be used [2][3]. 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 13.

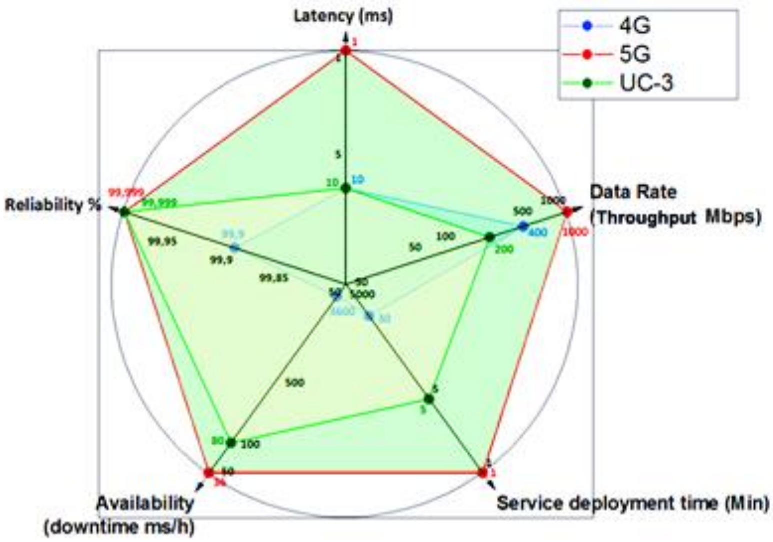


Figure 13: A typical multi-axis Radar chart that illustrates network requirements like latency, data rate, service deployment time, availability and reliability and a comparison with 4G/5G capabilities

9.2 General use case technical requirements description

The explanation and definition of all General Requirements [2] are provided next. Although a general definition is given, a more specific interpretation is also possible. For example, Latency E2E 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, RAN Latency (radio access network latency) might be the time for a location-information of a vehicle to be send to Edge Cloud Application Sever (located close to eNB).

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

- **Latency (also end-to-end or E2E Latency) - round trip:** 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.
- **Radio Access Network Latency - one way:** Radio Access Network (RAN) Latency is defined as the time it takes for a source (UE / mobile phone) to send a packet of data to a receiver at the Radio Network Base Station (i.e. eNB). RAN Latency is measured in milliseconds.
- **Throughput:** Throughput (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 below for different levels of availability).

Table 13: Different levels (%) of Availability (*month = 30 days)

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

- **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.
- **Slice/Service Deployment Time:** In the context of 5G Networks, Slice deployment time is the amount of time it takes for a Slice (see above) to be established end-to-end after the initializing 'signalling' command has been issued in order to be created (if new) or activated (if predefined). The Slice Deployment time is measured in minutes (min) i.e. $\leq$ 90 minutes ($\leq$3 minutes for planned/predefined slice)
- **Security:** Network resilience against signalling 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 Mbit/s/m^2 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 kilometre shall be supported for massive sensor deployments. Here, active means the devices are exchanging data with the network. Device density is measured in Dev/Km^2
- **Location Accuracy:** Location Accuracy refers to the "degree closeness" of a measured end-user device location (by means of the communication network infrastructure/technologies) to the real location of the device at the time of the measurement. Location Accuracy is measured in meters (m). Location accuracy can be measured in the horizontal as well as in the vertical direction. For the need of the 5G-Tours only horizontal accuracy is considered.

Table 14: Table for collecting general 5G network requirements for each use case of the Greek node

5G-Tours - Use Cases: direct specific Technical requirements		Units	Use case name			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec						
2	**RAN** Latency (in milliseconds) - one way	msec						
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps						
4	Reliability (%) - Min/Max	%						
5	Availability (%) - Min/Max	%						
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h						
7	Broadband Connectivity (peak demand)	Y/N or Gbps						
8	Network Slicing (Y/N) - if Y sercice deployment time (min	Y/N						
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N						
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2						
11	Device Density	Dev/Km^2						
12	Location Accuracy	m						

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 10 axes is used. Even though we could have used a 12 axis graph (since this is the number of general requirements presented above) a 10 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 the table (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.

Table 15: 4G/5G capabilities for mapping the vertical's use cases requirements

General 4G/5G Capabilities		Units	4G	5G
1	Latency (in milliseconds) - round trip - Min/Max	msec	25	10
2	**RAN** Latency (in milliseconds) - one way	msec	10	1
3	Throughput (in Mbps) - Min/Max - sustained demand	Mbps	400	1000
4	Reliability (%) - Min/Max	%	99,9%	99,999%
5	Availability (%) - Min/Max	%	99,9%	99,999%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	300	500
7	Broadband Connectivity (peak demand)	Y/N or Gbps	1	20
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	N	Y (1 min)
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y	Y
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	0,1	10
11	Device Density	Dev/Km^2	100K	1000K
12	Location Accuracy	m	<5	<1

In the first Radar Graph of this Deliverable, the inner area (see Figure 14- shown below) shaded light green 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 light yellow). 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.

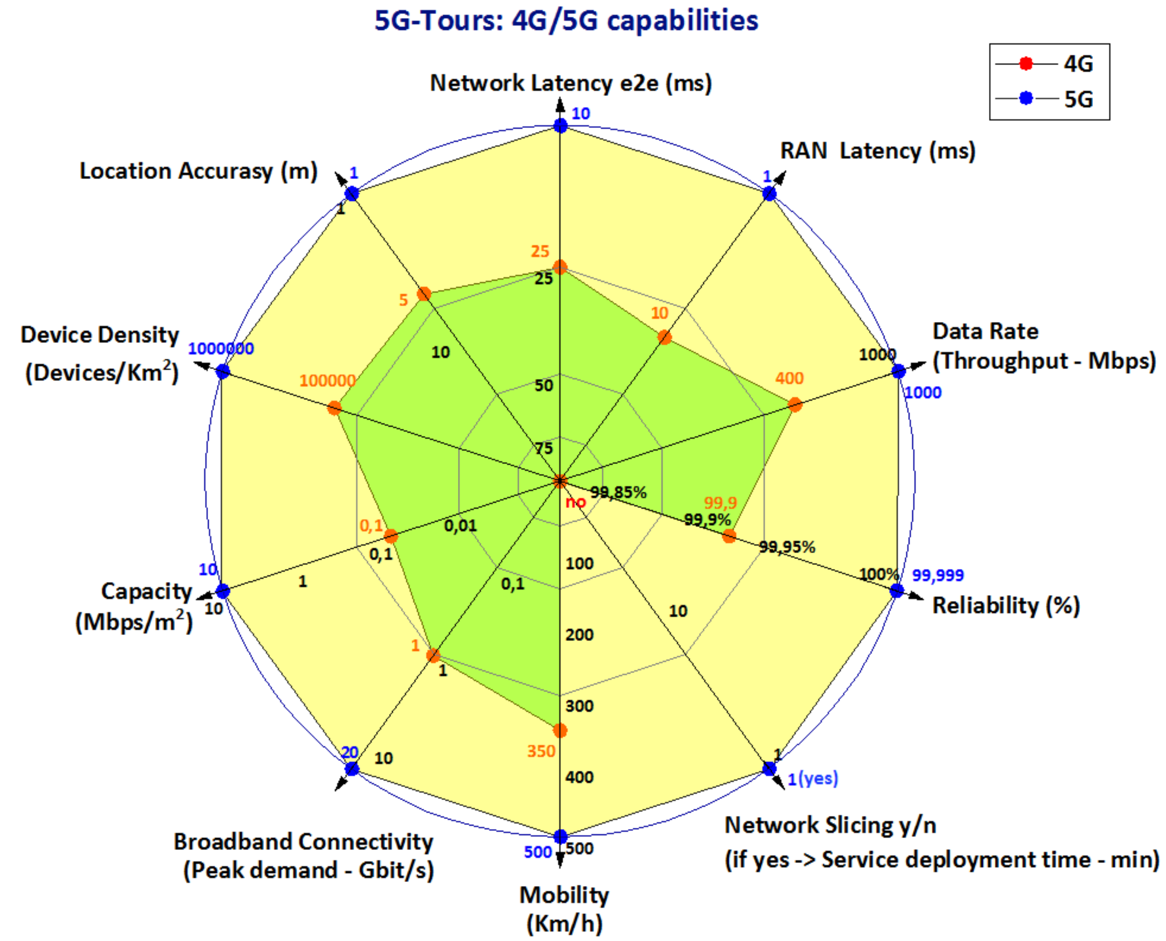


Figure 14: Radar Graph for 4G/5G capabilities

The first radar chart which corresponds to Table 15 (above) 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.

The radar chart above will serve as backdrop where the general requirements of all Use Case included in this deliverable 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, radar graphs and a basic analysis of all use cases of ICT19/22 projects that relying on 5G-EVE 4 sites infrastructures will be presented.

9.3 5G Tours project use cases

9.3.1 5G Tours Use case 1 – Augmented tourism experience Technical Requirements analysis

The general vertical use case requirements for the Use-Case 1 of 5G-Tours are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 15.

Table 16: Use Case 1 – Augmented tourism experience network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC1: Augmented tourism experience			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec	15	15	15		15*	None
2	**RAN** Latency (in milliseconds) - one way	msec	2	2	2		2	5
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	40	40	40		15	40
4	Reliability (%) - Min/Max	%	99,00%	99,00%	99,00%		99,00%	99,00%
5	Availability (%) - Min/Max	%	99,00%	99,00%	99,00%		99,00%	99,00%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	10	10	10		5	10**
7	Broadband Connectivity (peak demand)	Y/N or Gbps	0,08	0,08	0,08		0,04	0,08
8	Network Slicing (Y/N) - if Y service deployment time (min	Y/N	N	N	N			
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	N	N	N			
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	12	12	12		6	12
11	Device Density	Dev/Km^2	400	400	400		400	400
12	Location Accuracy	m	0.5	0.5	0.5		0.5	1(***)
(*) Latency very low because there is some interactivity - tha same for RAN latency (**) A priori it will be people walking with which a very high value is not necessary (***) Especially for the topic of beacons no?								
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)		15 ms	15 ms				
	Highest Acceptable jitter (msec)		5 ms					
	Number of Class of Service / QoS (1-8, more)							
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**		Smartphone	IoT Sensors				
	Bitrate required (Kbps / Mbps / Gbps)		40 Mbps					
	Max Latency Allowable (in msecs)		10 ms	10 ms				
	Max Moving Speed (km/h, 0 if stationary)		10 km/h					
	IPv4 & IPv6 support (or both)		IPv4	both				
	Connnection of Device to End Point (Wired/Wireless)		Wireless	WIRELESS				
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)		WLAN	SIM				
	Authenication method (i.e. SIM, eSIM, Key..)		¿?	SIM				
non-Network related Requirements)								
	i.e Battery life requirement		At least 2 hour	At least one month				

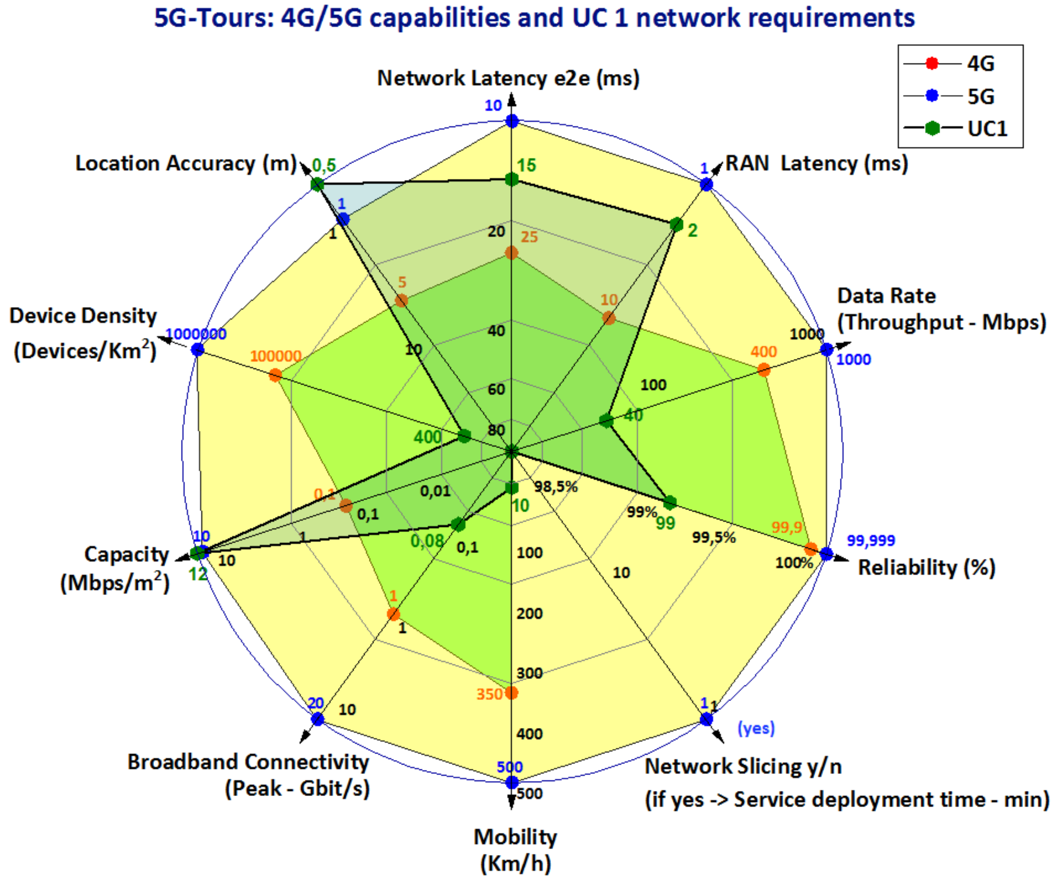


Figure 15: 5G-Tours Radar Graph for UC 1: – Augmented tourism experience network requirements

From the 10 major Requirements of the Augmented Tourism Experience Use Case, 6 (or 60%) appear to be fulfilled using a LTE/4G network, but the following 4:

- Capacity
- RAN Latency
- Network Latency and
- Location Accuracy

require the more advanced capabilities of a 5G Network. Especially the Location Accuracy Requirement of 50 cm, stretches the limits of 5G Networks. In order to achieve such accuracy with the mobile RAN, one would have to operate in higher frequencies and at the same time utilize other modalities like GPS (and more), in order to acquire the accurate position of the end user. Therefore, a multi-modal positioning algorithm is something to be investigated (in order to improve the accuracy that the 5G network will provide).

9.3.2 5G Tours Use case 2 – Telepresence Technical Requirements analysis

The general vertical use case requirements for the Use-Case 2 of 5G-Tours are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 16.

Table 17: Use Case 2 – Telepresence network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC2 – Telepresence			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	2			High	1	10
2	**RAN** Latency (in milliseconds) - one way	msec	1			high	1	5
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	30			High	~10	~30
4	Reliability (%) - Min/Max	%	99,9999%				99,000%	99,9999%
5	Availability (%) - Min/Max	%	99,9999%				99,000%	99,9999%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	1				0,1	1
7	Broadband Connectivity (peak demand)	Y/N or Gbps	0,1					0,1
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N	Y (30)					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y					
10	Capacity (Mbps/m² or Km²)	Mbps/m²	30				~10	~30
11	Device Density	Dev/Km²	5				1	5
12	Location Accuracy	m	0,1				0,1	0,5

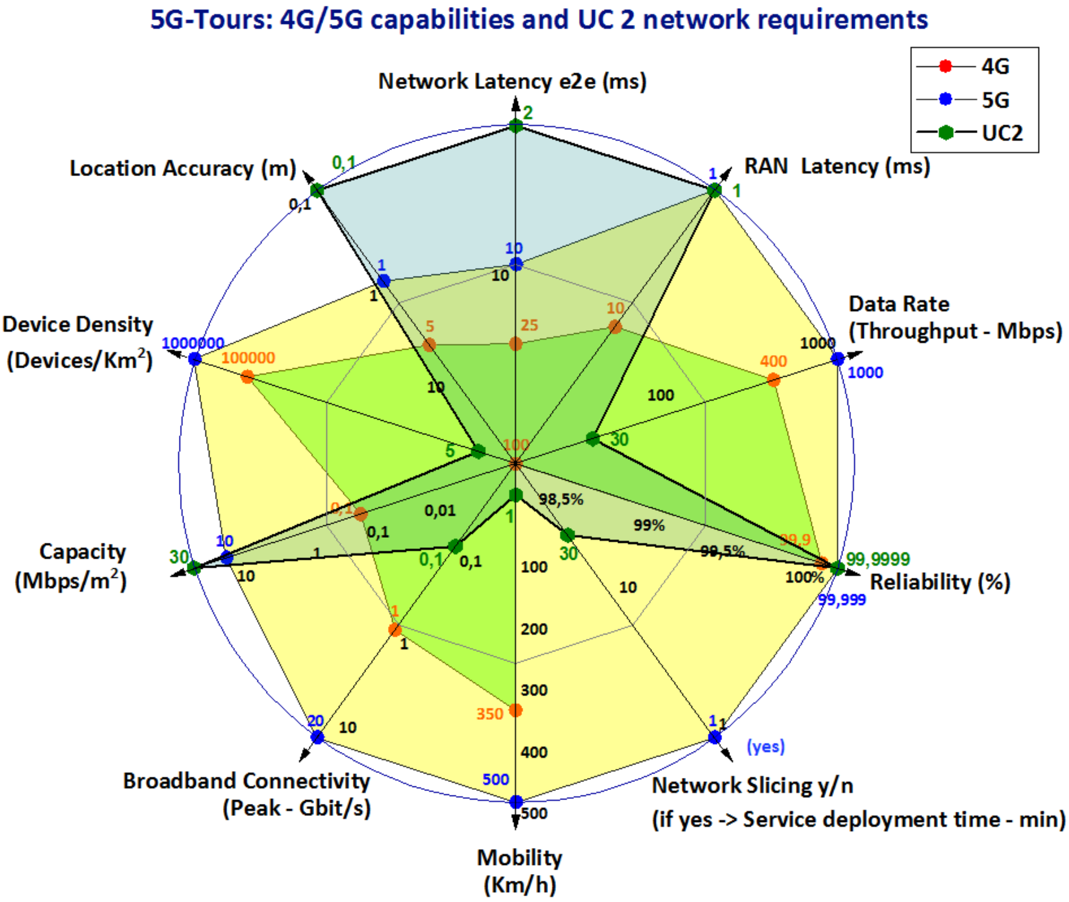


Figure 16: 5G-Tours Radar Graph for UC 2 – Telepresence network requirements

The Use Case of Telepresence need a 5G network order to achieve the required

- Capacity
- Network Latency
- RAN Latency
- Location Accuracy
- Reliability and

- Slicing

For the Network Latency (round trip), even the capabilities of the 5G technologies are stretched to the limit. The 2msec that is required is a LAN type latency and not the Access+Core Network Latencies. Therefore either this capability should be relaxed to approximately 10 msec, or provisioning of Edge Storage/Computing should be investigated. The latter case (Support of Edge Cloud) would make the implementation of the Service rather expensive.

Furthermore, the Location Accuracy Requirement of 10 cm, also stretches the limits of 5G Network capabilities. In order to achieve such accuracy using only the capabilities of the 5G network is difficult. One would have to operate in higher frequencies and at the same time utilize other modalities like GPS, in order to acquire the accurate position of the end user/device. Therefore a multi-modal positioning algorithm is something to be investigated (in order to improve of the location accuracy that the 5G network will provide).

9.3.3 5G Tours Use case 3 - Robot-assisted museum guide and monitoring Technical Requirements analysis

The general vertical use case requirements for the Use-Case 3 of 5G-Tours are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 17.

Table 18: Use Case 3 – Robot-assisted museum guide and monitoring network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC3: Robot-assisted museum guide and monitoring			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	2			High	1	10
2	**RAN** Latency (in milliseconds) - one way	msec	1			high	1	5
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	30			High	~10	~30
4	Reliability (%) - Min/Max	%	99,9999%				99,0000%	100,0000%
5	Availability (%) - Min/Max	%	99,9999%				99,0000%	100,0000%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	0,5				0,1	0,5
7	Broadband Connectivity (peak demand)	Y/N or Gbps	0,1					100Mbps
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N	Y (30)					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y					
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	30				~10	~30
11	Device Density	Dev/Km^2	1				1	1
12	Location Accuracy	m	0,1				0,1	0,5

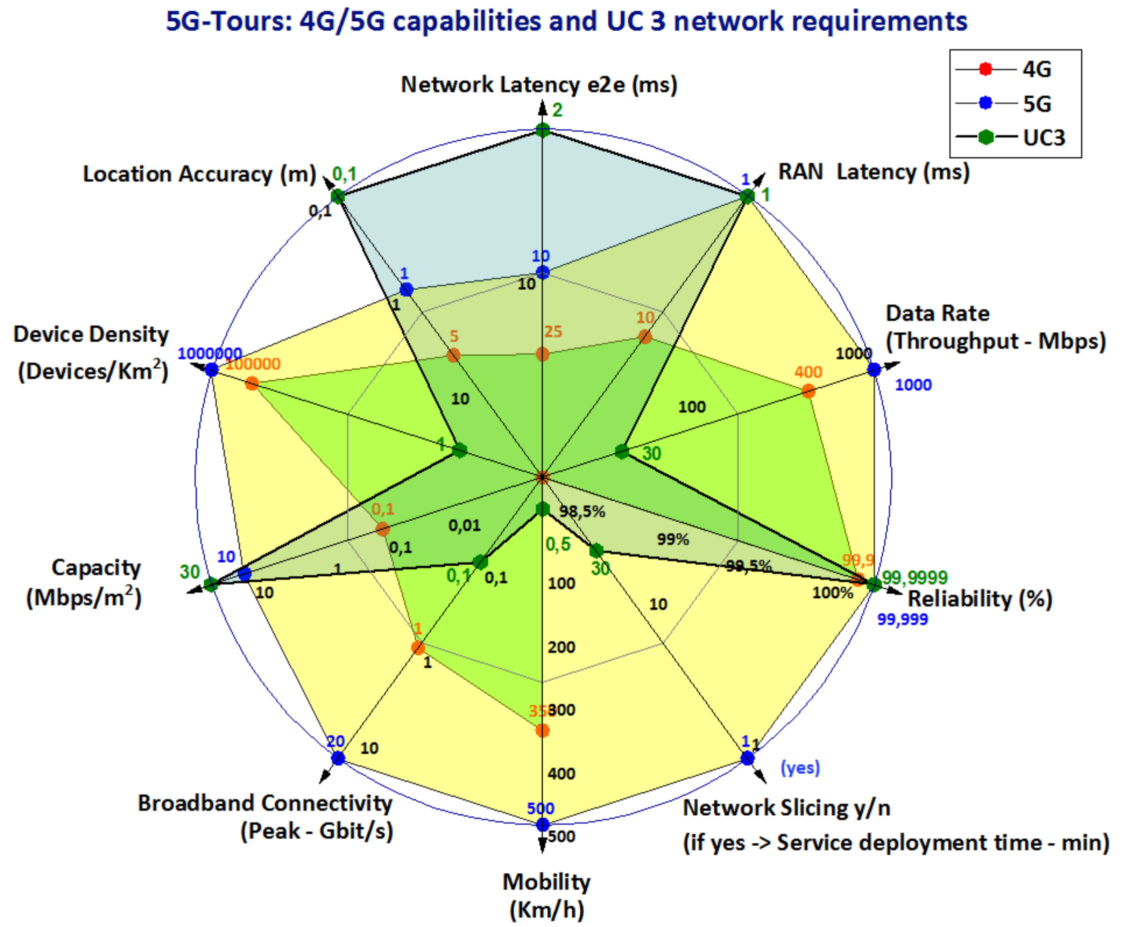


Figure 17: 5G-Tours Radar Graph for UC 3: Robot-assisted museum guide and monitoring network requirements

Very similar to the previous Use Case, the Robot-assisted museum guide, requires Network Latency (round trip) that even the capabilities of the 5G technologies are stretched to their limit. The 2msec that is required is LAN type latency and not Access+Core Network Latencies. Therefore, either this capability should be relaxed to approx. 10 msec, or provisioning of Edge Cloud capabilities should be investigated. The latter case (Support of Edge Computing and/or Storage) would make the implementation of the Robot-assisted museum guide service expensive.

Furthermore, the Location Accuracy Requirement of 10 cm, also stretches the limits of 5G Network capabilities. In order to achieve such accuracy either the RAN would have to operate in higher frequencies and simultaneously, other modalities like GPS (or location beacons for indoor) should also assist for acquiring the accurate position of the end user/robot. Therefore, a multi-modal positioning algorithm should be investigated (in order to improve of the accuracy that the 5G network will provide).

Additionally (to the Network Latency and Location Accuracy)

- Capacity,
- Slicing,
- Reliability and
- RAN latency requirements,

dictate the use of a 5G Network for successful implementation of this Use Case.

9.3.4 5G Tours Use case 4 – High quality video services distribution Technical Requirements analysis

The general vertical use case requirements for the Use-Case 4 of 5G-Tours are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 18.

Table 19: Use Case 4 – High quality video services distribution network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC4: High quality video services distribution			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec			10 ms	Medium	10 ms (bi-directional)	None (broadcast)
2	**RAN** Latency (in milliseconds) - one way	msec			5 ms	Low		
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps			25	High	25 Mbps	-
4	Reliability (%) - Min/Max	%			99,9999%	High	99,999%	99,9999%
5	Availability (%) - Min/Max	%			99,90%	Medium		
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h			100	Medium	10	100
7	Broadband Connectivity (peak demand)	Y/N or Gbps			0,1	-	0,05	0,1
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N			Y (60)	Medium	60 min	120 min
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N			N	-		
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2			-			
11	Device Density	Dev/Km^2			N/A (multicast/broadcast)	Low		
12	Location Accuracy	m			-	-		
Specific Vertical/Use Case Requirements								
Network	Number of End Points				?	Medium		
	Number (Range) of End Devices per End Point					Medium	10	50
	Density of End Devices (per sq. meter)				Multicast / broadcast	Low		
	Bitrate needs per end point (Kbps,Mbps, Gbps)					High	25 Mbps? (broadcast)	-
	End -to-end Latency (msecs)					Low	10 ms (multicast)	None (broadcast)
	Highest Acceptable jitter (msec)				-			
	Number of Class of Service / QoS (1-8, more)				-			
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**				Smartphones, AR and TV			
	Bitrate required (Kbps / Mbps / Gbps)					High	25 Mbps	-
	Max Latency Allowable (in msecs)					Low	10	None (broadcast)
	Max Moving Speed (km/h, 0 if stationary)				100	Medium		
	IPv4 & IPv6 support (or both)				IPv4?			
	Connnection of Device to End Point (Wired/Wireless)				Wireless			
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)				Ethernet?			
	Authenication method (i.e. SIM, eSIM, Key..)							
ic (non-Network related Requirements)								
	i.e Battery life requirement				-			

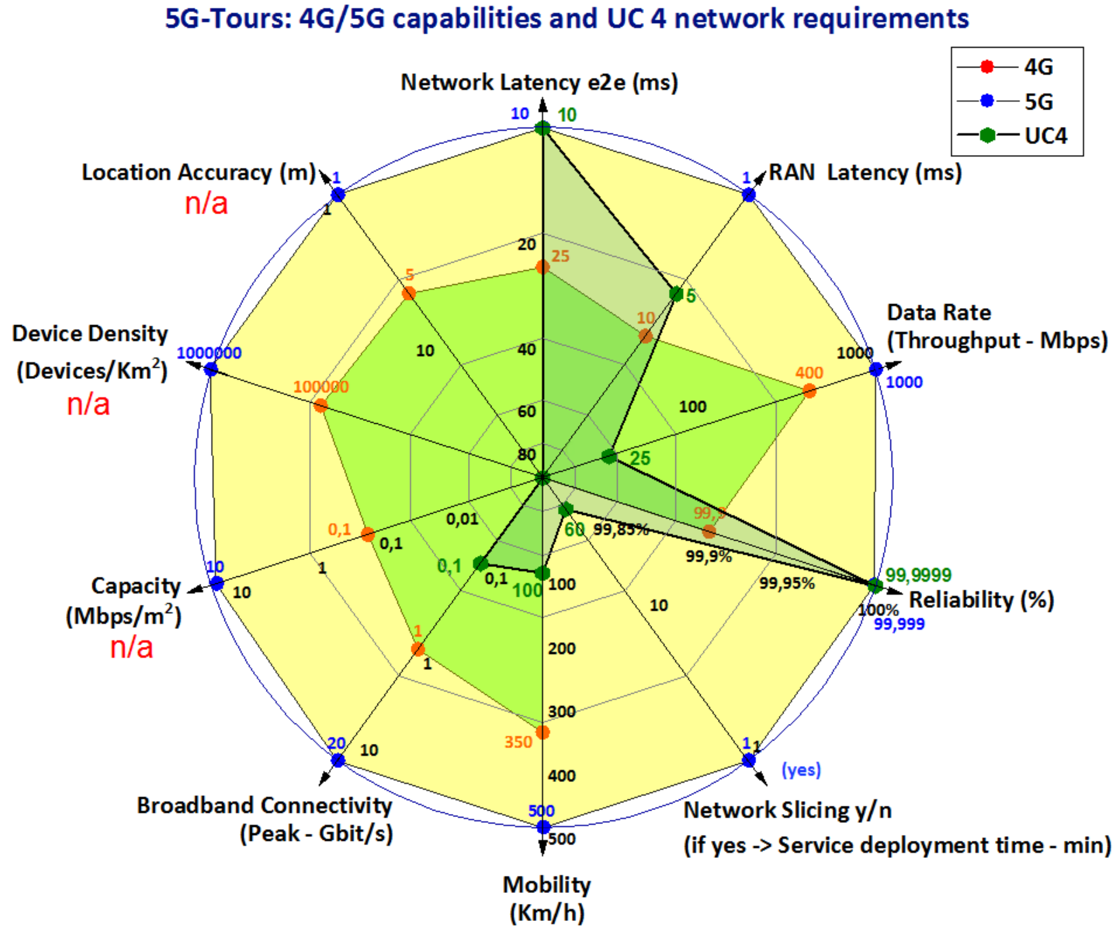


Figure 18: 5G-Tours Radar Graph for UC 4: High quality video services distribution network requirements

The Use Case of High-Quality Video Distribution appears to be easier to implement since in terms of requirements, only the

- RAN Latency,
- Network Latency and
- Reliability are the ones that need a 5G-Network.

If it was not for the 2 Latencies even a Ultra-Reliable 4G/LTE network would have sufficed for implementation of this use-case.

9.3.5 5G Tours Use case 5 - Distributed video production Technical Requirements analysis

The general vertical use case requirements for the Use-Case 5 of 5G-Tours are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 19.

Table 20: Use Case 5 – Distributed video production network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC5 – Distributed video production			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	15		15	High	10	20
2	**RAN** Latency (in milliseconds) - one way	msec	1		1	High	1	1
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	180		180	High	150	200
4	Reliability (%) - Min/Max	%	99,9999%		99,9999%	Low	99,9999%	99,9999%
5	Availability (%) - Min/Max	%	99,9999%		99,9999%	Low	99,9999%	99,9999%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	3		3	Low	0	10
7	Broadband Connectivity (peak demand)	Y/N or Gbps	0,25					
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N	Y (5)		Y	Low	5	15
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y		Y	Low		
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	360		360	Medium	180	900
11	Device Density	Dev/Km^2	2		2	Low	1	5
12	Location Accuracy	m	n.a.		n.a.	n.a.	n.a.	n.a.

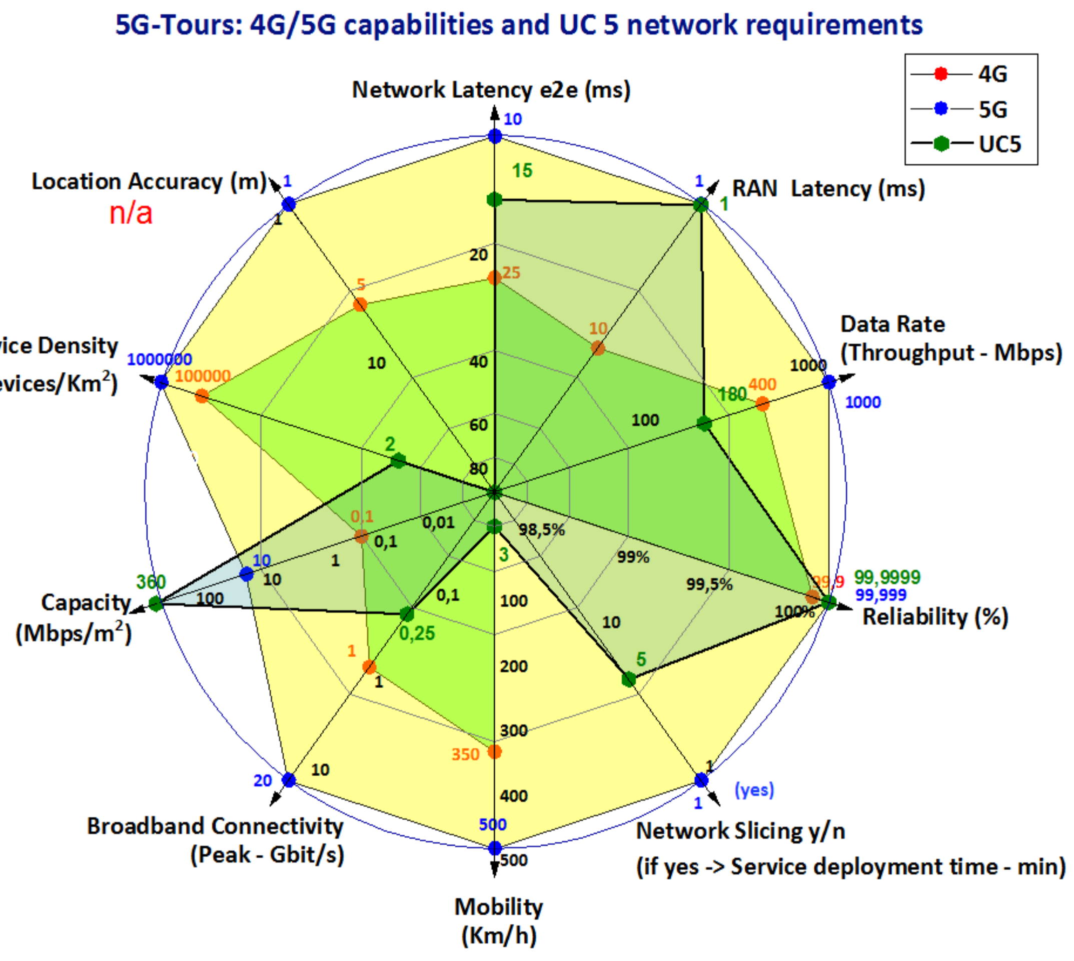


Figure 19: 5G-Tours Radar Graph for UC 5: Distributed video production network requirements

The Use Case of Location Accuracy cannot be implemented satisfactorily in a 4G/LTE network due to the higher requirements in terms of

- RAN Latency (1 msec)
- Network Latency (15 msec)
- Reliability (99.9999%)
- Slicing and
- Capacity of 360 Mbps/m^2

Even for 5G Network implementations the Capacity Requirement appears high, and it can be satisfied as long as the number of end users in each cell are kept within predefined limits. The provisioning of such high Capacity requires careful Radio Access Network Planning and Careful Resource allocation in the Core and Transport Network.

9.3.6 5G Tours Use case 6 - Remote health monitoring and emergency situation notification Technical Requirements Analysis

The general vertical use case requirements for the Use-Case 6 of 5G-Tours are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 20.

Table 21: Use Case 6 – Remote health monitoring and emergency situation network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC6 –Remote health monitoring and emergency situation notification			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	10	10		High	10	50
2	**RAN** Latency (in milliseconds) - one way	msec	1	1		High	5	10
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps				High	10	50
4	Reliability (%) - Min/Max	%	99,9999%	99,9999%		High		
5	Availability (%) - Min/Max	%	99,99%	99,99%		High		
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h				High	5Km/h	100 Km/h
7	Broadband Connectivity (peak demand)	Y/N or Gbps		Y		High	N/A	N/A
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N		Y		Medium	N/A	N/A
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N		Y		Medium	N/A	N/A
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2					N/A	N/A
11	Device Density	Dev/Km^2					N/A	N/A
12	Location Accuracy	m		0,1		High		1m
Specific Vertical/Use Case Requirements								
Network	Number of End Points			2				
	Number (Range) of End Devices per End Point			5				
	Density of End Devices (per sq. meter)							
	Bitrate needs per end point (Kbps,Mbps, Gbps)							
	End -to-end Latency (msecs)						10	50
	Highest Acceptable jitter (msec)							
	Number of Class of Service / QoS (1-8, more)			82				
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**			Sensor/Wearable				
	Bitrate required (Kbps / Mbps / Gbps)							
	Max Latency Allowable (in msecs)							
	Max Moving Speed (km/h, 0 if stationary)			30				
	IPv4 & IPv6 support (or both)			both				
	Connnection of Device to End Point (Wired/Wireless)			Wireless				
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)			NB-IoT				
	Authenication method (i.e. SIM, eSIM, Key..)			SIM				
ic (non-Network related Requirements)								
	i.e Battery life requirement							

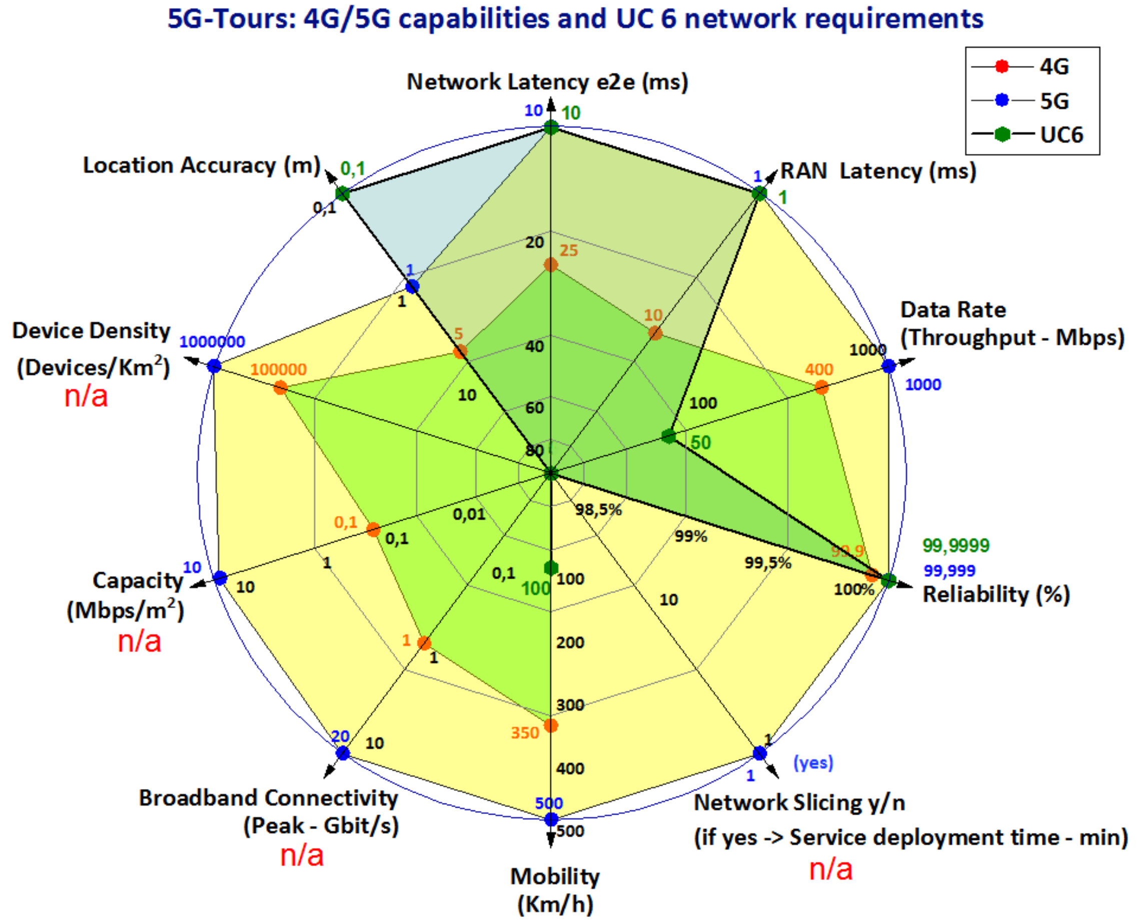


Figure 20: 5G-Tours Radar Graph for UC 6: Remote health monitoring and emergency situation network requirements

- Reliability of 6 nines (99,9999%),
- Low RAN and Networks Latencies and
- Ultra High Location Accuracy,

are the primary requirements of the Remote Health monitoring Use Case that indicate the need of a highly Reliable 5G-Network.

Furthermore the ultra-high location accuracy requirement of 10 cm dictates the use of multi-modal positioning systems. Either the RAN would have to operate in high frequencies (3.6-3.8 GHz an up) and simultaneously, other modalities like GPS (for outdoors and location beacons or use of 26 GHz for indoor) should be utilized for accurate positioning of the end user/patient. Therefore, a multi-modal positioning algorithm should be investigated (in order to improve of the accuracy that the 5G network will provide).

9.3.7 5G Tours Use case 7 - Teleguidance for diagnostics and intervention support Technical Requirements Analysis

The general vertical use case requirements for the Use-Case 7 of 5G-Tours are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 21.

Table 22: Use Case 7 – Teleguidance for diagnostics and intervention support network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC7 – Teleguidance for diagnostics and intervention support			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	10				10	25
2	**RAN** Latency (in milliseconds) - one way	msec	2					
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	1000				150	1000
4	Reliability (%) - Min/Max	%	99,999%				99,00%	99,999%
5	Availability (%) - Min/Max	%	99,999%				99,00%	99,999%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	120				0	120
7	Broadband Connectivity (peak demand)	Y/N or Gbps	1,5				1000	1500 Mbps
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N	Y(1)				1	5
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y				Y	Y
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	6				150	6000
11	Device Density	Dev/Km^2	30				5	30
12	Location Accuracy	m	1				1	25

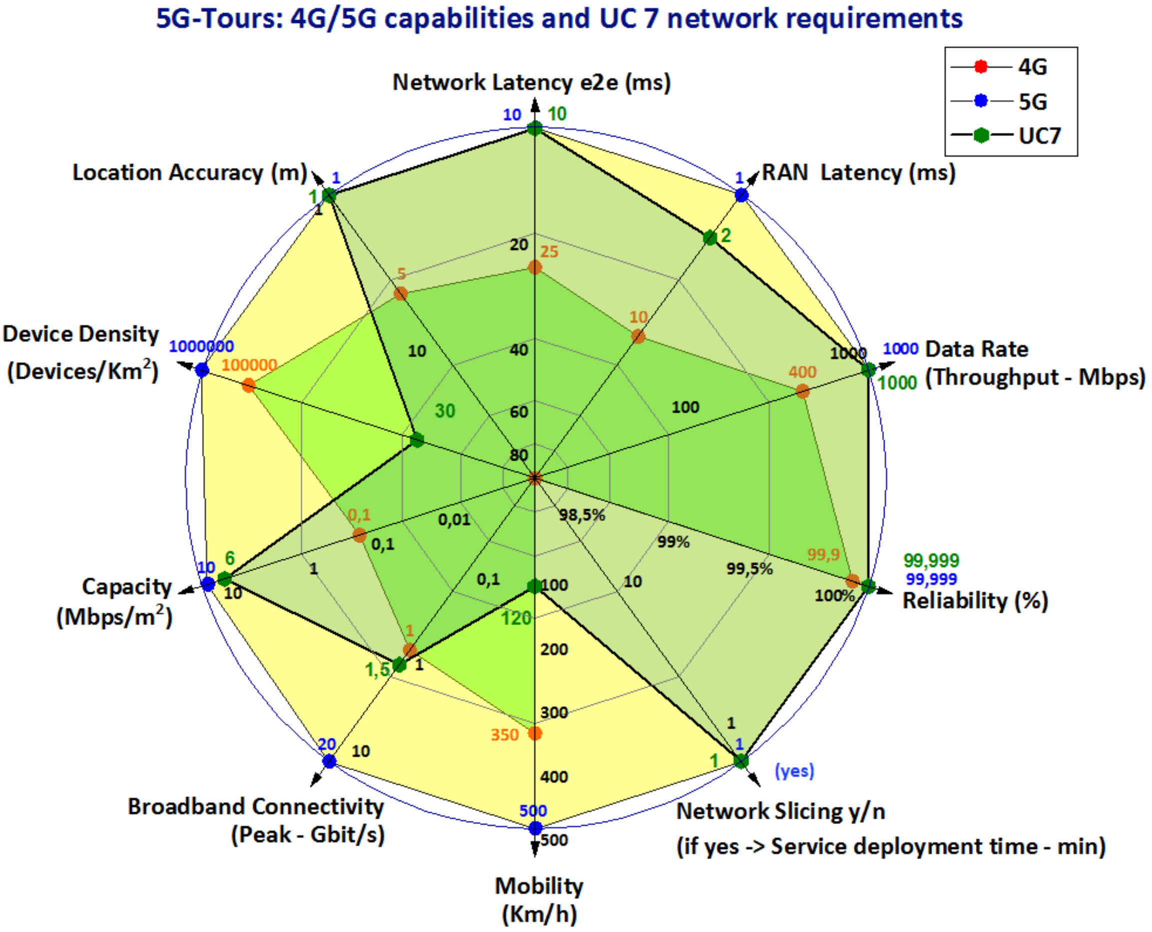


Figure 21: 5G-Tours Radar Graph for UC 7: Teleguidance for diagnostics and intervention support network requirements

From the 10 primary requirements of the Teleguidance Use Case, only the Device Density and the Mobility can be satisfied with 4G. All the rest (80%) namely:

- Broadband Connectivity,
- Capacity

- Location Accuracy,
- Network Latency
- RAN Latency
- Reliability
- Date Rate and
- Network Slicing,

indicate that a 5G Network is needed to successfully implement the use case.

9.3.8 5G Tours Use case 8 - Wireless Operating Room Technical Requirements Analysis

The general vertical use case requirements for the Use-Case 8 of 5G-Tours are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 22.

Table 23: Use Case 8 – Wireless Operating Room network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC8 – Wireless Operating Room			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	20				10	30
2	**RAN** Latency (in milliseconds) - one way	msec	5				2	7
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	800				600	7000
4	Reliability (%) - Min/Max	%	99,99999%					
5	Availability (%) - Min/Max	%	99,99999%					
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	0					
7	Broadband Connectivity (peak demand)	Y/N or Gbps	0,8					
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N	Y (5)					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	N					
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	N/A					
11	Device Density	Dev/Km^2	N/A					
12	Location Accuracy	m	N/A					
Specific Vertical/Use Case Requirements			1					
Network	Number of End Points		4				3	6
	Number (Range) of End Devices per End Point		N/A					
	Density of End Devices (per sq. meter)		800 Mps				600 Mps	7 Gbps
	Bitrate needs per end point (Kbps,Mbps, Gbps)		10					
	End -to-end Latency (msecs)	ical for PTP synchronization (microsecond range?)						
	Highest Acceptable jitter (msec)		3				2	4
	Number of Class of Service / QoS (1-8, more)	US probe, X-Ray eqt, Smart glass, Pro TV						
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**		800 Mbps				20 Mbps	3 Gbps
	Bitrate required (Kbps / Mbps / Gbps)		5 ms					
	Max Latency Allowable (in msecs)		N/A					
	Max Moving Speed (km/h, 0 if stationary)		IPv4				IPv4	both
	IPv4 & IPv6 support (or both)		Wireless+Wired					
	Connnection of Device to End Point (Wired/Wireless)		WLAN+Ethernet					
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)		N/A (LAN)					
	Authenication method (i.e. SIM, eSIM, Key..)							
ic (non-Network related Requirements)			Only for smart glasses					
	i.e Battery life requirement							

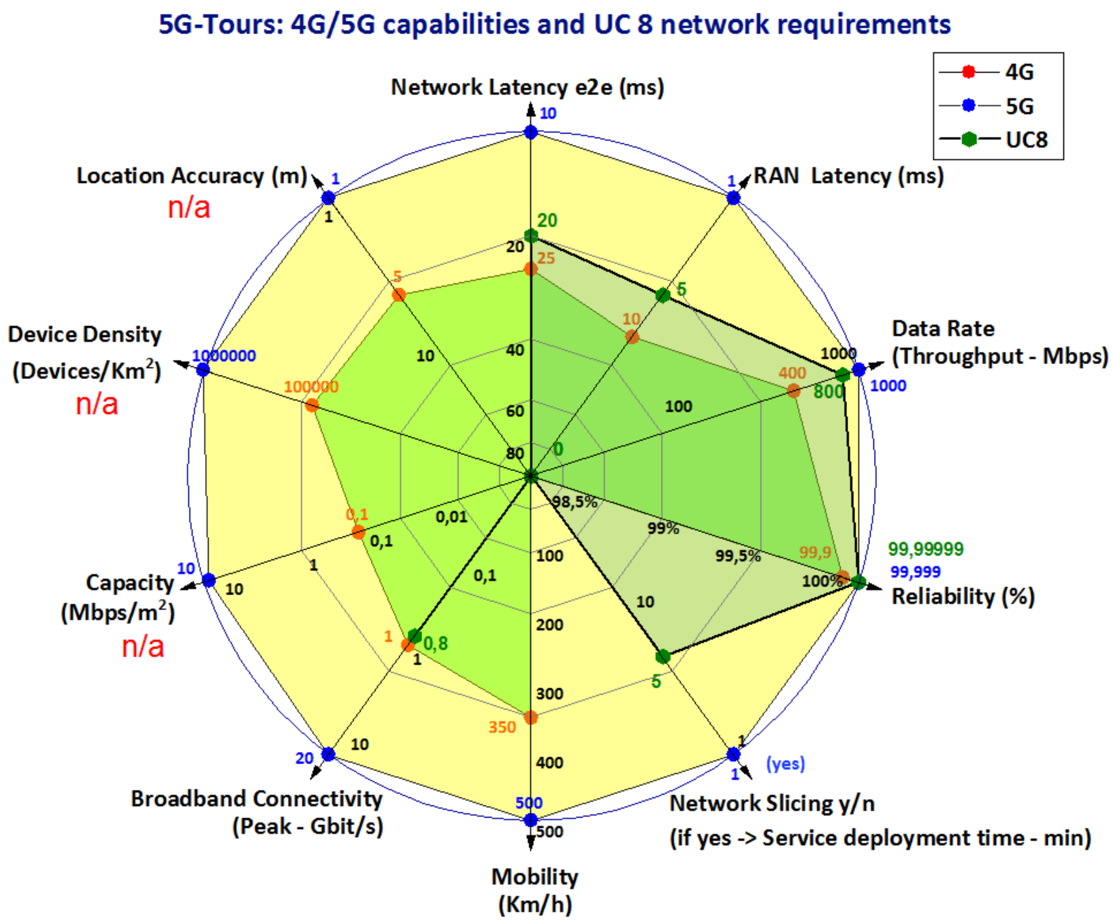


Figure 22: 5G-Tours Radar Graph for UC 8: Wireless Operating Room network requirements

The Wireless Operating Room Use Case focuses primarily in the Ultra High Reliability of 7 nines (99.99999%). This together with the

- Network Latency,
- RAN Latency,
- Data Rate and
- Demand for one or more dedicated Network Slices,

clearly indicate the need for a 5G-Network infrastructure.

9.3.9 5G Tours Use case 9 - Optimal Ambulance Routing Technical Requirements Analysis

The General vertical use case requirements for the Use-Case 9 of 5G-Tours are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 23.

Table 24: Use Case 9 – Optimal Ambulance Routing network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC9 – Optimal Ambulance Routing			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec		10		High	10	50
2	**RAN** Latency (in milliseconds) - one way	msec		1		High	5	10
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps		50		High	10	50
4	Reliability (%) - Min/Max	%		99,9999%		High		
5	Availability (%) - Min/Max	%		99,99%		High		
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h		>=100Km/h		High		
7	Broadband Connectivity (peak demand)	Y/N or Gbps		Y (1)		High		
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N		Y (1)				
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N		Y		Medium		
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2		n/a				
11	Device Density	Dev/Km^2		n/a				
12	Location Accuracy	m		0,1		High		
Specific Vertical/Use Case Requirements								
Network	Number of End Points			2				
	Number (Range) of End Devices per End Point			2				
	Density of End Devices (per sq. meter)							
	Bitrate needs per end point (Kbps,Mbps, Gbps)							
	End -to-end Latency (msecs)						10	50
	Highest Acceptable jitter (msec)							
	Number of Class of Service / QoS (1-8, more)			3				
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**			Smartphone/Tablet				
	Bitrate required (Kbps / Mbps / Gbps)							
	Max Latency Allowable (in msecs)							
	Max Moving Speed (km/h, 0 if stationary)			100				
	IPv4 & IPv6 support (or both)			both				
	Connnection of Device to End Point (Wired/Wireless)			Wireless				
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)			NB-IoT				
	Authenication method (i.e. SIM, eSIM, Key..)			SIM				
ic (non-Network related Requirements)								
	i.e Battery life requirement							

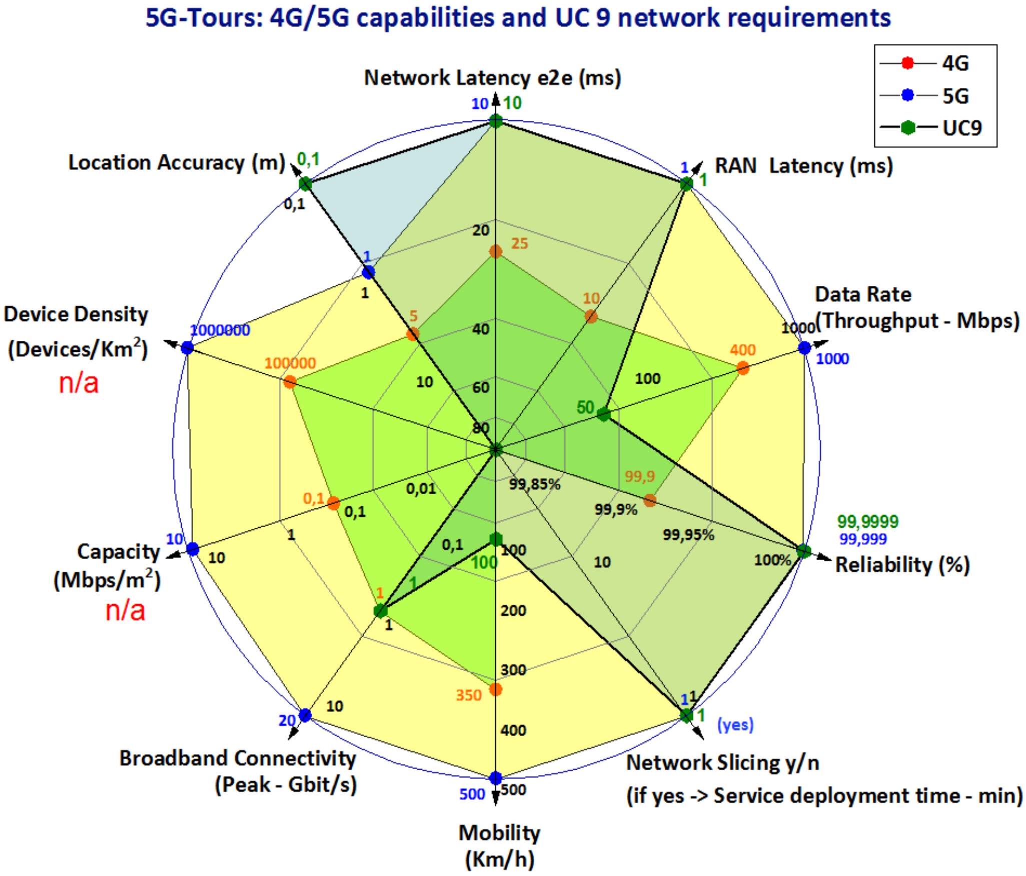


Figure 23: 5G-Tours Radar Graph for UC 9: Optimal Ambulance Routing network requirements network requirements

50% of the Requirements for the Optimal-Ambulance Routing Use Case can be fulfilled by currently available 4G Network but the other 50% namely:

- Location Accuracy
- Network Latency
- RAN Latency
- Reliability and
- Dedicated Network Slice,

indicate the need for 5G technology.

Additionally, the ultra-high location accuracy requirement of 10 cm dictates the use of multi-modal positioning systems. Such high accuracy should be justified since an ambulance with size of a few meters should be routed optimally. Nevertheless, if this is the case and sub-meter accuracy is needed, either the RAN would have to operate in high frequencies (3.6-3.8 GHz an up) and simultaneously, other modalities like GPS/GNSS (for outdoors and positioning beacons or use of 26 GHz for indoor) should be exploited for accurate positioning of the “target”. In conclusion, a multi-modal positioning algorithm should be investigated (in order to improve of the accuracy that the 5G network will provide).

9.3.10 5G Tours Use case 10 - Smart Parking Management Technical Requirements analysis

The General vertical use case requirements for the Use-Case 10 of 5G-Tours are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 24.

Table 25: Use Case 10 - Smart Parking management network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC 10 – Smart parking management			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec		10		High	10	50
2	**RAN** Latency (in milliseconds) - one way	msec		5		High	5	10
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps		50		High	10	50
4	Reliability (%) - Min/Max	%		99,9999		High	99,9990	99,9999
5	Availability (%) - Min/Max	%		99,99		High	99,99	99,99
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h		30		High	5	30
7	Broadband Connectivity (peak demand)	Y/N or Gbps		1		High	0,01	0,1
8	Network Slicing (Y/N) - if Y sercice deployment time (m	Y/N		Y		Medium	1	3
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N		Y		medium		
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2		0,1			0,1	0,1
11	Device Density	Dev/Km^2		100K		High	1K	100K*
12	Location Accuracy	m		<0,5		High	0,5	1

(*) 1 parking space = 10m^2 => 1 Km^2 = 100.000 parking spaces

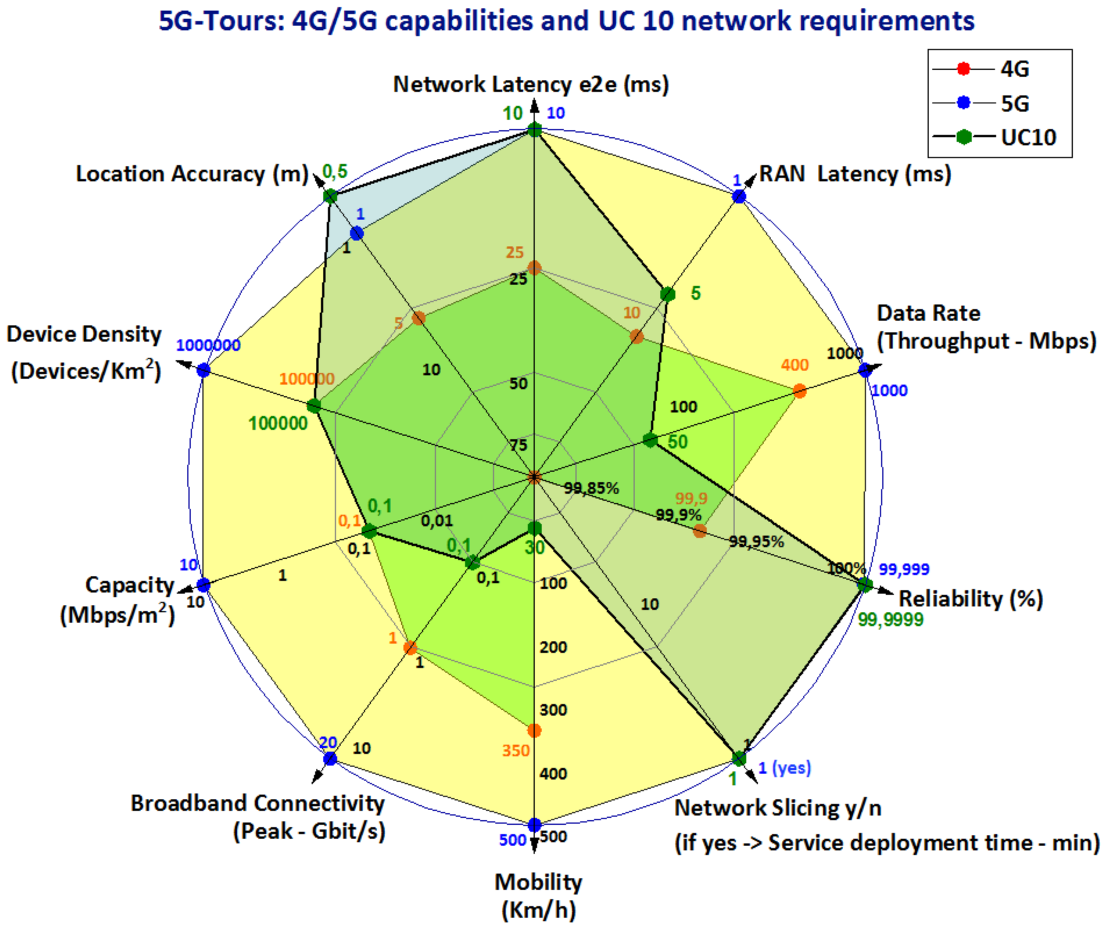


Figure 24: 5G-Tours Radar Graph for UC 10: Smart Parking management requirements

Analysis: For the UC-10 (Smart Parking) it appears that a 5G network will be needed. Although with respect to the

- Throughput,
- Mobility,
- Peak Traffic Demand (Broadband Connectivity) and
- Capacity

Even existing 4G/LTE and 4G+ technology/network will suffice. When it comes to

- Device Density and
- RAN Latency,

a 5G network is required.

Furthermore, for the case of E2E Network Latency and the Location Accuracy the UC-10 requirements stretch the limits of 5G Networks. With respect to the very low E2E latency the possibility of Edge Computing and/or Edge Cloud architectures should be considered. This will reduce the overall latency at significant cost. There are two alternative approaches. Either a Proof of Concept trial should evaluate whether the 5G network offered E2E Latency of approximately 15 ms is good enough for the Service, or a techno-economic analysis for using Edge Cloud/Computing architectures should be performed.

Finally, the desired Location Accuracy of 0.5 m indicates that hybrid location identification technologies should be utilized. For outdoor parking spaces a combination of military grade GPS together with a 5G network location information should suffice. For indoor parking environments a WiFi assisted / 5G network together will other modalities should be utilized in order to provide 0.5 meters location accuracy.

9.3.11 5G Tours Use case 11 –Emergency Airport Evacuation Technical Requirements analysis

The General vertical use case requirements for the 5G-Tours Use-Case 11 are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 25.

Table 26: Use Case 11 - Emergency Airport evacuation network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC 11 - Emergency airport evacuation			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec	15	25			15	100
2	**RAN** Latency (in milliseconds) - one way	msec	10	10			10	20
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	500	100			100	500 *
4	Reliability (%) - Min/Max	%	99,9999	99,9999			99,999	99,9999
5	Availability (%) - Min/Max	%	99,99	99,99			99,99	99,99
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	10	0			0	10**
7	Broadband Connectivity (peak demand)	Y/N or Gbps	10	10			1	10
8	Network Slicing (Y/N) - if Y sercice deployment time (min)	Y/N	1	1			1	5
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y	Y			Y	
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	100	100			2	20***
11	Device Density	Dev/Km^2	1000K	1000K			1000K	1000K*****
12	Location Accuracy	m	<1	<1			1	0,3

(*) Total per UE
(**) 10 km/h running speed of a peson evacuating
(***) 2 persons per m^2 at 10 Mbps/person
(*****) 1 or 2 persons per m^2

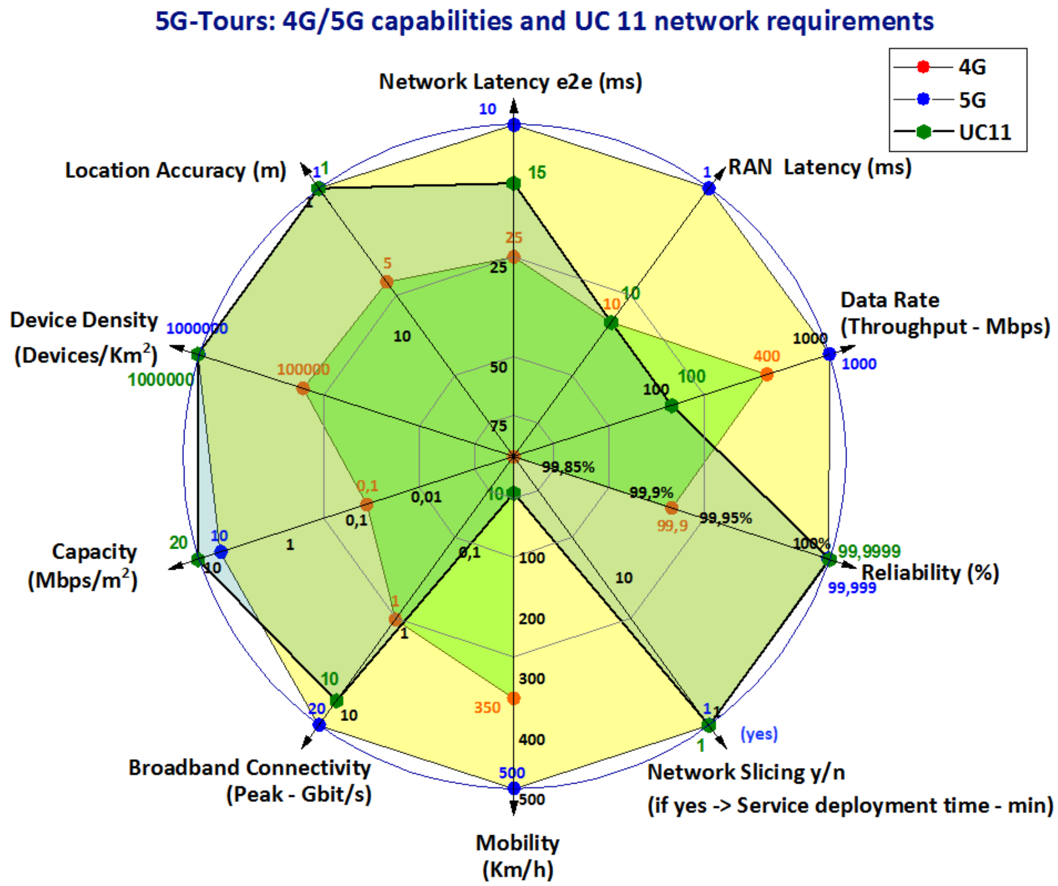


Figure 25: 5G Tours Radar graph for UC 11: Emergency Airport Evacuation Requirements

For UC-11 a 4G/LTE network will only be able to satisfy the

- RAN Latency and
- Throughput Requirements

With respect to the

- Broadband Connectivity,
- Device Density
- Reliability,
- Network Slicing
- Latency and
- Location Accuracy

definitely advanced 5G Network technology should come to the rescue.

It is interesting to observe that the UC-11 requirement for Capacity stretches 5G Network requirements to the limit. Therefore, for a successful implementation of this UC, careful planning of the 5G NR gNBs and dimensioning of the Network resources should be performed. Since also the required capacity should also be delivered in well-defined and confined spaces of the AIA, even the stringent Capacity requirement can be achieved with 5G technology.

9.3.12 5G Tours Use case 12 –Video enhanced ground based moving vehicles Technical Requirements analysis

The General vertical use case requirements for the 5G-Tours Use-Case 12 are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 26.

Table 27: Use Case 12 – Video enhanced ground based moving vehicles network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC 12 - Video-enhanced ground-based moving vehicles			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec			100		100	500
2	**RAN** Latency (in milliseconds) - one way	msec			50		50	100
3	Throughput (in Mbps) - Min/Max - sustained demand	Mbps			50		10	50*
4	Reliability (%) - Min/Max	%			99,99		99,9	99,99
5	Availability (%) - Min/Max	%			99,999		99,99	99,999
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h			150		80	150
7	Broadband Connectivity (peak demand)	Y/N or Gbps			0,25		25 Mbps	250 Mbps
8	Network Slicing (Y/N) - if Y sercice deployment time (min)	Y/N			30		60	30
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N			Y		Y	
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2			0.00256		1 Gbps/Km^2	2,5 Gbps/Km^2 **
11	Device Density	Dev/Km^2			50		5	50 ***
12	Location Accuracy	m			1		5	1
(*) per vehicle 50 Mbps video stream is transmitted								
(**) assume 50 vehicles at 50 Mbps/vehicle in one Km^2 = 2,5Gbps/Km2 = 0,00256Mbps/m^2								
(***) 50 vehicles								

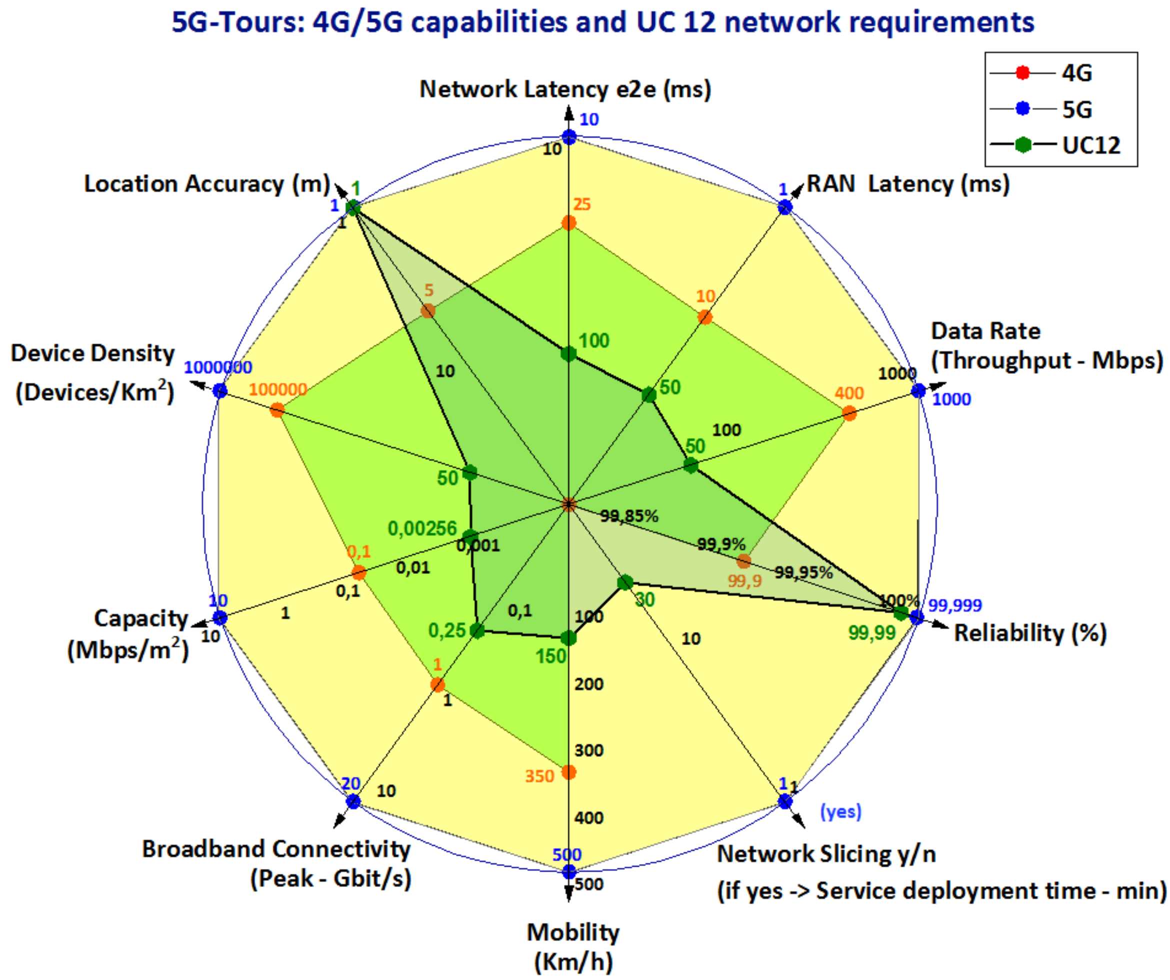


Figure 26: 5G-Tours Radar graph for UC 12: Video enhanced ground based moving vehicles Requirements

UC-12 would have been able to run on current 4G Networks if it wasn't for the

- Reliability,

- Location Accuracy and
- Network Slicing Requirements.

Therefore, if we consider that Reliability of 4G Networks is also improving and that Location Accuracy (see also the Smart Parking UC-10) can also be achieved by other means in outdoor environments the only requirement that necessitates 5G technology is Network Slicing. This UC-12 can serve as an example of a service that although does not strictly require 5G it definitely benefit from such deployments.

9.3.13 5G Tours UC 13 – AR/VR bus excursion technical requirements analysis

The General vertical use case requirements for the Use-Case 13 are shown in Table 28 below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 27.

Table 28: Use Case 13 – Excursion on an AR/VR-enhanced bus tour excursion network requirements

5G-Tours - Use Cases: direct specific Technical requirements		Units	Use case 13 – Excursion on an AR/VR-enhanced bus			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec			100		100	500
2	**RAN** Latency (in milliseconds) - one way	msec			25		25	50
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps			120		80	120
4	Reliability (%) - Min/Max	%			99,99		99,9	99,99
5	Availability (%) - Min/Max	%			99,99		99,9	99,99
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h			100		4	100
7	Broadband Connectivity (peak demand)	Y/N or Gbps			0,01		2	10 *
8	Network Slicing (Y/N) - if Y sercice deployment time (min	Y/N			Y		30	5
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N			N			
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2			10		1	10 **
11	Device Density	Dev/Km^2			1000		10K	1000K***
12	Location Accuracy	m			<1		<4	<1
(*) 10 Mbps per VR device downstream = 0,01 Gbps								
(**) 1 device per m^2								
(***) 1 or 2 students per m^2 = 1000K devices (AR/VR gogles) per Km^2								

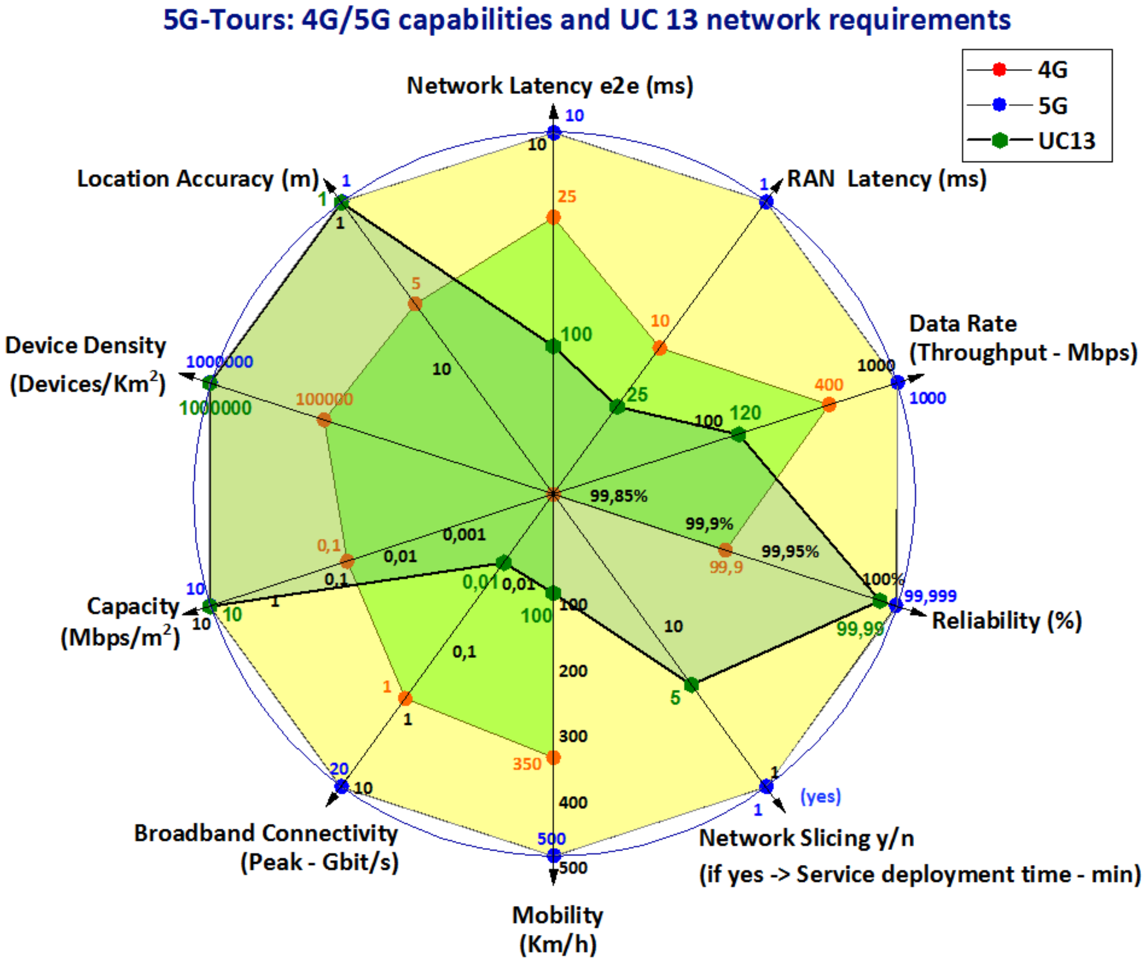


Figure 27: Radar graph for UC 13: Excursion on an AR/VR-enhanced bus Requirements

Half of 5G-Tours U-13 requirements need a 5G network for the Service implementation. More precisely

- Location Accuracy
- Device Density
- Capacity
- Network Slicing and
- Reliability

require 5G Network Technology. The remaining can currently be implemented even with existing 4G/LTE.

Nevertheless, as AR/VR devices acquire higher resolutions and quality the required Broadband Connectivity, Latency (both RAN and Network) as well as Throughput will stretch existing networks to their limits. It is a matter of time that even rudimentary AR/VR Applications /Services will be unable to provide the expected User Experience over our current networks.

9.4 5G Heart project use cases

9.4.1 5G Heart Use case Remote monitoring of water and fish quality requirements

The General vertical use case requirements for the 5G Heart UC “Remote monitoring of water and fish quality requirements” are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 28.

Table 29: 5G-Heart Use Case "Remote monitoring of water and fish quality requirements"

5G-Heart - UCases: direct specific requirements		Units	Use Case: Remote monitoring of water and fish quality			Priority	Range	
			URLLC	mMTC	eMBB[10]		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in miliseconds) - round trip - Min/MAX	msec	10	50	25	High	10	50
2	**RAN** Latency (in milliseconds) - one way	msec	3	5	5	High	5	10
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	50	0,5	50	High	15	50
4	Reliability (%) - Min/MAX	%	99,9999	99,9999	99,9999	High		
5	Availability (%) - Min/MAX	%	99,99	99,99	99,99	High		
6	Mobility (in m/sec or Km/h) - Min/MAX	km/hour	10	0	0	Low		
7	Broadband Connectivity (peak demand)	Gbps	0,3	0,5	12,5**	High	1	12,5
8	Network Slicing (Y/N) - if Y Service deployment time (mi	Y/N	y (30)	y	y	High		30
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	y	y	y	High		
10	Capacity (Mbps/m^2 or Km^2)	Mbps/km^2	0,3	0,05	0,5***	High	300	1000
11	Device Density	Dev/Km^2	6	100.000*	250	High		100
12	Location Accuracy	m	0,1	1	1	High		
›rs cage with area of 500m^2								
** 50 cages, 5 cameras in each cage x 50 Mbps = 12,5 Gbps								
ınd each cage should require 250 Mbps (for the cameras)								
rtical/Use Case Requirements								
Network	Number of End Points		10	10	10			
	Number (Range) of End Devices per End Point		50	50	50			
	Density of End Devices (per sq. meter)		100	100	100			
	Bitrate needs per end point (Kbps,Mbps, Gbps)	Mbps					15	50
	End -to-end Latency (msecs)						10	50
	Highest Acceptable jitter (msec)		2	2	2			
	Number of Class of Service / QoS (1-8, more)		1	1	1			
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**		Drone	Sensor	Camera			
	Bitrate required (Kbps / Mbps / Gbps)		15-50 Mbps	250-500 Kbps	15-50 Mbps			
	Max Latency Allowable (in msecs)		10	1000	1000			
	Max Moving Speed (km/h, 0 if stationary)		10	10	10			
	IPv4 & IPv6 support (or both)		both	both	both			
	Connnection of Device to End Point (Wired/Wireless)		Wireless	Wired	Wired			
	Type of Connection (i.e. Ethernet, WLAN, Zigbee)		Sonar/Ethernet	Ethernet	Ethernet			
	Authenication method (i.e. SIM, eSIM, Key..)		SIM	SIM	SIM			
ic (non-Network related Requirements)								
	Battery life requirement (years)		15	15	15			
Services USER REQUIREMENTS								
	City		Megara, Attica	Megara, Attica	Megara, Attica			
	Address & End Tel. Number[1]		P.C.: 19100, Tel: 229602151	19100, Tel: 229602	: 19100, Tel: 2296021514			
	Competent, Tel. Number, FAX							
	Type of Service[2]		Fixed	Fixed	Fixed			
	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)							

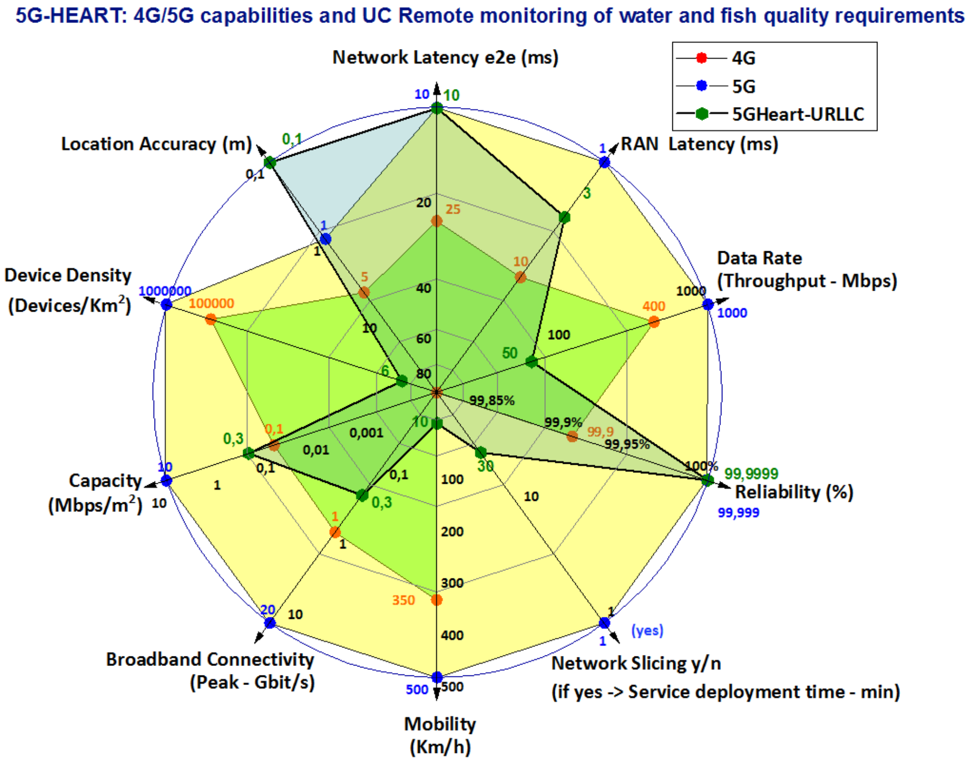


Figure 28: Radar Chart for 5G-Heart URLLC Use Case Remote monitoring of water and fish quality network requirements

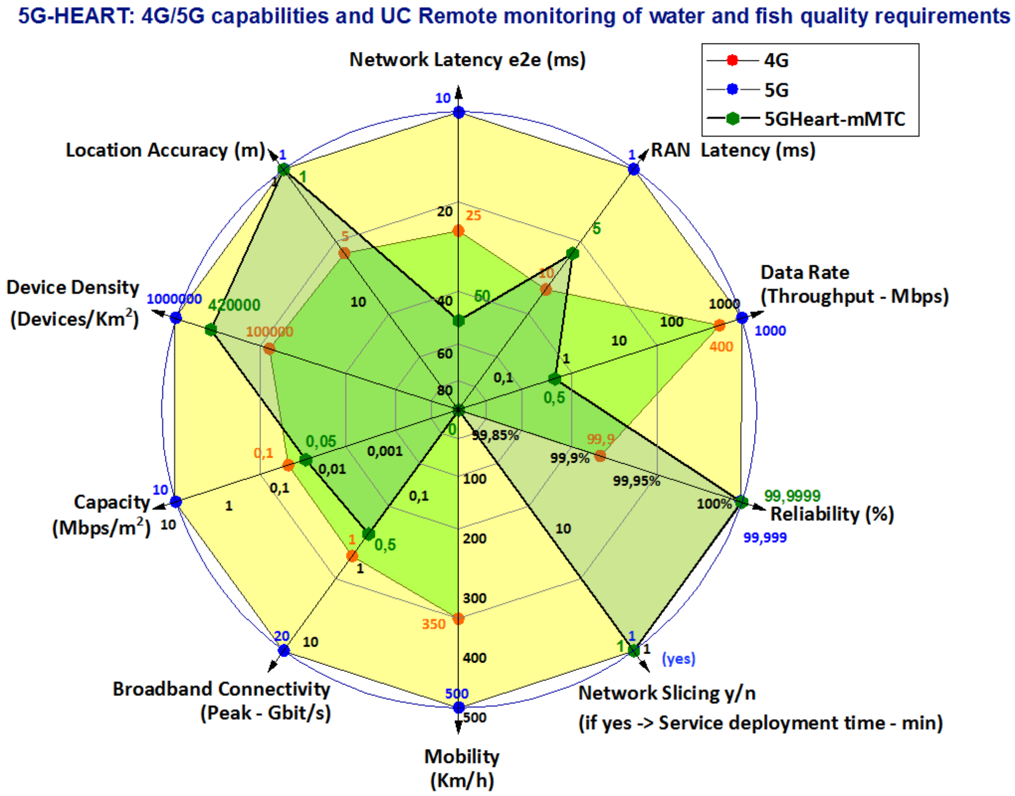


Figure 29: Radar Chart for 5G-Heart mMTC Use Case Remote monitoring of water and fish quality network requirements

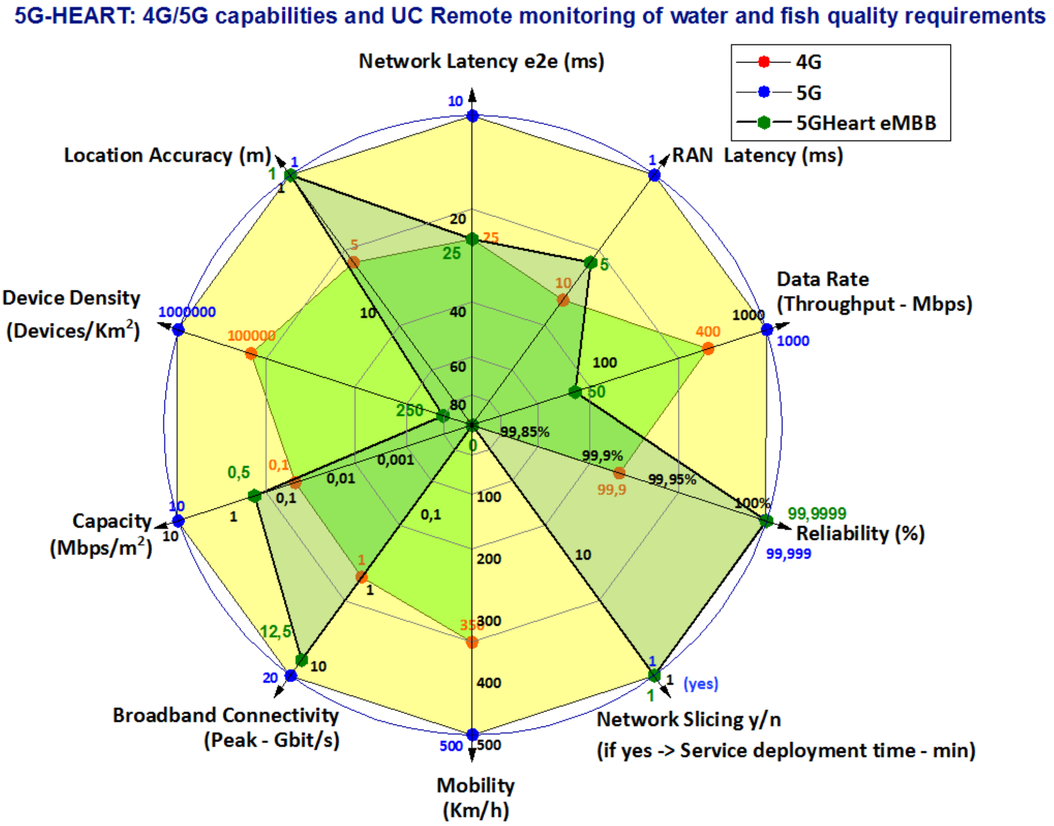


Figure 30: Radar Chart for 5G-Heart eMBB Use Case Remote monitoring of water and fish quality network requirements

The Aquaculture Use Case has 2 distinct sub-use-cases.

The 3 Services, beyond their individual requirements, demand a separate Network Slice for each Service that will be mMTC, URLLC and eMBB respectively.

For the first Service (mMTC) it appears that a 5G network is required in order to satisfy the

- Location Accuracy,
- Network Latency,
- RAN Latency
- Reliability,
- Network Slice Support and
- Capacity requirements.

For the Ultra High Location Accuracy requirement of 10 cm, as mentioned before, dictates the use of multi-modal location identification systems. A Location Accuracy of 10cm for a sensor network should be justified or be relaxed to approx. 1 m. Nevertheless, if this is the case and sub-meter accuracy is needed, either the RAN would have to operate in high frequencies (3.6-3.8 GHz an up) and simultaneously, other modalities like GPS/GNSS (for outdoors and positioning beacons or use of 26 GHz for indoor) should be exploited for accurate positioning of the “target”. In conclusion, a multi-modal positioning algorithm should be investigated (in order to improve of the accuracy that the 5G network will provide).

For the second Service (URLLC) a 5G network is needed in order to satisfy only 50% of the requirements. Namely,

- RAN Latency,

- Reliability,
- Slice Support,
- Device Density and
- Location Accuracy.

The rest can be easily provided even by current 4G/LTE Networks.

Finally for the 3rd Service (eMBB), a 5G Network is needed for 6 of the 10 primary requirements,

These are:

- RAN Latency,
- Reliability,
- Slice Support
- Broadband Connectivity
- Capacity and
- Location Accuracy.

From analysis above, it is obvious that for successful implementation of the Aquaculture Use Case a 5G Network needs to be deployed in the end-use site.

9.5 5G VICTORI project use cases

9.5.1 5G Victori UC1 - On-demand network creation for emergency services Technical Requirements Analysis

The general vertical use case requirements for the 5G Victori UC1 are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 31.

Table 30: 5G-Victori Use Case 1 - On-demand network creation for emergency services network requirements

5G-VIctori - Use Cases: direct specific technical requirements		Units	5G-Victori UC1: On-demand network creation for emergency services			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	10				5	10
2	**RAN** Latency (in milliseconds) - one way	msec	1				1	2
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	10Mbps					
4	Reliability (%) - Min/Max	%	99,999%					
5	Availability (%) - Min/Max	%	99,999%					
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	30Km/h				20	50
7	Broadband Connectivity (peak demand)	Y/N or Gbps	N					
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N	Y(1 min)					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y					
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	10Mbps/m^2					
11	Device Density	Dev/Km^2	100					
12	Location Accuracy	m	0,3					

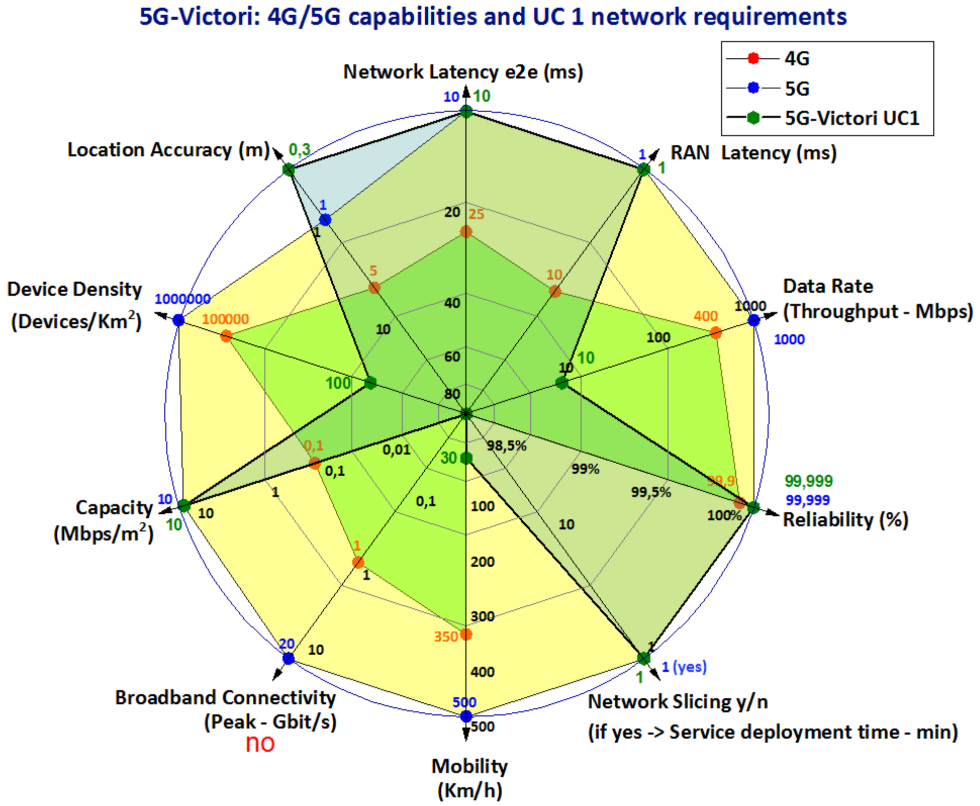


Figure 31: Radar Chart for 5G-Victori Use Case 1: On-demand network creation for emergency services network requirements

The Use Case for On-Demand Network Creation for emergency services absolutely requires the capabilities of 5G network, especially that of

- Network slicing (with 1 min setup time) but also

- Mobility,
- Capacity,
- Location Accuracy,
- Network Latency
- RAN Latency and
- Reliability.

It has to be noted that Location accuracy of 50cm is difficult to be achieved based only on 5G Network Capabilities. Therefore for sub-meter accuracy, either the RAN would have to operate in high frequencies (3.6-3.8 GHz an up) and simultaneously, other modalities like GPS/GNSS (for outdoors and positioning beacons or use of 26 GHz for indoor) should be exploited. In conclusion, a multi-modal positioning algorithm should be investigated (in order to improve of the accuracy that the 5G network will provide).

9.5.2 5G Victori UC2 - Energy Metering for LV Technical Requirements Analysis

The general vertical use case requirements for the 5G Victori UC2 are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 32.

Table 31: 5G-Victori Use Case 2 - Energy Metering for LV network requirements

5G-VIctori - Use Cases: direct specific technical requirements		Units	5G-Victori UC1: On-demand network creation for emergency services			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	10				5	10
2	**RAN** Latency (in milliseconds) - one way	msec	1				1	2
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	10Mbps					
4	Reliability (%) - Min/Max	%	99,999%					
5	Availability (%) - Min/Max	%	99,999%					
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	30Km/h				20	50
7	Broadband Connectivity (peak demand)	Y/N or Gbps	N					
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N	Y(1 min)					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y					
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	10Mbps/m^2					
11	Device Density	Dev/Km^2	100					
12	Location Accuracy	m	0,3					

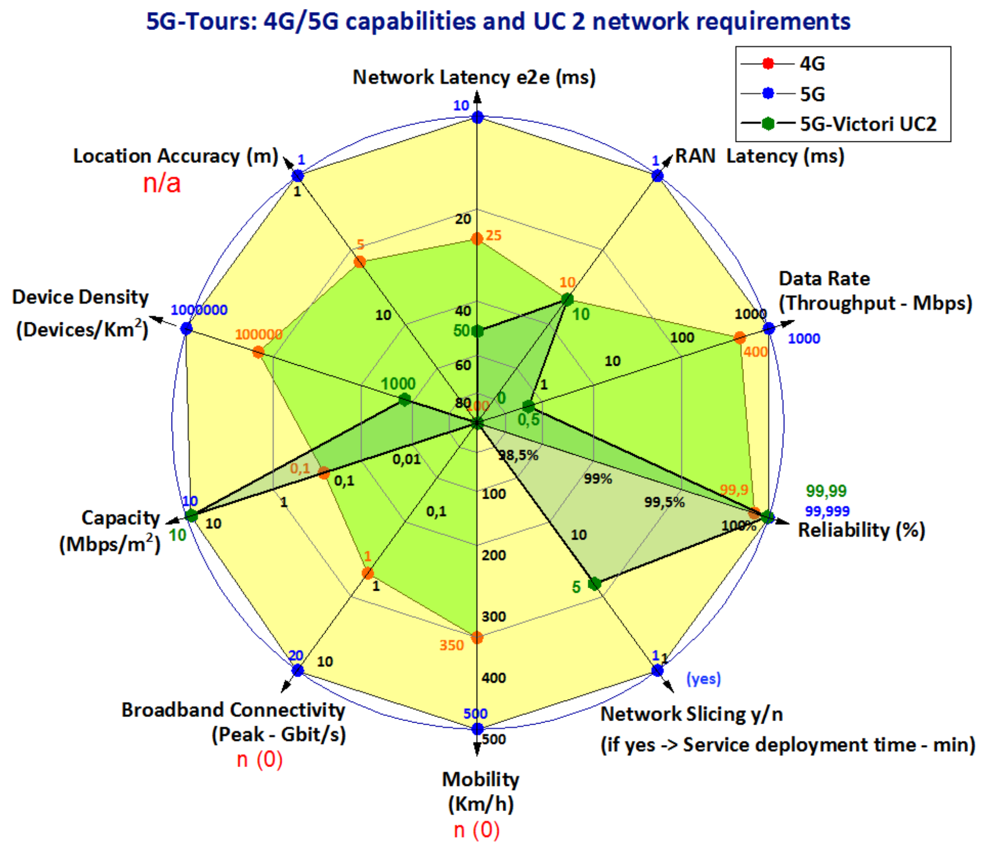


Figure 32: Radar Chart for 5G-Victori Use Case 2: Energy Metering for LV network requirements

The Use Case of Energy Metering only requires the improved Capacity of the 5G network. Slicing is something required, but it can also be achieved using similar 4G/LTE IoT network QoS mechanism. Such Use Cases/Service are needed in order to reduce the payback period of the 5G Networks.

9.6 5G-SOLUTIONS project use cases

9.6.1 5G-Solutions UC1 - Living Lab Smart Energy Technical Requirements Analysis

The general vertical use case requirements for the 5G-Solutions UC "Living lab smart energy" are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 33.

Table 32: 5G-Solutions Use Case 1 - Living Lab Smart Energy network requirements

5G-Solutions- Use Cases: direct specific technical requirements		Units	5G-Solutions Use Case: Living Lab Smart Energy			Priority	Range	
			URLLC	mMTC	eMMB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	10				1	10
2	**RAN Latency (in milliseconds) - one way**	msec	not critical					
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	not critical					
4	Reliability (%) - Min/Max	%	99,9999%				99,999%	99,9999%
5	Availability (%) - Min/Max	%	99,9990%				99,90%	99,9990%
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	not critical					
7	Broadband Connectivity (peak demand)	Y/N or Gbps	not critical					
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N	not critical					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	not critical					
10	Capacity (Mbps/m2 or Km2)	Mbps/m2	not critical					
11	Device Density	Dev/Km2	not critical					
12	Location Accuracy	m	not critical					

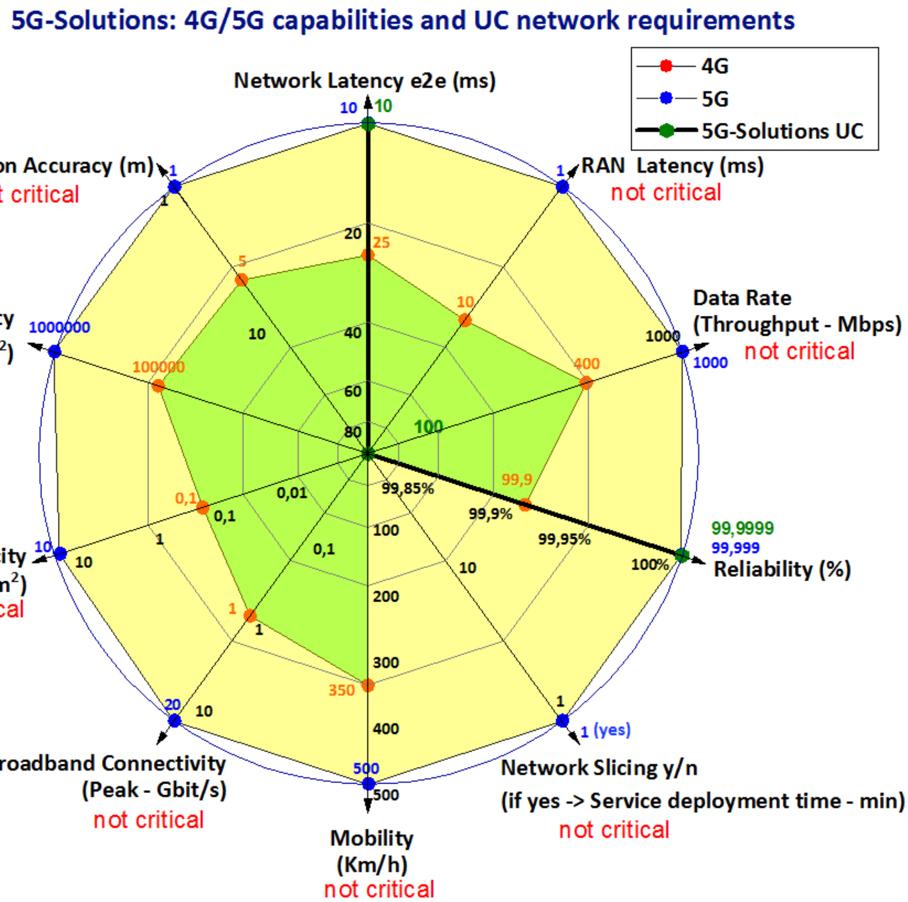


Figure 33: Radar Chart for 5G-Solutions Use Case Living Lab Smart Energy network requirements

The only critical network requirement that Smart Energy Living Lab Use Case needs from a 5G network is the Low Network Latency. Otherwise would be easily satisfied by existing 4G/LTE networks.

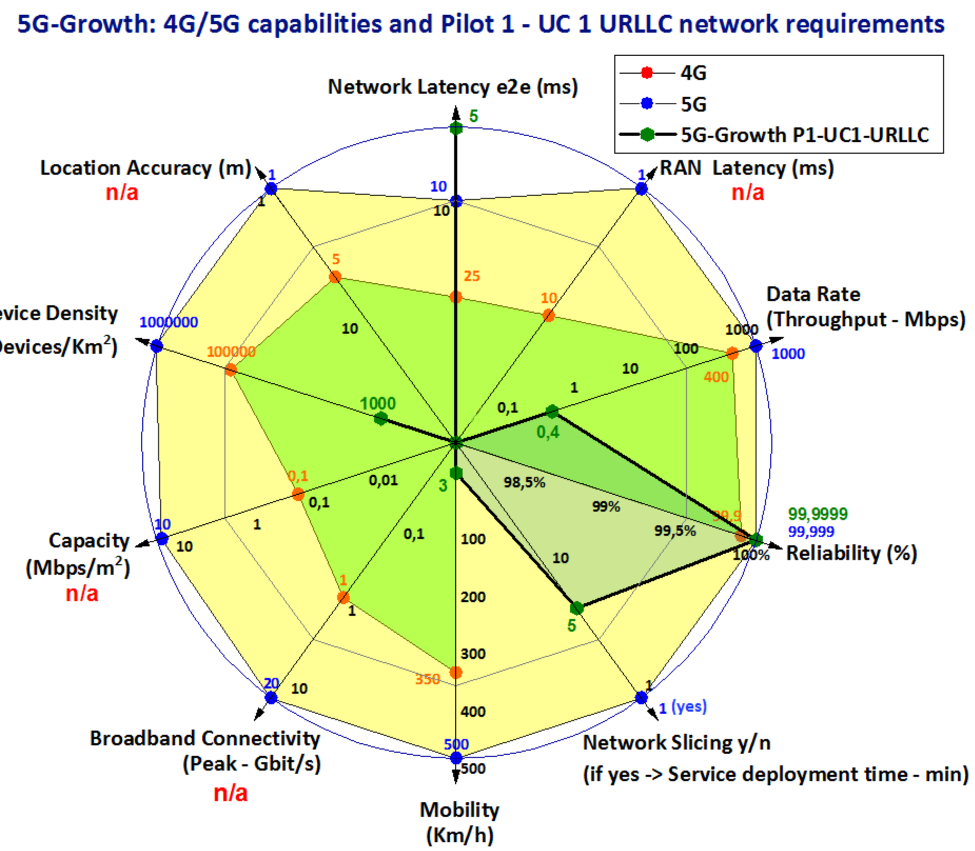
9.7 5G-GROWTH project use cases

9.7.1 5G-Growth Pilot1 - UC1 – Industry 4.0: Connected Worker Remote Operation of Quality Equipment Technical Requirements Analysis

The general vertical use case requirements for the 5G-Growth Pilot1 - UC1 are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 34.

Table 33: 5G-Growth Pilot1 – UC1 Industry 4.0: Connected Worker Remote Operation of Quality Equipment network requirements[7]

5G-Growth - Use Cases: direct specific technical requirements		Units	Industry 4.0: Connected Worker Remote Operation of Quality Equipment			Priority	Range	
			URLLC	mMTC	eMMB[10]		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	5		30			
2	**RAN** Latency (in milliseconds) - one way	msec						
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	0.128 - 0.4		100			
4	Reliability (%) - Min/Max	%	99.9999%					
5	Availability (%) - Min/Max	%	99.9999%					
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	3					
7	Broadband Connectivity (peak demand)	Y/N or Gbps			Y			
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N	Y (5)		Y (5)			
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y		Y			
10	Capacity (Mbps/m² or Km²)	Mbps/m²			20			
11	Device Density	Dev/Km²	1000					
12	Location Accuracy	m						



[7] The updated final figures published by 5GROWTH on October 31st are 99.99% for reliability/availability.

Figure 34: Radar Chart for 5G-Growth Pilot1 – UC1 Industry 4.0: Connected Worker Remote Operation of Quality Equipment (URLLC) network requirements

This Use Case of Remote Operation is focused in Ultra Reliable Communication but also in Ultra Low Network (round trip Latency). The 5 ms required for a round trip delay cannot be easily achieved even with a 5G network. Such low network latency limits the number of hops (or network elements) that can be inserted between the Operator (human) and the Actuator (equipment under control). Furthermore, limits the distance that tow (Operator and Equipment) can be located. For certain cases dedicated not only Slices but also Links should be provisioned, making implementation of such use case for large distances expensive.

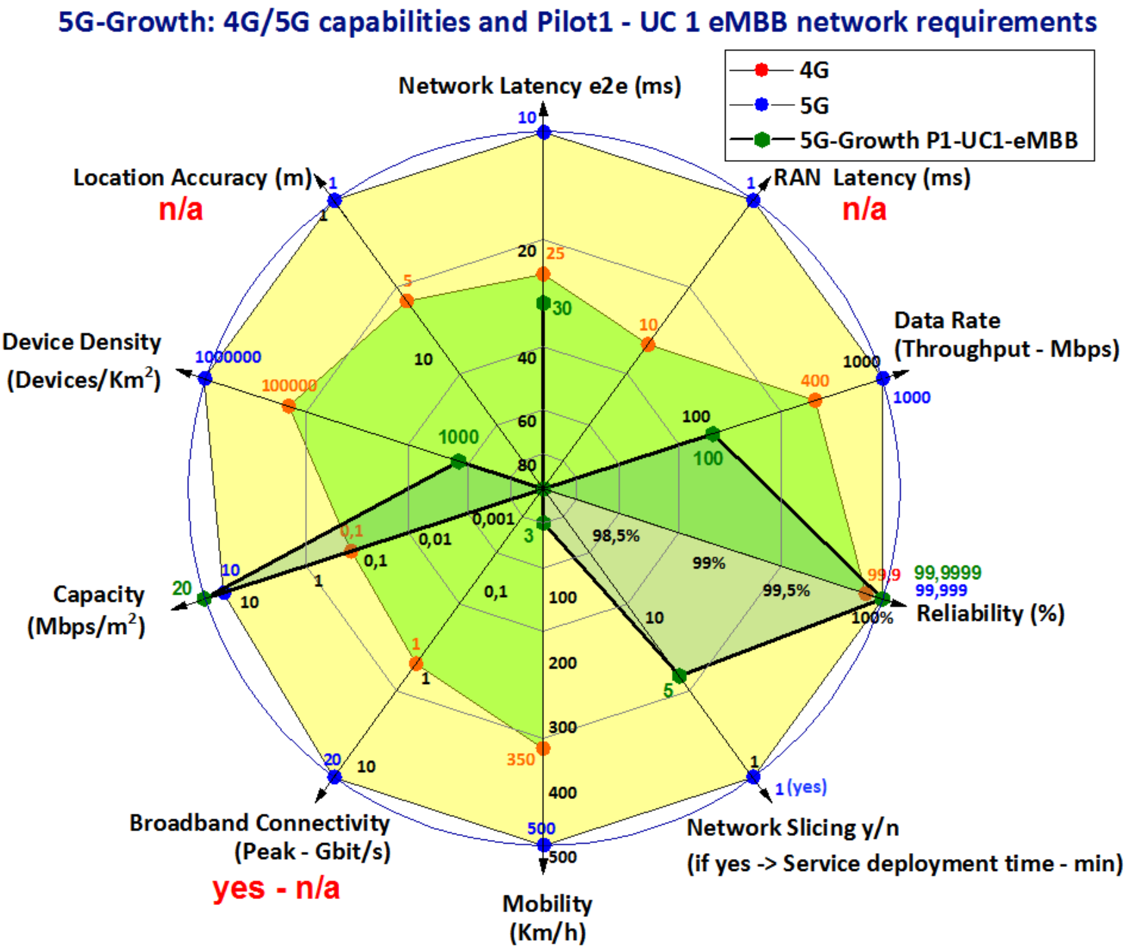


Figure 35: Radar Chart for 5G-Growth Pilot1 – UC1 Industry 4.0: Connected Worker Remote Operation of Quality Equipment (eMBB) network requirements

The second case of Remote Operation is focusing on delivery of High-Quality Video to the Operator and in this case, the parameters dictate the use of 5G network.

- Capacity,
- Reliability and support of
- Network Slicing are the only

9.7.2 5G-Growth Pilot1 - UC2 – Industry 4.0: Connected Worker Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS) Technical Requirements Analysis

The general vertical use case requirements for the 5G-Growth Pilot1 – UC2 are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 36.

Table 34: 5G-Growth Pilot1 – UC2 Industry 4.0: Connected Worker Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS) network requirements[8]

5G-Growth - Use Cases: direct specific technical requirements		Units	Industry 4.0: Connected Worker Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS)			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec			5			
2	**RAN** Latency (in milliseconds) - one way	msec						
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps			1			
4	Reliability (%) - Min/Max	%			99.99999%			
5	Availability (%) - Min/Max	%			99.99999%			
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h			3-50			
7	Broadband Connectivity (peak demand)	Y/N or Gbps			Y (1Gbps)			
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N			Y (5)			
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N			Y			
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2			200			
11	Device Density	Dev/Km^2			low (10)			
12	Location Accuracy	m						

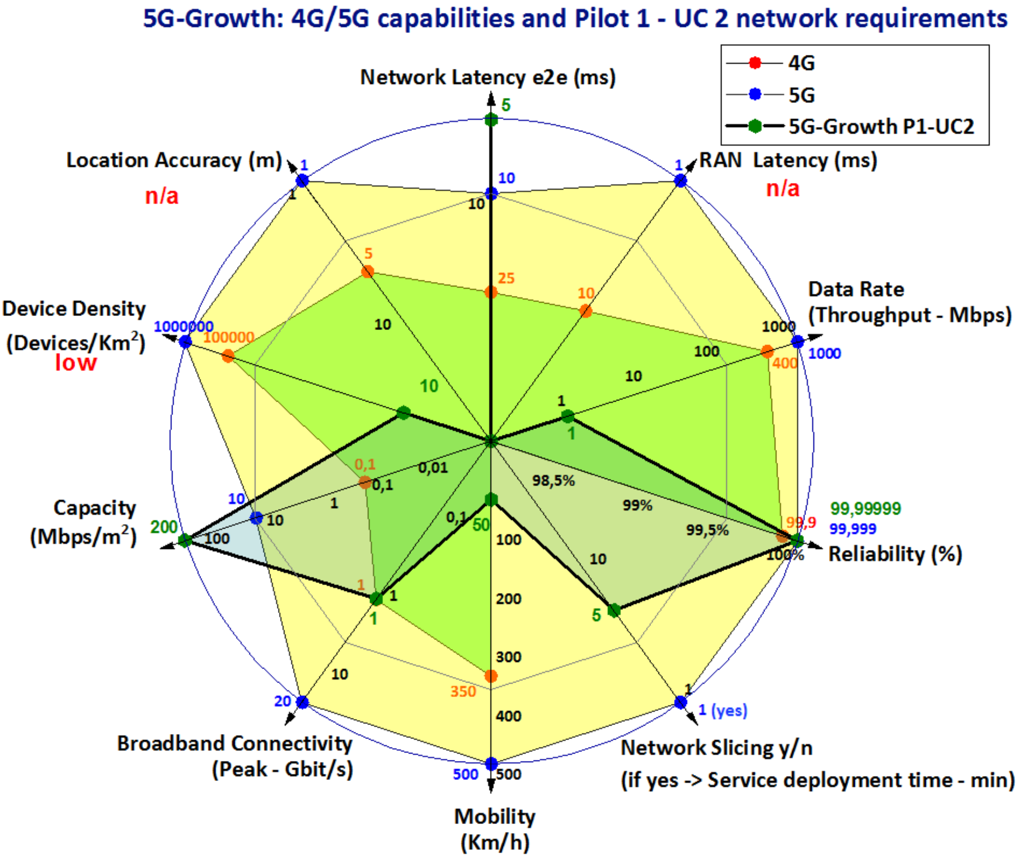


Figure 36: Radar Chart for 5G-Growth Pilot1 – UC2 Industry 4.0: Connected Worker Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS) network requirements

Similarly, to the Use Case above, the

- Capacity,
- Reliability and

[8] The updated final figures published by 5GROWTH on October 31st are 99.99% for reliability/availability.

- Network Slicing

are the only requirements expected from the 5G Network.

The 5 ms required for a round trip delay cannot be easily achieved even with a 5G network. Such low network latency limits the number of hops (or network elements) that can be inserted between the Operator (human) and the Actuator (equipment under control). Furthermore, limits the distance that the Operator and Equipment can be located. For certain cases dedicated not only Slices but also Links should be provisioned, making implementation of such use case for large distances expensive.

9.7.3 5G-Growth Pilot2 - UC1 – Industry 4.0: Digital Twin Apps Technical Requirements Analysis

The general vertical use case requirements for the 5G-Growth Pilot2 – UC1 are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 37.

Table 35: 5G-Growth Pilot2 – UC1 Industry 4.0: Digital Twin Apps network requirements

5G-Growth - Use Cases: direct specific technical requirements		Units	Industry 4.0: Digital Twin Apps			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	15					
2	**RAN** Latency (in milliseconds) - one way	msec						
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	250					
4	Reliability (%) - Min/Max	%	99.99999%					
5	Availability (%) - Min/Max	%	99.99999%					
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	3-50					
7	Broadband Connectivity (peak demand)	Y/N or Gbps	Y					
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N	Y (5)					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	N					
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	50					
11	Device Density	Dev/Km^2	5000					
12	Location Accuracy	m						

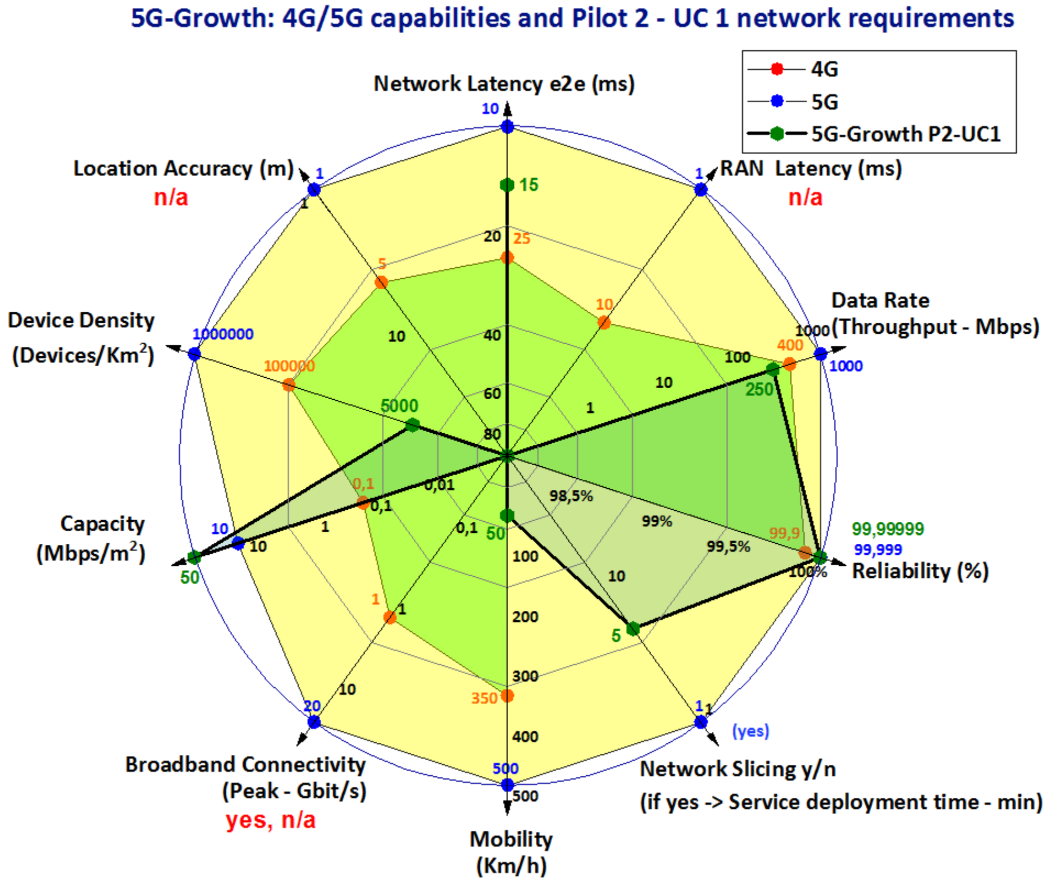


Figure 37: Radar Chart for 5G-Growth Pilot2 – UC1 Industry 4.0: Digital Twin Apps network requirements

The Digital Twin App Use Case requires improved

- Capacity,
- Reliability and support of
- Network Slicing

from the 5G Network, that cannot be delivered using 4G/LTE.

9.7.4 5G-Growth Pilot2 – UC2 – Industry 4.0: Telemetry/Monitoring Apps Requirements Analysis

The general vertical use case requirements for the 5G-Growth Pilot2 – UC2 are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 38.

Table 36: 5G-Growth Pilot2 – UC2 Industry 4.0: Telemetry/Monitoring Apps network requirements

5G-Growth - Use Cases: direct specific technical requirements		Units	Industry 4.0: Telemetry/Monitoring Apps			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec		3				
2	**RAN** Latency (in milliseconds) - one way	msec						
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps		250				
4	Reliability (%) - Min/Max	%		99.99999%				
5	Availability (%) - Min/Max	%		99.99999%				
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h		3-50				
7	Broadband Connectivity (peak demand)	Y/N or Gbps		Y				
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N		Y (5)				
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N		N				
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2		50				
11	Device Density	Dev/Km^2		5000				
12	Location Accuracy	m						

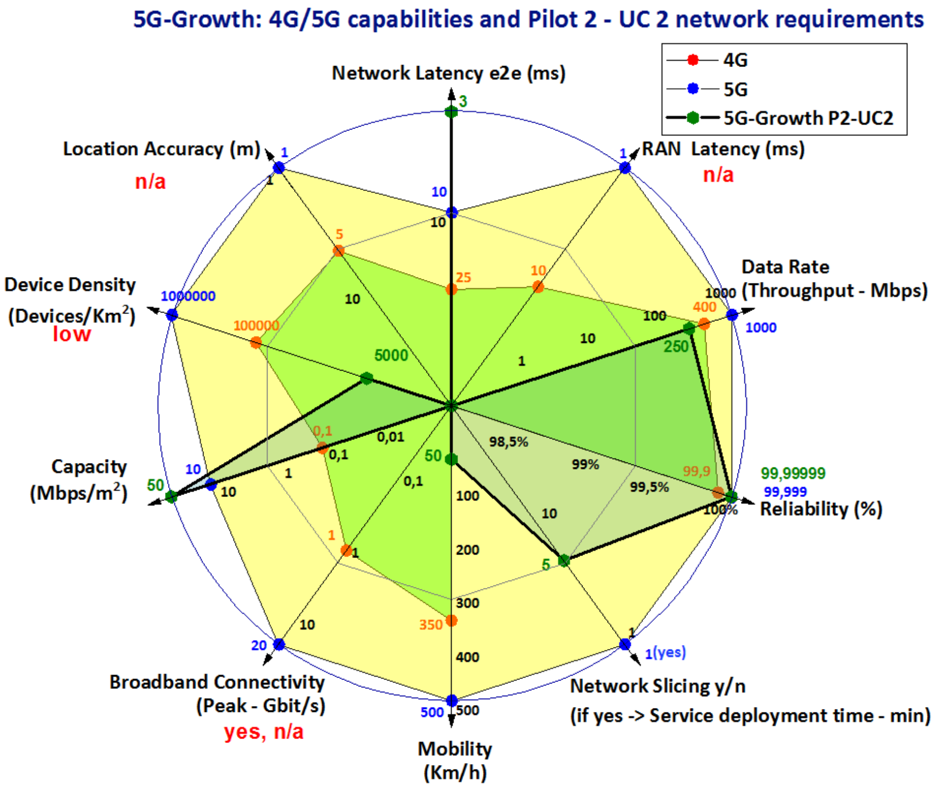


Figure 38: Radar Chart for 5G-Growth Pilot2 – UC2 Industry 4.0: Telemetry/Monitoring Apps network requirements

The Use Case of Telemetry/Monitoring requires a 5G Network due to the expectations in

- Capacity,
- Reliability and
- Network Slicing

The 3 ms required for a Network round trip delay stretches the capabilities of even 5G networks. Such low network latency limits the number of hops (or network elements) that can be inserted between the System Under Observation (SUO) and the Operating Center. Furthermore, limits the distance that the (Sensors and Platforms) can be located. For certain cases dedicated not only Slices but also Links should be provisioned, making implementation of Telemetry/Monitoring for large distances expensive. Such Low Round Trip Latency can be easily be achieved in LAN type Environments or Private 5G Networks.

9.7.5 5G-Growth Pilot2 – UC3 – Industry 4.0: Digital Tutorials and Remote Support Requirements Analysis

The general vertical use case requirements for the 5G-Growth Pilot2 – UC3 are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 39.

Table 37: 5G-Growth Pilot2 – UC3 – Industry 4.0: Digital Tutorials and Remote Support network requirements

5G-Growth - Use Cases: direct specific technical requirements		Units	Industry 4.0: Digital Tutorials and Remote Support			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec			50			
2	**RAN** Latency (in milliseconds) - one way	msec						
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps			500			
4	Reliability (%) - Min/Max	%			99.99999%			
5	Availability (%) - Min/Max	%			99.99999%			
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h			3			
7	Broadband Connectivity (peak demand)	Y/N or Gbps			Y			
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N			Y (5)			
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N			N			
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2			100			
11	Device Density	Dev/Km^2			1000			
12	Location Accuracy	m						

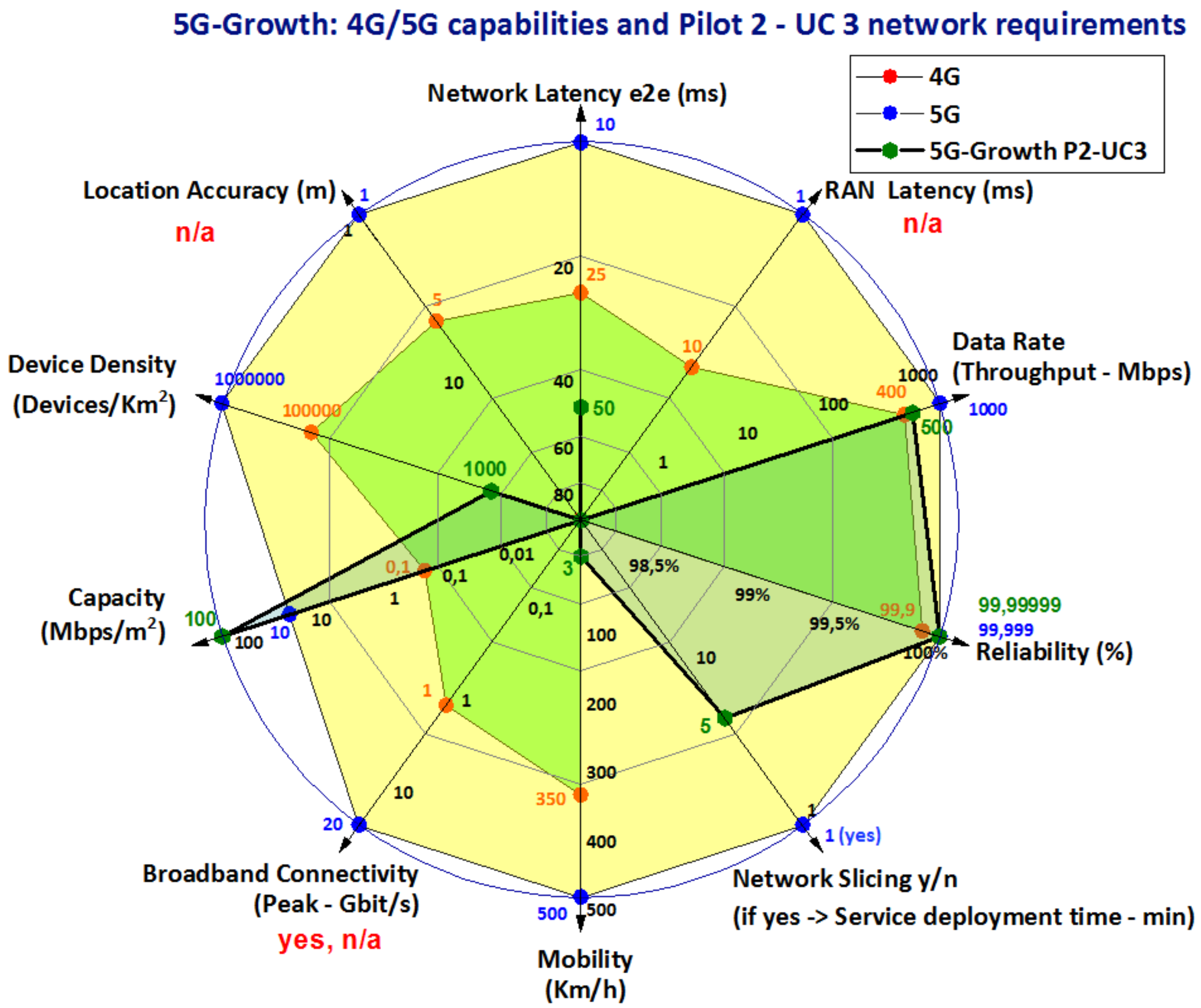


Figure 39: Radar Chart for 5G-Growth Pilot2 – UC3 – Industry 4.0: Digital Tutorials and Remote Support network requirements

The Digital Tutorial Use Case needs the 5G Network only due to the

- Throughput
- Reliability,
- Support of Network Slicing and
- Capacity requirements.

9.7.6 5G-Growth Pilot3 – UC1 – Transportation: Safety Critical Communications Requirements Analysis

The general vertical use case requirements for the 5G-Growth Pilot3 – UC1 are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 40.

Table 38: 5G-Growth Pilot3 – UC1 – Transportation: Safety Critical Communications network requirements

5G-Growth - Use Cases: direct specific technical requirements		Units	Transportation: Safety Critical Communications			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	10					
2	**RAN** Latency (in milliseconds) - one way	msec						
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	1.2					
4	Reliability (%) - Min/Max	%	99,99%					
5	Availability (%) - Min/Max	%	99,99%					
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	N					
7	Broadband Connectivity (peak demand)	Y/N or Gbps	N					
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N	Y (5)					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y					
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	1					
11	Device Density	Dev/Km^2	low (10)					
12	Location Accuracy	m						

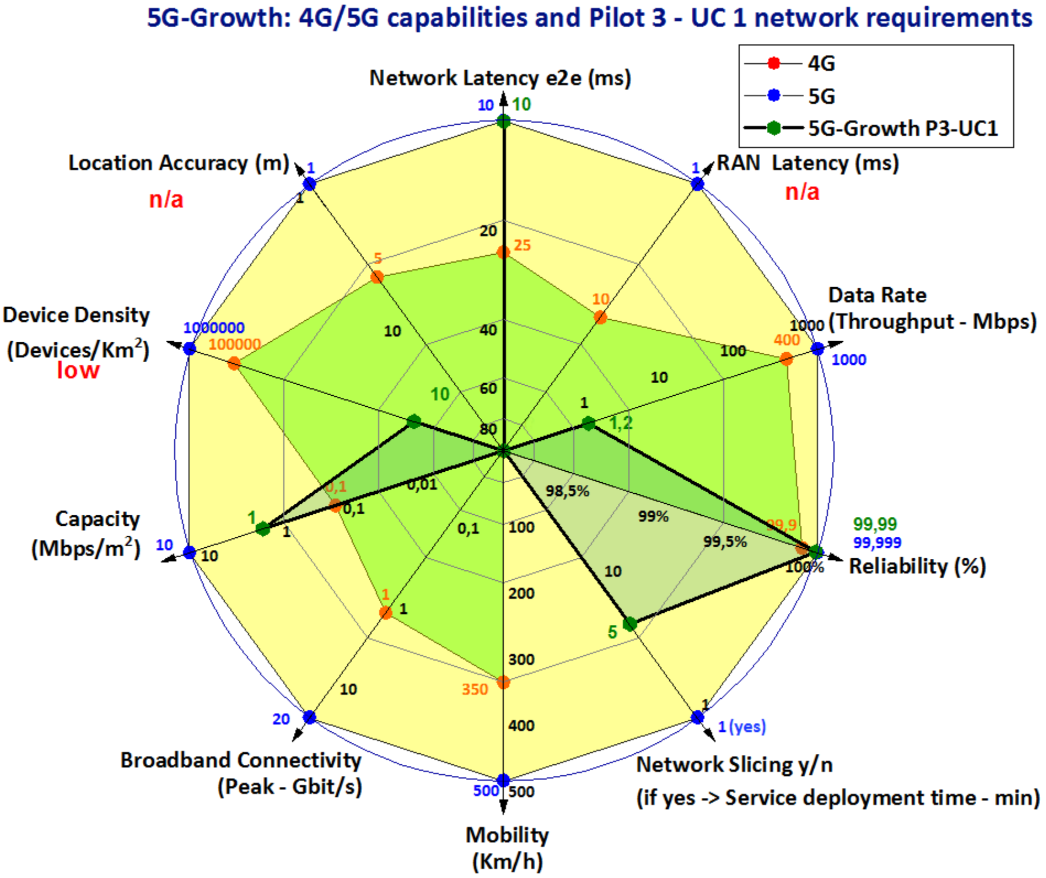


Figure 40: Radar Chart for 5G-Growth Pilot3 – UC1 – Transportation: Safety Critical Communications network requirements

Reliability and Capacity together with support of Network Slices are the requirements that the 5G Network is called to provide for the Transportation Safety Critical Communication Network Use Case.

9.7.7 5G-Growth Pilot3 – UC2 – Transportation: Non-Safety Critical Communications Requirements Analysis

The general vertical use case requirements for the 5G-Growth Pilot3 – UC2 are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 41.

Table 39: 5G-Growth Pilot3 – UC2 – Transportation: Non-Safety Critical Communications network requirements

5G-Growth - Use Cases: direct specific technical requirements		Units	Transportation: Non-Safety Critical Communications			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec			10			
2	**RAN** Latency (in milliseconds) - one way	msec						
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps			120			
4	Reliability (%) - Min/Max	%			99,99%			
5	Availability (%) - Min/Max	%			99,99%			
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h			160			
7	Broadband Connectivity (peak demand)	Y/N or Gbps			Y			
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N			Y (5)			
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N			Y			
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2			60			
11	Device Density	Dev/Km^2			low (10)			
12	Location Accuracy	m						

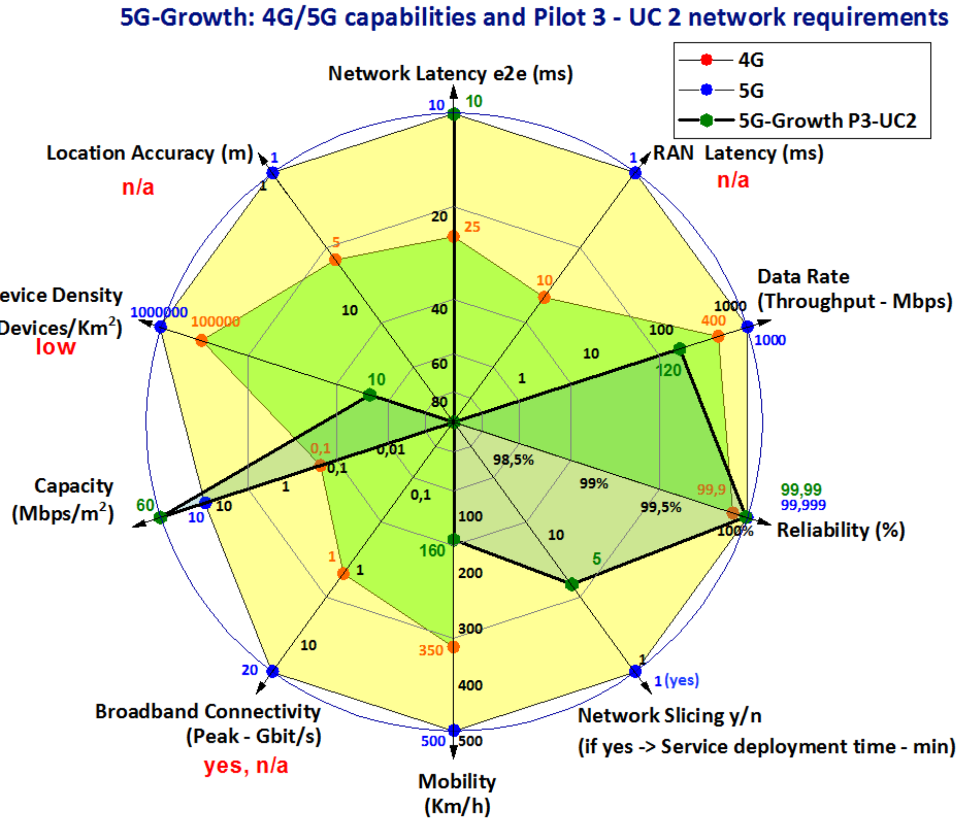


Figure 41: Radar Chart for 5G-Growth Pilot3 – UC2 – Transportation: Non-Safety Critical Communications network requirements

Similarly to the previous UC, Reliability and Capacity together with support of Network Slices are the requirements that the 5G Network is called to provide for the Transportation Non-Safety Critical Communication Network Use Case

9.7.8 5G-Growth Pilot4 – UC1 – Energy: Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV distribution substation Requirements Analysis

The general vertical use case requirements for the 5G-Growth Pilot4 – UC1 are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 42.

Table 40: 5G-Growth Pilot4 – UC1 – Energy: Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV distribution substation network requirements

5G-Growth - Use Cases: direct specific technical requirements		Units	Energy: Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV distribution substation			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec			100			
2	**RAN** Latency (in milliseconds) - one way	msec						
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps			100			
4	Reliability (%) - Min/Max	%			99,99%			
5	Availability (%) - Min/Max	%			99,99%			
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h			120			
7	Broadband Connectivity (peak demand)	Y/N or Gbps			Y			
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N			Y (5)			
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N			Y			
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2			10			
11	Device Density	Dev/Km^2			low (10)			
12	Location Accuracy	m						

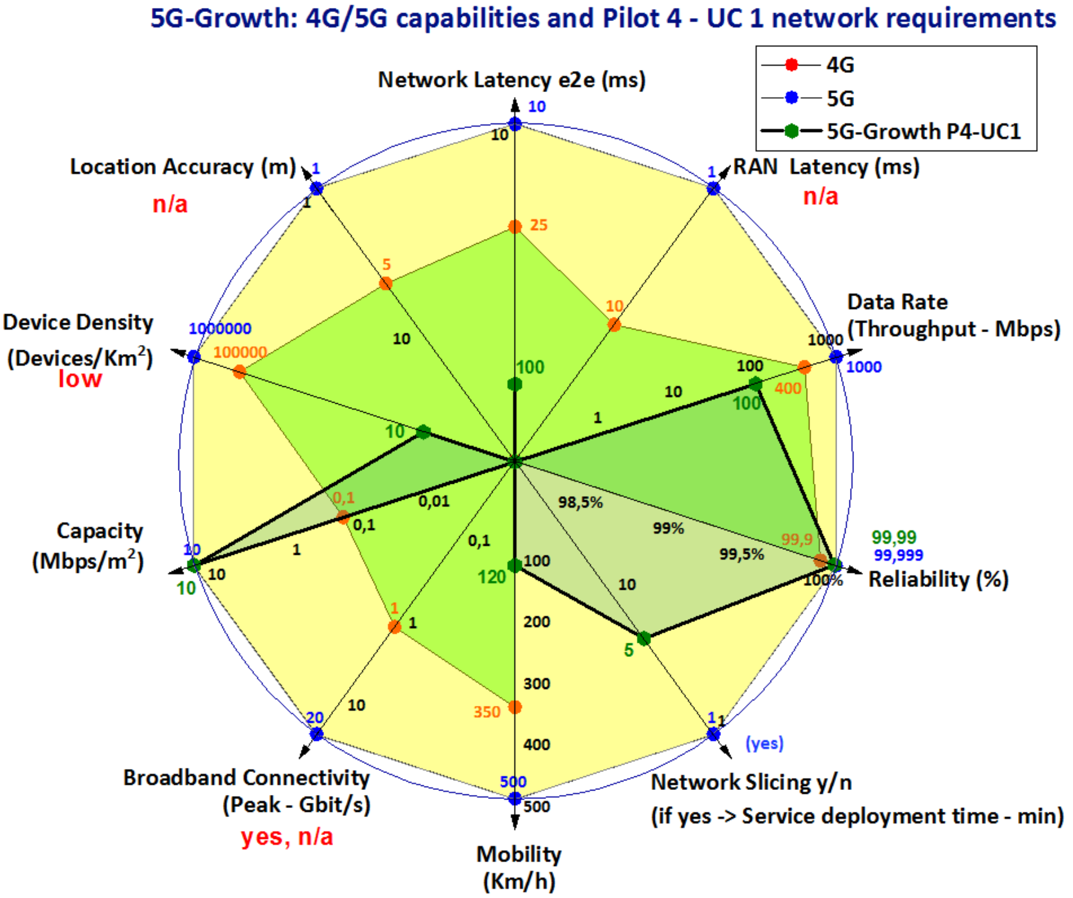


Figure 42: Radar Chart for 5G-Growth Pilot4 – UC1 – Energy: Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV distribution substation network requirements

Similarly to the previous UC, Reliability and Capacity together with support of Network Slices are the requirements that the 5G Network is called to provide for the Energy: Advanced Monitoring and Maintenance Support for Secondary Substation Medium Voltage/Low Voltage Use Case.

9.7.9 5G-Growth Pilot4 – UC2 – Energy: Advanced critical signal and data exchange across wide smart metering and measurement infrastructures Requirements Analysis

The general vertical use case requirements for the 5G-Growth Pilot4 – UC2 are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 43.

Table 41: 5G-Growth Pilot4 – UC2 – Energy: Advanced critical signal and data exchange across wide smart metering and measurement infrastructures network requirements

5G-Growth - Use Cases: direct specific technical requirements		Units	Energy: Advanced critical signal and data exchange across wide smart metering and measurement infrastructures			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	1 (sync.), 5 (last gasp), 20 (control plane)					
2	RAN Latency (in milliseconds) - one way	msec						
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	1					
4	Reliability (%) - Min/Max	%	99,99%					
5	Availability (%) - Min/Max	%	99,99%					
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	N					
7	Broadband Connectivity (peak demand)	Y/N or Gbps	N					
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N	Y (5)					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y					
10	Capacity (Mbps/m² or Km²)	Mbps/m²	low (0.01)					
11	Device Density	Dev/Km²	low (10)					
12	Location Accuracy	m						

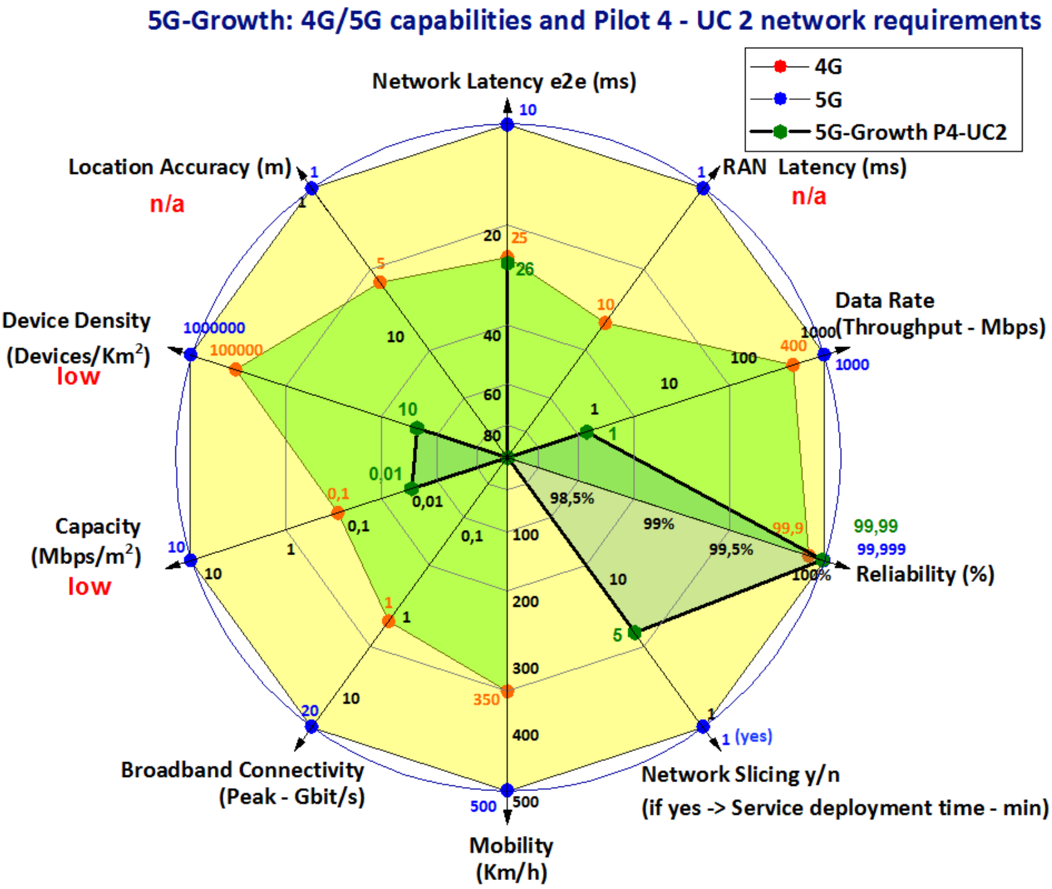


Figure 43: Radar Chart for 5G-Growth Pilot4 – UC2 – Energy: Advanced critical signal and data exchange across wide smart metering and measurement infrastructures network requirements

The Use Case of "Energy: Advanced critical signal and data exchange across wide smart metering and measurement infrastructures" does NOT require a 5G network. The requirement of a dedicated network slice can be fulfilled with other 4G/LTE QoS / Security mechanism. This is an example of a Use Case that is needed in order (due to the revenues) to shorten the payback time for building the 5G networks.

9.8 5G-DRONES project use cases

9.8.1 5G-Drones UC1 – UTM Command and control application Technical Requirements Analysis

The general vertical use case requirements for the 5G-Drones UC1 "UTM command and control application" are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 44.

Table 42: 5G-Drones Use Case 1 – UTM Command and control application network requirements

5G-Drones - Use Cases: direct specific technical requirements		Units	Use Case: UTM Command and control application			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	around 5 ms					
2	**RAN Latency (in milliseconds) - one way**	msec	1ms					
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	around 50 kbit/s					
4	Reliability (%) - Min/Max	%	99,9999%					
5	Availability (%) - Min/Max	%	99,9999%					
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	N/A					
7	Broadband Connectivity (peak demand)	Y/N or Gbps	100 kbit					
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N	Y (5)					
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y					
10	Capacity (Mbps/m2 or Km2)	Mbps/m2	N/A					
11	Device Density	Dev/Km2	To be defined					
12	Location Accuracy	m	N/A					
Specific Vertical/Use Case Requirements								
Network	**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 / QoS (1-8, more)							
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**		Flying drones					
	Bitrate required (Kbps / Mbps / Gbps)		Kbps					
	Max Latency Allowable (in msecs)		5 ms					
	Max Moving Speed (km/h, 0 if stationary)		To be defined					
	IPv4 & IPv6 support (or both)		IPv4					
	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					
(non-Network related Requirements)								
	i.e Battery life requirement		N/A					

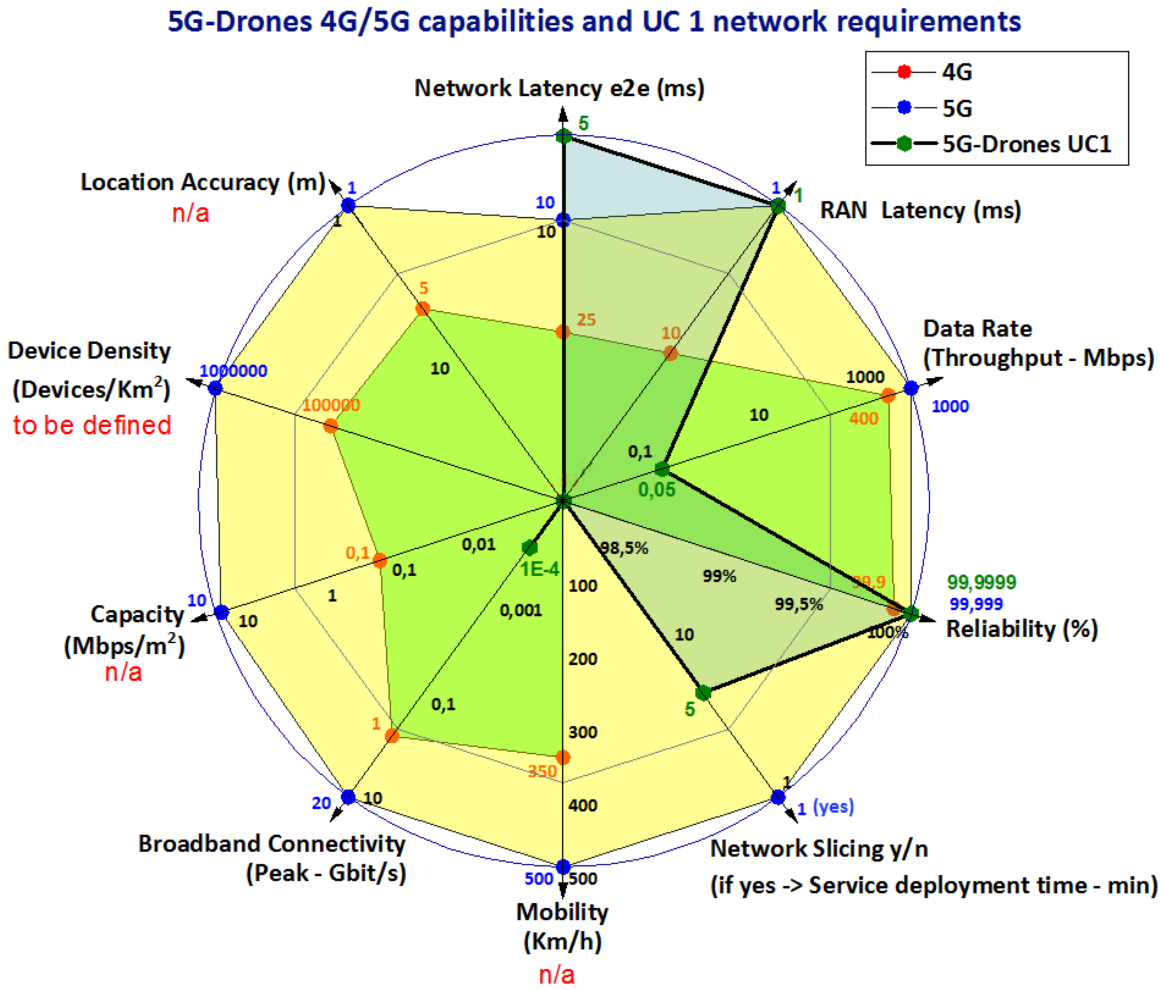


Figure 44: Radar Chart for 5G-Drones Use Case UTM Command and control application network requirements

The UTM command and Control Use Case, needs the 5G network for providing the

- Low Network Latency,
- RAN Latency,
- High Reliability and.
- Dedicated Slice.

The 5 ms required for a round trip delay cannot be easily achieved even with a 5G network. Such low network latency limits the number of hops (or network elements) that can be inserted between the Operator (human) and the Drone, unless there is an Autonomous Drone in which case Edge Cloud/Computing should be provided. Furthermore, limits the distance that the Operator and Equipment can be located. For certain cases, dedicated not only Slices but also Links (wireless and/or wired) should be provisioned.

9.8.2 5G-Drones UC2 – Public Safety Technical Requirements Analysis

The general vertical use case requirements for the 5G-Drones UC2 “Public Safety” are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 45.

Table 43: 5G-Drones Use Case 2 – Public Safety network requirements

5G-Drones - Use Cases: direct specific technical requirements		Units	Use Case: Public Safety			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	around 5 ms					
2	**RAN Latency (in milliseconds) - one way**	msec	1ms					
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	around 50 kbps		up to 20 Mbps			
4	Reliability (%) - Min/Max	%	99,9999%		90,000%			
5	Availability (%) - Min/Max	%	99,9999%		99,9999%			
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	N/A		N/A			
7	Broadband Connectivity (peak demand)	Y/N or Gbps	100 kbit		100 Mbps%			
8	Network Slicing (Y/N) - if Y service deployment time (m	Y/N	Y (5)		Y			
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y		Y			
10	Capacity (Mbps/m2 or Km2)	Mbps/m2	N/A		N/A			
11	Device Density	Dev/Km2	To be defined		To be defined			
12	Location Accuracy	m	N/A		N/A			
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 / QoS (1-8, more)							
End Devices	**Type of Device (i.e. Smartphone, TV, VR)**		Flying drones					
	Bitrate required (Kbps / Mbps / Gbps)		Kbps					
	Max Latency Allowable (in msecs)		5 ms		100			
	Max Moving Speed (km/h, 0 if stationary)		To be defined					
	IPv4 & IPv6 support (or both)		IPv4					
	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					
non-Network related Requirements)								
	i.e Battery life requirement		N/A					

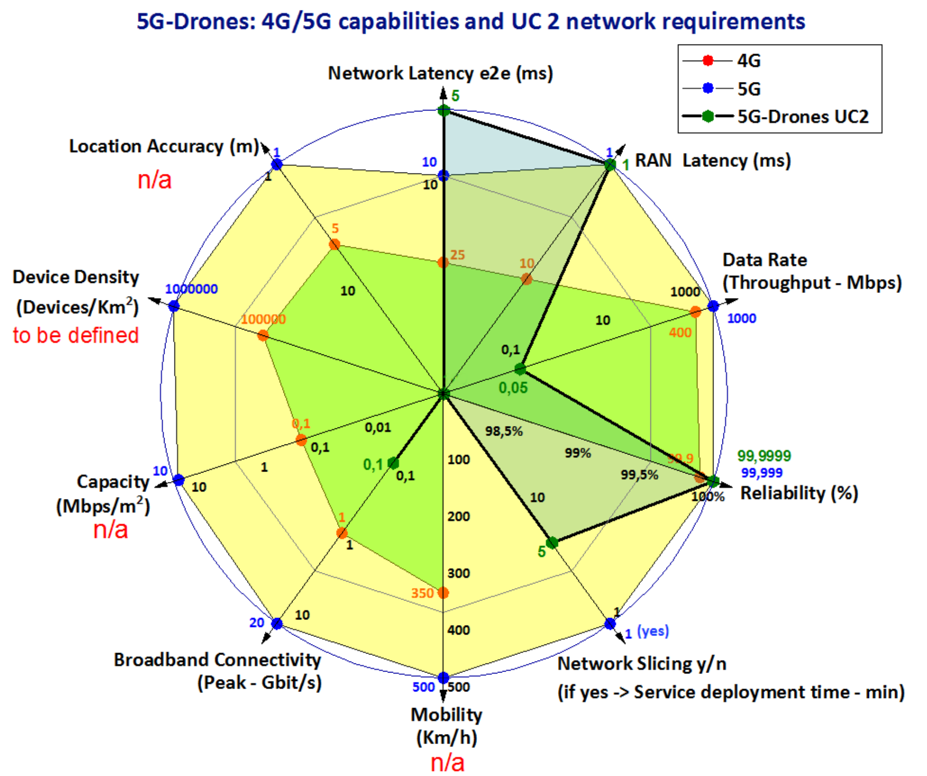


Figure 45: Radar Chart for 5G-Drones Use Case Public Safety network requirements

The 5G-Drones Public Safety Use Case, needs the 5G network for providing the

- Low Network Latency,

- RAN Latency,
- High Reliability and.
- Dedicated Slice.

The 5 ms required for a round trip delay cannot be easily achieved even with a 5G network. Here the same limitation holds as in the previous Use Cases. Most probably the use of Edge Cloud/Computing should be investigated.

9.9 5G-DRIVE project use cases

9.9.1 5G-Drive UC – eMBB Service Requirements Analysis

The general vertical use case requirements for the 5G-Drive UC "eMBB Service" are shown in table shown below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 46.

Table 44: 5G-Drive Use Case – eMBB Service network requirements

5G-EVE - Use Cases: direct specific technical requirements		Units	Use Case: 5G-DRIVE eMBB service			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec			10		5	50
2	**RAN Latency (in milliseconds) - one way**	msec			n/a			
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps			200		100	500
4	Reliability (%) - Min/Max	%			n/a			
5	Availability (%) - Min/Max	%			n/a			
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h			50		0	80
7	Broadband Connectivity (peak demand)	Y/N or Gbps			Y			
8	Network Slicing (Y/N) - if Y service deployment time (mi	Y/N			Y (10)			
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N			n/a			
10	Capacity (Mbps/m2 or Km2)	Mbps/m2			n/a			
11	Device Density	Dev/Km2			5			
12	Location Accuracy	m			n/a			

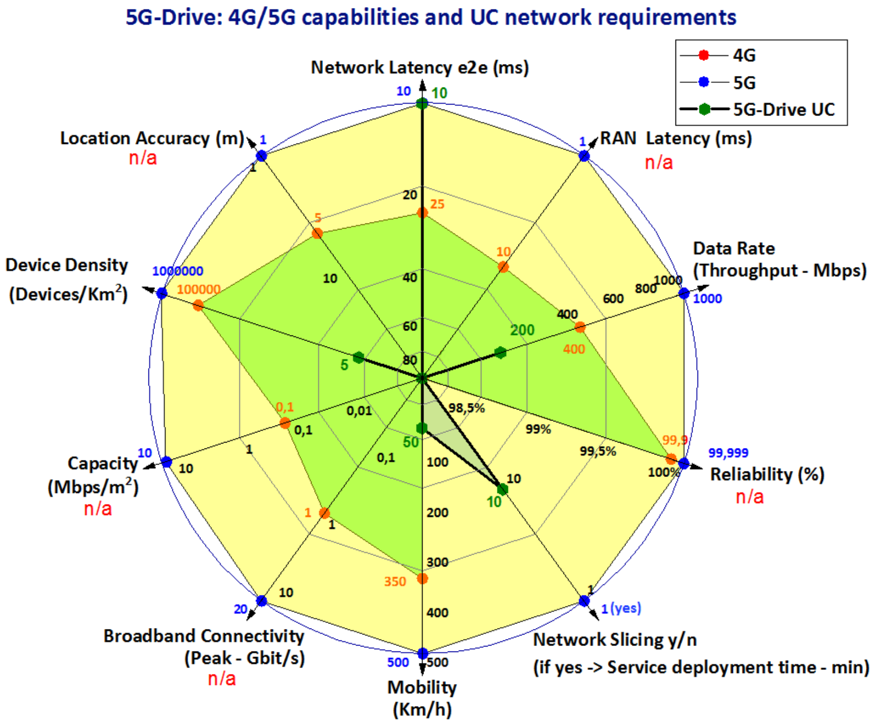


Figure 46: Radar Chart for 5G-Drive Use Case eMBB Service network requirements

The fact that provisioning of Network Slicing is the only 5G Network requirement that the Use Case demands, while all other requirements can be fulfilled using existing 4G/LTE networks lead to the conclusion that this is another Use Case that the 5G Network will benefit from and not the other way around.

10 Conclusions

This report serves as the interface between 5G-EVE and all ICT-19/22 Projects. In total 32 Use Cases from 5G-TOURS, 5G-HEART, 5G-VICTORY, 5G-SOLUTIONS, 5GROWTH, 5G-DRONE and 5G-DRIVE were briefly presented, and the Network Requirements were Collected, Normalized, Processed and Analysed.

The Result of the Analysis is shown in Section 9 together with the 32 Radar Charts for each UC. The percentage of the overall requirements that are being covered by existing technologies (4G/LTE) and those that need the 5G capabilities is shown on Table 45.

Table 45: Network requirements analysis overview

Network Requirements	Covered by 4G	Need 5G	Exceed 5G
Network Latency (e2e)	28,1%	71,9%	30,4%
RAN Latency (one way)	50,0%	50,0%	0,0%
Throughput	90,6%	9,4%	0,0%
Reliability	6,3%	93,8%	60,0%
Network Slicing	9,4%	90,6%	0,0%
Mobility	100,0%	0,0%	0,0%
Broadband Connectivity	90,6%	9,4%	0,0%
Capacity	43,8%	56,3%	66,7%
Device Density	90,6%	9,4%	0,0%
Location Accuracy	53,1%	46,9%	60,0%

In brief, as also shown in Figure 48 below the most requested network capability is Reliability. Second most requested capability is the support of Network Slicing.

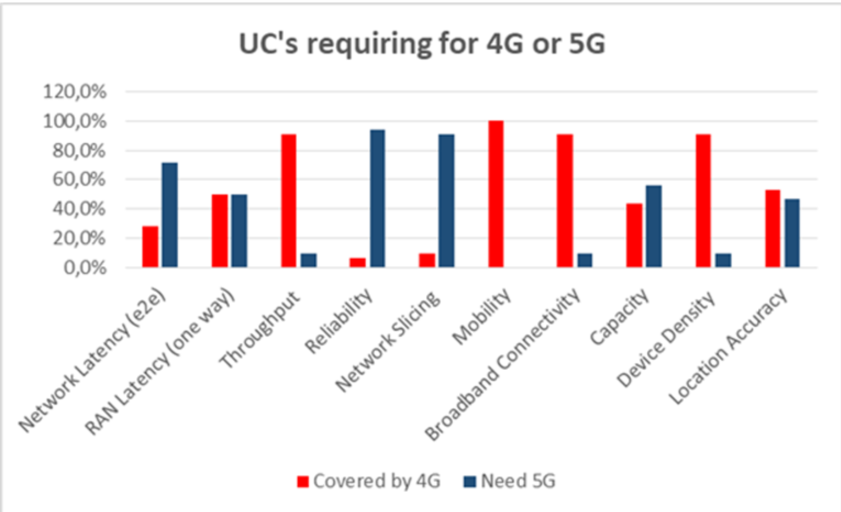


Figure 47 Request capabilities in terms of mobile technologies.

As mentioned also in the Analysis some UCs requirements exceed even the capabilities of the 5G Networks. These demanding requirements are mainly in term (shorted in term of demand) of Capacity, Location Accuracy, Reliability and finally Network Latency, as shown also in the Figure 49.

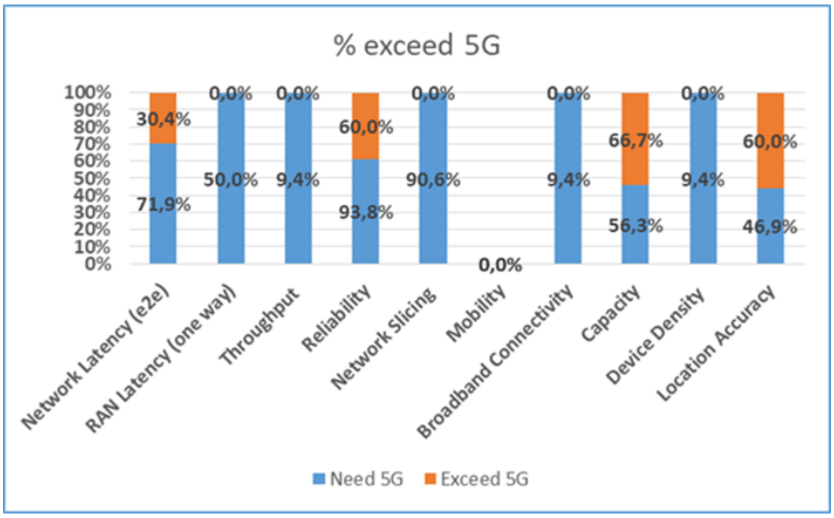


Figure 48 Use cases requesting capabilities beyond 5G.

The solution for satisfying the extra required Capacity is usually to carefully plan the Radio Access Network and expanding the Network throughput Resources. The answer to provide the ultra-high Location Accuracy is described in the analysis and is to consider (if the requirement cannot be relaxed) other positioning modalities. The solution is complicated when mobility is also required. The extra Reliability can be addressed by planning, redundancy in resources and higher quality equipment / components at the expense of price. Finally, the Network Latency can also be improved at a cost or imposes limits to the location and distance between the actors of certain Use Cases (like distance between Operator and Machine). The analysis performed in this report is a valuable insight into what and how the 5G Network technologies should focus on in order to better sever the needs of the end-users.

11 Acknowledgments

We would like to thank all the participants from the ICT-19/22 Projects that have provided input and feedback for this Deliverable.

12 References

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