5G smarT mObility, media and e-health for toURists and citizenS

Deliverable D6.1
5G-enabled solutions for mobility-efficient cities

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List of Acronyms and Abbreviations

Acronym	Description
3GPP	Third Generation Partnership Project
ADO	Airport Duty Officer
AGV	Automatically Guided Vehicles
AI	Artificial Intelligence
AIA	Athens International Airport
AMIS	Airside Monitoring Inspection Specialist
AOC	Airport Operation Center
AP	Access Point
API	Application Programming Interface
AR	Augmented Reality
ASOC	Airport Service Operations Center
BBU	Baseband Unit
BS	Base Station
CN	Core Network
CPRI	Common Public Radio Interface
E2E	End-to-end
EA	Ellinogermaniki Agogi School Panagea Savva S.A.
eMBB	enhanced Mobile Broadband
eMBMS	enhanced Multimedia Broadcast Multicast Service
eNB	enhanced Node B
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Duplexing
FTP	File Transfer Protocol
GPRS	General Packet Radio Services
GPS	Global Positioning System
GUI	Graphical User Interface
HDFS	Hadoop Distributed File System
HSS	Home Subscriber Server
ICAO	International Civil Aviation Organization
ICT	Information and Communication Technology
IoT	Internet of Things
IP	Internet Protocol
KPI	Key Performance Indicator
KVaP	KPI Validation Platform
LPWAN	Low Power Wide Area Networks
LoRA	Long Range
LTE / -A	Long Term Evolution / -Advanced
LWM2M	Lightweight M2M
M2M	Machine to Machine
MANO	Management and Organization
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
mMTC	massive Machine Type Communications
MP	Mega Pixel
mRRH	Massive Remote Radio Head
NB-IoT	Narrowband IoT
NFV	Network Functions Virtualization
NFVI	NFV Infrastructure
NFVM	NFV Management
NFVO	NFV Orchestrator
NR	New Radio
NoSQL	Not only SQL
NSA	Non-Standalone
OMA	Open Mobile Alliance
OTE	Organismos Tilepikininonion Ellados (Hellenic Telecom Organization)
PCB	Printed Circuit Board
PCRF	Policy and Charging Rules Function

PRM	Passengers with Reduced Mobility
PTP	Precision Time Protocol
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
S-/P-GW	Serving / Packet Gateway
SCTP	Stream Control Transmission Protocol
SDS	Security Duty Supervisor
SGSN	Serving GPRS Support Node
SIM	Subscriber Identity Module
SOM	Self-Organizing Maps
TCP	Transmission Control Protocol
UC	Use Case
UE	User Equipment
UI	User Interface
URLLC	Ultra-Reliable Low-Latency Communications
vEPC	virtual EPC
VIM	Virtualized Infrastructure Management
VLAN	Virtual Local Area Network
VNF	Virtual Network Function
VNFC	VNF Components
VoLTE	Voice over LTE
VPN	Virtual Private Network
VR	Virtual Reality
VS	Vertical Slicer
WG	Working Group

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Executive Summary

One of the three main themes addressed by the 5G-TOURS project is the mobility-efficient city, which aims at presenting a set of use cases that improve the tourism and tourism-related experiences from various perspectives. The associated use cases focus on how airport processes can be improved leveraging the offering of 5G both from the side of the visitors and of the airport management. These use cases revolve around the Athens site, including to the Athens International Airport and at the airport itself as well.

This deliverable is the first document produced by WP6 - Mobility-efficient city use cases implementation, which focuses on the implementation of the use cases of the mobility-efficient city. It presents the high-level implementation plans for the four mobility-efficient city Use Cases (UCs) that will be implemented by WP6 on the 5G-TOURS platform. The scope of this deliverable to describe the Athens node and the vertical UCs foreseen for the mobility-efficient city:

- Use case 10 – Smart airport parking management: In this use case, parking customers at the airport obtain real time information on available and occupied spaces and are able to locate available parking spaces directly through a mobile application and will be guided there via the optimal route.
- Use case 11 - Video-Enhanced ground-based moving vehicles: This use cases provides high definition cameras to the 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, improving day-to-day airport operations as well as response activities to emergencies.
- Use case 12 – Emergency airport evacuation: This use cases focuses on the evacuation of the airport in a quick and organized fashion in case of an emergency, providing automated guidance of emergency routes from the affected area up to the muster areas.
- Use case 13 – Excursion on an Augmented Reality (AR)/Virtual Reality (VR)-enhanced bus: This use case focuses on school students travelling to a destination of educational interest, generating good quality digital learning experiences both during the transportation to the destination and the visit of the exhibit.

For each of the above use cases, this deliverable analyses the main characteristics as well as the challenges that need to be addressed, and presents the implementation plans in order to realise the use cases. Additionally, it also describes the common 5G network infrastructure, deployed in the Athens trial site, to support all these use cases and the associated end-user applications. In particular, for each of the UCs deployed in the Athens 5G-TOURS node, this deliverable provides:

- A description of the use case from the perspective of the customer side, which is the vertical service provider; in the particular case of the Athens site, these are the Athens International Airport (AIA) and the school Ellinogermaniki Agogi (EA).
- An indication of UC application components, i.e. all developments and prototypes needed for the service implementation and delivery, described by industrial partner(s) that develops the specific solution; theses includes, among others, the smart parking application, the application for digital learning, etc.
- A description of the network elements required by the UC is provided, in line with the 5G-TOURS architecture developed by WP3.
- A description of the trials that validate the UCs, including the tests setup and the required equipment, in line with the evaluation methodology designed by WP7.

In addition to the above, this deliverable also presents a first analysis of the requirements involved with each of the UCs, showing the need for 5G in order to meet such stringent requirements.

1 Introduction

The **mobility-efficient city** aims at presenting a set of use cases (UCs) that improve tourism and tourism-related experiences from various perspectives. The UCs involved in the mobility-efficient city show how airport and mobility-related educational processes can be improved by leveraging the offering of 5G both from the side of the visitors and of the airport management. To this end, the project focuses on: (i) smart sensor- and AI-based parking management, (ii) personalised evacuation procedure, (iii) follow-me vehicles enhanced with high-quality video streaming capabilities, iv) efficient ways of entertaining/educating travellers/students going on an excursion on a smart bus, use cases are foreseen.

This deliverable presents the implementation plan for the mobility-efficient city UCs that will be in the Athens node of the 5G-TOURS project. Specifically, the content of this deliverable is structured as follows.

In Chapter 2 a detailed description of the Athens node is presented. This includes the description of the AIA area, the existing 5G-EVE infrastructure that will be used by 5G-TOURS as a baseline, as well as the additional extensions on the 5G-EVE Athens site for the implementation of the four 5G-TOURS use cases.

In Chapter 3 the four use cases are described in detail:

a) **Smart airport parking management:** This is a solution that relies on the massive Machine Type Communications (mMTC) functionality provided by 5G. A large number of sensors, installed at each parking position, will help keep track of available and occupied spots in real time, facilitating the parking process within an airport, as well as in any other controlled parking area.
b) **Video-enhanced follow-me moving vehicles:** Follow-me vehicles, which lead aircrafts to parking positions, monitor and oversee the activity at the airport airside area, and attend to incidents, emergencies and critical events. 5G-TOURS will develop a solution to equip mobile units of the airport with high definition cameras, sending multiple live feeds to the Airport Operations Centers (AOCs) and other stakeholders.
c) **Emergency airport evacuation:** This UC will monitor the location of the different users and provide them with instructions for evacuation in a real AIA environment.
d) **Excursion on an Augmented Reality (AR)/Virtual Reality (VR)-enhanced bus:** Applications based on AR or VR can easily attract and retain students' attention and help them focus on valuable informative sessions on the road during excursions, as well as at the places they visit, which were not feasible before 5G.

In Chapter 4 the definition of all requirements for the four mobility-efficient city use cases is given along with an introduction to the methodology of information gathering and analysis. Also, the results of the requirements definition for each use case are listed. The tables with the requirement values are given, with the specific analysis and explanation. Based on the requirements compilation (per UC), a radar chart that visualizes the general requirements per UC is included using as a backdrop the capabilities of 4G/LTE and 5G networks. From each radar chart, and the corresponding tables, information with respect to the adequacy (or sufficiency) of the existing 4G/LTE networks, as well as the urgency (or need) for 5G network capabilities (per use case) are drawn. Furthermore, an initial timeplan that will drive the implementation of the use cases is also presented in this section.

In summary, this deliverable has served to further detail the different use cases that will be addressed by the Athens node of 5G-TOURS. Each of the UC case has been motivated by showing the usefulness for the corresponding vertical partners, highlighting the value for each partners. Furthermore, an analysis of the different components required to run the UC case has been performed, identifying the different applications and vertical equipment required in each case. Beyond the vertical perspective, the deliverable has also analysed the network side of the UCs, describing the infrastructure required as well as the network level requirements involved in the use case, showing the need for 5G. Thus, this deliverable provides the basis for the implementation of the use cases, identifying the various needs at the network and application levels in order to realise the UCs and providing initial plans and timelines for their implementation.

2 Athens node

The 5G-TOURS project, is one of the main ICT19 projects that largely relies on the 5G platforms of the four implemented sites of the 5G-EVE ICT17 project. During the scope of the 5G-EVE project four existing European site facilities, which are further developed and interconnected to form the 5G end to end facility, are offered to the vertical industries of the ICT19/22 projects for pilot execution and validation. Each European site facility is sponsored by an operator, as well as network equipment provider(s). The 5G end-to-end facility is composed of 4 interconnected site facilities located in Greece, Italy, Spain and France, as shown in Figure 1. Also, the French site is itself a cluster of site facilities deployed in 4 different cities.

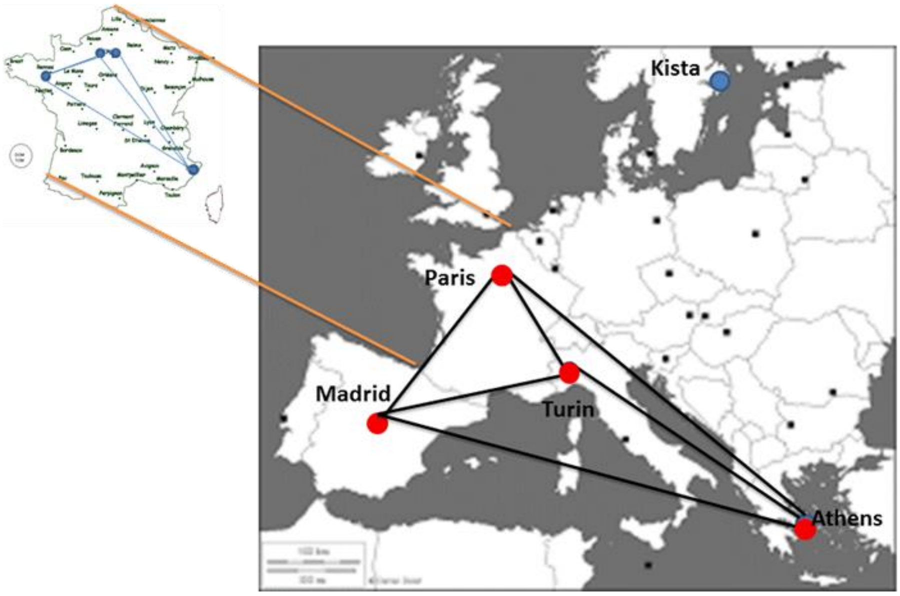


Figure 1. Location of the four European site facilities.

The objective of the 5G-EVE project is to build a European 5G end-to-end facility that will host a selection of use-cases to be deployed by verticals. At of the date of this document, 5G-EVE has already been running for one year and 4 different sites are implemented to a large extent and in the very near future will be able to support 5G services and capabilities.

The Greek 5G-EVE site facility [5], covers a region of northern Athens, around the R&D site of the Greek OTE. The OTE site serves as a testing ground for services, equipment, and new features prior to their commercial release (including [pre-] 5G equipment), while it also maintains a connection to the commercial 4G+ network of OTE. The existing equipment and network functionality are a mix of NOKIA-GR and ERICSSON-GR technologies, which will be progressively extended to support 5G during the lifetime of the project by both vendors.

2.1 Description of the AIA area

For the 5G-TOURS Athens node, the 5G-EVE Greek site infrastructure will be extended to cover the area of AIA (Athens International Airport – Spata area of Attica).

The Athens International Airport "Eleftherios Venizelos" (the "Airport") covers an area of approximately 16,000km^2 and has two runways in compliance with the International Civil Aviation Organization Aerodrome Reference Code "4E", (03L/21R: 3,800x60m and 03R/21L: 4,000x60m - incl. shoulders on both sides with a width of 7.5m). The Airport features a 168,000m^2 main terminal building and a 34,000m^2 Satellite Terminal Building with a total of 24 Contact Bridges and 75 active remote aircraft parking positions. The Airport is certified for all known types of currently operating aircrafts, including the Boeing 747- 8 and the Airbus A380.

Table 1: AIA area

	Area
The airport extends in an area of approximately	16,000km^2
Main Terminal building	168,000m^2
Satellite terminal building	34,000m^2
Contact bridges	24

Figure 2. General view of the Athens International Airport

Figure 3. General view of the Athens International Airport

Figure 4. Apron area of the Athens International Airport

The AIA areas selected for the implementation of the different mobility-efficient city use cases are the following:

- UC10: Smart airport parking Management: Staff parking at building 17
- UC11: Video-enhanced ground-based moving vehicles – On the Apron area
- UC12: Emergency airport Evacuation – Satellite building (south of main terminal) at the departures level (gates A37-39)
- UC13: Excursion on an Augmented Reality (AR)/Virtual Reality (VR)-enhanced bus – An exhibition area at the main terminal building

2.2 Existing 5G-EVE Greek Site infrastructure

The four Greek partners of 5G-EVE, i.e. OTE, NOKIA-GR, ERICSSON-GR, and WINGS, have made significant progress during the first year of the 5G-EVE project, towards preparing and deploying the Greek site facility, which will host trials for three verticals (***Smart city, Industry 4.0 and Utilities***). Overall, during the first year of the project, the Greek team has defined the ***architecture*** of the Greek site and the ***integration of all the 5G equipment*** and platforms into the OTE network in detail. The architecture definition was based on an in-depth ***analysis of the vertical requirements*** needed to be supported for experimentation as did the ***definition of the interworking capabilities*** of the site and the ***recommendations for interconnecting*** with the rest of the 5G-EVE sites, in which the Greek partners participated [5].

OTE is the 5G-EVE Greek site facility leader, providing the existing 4G+ network, backhaul links and interconnectivity with the other 5G-EVE sites. During 5G- EVE 1-year life OTE has:

- Assembled and installed the necessary servers to host the 5G-EVE functionalities, and management software
- Provided interconnection to the other 5G-EVE facilities
- Provided the facilities for the 5G-EVE software/hardware installations by the vendors and led the integration planning with their existing network

NOKIA-GR provides the 5G Radio Access Network (RAN), cloud core (virtual Evolved Packet Core (vEPC)), software, and end equipment to support the smart city vertical trials to be performed at the Greek site. During 5G-EVE one year life NOKIA-GR has:

- Delivered, installed and configured their 5G RAN solution comprised of multiband Frequency Division Duplexing (FDD) small cells and the corresponding software
- Delivered, installed and configured their cloud packet core solution comprised of multiple virtual Network Functions (VNFs) (Mobility Management Entity (MME), Serving GPRS Support Node (SGSN)), switches, routers and the corresponding management environment
- Delivered, installed and configured their NOKIA-GR Internet of Things (IoT) platform and corresponding end-user equipment (sensors, user equipments (UEs)) to enable initial stage experimentation for smart city scenarios

The architecture of the 5G-EVE OTE, NOKIA-GR and WINGS platform that will be used during the 5G-TOURS project is the following (exemplified in Figure 5):

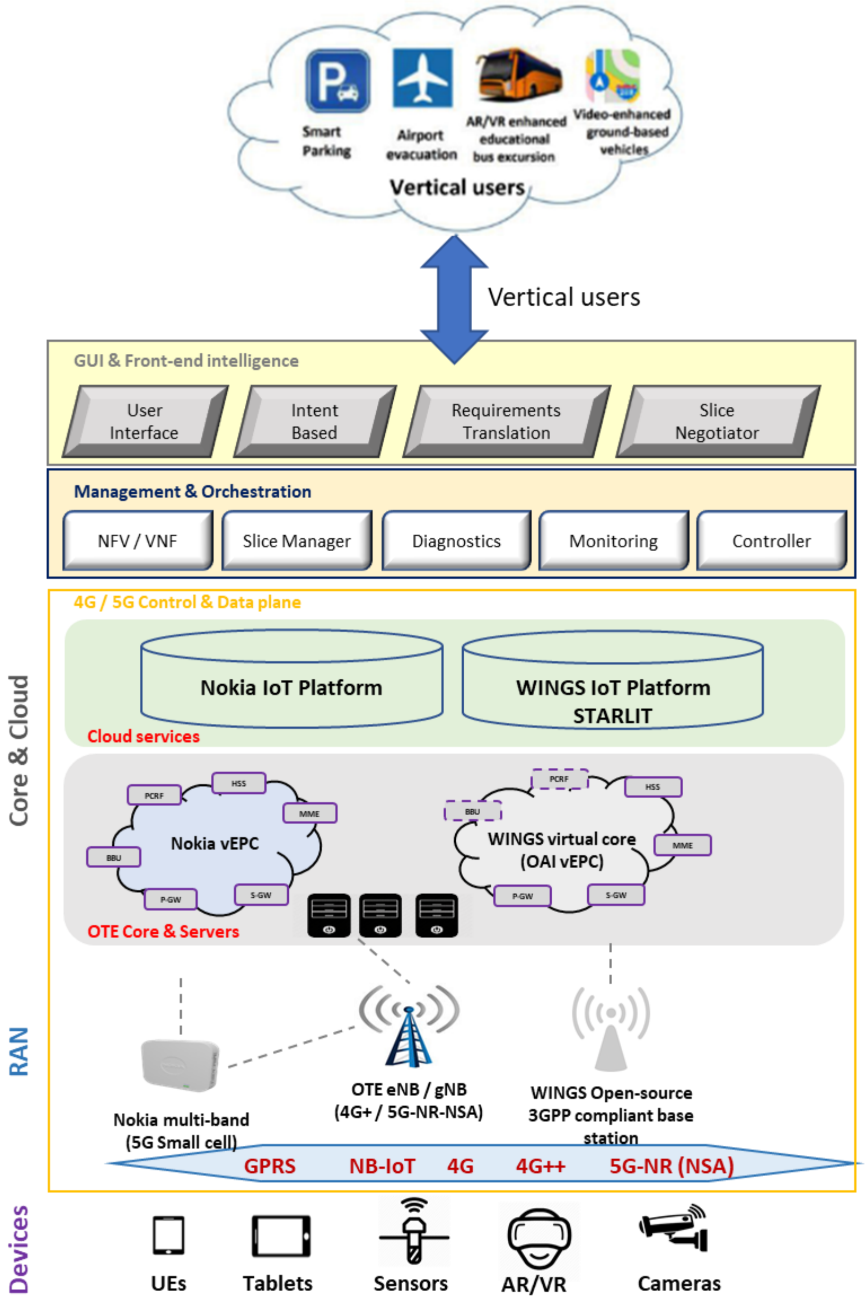


Figure 5. Architecture of the 5G-EVE OTE, NOKIA-GR and WINGS platform.

2.3 Infrastructure extensions for supporting the 5G-TOURS Athens node

OTE, NOKIA-GR and WINGS are responsible for the preparation and upgrading of the 5G-EVE Greek site infrastructure to cover the area of AIA (Spata area of Attica) and be able to handle four 5G oriented vertical use-cases (Figure 6), namely:

- UC10: Smart airport parking management
- UC11: Video-enhanced ground-based moving vehicles
- UC12: Emergency airport evacuation
- UC13: Excursion on an Augmented Reality (AR)/Virtual Reality (VR)-enhanced bus

Note that the airport covers a substantially large area of around 16 Km^2, as it needs to cover not only the airport building but also the outer area for some of the use cases. The current deployment covers about 0.5 Km^2 and is expected to increase substantially with the roll-out of commercial 5G deployments, allowing for transportation-related use cases. The areas covered by these deployments are depicted in the figures below.

Figure 6. Coverage area at the AIA

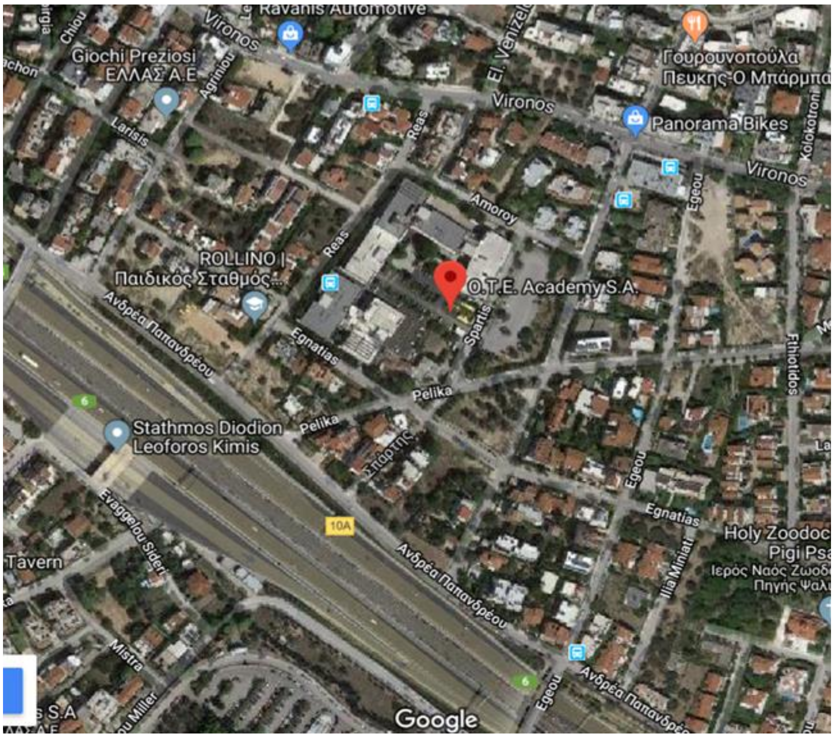


Figure 7. Coverage area in Psalidi (northern Athens, right)

For the implementation of the four use cases:

- NOKIA-GR will install antennas (5G multi band small cells[1]) to cover about 3-5 km^2,

[1] Small cells — about the size of a pizza box — contain lower power radios and antennas. They add density to the cellular net-work to boost range and increase the number of smartphone/ endpoint users who can then gain high speed connections to the Internet. This is done via frequency reuse– small cells in one area of town may use the same frequency bands as other small cells in a different part of the city. Small cells are expected to be a key component of high speed 5G mobile networks.

~5 pairs of LTE/5G mRRH will be used for the needs of the use cases.

Frequency bands of LTE mRRH are:

- Band 43
- Band 7

Those antennas will be connected via Common Public Radio Interface (CPRI)-fiber connection to NOKIA-GR AirScale Baseband Unit (BBU). Then AirScale BBU is connected towards OTE's edge network in AIA via an <=10Gbps ethernet cable. OTE will connect via Virtual Private Network (VPN) connection towards the AIA network (AIA control room) and will also provide the backhaul wired connectivity towards 5G-EVE EPC network. The backhaul wired connectivity to 5G-EVE EPC will be a <=10Gbps ethernet connection.

Measurement probes will be deployed as follows:

a. Multiple probe based, layer 2 & 3, active & passive Key Performance Indicators (KPIs) continuous measurement (monitoring) platform.
    i. At the AIA, between the NOKIA-GR BBU and OTE edge network at OTE site in AIA premises (1GE/10GE interface).
    ii. At OTE Psalidi premises, just before the NOKIA-GR vEPC (1GE/10GE interface).
    iii. At OTE Psalidi premises, between the NOKIA-GR Core network and the WINGS' STARLIT platform (1GE/10GE interface).
    iv. Control of all the probes and collected measurements transportation to the KPI Validation Platform (KVaP) platform will be achieved through virtual circuits over the 5G available network capacity (limited bandwidth required). The KVaP platform will deployed at OTE Psalidi site.
b. Single probe based, layer 3 & 4, passive KPIs continuous measurement (monitoring) platform.
    i. At OTE Psalidi premises, just before the NOKIA-GR vEPC (1GE/10GE interface).
        - With connection to the OTE's core network the existing 5G-EVE 4G/5G facility of OTE will be used (NOKIA-GR vEPC). A 10Gbit line will connect OTE's 4G/5G facility in Psalidi with the AIA.
        - NOKIA-GR will install antennas (5G multi band small cells) for covering the internal area with 5G network
        - Also, a corresponding number of Subscriber Identification Modules (SIM) cards will be installed by OTE for the needs of the UCs
        - Outdoor/indoor 5G coverage is needed
        - WINGS STARLIT platform will be enhanced to support the Greek node use cases
        - WINGS will also install parking occupancy sensors in AIA for the smart parking use case.

The infrastructure extension has to be able to operate with all three basic service types (eMBB, mMTC, URLLC) and combinations of them, in order to support all four aforementioned use cases. These use cases will rely on a common basic network infrastructure, comprising of RAN solution, transport solution, Cloud Packet Core (vEPC and/v5GS), with compatible components to the Management and Orchestration (MANO) ETSI architecture to support network management, orchestration, virtualization and slicing in accordance to each use case needs.

To reliably support all use cases that will be showcased in the Athens node, the infrastructure must offer slicing mechanisms, which in turn may entail different RAN requirements, e.g. different number of base stations/antennas, different type of antennas (indoor, outdoor), different scheduling and resource allocation mechanisms, etc. These (and many more) open issues will be shaped to comply with technical aspects and requirements of the diverse use cases.

In particular, the following equipment needs to be available for mobility-efficient city trial:

- NOKIA-GR Airscale radio access network that enables support for Non-Standalone (NSA) 5G New Radio (NR) technology, making it possible to deploy 5G service on existing LTE bands, as well as new bands such as mmWave. It includes NOKIA-GR AirScale Base Station, NOKIA-GR AirScale active antennas (compact active antennas as well as massive Multiple Input Multiple Output (MIMO) adaptive antennas), and NOKIA-GR Airscale Cloud RAN. Based on current estimations 1- 2 pairs of 4G, 5G antennas will be needed in order to fulfil the requirements of 5G-TOURS' use cases, and cover the area of AIA and its surroundings. This kind of antenna supports both indoor/outdoor coverage. E-UTRAN New Radio-Dual Connectivity (EN-DC) option 3/3x will be used to enable 5G radio connectivity (Figure 8).

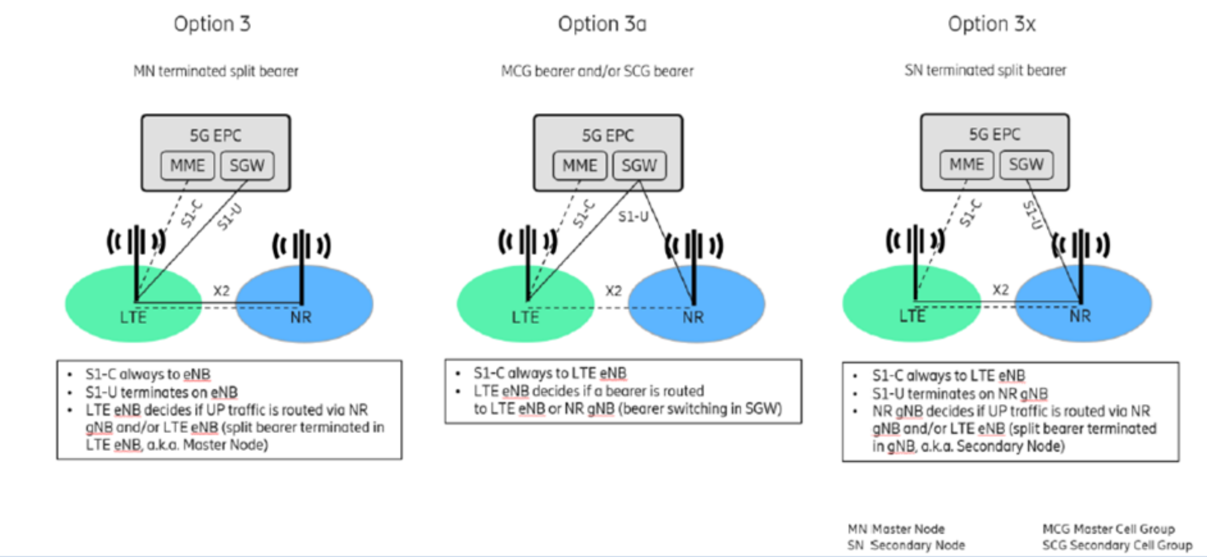


Figure 8. Option 3, including all three variants 3, 3a & 3x

- NOKIA-GR CloudBand Network Director & Application Manager, which is a NOKIA-GR solution for MANO and NFV management. The Network Director provides an NFV Orchestration (NFVO) solution that implements network service orchestration, resource orchestration and optimization and provides an integrated view of the architecture. Concerning the Application Management part, it implements the NFV Management (NFVM) functionality. It handles the configuration, lifecycle management and element management of the virtualized network functions.
- NOKIA-GR Cloudband Infrastructure Software, which is a multi-purpose NFV Infrastructure (NFVI) and Virtualized Infrastructure Manager (VIM), built for OpenStack. It virtualizes and manages compute, storage, and network resources and enables VNFs to run ensuring that they meet strict robustness, performance, and security requirements.
- NOKIA-GR Cloud Mobility Management, Cloud Mobility Gateway. These are Virtualized Network Function Components (VNFC) of the MME, SGSN and Serving/Packet Gateway (S-/P-GW) network functions. This solution includes edge-cloud capabilities, enabling cloud RAN. The solution comprises compact size hardware, as well as real-time and low latency optimized infrastructure software. It supports pluggable acceleration modules enabled by specific processing acceleration technologies.

NOKIA-GR IoT Platform acts as a middleware that connect sensors and IoT devices to 3rd party applications or end-user applications if/when required. Data is conveyed via the EPC radio interfaces to the IoT platform where it is consumed accordingly (depending on the protocols and interfaces used). The NOKIA-GR IoT Platform, whose high-level architecture is depicted in Figure 9 below, interoperates with network equipment from a variety of network vendors and is agnostic in terms of network connectivity, supporting a variety of technologies, including 3G, 4G/LTE, Wi-Fi. Several Low-Power Wide Area Network (LPWAN) connectivity interfaces are also available, including Narrowband IoT (NB-IoT) (licensed) and Long Range (LoRA) (unlicensed). Virtual EPC will be available by OTE's Athonet platform, which provides a complete software-based mobile packet core solution (EPC) that includes a Home Subscriber Server (HSS), an IP Multimedia Core Network Subsystem(IMS) to offer Voice-over-LTE (VoLTE), and LTE Broadcast (enhanced Multimedia Broadcast Multicast Service (eMBMS)). This mobile core solution can be deployed in fully virtualized environments, enterprise data centers or standard off-the-shelf servers. It is worth noting that all of the above infrastructure will be provided as a combination of the usage of the 5G-EVE platform and/or via hardware/software upgrades.

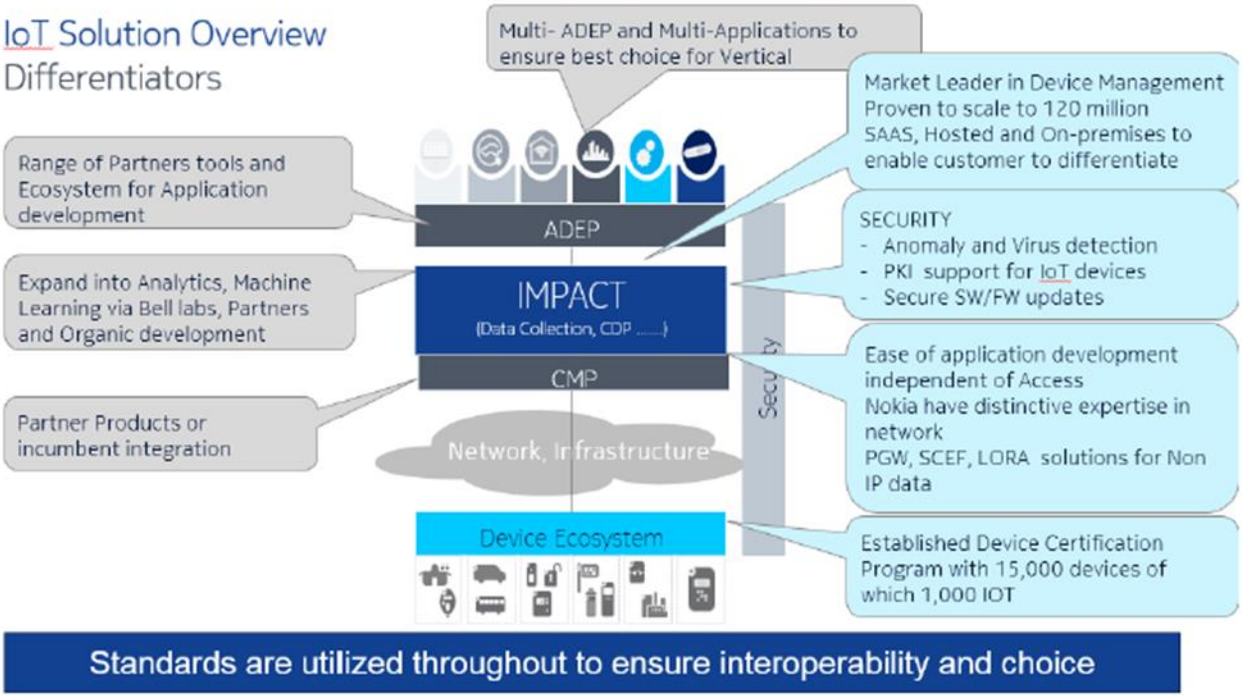


Figure 9. NOKIA-GR IoT Platform high-level architecture

The current 5G-EVE Greek site facilities are going to be upgraded to Release 15 [6] during Q4 New antennas (indoor/outdoor), as well as the corresponding equipment will also be installed to the AIA area in order to support 5G-TOURS use cases for the project lifecycle.

3 Use Cases detailed description

In the next paragraphs each Use case is described in detail starting from objectives to the trial implementation.

3.1 UC10 – Smart Parking management

This use case will allow the AIA parking customers to obtain real time information on available and occupied spaces. They will be able to locate available parking spaces directly through a mobile application and will be guided there via the optimal route. The smart parking management will contribute to the emission reduction by reducing unnecessary vehicle movements to locate a parking space.

3.1.1 Use case description

On August 14th, a peak departure day for AIA, approximately 50 vehicles can become congested in parking facility 1 (P1). It would appear that upon arrival to park within the facility, the vehicles begin to search for an adequate parking spot, ideally near the staircase and elevators. Unfortunately, with so many vehicles, simultaneously in search of the ideal spot and rushing to park, this inevitably causes congestion and vehicles driving in the wrong direction. Whilst driving in the wrong direction, a passenger driving to get a spot before another driver gets to it first, can end up colliding with the second driver who had been driving in the correct direction. Consequently, the drivers will proceed to make the necessary arrangements to report the said accident. Both drivers in question were scheduled to depart on flights at approximately two hours after the accident, and will thus inevitably miss their flights. At the same time, a driver who had been searching for a spot to no avail, eventually found a more distant spot and upon arriving at the terminal, proceeded to the check-in counters to check in his bag, only to be informed that the check-in process was closed and therefore, he was unable to fly and missed his flight.

The developed service aims to minimize the time spent finding an available parking spot within the parking facility of AIA simultaneously optimizing the management and monitoring of the facility from the side of the respective authority. Specifically, an app-based service will be developed, which enables the user of the app to inspect the available parking places within the respective parking facility and get a recommendation for a parking slot, according to the specified criteria (e.g. the one closest to the exit towards the arrival or departures sector, the one closest to the entrance of the facility, etc.).

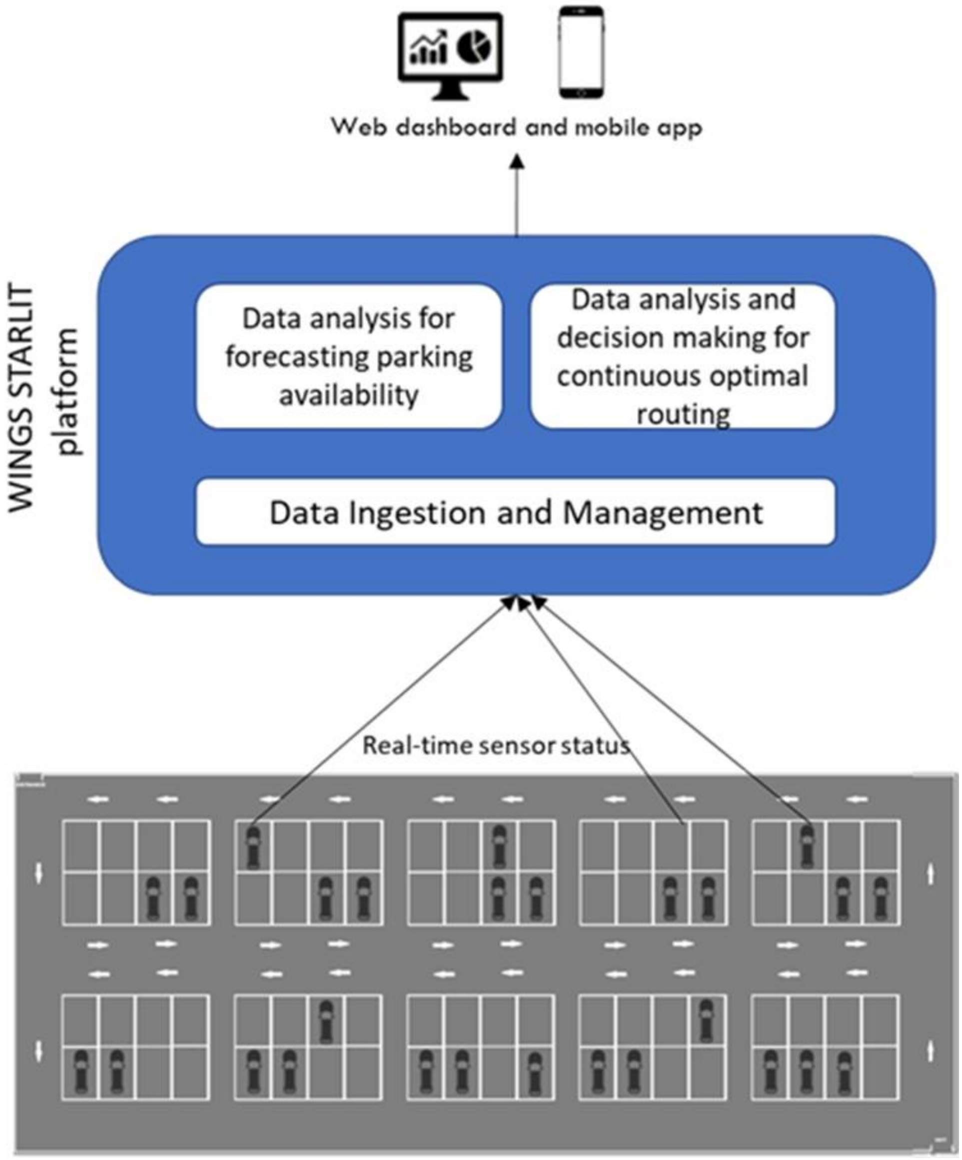


Figure 10. Sensors communication with STARLIT platform.

3.1.2 Vertical Components

3.1.2.1 Overall Architecture

The service provided will be an extension in the functionality of the existing WINGS' STARLIT platform and will consist of:

- a mobile application that will provide the user searching for parking with the aforementioned capabilities (visualizing the available parking slots and guidance/instructions to the optimal slot),
- a web-based application for controlling the parking area offered to the respective airport authority, and
- 5G-supporting occupancy sensors.

These sensors that monitor the state of the respective parking slots (available or occupied) will be installed at each individual slot. This will enable the real-time monitoring of the available and occupied spaces. In parallel, a relational database which will contain the state and other relevant information for each sensor will be maintained on the server side hosted in WINGS cloud infrastructure. Every time the state of the slot changes, the sensor will send the respective information of the state change through a gateway to a server which will update the state in the database. Each time a request from the user-side (client) to get the optimal available parking slot is sent, the server will query the database to get the state of each sensor and calculate the slot that meets the specified needs, as well as the shortest route towards this slot. The route and the parking slot are drawn on the respective map. Below, a schematic representation of the proposed architecture is shown:

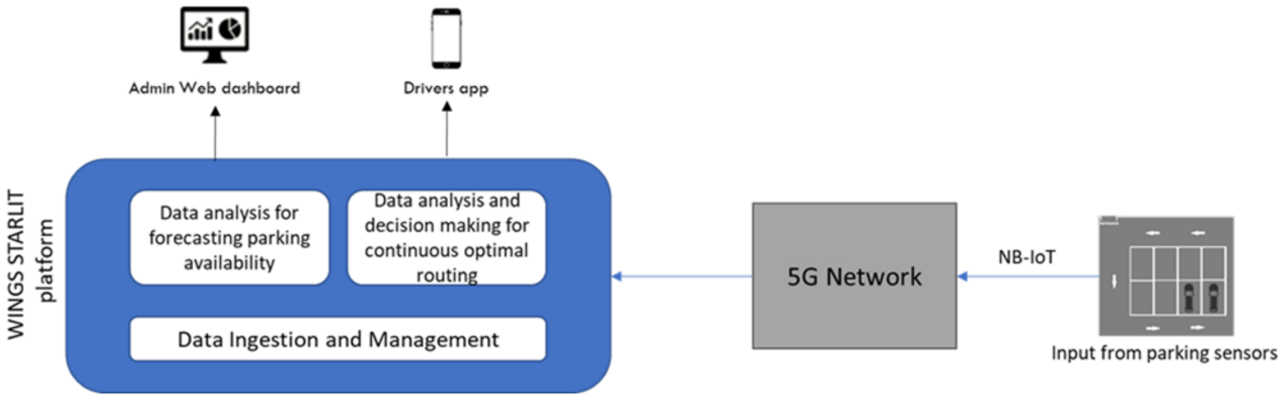


Figure 11. High level system architecture

3.1.2.2 Platform

For the Smart Parking use case WINGS' STARLIT platform will be utilized. STARLIT is a cloud-based platform that interacts with sensors and actuators and comprises of: (i) capabilities for self-management of services/application to facilitate greater flexibility, reliability and robustness; (ii) machine learning functionality (e.g., Bayesian statistics, time series forecasting, self-organising maps) for building knowledge and predicting contextual factors (e.g., traffic, pollution, parking space availability, user's vital signs evolution, etc.), the derived knowledge being exploitable for reliable raising of alarms, efficient recommendations and application and system configuration; (iii) decision making capabilities for the autonomous selection of the optimal actions taking into account current context, user profiles and knowledge. For example, in the case of smart parking, the driver can be routed towards the suggested spot taking into account his context and preferences. Figure 12 provides a more detailed view of the STARLIT functional architecture. The key components in the smart parking case are the Sensors and data sources, Communication technologies, Data ingestion and management, the Data analysis and the Dashboards.

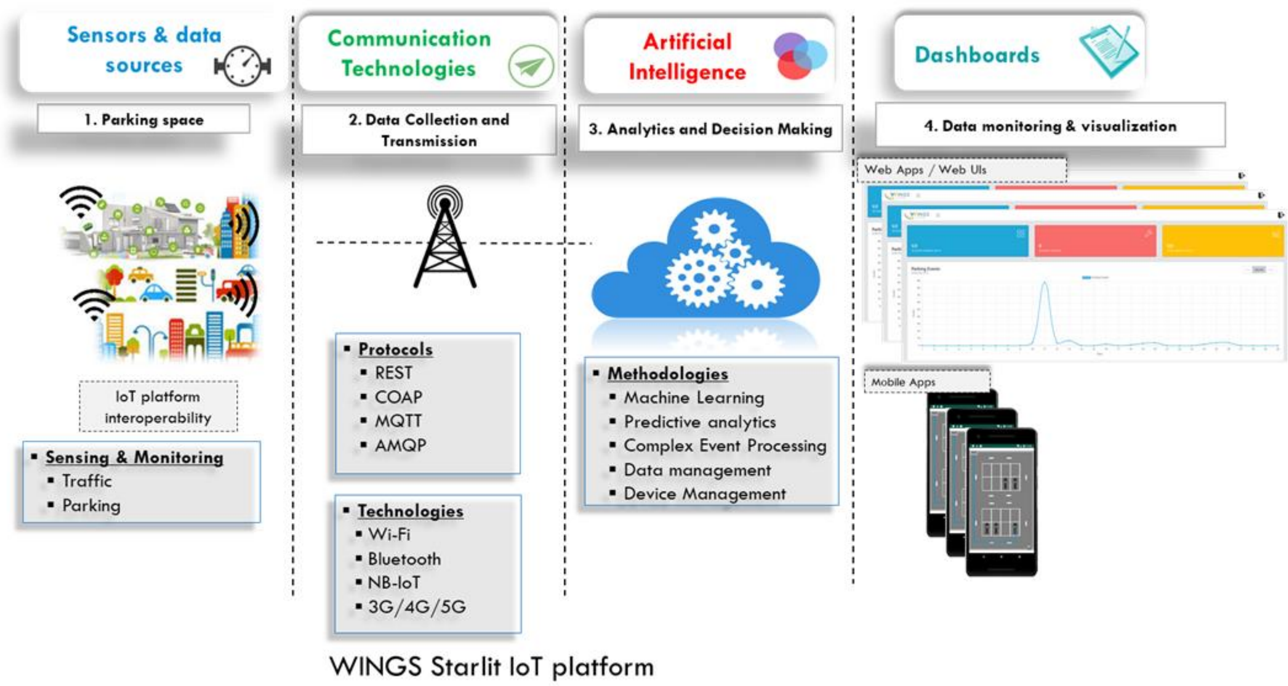


Figure 12. WINGS STARLIT IoT platform

Overall, STARLIT can combine data from various devices (e.g., parking sensors, mobile phones, cameras, etc.) and automatically control different types of actuators, such as lights, heating/cooling, but also robots and Automatically Guided Vehicles (AGVs). STARLIT leverages diverse communication technologies and communication protocols. In terms of cloud deployment STARLIT components can be deployed as virtual machines and docker images.

The STARLIT data ingestion and management comprises various functionalities for deriving the data from the various devices and delivering them to any other platform components, services and applications as well as triggering actuators.

The data ingested into the system is processed and also stored in a hybrid database system that comprises various types of databases (e.g., NoSQL, HDFS-based, etc.) for various types of information, such as raw data from devices, knowledge derived through data analytics and learning mechanisms, information on available devices and services.

Data analysis, insights and predictions comprise functionalities for monitoring, event-detection, forecasting of events and issues, large-scale data processing, image processing and automated decision making. The data analysis mechanisms continuously run, retrieving data from available data sources and applications and update the inferred data and knowledge stored in the platform databases. Methods for Artificial Intelligence (AI) and machine learning functionality are included for building knowledge and predicting contextual factors from data, which can be characterized (at least) by high-velocity/volume/variability), to empower decision making include Bayesian statistics, time series forecasting, Self-Organising Maps (SOMs), Deep Learning, Re-enforcement learning, k-Nearest Neighbour(s) (k-NN).

As part of the WINGS STARLIT applications, dashboards are provided for visualization of measurements on interactive graphs, notifications and alerts. Real-time and historical data as well as forecasts/predictions can be depicted. Dashboards are provided as web-based User Interfaces (UIs) that can run from any tablet, smartphone or PC computers

Finally, the WINGS STARLIT platform integrates an OpenStack software module, namely Keystone, for ensuring data security and privacy both at data and system level. Specifically, OpenStack Keystone is a security module complemented with a REST Application Programming Interface (API) that allows the access control of users, applications, etc., and is used to control the access on the data, ensuring their privacy at the same time. In addition to the above, the platform communications among the services/applications/user interactions are secured and the data is transferred as encrypted payloads based on trusted certificates.

NOKIA-GR’s IoT platform (IMPACT) may also be utilized for the Smart Parking use case as an integrating platform of a vertical Smart Parking application to achieve co-ordination of communication between applications and devices. It is based on a horizontal platform architecture that allows for mix-and-match deployment of individual or multiple components to meet varying consumer demands and strategies across a wide array of use cases and verticals. IMPACT platform provides granular REST APIs that is used by northbound applications. These APIs allows multiple applications to:

- access device data
- filter device data
- send data and commands to devices
- manage device lifecycle
- manage resources

IMPACT platform integrates with southbound devices and gateways which are protocol agnostic, by providing the needed service adaptation/integration layer between devices and gateways, as depicted in Figure 13.

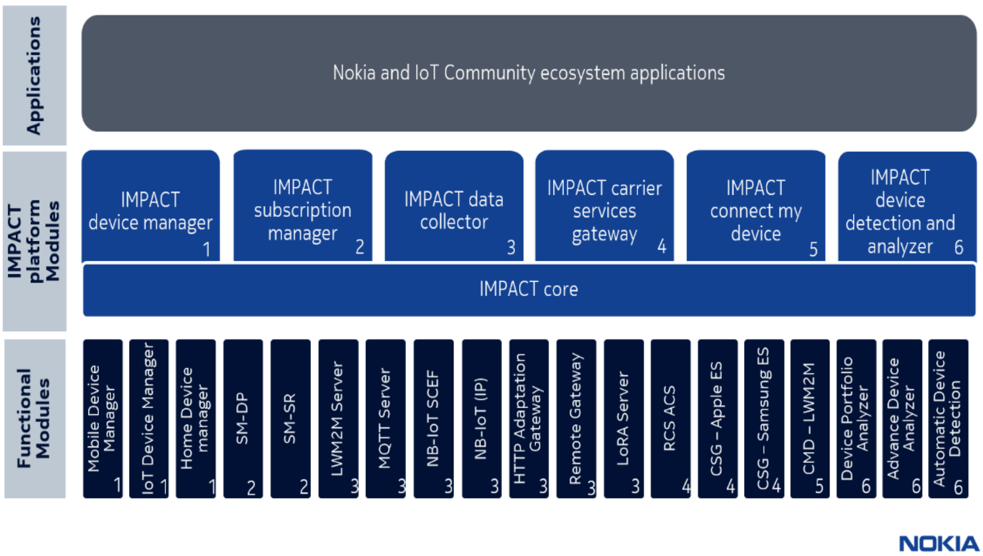


Figure 13. NOKIA IOT platform-IMPACT

The supported interfaces and features are given below:

Supported protocols, interfaces and standards:

- Architecture enhancements for non-3GPP access, according to 3GPP 23.402;
- Intra-domain connection of RAN nodes to multiple Core Network (CN) nodes according to 3GPP 23.236;
- Network sharing according to 3GPP 23.251;
- Stream Control Transmission Protocol (SCTP) according to RFC 4960;
- User Datagram Protocol according to RFC 768;
- Internet Protocol according to RFC 791;
- Transmission Control Protocol (TCP) according to RFC 793;
- Internet Protocol version 6 (IPv6) specification according to RFC 2460;
- GTP-U based interfaces according to 3GPP 29.060-29.281;
- Quality of Service (QoS) architecture according to 3GPP 23.107;
- Diameter interfaces according to 3GPP 29.230;
- S1-AP according to 3GPP 36.413;
- S1 data transport according to 3GPP 36.414;
- NAS-EPS according to 3GPP 24.301;
- Gy interface according to 3GPP 32.299 and RFC 4006;
- Bx interface according to 3GPP 32.251, 3GPP 32.297, 3GPP 32.298;
- Rx interface according to 3GPP 23.203;
- Gx interface according to according to 3GPP 29.212;
- Cx interface according to 3GPP 29.228-9.

Interconnections of the vEPC of the OTE Athonet platform in 5G-EVE:

- Rx: connects the PCRF to external AF (application function such as IMS) which notifies the Policy and Charging Rules Function (PCRF) of some events (e.g. user making a VoLTE call);
- S1: Connects EPC to access nodes;
- S11: Connects MME to S-GW
- S5/S8: connects S-GW and P-GW;
- S6a: connects MME and HSS for the authentication of user access and profiling;
- Gx: connects PCRF and P-GW and enables the PCRF to prioritize certain type of data;
- Rx: connects the PCRF to external AF (application function such as IMS);

- Gx: connects PCRF and P-GW and enables the PCRF to prioritize certain type of data traffic;
- Gy: for online charging;
- Bx: File Transfer Protocol (FTP(S)) based interface which allows billing systems;
- Cx: Diameter interface;
- SGi: connects the P-GW to Intranet and Internet.

MME

The MME supports the following interfaces:

- S1-MME: it is the interface to connect the MME to enhanced NodeBs (eNBs);
- S11c: it is the control plane interface to connect the MME to the S-GW
- S11u: GTPv1-U interface for propagating CIoT user traffic between MME and the S-GW
- S6a: Diameter interface for authorization/authentication and subscription retrieval of the users.

S-GW

The S-GW follows 3GPP specifications R14 and supports the following interfaces:

- S1-U: GTPv1-U interface for connecting the S-GW to the eNBs
- S11c: it is the control plane interface to connect the MME to the S-GW
- S11u: GTPv1-U interface for propagating CIoT user traffic between MME and the S-GW
- S5/S8: GTPv2 interface to connect S-GW and P-GW;

P-GW

The P-GW follows 3GPP specifications R14 and supports the following interfaces:

- SGi: connects the P-GW to Intranet and Internet;
- S5/S8: GTP2v interface to connect S-GW and P-GW;
- Gx: connects PCRF and P-GW and enables PCRF to prioritize traffic;
- VRF support.

PCRF

The PCRF also follows R14 and supports the features:

- Rx: to connect PCRF to external application function;
- Create/delete bearers;
- Subscription repository
- Policy-based services

HSS

The HSS follows also 3GPP R13 specifications and supports the following features:

- S6a: Diameter interface for transfer transcription;
- SIM credentials;
- EPC user profile management.

3.1.2.3 Devices and gateways

Low-rate, low-power MTC/IoT devices will be attached to the cellular network in order to provide real-time parking space data to the parking space administrator as well as to the parking users as they enter the parking area. In that direction, SEQ will provide up to 10 samples of LTE cat-M/NB-IoT modems with advance instrumentation features to prototype the initial testing and development of this mMTC use case using OTE NB-IoT live network. To scale up the deployment with high number of devices (e.g. 100), it is expected that AIA will get additional, equivalent off-the-shelf devices, or that WINGS will provide the remaining MTC/IoT devices. It is also expected that an NB-IoT network will be available on-site, at the same frequency bands as the one considered for initial prototyping.

It is anticipated that the required mMTC devices will mostly remain idle and provide uplink user data, typically in small payloads. A possible modem that an mMTC device could integrate is Sequans Monarch family of solutions. Monarch is a single-chip LTE CatM1/NB1 solution designed specifically for NB-IoT applications, including sensors, wearables, and other low data, low power Machine to Machine (M2M) and IoT devices. Monarch complies with the ultra-low-power and reduced complexity feature requirements of the 3GPP mMTC, defining narrowband, low data rate LTE technology for MTC. Monarch achieves a very high level of integration, whereby baseband, RF transceiver, power management, and RAM memory are integrated into a tiny 6.5 x 8.5 mm package, running Sequans carrier-proven LTE protocol stack, an OMA (Open Mobile Alliance) lightweight M2M (LWM2M) client for over-the-air device management, and a rich set of AT commands.

Using for instance the Monarch SiP integrated module, frequencies from 700MHz to 2.2GHz can be supported. This is in line with the current support of Cat-M and NB-IoT from OTE's commercial network that covers the location of the AIA and supports Band 20 that corresponds to uplink 832 - 862 MHz and downlink 791 - 821 MHz. It should be noted here that it is not expected that mMTC will be deployed in higher frequency ranges, due to the more challenging link budget and the required high coverage; thus, the aforementioned solutions will be relevant even at the later demonstration stage of pure 5G deployment.

Developing an end-user device prototype directly based on a chipset or a module requires long development and integration time at printed circuit board (PCB) level, with design of dedicated hardware boards (i.e. design a specific PCB and extra work on front-end, power supply, interfaces etc.). For easier end-user prototype, it would be safer to consider almost ready to use modules or pre-integrated solutions. The GM01Q-STMOD expansion board is an example of such pre-integrated solutions[2]. This could provide cellular LTE-M and NB-IoT connectivity to any STM32 Discovery kit[3]. The use of such board would mean that the end-user device is developed in a STM32-like environment, which is perfectly suited to sensor type of devices.

Figure 14. STMOD extension board

Currently, the parking occupancy sensor leverages on a custom board designed by WINGS. The communication protocol used in this case is NB-IoT, while a magnetometer is utilized in order to detect whether a vehicle is on the parking spot. Its main parts are a STM32 processor, an lsm303c magnetometer, a QUEQTEL BG96 NB–IoT module and 18650 Li-ion batteries. The device is calibrated when turned on (by the absence of cars or other metal objects that may affect the magnetic field of the area), and measures the magnetic field in 3 axes. These measurements are used as thresholds for vehicle detection. The device wakes up every few seconds to take magnetic field measurements. When a change of state occurs, which means that a car arrived left, the device connects through OTE's NB-IoT network and transmits related information using the architecture presented above. Then, the device goes back to sleep, in order to achieve minimum power consumption. An image of the prototype is shown in the figure below.

[2] https://www.st.com/en/evaluation-tools/b-cell-gm01q.html

[3] https://www.st.com/en/evaluation-tools/stm32-discovery-kits.html

Figure 15. WINGS parking occupancy sensor prototype

3.1.2.4 Application

The application developed in the context of 5G-TOURS enables the user to have a real time view of the available parking slots in the parking facility of the airport. Moreover, it provides the user with the possibility to get the optimal parking slot according to the criteria specified, that is, the one closest to his point of interest. Specifically, when the driver is logged into the application, a top view of the parking facility is provided on the screen. There, the user has the choice:

- to select and see the available parking slots on the map of the parking facility, and
- to retrieve the available parking slot closest to the specified point of interest, as well as get the shortest navigation guideline towards it.

In the options section, he is given the choice to specify the point of interest, based on which the optimal parking slot is calculated. A mock-up screen of the described functionality is shown in the image below.

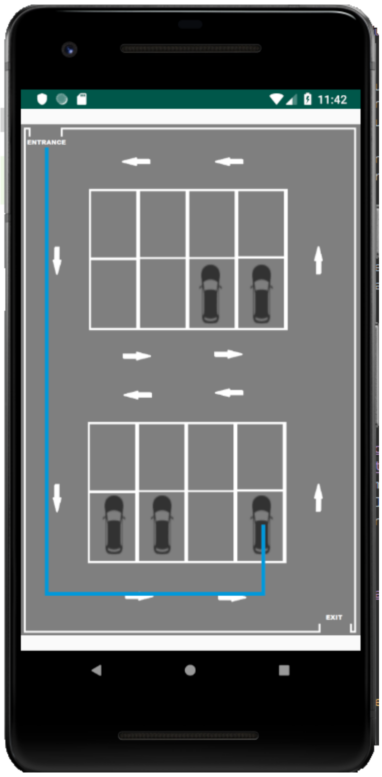


Figure 16. Smart Parking Mobile application mock-up

Also, a web dashboard will be developed in order for the administrative user to keep track of the whole smart parking system. The dashboard will provide information about all the parking events, and the occupancy time.

It will also include all the necessary information for each sensor such as status, battery level, exact position etc. Finally, a parking map will be also available presenting all the parking positions and their live status. Some mock-up screens of the described functionality are shown below.

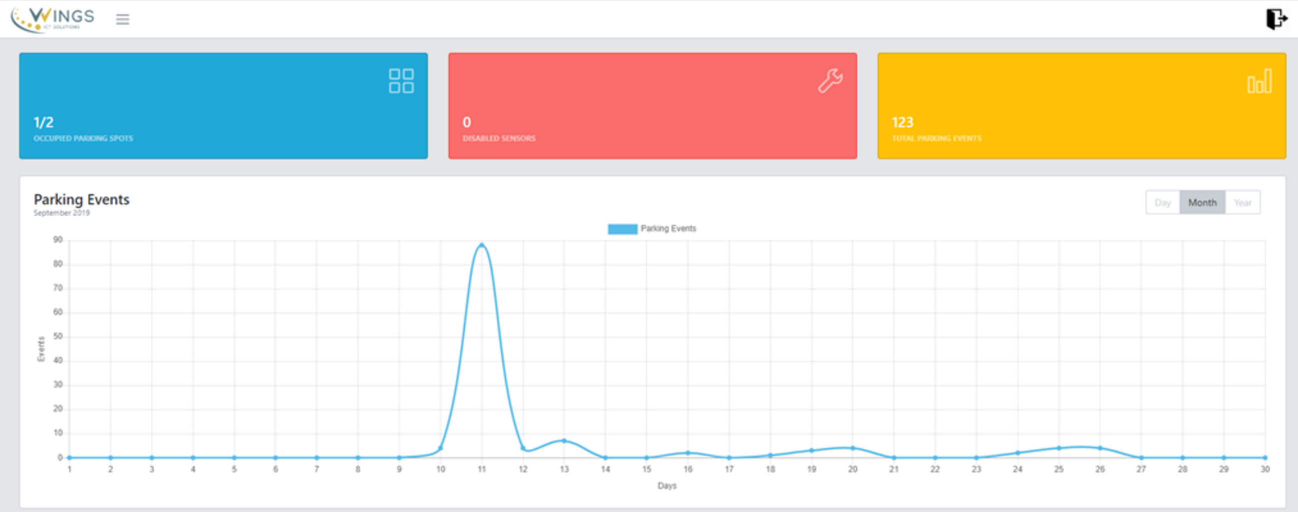


Figure 17. Smart Parking Web application - admin dashboard mock-up

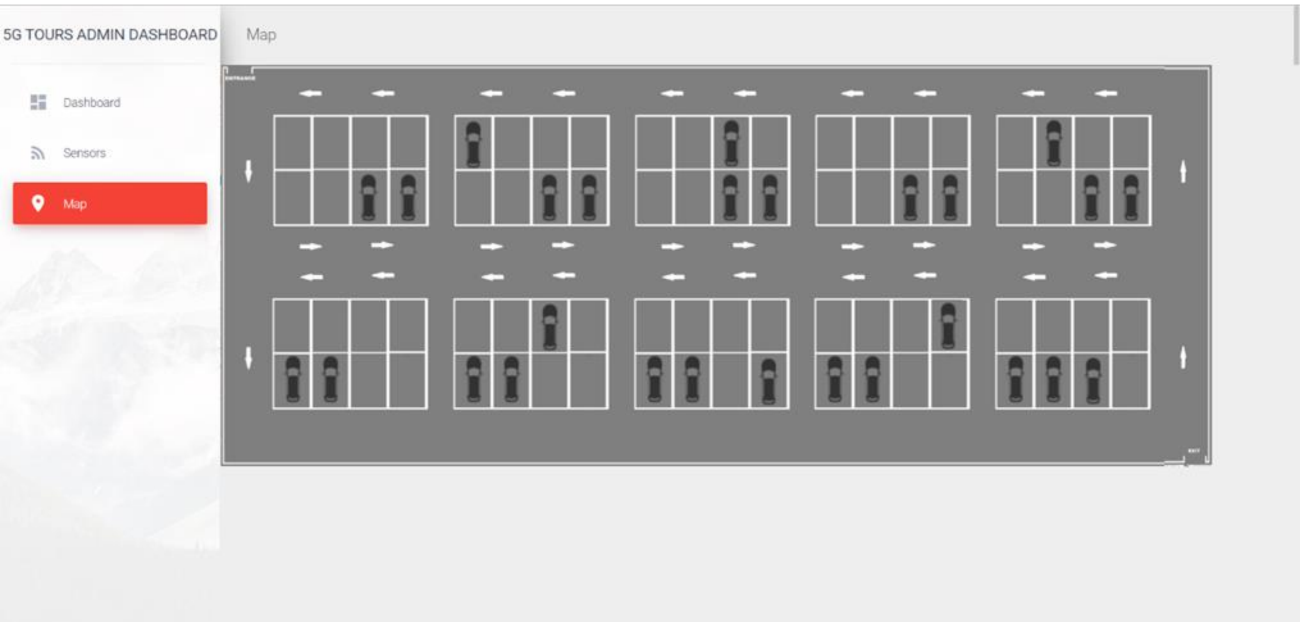


Figure 18. Smart Parking Web application - admin dashboard mock-up

3.1.3 Network Component/functions

In the smart parking use case, NOKIA-GR will provide the 4/5G radio coverage equipment (RAN) in the surrounding area of AIA, as highlighted in Figure 19:

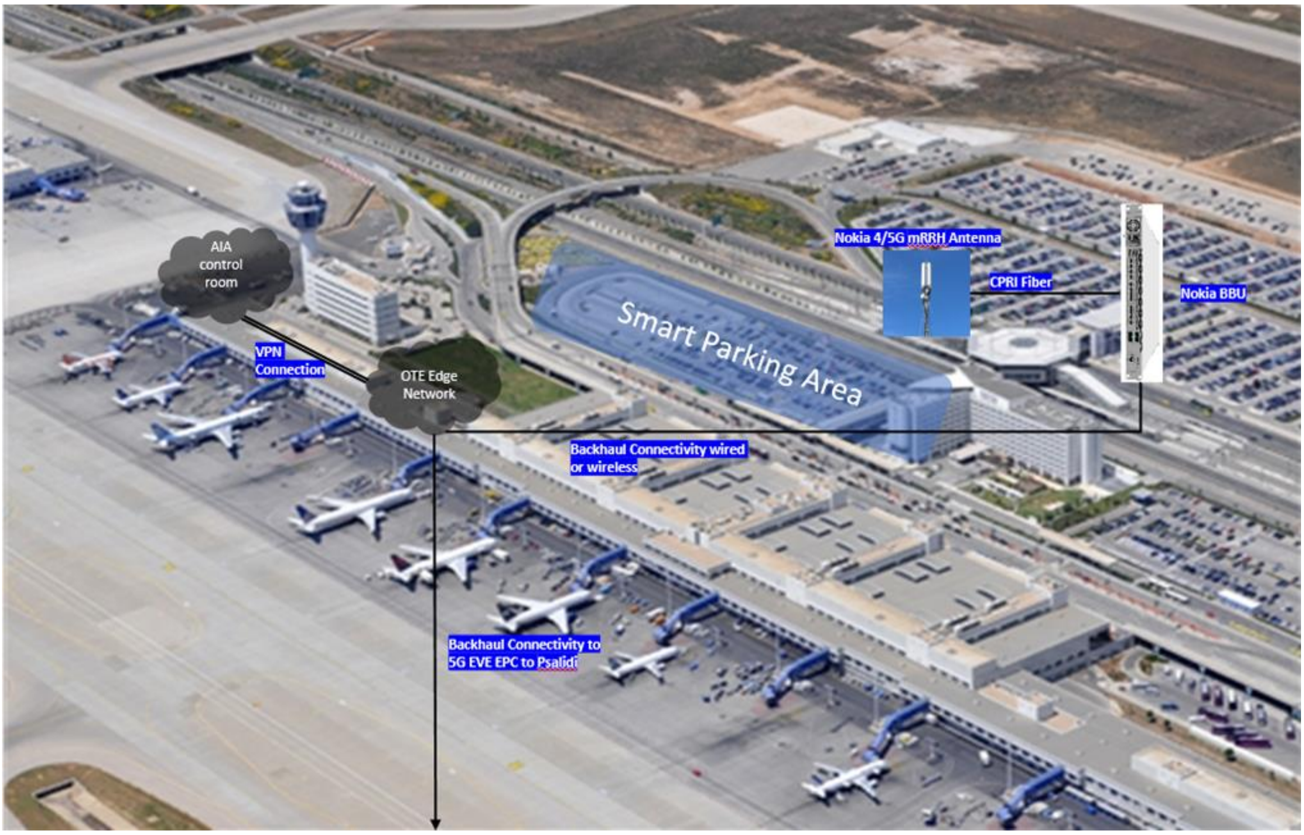


Figure 19. RAN coverage of AIA (logical view)

3.1.4 Trial description

The smart parking use case will take place at AIA premises and will include the installation of IoT sensors in a hundred (100) parking lot slots and will be executed in the following two stages:

Initial phase of the validation: the area selected for the trials is the parking located at the rear area of building 17, administration building, and specifically P8. This is a square area with 706 car parking spaces, 6 Passenger with Reduced Mobility (PRM) car parking spaces and 6 moto parking spaces.

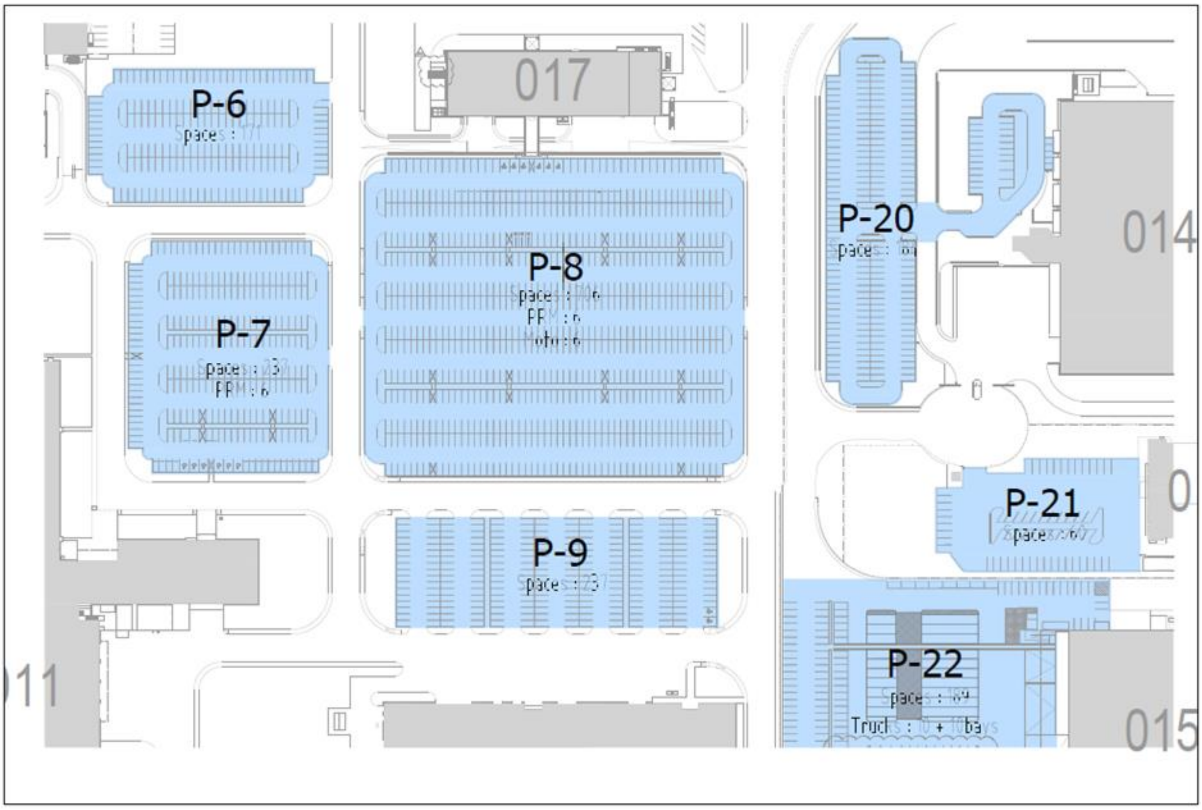


Figure 20. AIA staff parking

The sensors will be installed in the ground of each parking space, will sense whether a vehicle is present in a space and will communicate this information with NB-IoT communications technology in real time. The information will be represented to a web based application for controlling the parking area to the respective airport authority and to a mobility application that will provide the user searching for parking with guidance/instructions to the optimal slot.

3.2 UC11 - Video enhanced ground-based moving vehicles

In respect to the issues and concerns of the follow-me vehicles (efficiency of provisions for aircraft during their arrival and departure from parking positions, staff's misdemeanours, such as exceeding the speed limit or smoking, safety hazards such as fuel spillages, etc.), 5G technologies via the installation of high definition cameras on the follow-me vehicles with live video feeds to not only the ASOC, but also to other concerned third parties and stakeholders, will most certainly expedite the response to needs and emergencies as they occur, and will maintain the safety of the Apron area. Enhancing the ground-based moving vehicles with these technologies which provide real time notification on the Apron situation at any given time is of great value to the airport in sustaining an efficient and safe operation, for the customers (Airlines) for whom, safety and avoiding flight delays is vital, as well as other stakeholders (emergency resource personnel – Police, Ambulance Services, Fire Brigade) in efficiently responding to emergencies.

3.2.1 Use case description

On September 10th, 2021, during the night shift at 01:20 hours, an Airside Monitoring Inspection Specialist (AMIS), is driving northbound on the Apron and encounters two vehicles which have just collided, and the drivers appear to be slightly injured. The AMIS proceeds to notify the ASOC to summon the assistance of the necessary emergency resource personnel.

Figure 21. Airport's Apron Area

As the AMIS continues to carry out its duties and is driving along the airside service road, she notices that there is a fuel spillage on the tarmac near parking position B3. At the same time, there is a ground services employee who is about to light a cigarette and proceeded to promptly inform this employee that smoking is prohibited on the tarmac. During the peak morning hours at approximately 04:30 – 05:30, where there are several departures that the AMIS must facilitate, the AMIS is unable to accommodate all departing aircrafts which results in departure delays of the aircrafts. Simultaneously, the arriving aircraft are also delayed in parking at their final parking positions due to congestion.

The service aims to provide the follow-me vehicles, which lead aircraft to parking positions, on-demand and/or live video streaming or upload recorded data at a later time in order to monitor and oversee the activity at the airport airside area, and attend incidents, emergencies and critical events.

Figure 22. AMI Follow-Me Cars

This will result in 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 ASOC or other operating centers will be able to have an immediate overview and decide the required mitigation actions in a timely manner, regardless of the area of the airport hat the incident is taking place, and irrespectively of whether the ASOC has direct viewing capability of the area or not.

3.2.2 Vertical Components

3.2.2.1 Overall Architecture

The following diagram depicts the general network design in every vehicle:

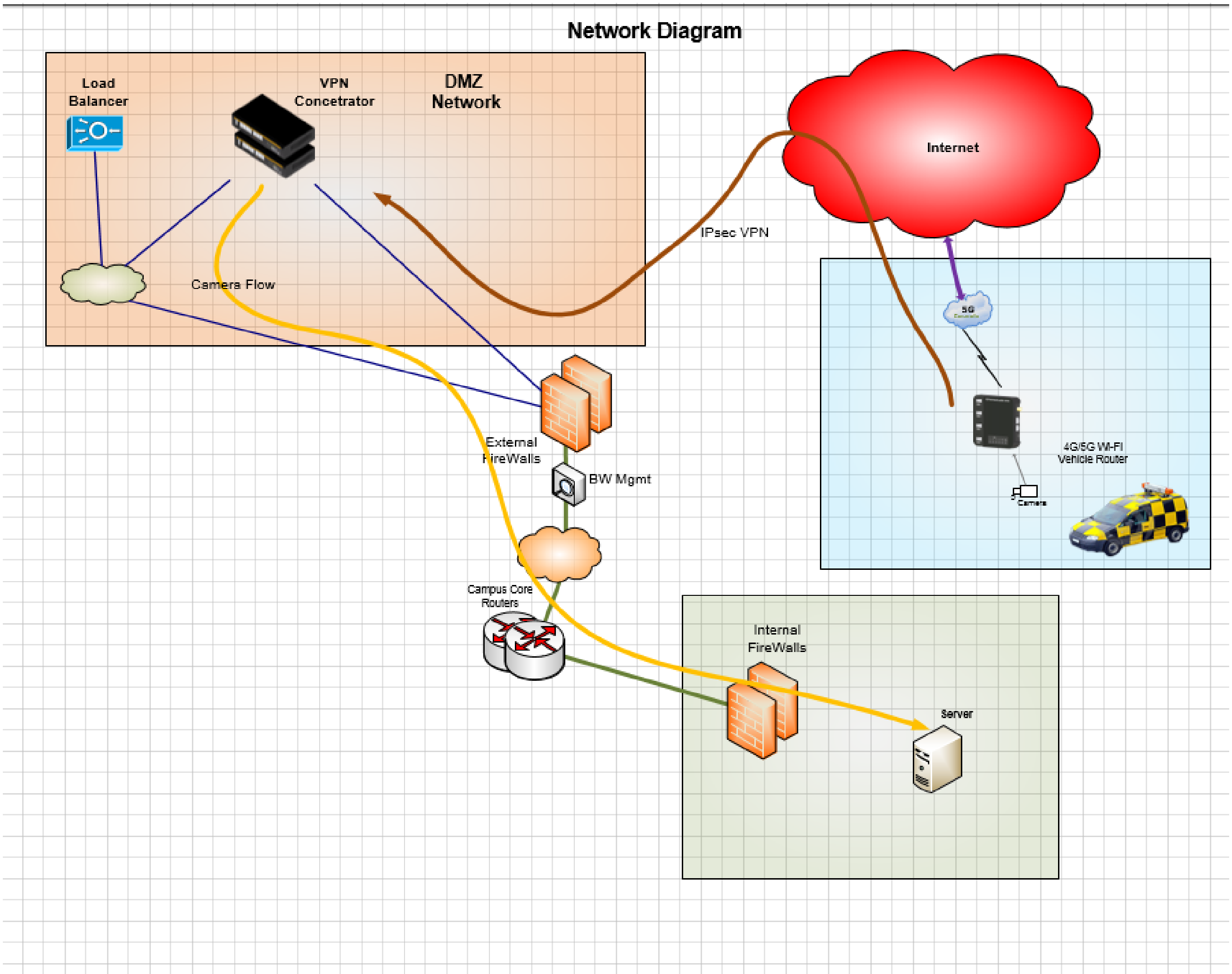


Figure 23. General networking architecture of use case 12.

More specifically, in every follow-me vehicle there will a 4G/5G Wi-Fi router which connects the vehicle via VPN with the main AIA network infrastructure.

Figure 24. Follow-me LTE antenna installation

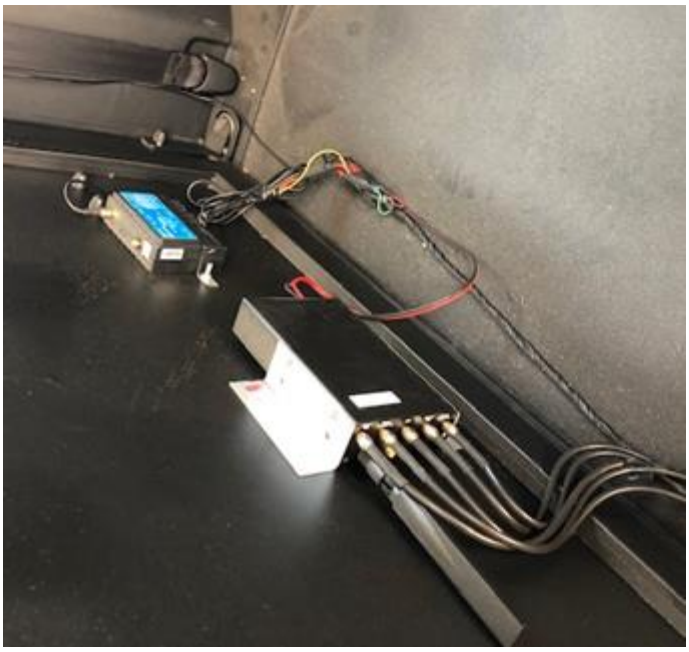


Figure 25. In-car LTE router installation

To achieve the live video streaming, high definition cameras (internal or external) will be installed on the follow-me vehicles and connected to the 4G/5G Wi-Fi router via an Ethernet interface. The cameras will propagate the feed to multiple stakeholders for multiple incidents in real-time. This will facilitate the airport staff (AMIS, ASOC) in expediting the response to emergencies and accurately inform emergency resource personnel (Police, Security, ASOC, Fire Brigade, Medical Response teams etc.)

3.2.2.2 Platform

The platform to be uses is similar to the one described in section 3.1.2.2.

3.2.2.3 Devices and gateways

- 5G Wi-Fi routers with Ethernet interfaces (provided by AIA and relevant consortium partners such as Samsung U.K.)
- Samsung 5G tablets (provided by AIA)
- High definition IP cameras with the following requirements:
    - The access network should provide a high coverage of the area of interest (180° field of view) so that the high capacity produced by the moving cameras will not be limited by the network.
    - 12MP resolution with minimum 25fps
    - Fixed lens, providing 180° Horizontal field of view (HFOV) with F2.8 or better. The lens also shall have IR corrected characteristic
    - Fixed type lens, Wide dynamic range
    - Automatic electronic day night function.
    - Automatic electronic shutter (1/12 to 1/15000)
    - Dynamic range >65db
    - Direct network Ethernet connection
    - Video multicast (one channel minimum)
    - Flickering reduction (50Hz and 60Hz)
    - Extended depth of field
    - Auto white balance
    - The uplink bandwidth should be high in order to accommodate the production of high data rates.
    - The latency in the access network should be low enough in order to have the high quality produced from the video equipment.

The equipment will be provided by AIA and relevant consortium partners such as Samsung U.K.

3.2.2.4 Application

The live streaming process will feed a dashboard presenting the live view from the different cameras that are installed on the follow-me vehicles. This user interface will be accessed by the airport security and other emergency resource personnel (Police, Security, ASOC, Fire Brigade, Medical Response teams etc.) as well.

The backend service of the described application will be based on the Tvheadend[4] open source project, which is a TV streaming server and recorder for Linux, FreeBSD and Android supporting DVB-S, DVB-S2, DVB-C, DVB-T, ATSC, ISDB-T, IPTV, SAT>IP and HDHomeRun as input sources. The deployment will be done on the media server provided by AIA. A mock-up screen of the described functionality is shown in the figure below.

[4] https://tvheadend.org/projects/tvheadend

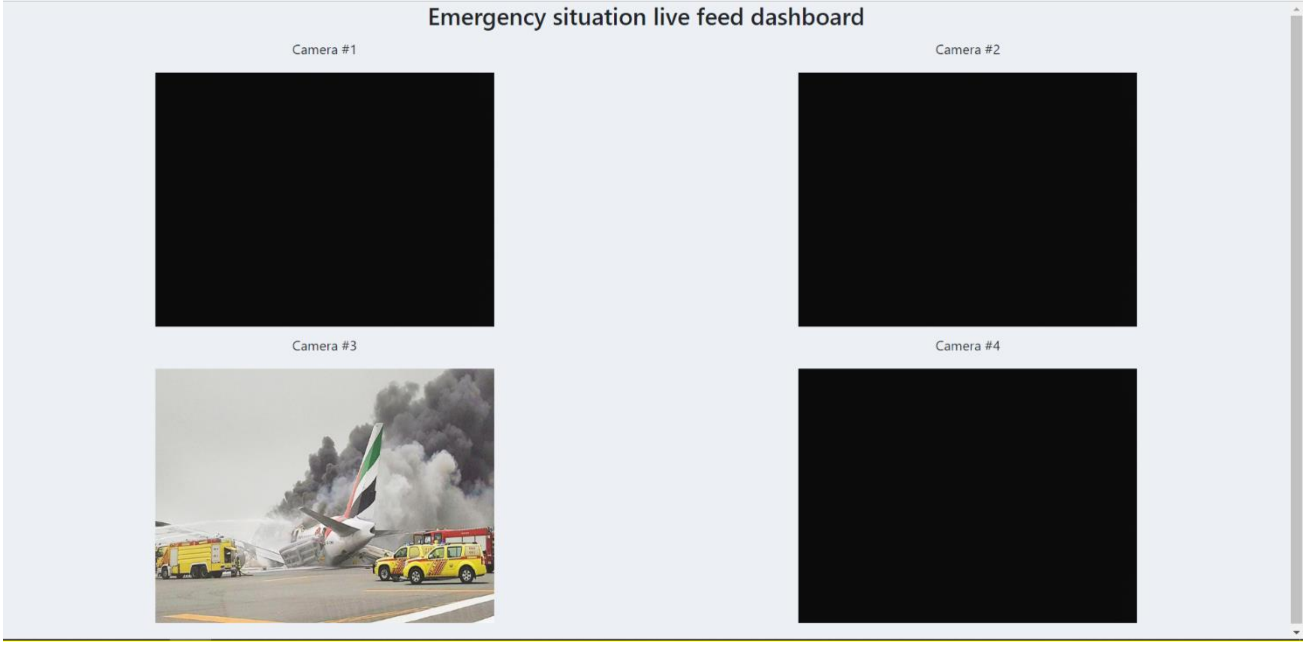


Figure 26. Situational awareness application mock-up screen

3.2.3 Network Component/functions

In the video enhanced ground-based vehicles use case, Nokia-GR will provide the 4G/5G radio coverage equipment (RAN) in the surrounding area of AIA, as highlighted in Figure 27 below:

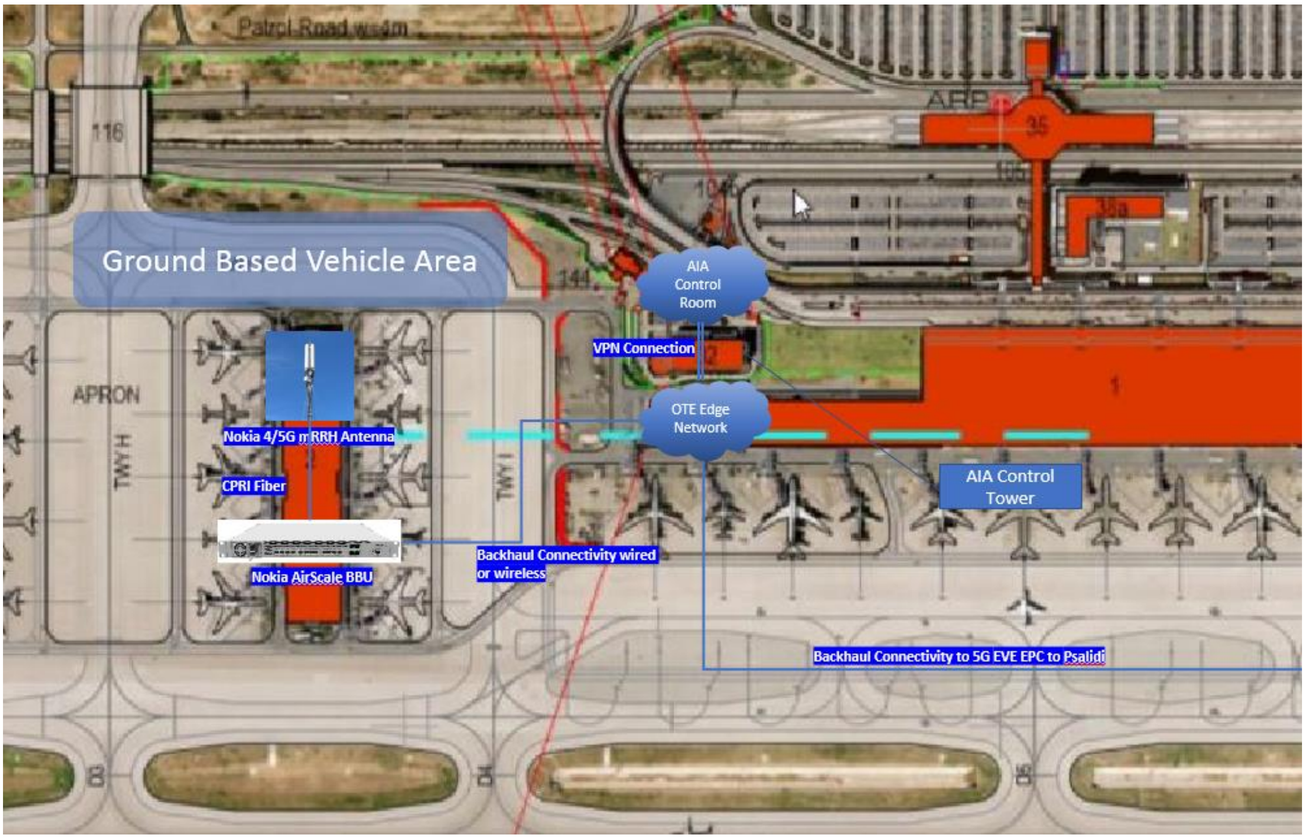


Figure 27. RAN coverage of AIA (logical view)

~5 pairs of LTE/5G mRRH will be used for the needs of the use cases.

Frequency bands of LTE mRRH are:

- Band 43
- Band 7

Those antennas will be connected via CPRI-fiber connection to Nokia's AirScale BBU. Then AirScale BBU is connected towards OTE's edge network in AIA via an <=10Gbps ethernet cable. OTE will connect via a VPN connection towards AIA network (AIA Control Room) and will also provide the back haul wired connectivity towards 5G-EVE EPC network. The backhaul wired connectivity to 5G-EVE EPC will be a <=10Gbps Ethernet connection.

Measurement probes will be deployed:

A. Multiple Probe based, layer 2 & 3, active & passive KPIs continuous measurement (monitoring) platform, from the following probes.

- At the AIA inside the vehicles, connected between the camera and the 4G/5G router (depending on the interfaces available).

-At the AIA, between the NOKIA BBU and OTE edge network at OTE site in AIA premises (1GE/10GE interface).

-At OTE Psalidi premises, just before the NOKIA vEPC (1GE/10GE interface).

-At OTE Psalidi premises, between the NOKIA Core network and the AIA video server (1GE interface).

Control of all the probes and collected measurements transportation to the KVaP platform will be achieved through virtual circuits over the 5G available network capacity (limited bandwidth required).

The KVaP platform will deployed at OTE Psalidi site.

B. Single Probe based, layer 3 & 4, passive KPIs continuous measurement (monitoring) platform.

--At OTE Psalidi premises, just before the NOKIA vEPC (1GE/10GE interface).

3.2.4 Trial description

The trial will take place by using some of the operational staff whom currently drive the follow-me vehicles on which the 5G technology will be applied. The trial intends to address potential problems and thus have the ability to rectify some of them prior to implementation of system with the scenarios. During previous implementations the ability to provide multiple concurrent feeds of high-resolution video streams captured from moving vehicles did not provide reliable results. The video feed transmitted to our ASOC was not reliable and to the level that the ASOC operators required in order to perform the required aircraft and crisis management operations.

Currently ASOC relies on the AMIS verbal feedback in order to obtain situational awareness in areas where they have no direct or CCTV cameras supervision, the use of high-resolution video streams from vehicles attending the vicinity where aircrafts operate or an incident is being escalated, is of paramount importance for the early mitigation and resolution.

3.3 UC 12 – Emergency Airport Evacuation

For efficient and rapid evacuations, in cases of either security emergencies (security threats, threatening phone calls etc.) or other related emergencies (fire, natural disaster etc.), 5G technologies may enhance the evacuation process and thus, reduce the possibility or magnitude of casualties. To evacuating in a quick and organized fashion, the automated guidance of emergency routes from the affected area up to the muster areas, is of the utmost importance. Through 5G enabled solutions, the operational control centres will obtain real-time data from the emergency environment which is to be evacuated, such as the number of occupants within the area, persons trapped in isolated areas of buildings in regards to the real-time flow management of evacuees.

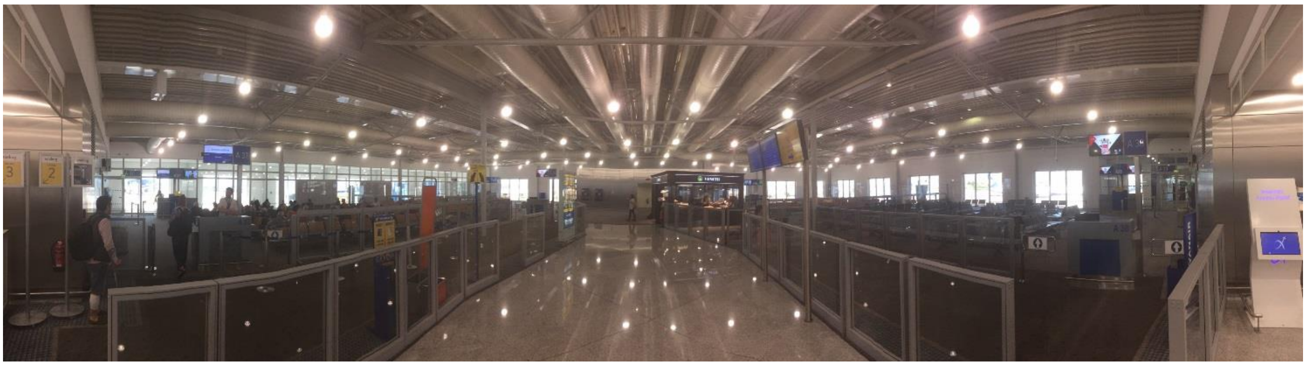


Figure 28. West Gate area of Satellite Terminal Building

3.3.1 Use case description

On January 15th, 2020 at 22:45 hours at Gate A36 of the Satellite Terminal Building (STB), a suspect backpack has been located underneath a seat within the area, by a passenger destined to depart from the same gate on flight AX375 at STD 23:15 hours. Most passengers for this flight have already arrived at the gate and are waiting to board. The passenger in question begins to ask other passengers in the immediate vicinity if the backpack is theirs, however, to no avail. At the same time, a male Caucasian, presumably a passenger on the same flight is seen briskly walking away whilst efforts are still being made to locate the potential owner of the backpack. At 22:48 hours, the passenger approaches the airline staff at the departure gate informing them of the package and suspect behaviour. At 22:49 hours, the gate attendant immediately reports the above details to the Airport Services Operations Center Security (ASOC) Staff Security. The ASOC Security immediately informs the Security Duty Supervisor (SDS) and proceeds to summon the assistance of uniformed security staff and the Police to the area in order to investigate the unattended backpack and suspect passenger.

While the developments at the gate continue to prevail, at 22:55 hours, the airport's call center receives an anonymous call from a female voice stating that there will be an attack on flight AX375. The call center staff immediately informs ASOC (Security. The ASOC who had shortly before been informed of the imminent unattended package threat and suspect at Gate A36 from which flight AX375 will be departing, immediately informs the Airport Duty Officer (ADO), the SDS and ASOC Security of the developments. At 22:58, arrangements are made by the ADO, to call in the Threat Evaluation Committee with regard to the telephone threat, also taking into consideration the current developments at Gate A36.

While the congregation of the committee is underway, at 22:49 a Security Foot Patrol Officer arrives at Gate A36 to protect the area of the unattended backpack until the arrival of the Police. At 22:54, two police officers arrive on site and commenced their investigation of the unattended package while monitoring the behaviour of the suspect passenger.

At 22:58, after the careful on-site investigation conducted, the Police informs their operations center that an evacuation of the area is deemed necessary, as they are not able to determine the nature of the suspect item which remains a threat. At 22:59, this information is communicated by the Police to the Threat Evaluation Committee and the Threat Evaluation Committee decides to initiate the evacuation of the relevant areas affected within the STB. All occupants circulating within the affected area are evacuated from the boarding bridges of exits at Gates A37, A39 and from the staircase between the two (2) gates.

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.

Figure 29. Gate area - Evacuation route

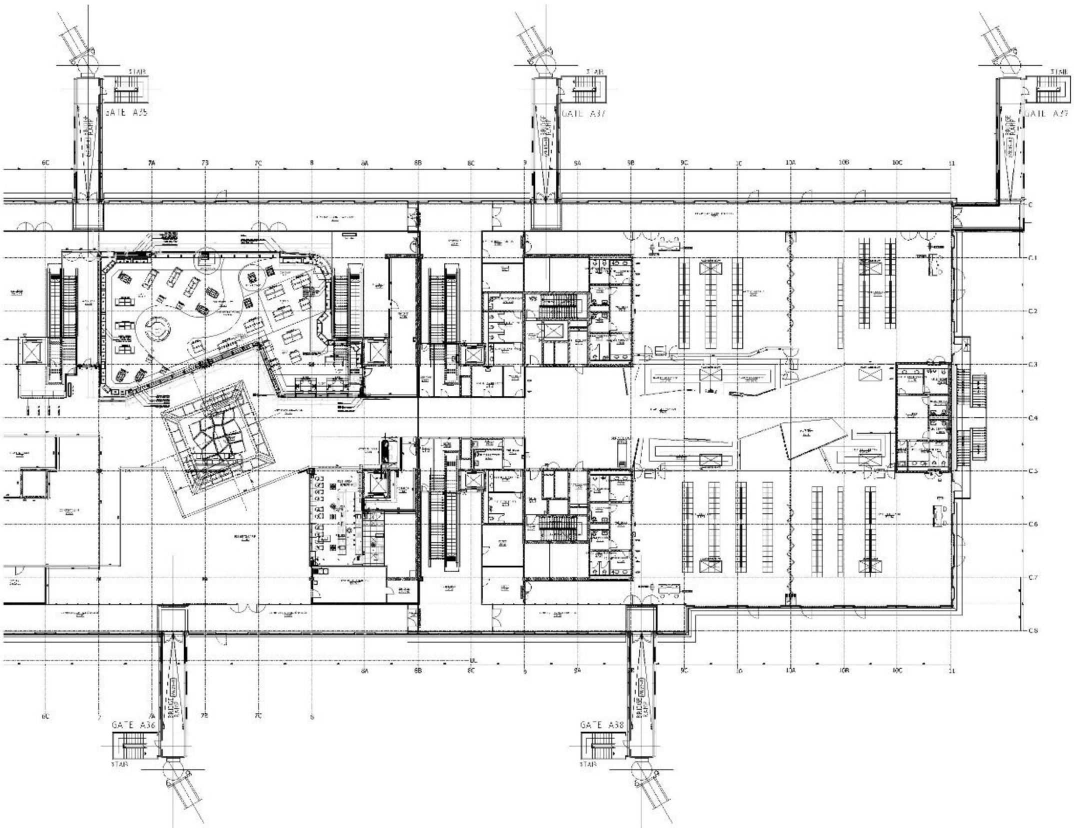


Figure 30. Layout of use case area

This scenario aims to showcase the way airports (in general) and other large-scale public infrastructures, can exploit 5G capabilities to bring in place an effective evacuation plan, where personalized, dynamic and smart instructions can be provided in a reliable, instantaneous and massive-scale manner.

3.3.2 Vertical components

3.3.2.1 Overall Architecture

The provided service will be an extension in the functionality of the existing WINGS' STARLIT platform and will consist of a mobile application that will provide the user with personalized suggestions aiming to evacuate the area that the use case will take place as fast as possible, while ensuring that the people are safely guided out of the area. To achieve this, indoor 5G micro cells provided by NOKIA-GR will be installed in order to calculate each user's location accurately. AIA will provide the exact layout of the area in order for WINGS to create its digital twin in the mobile application. In such a way the user can have an instant view of his location within the area while the system will provide him/her with personalized suggestions on how to evacuate the building taking into account important information retrieved from his/her boarding pass, as well as the others users' locations, in order to avoid congestion of users in a specific route, as explained in section 3.2.2.4. Below, a schematic representation of the proposed architecture is shown:

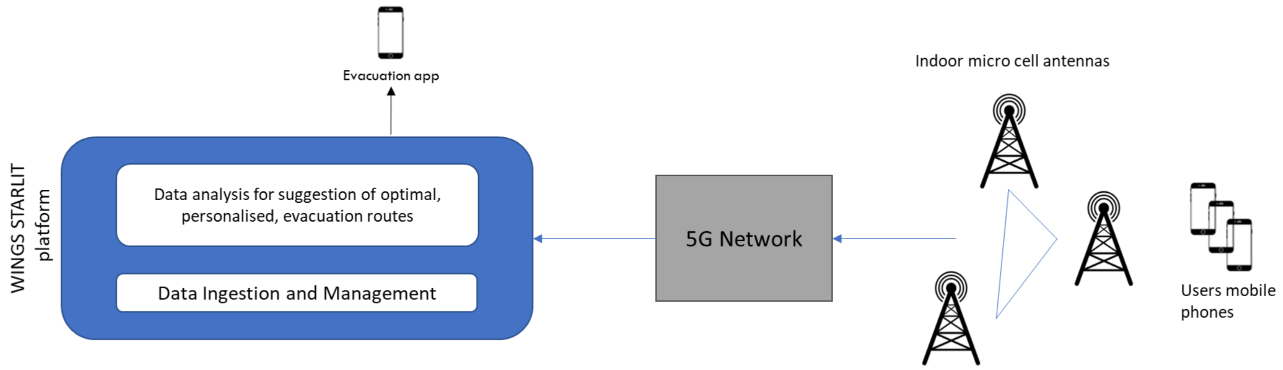


Figure 31. UC11 overall architecture

3.3.2.2 Platform

For the evacuation use case WINGS' STARLIT platform will be utilized. STARLIT is a cloud-based platform as already described on UC 10. For example, in the evacuation use case, each individual person can be routed towards the suggested exit taking into account his context, preferences and/or special needs. Figure 32 provides a more detailed view of the STARLIT functional architecture. The key components in the evacuation use case are the Sensors and data sources, Communication technologies, Data ingestion and management, the Data analysis and the Dashboards.

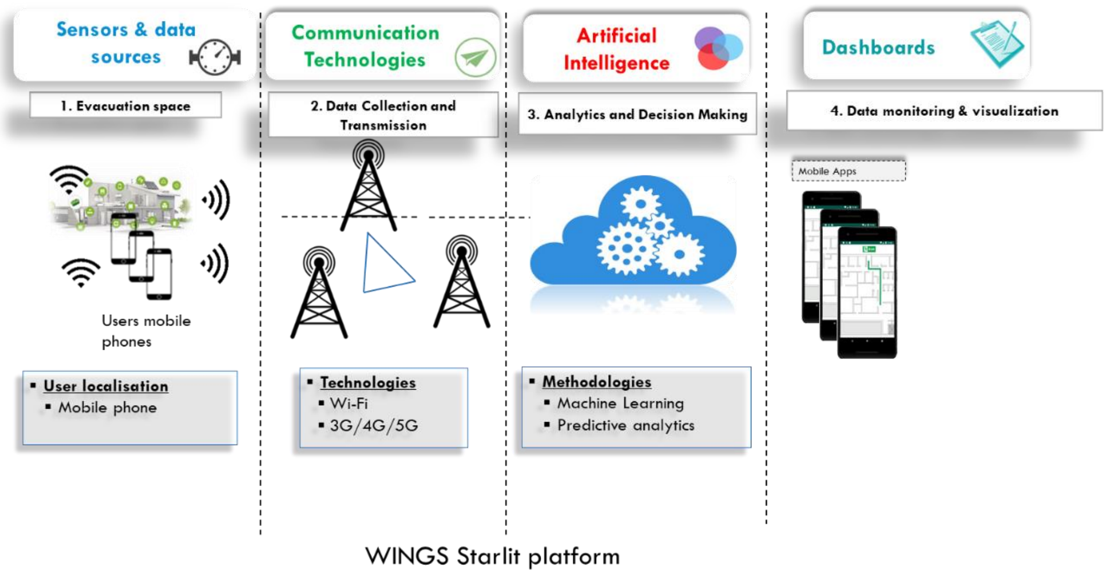


Figure 32. WINGS STARLIT IoT Platform

NOKIA-GR's IoT platform may also be considered for this use case using the functionality described in Sections 2.3 and 3.1.2.2.

3.3.2.3 Devices and gateways

Devices

Samsung will provide 5G S10 smartphones[5] (and 5G tablets for all the participants of the evacuation use case.

Gateways

Nokia indoor 5G micro-cells.

3.3.2.4 Application

A mobile application will be developed for the needs of the Emergency Evacuation use case. The application will load a map that will be the virtual representation of the specific space that the use cases will take place (Figure 33). Each user's location will be shown on the map and the application will provide personalized guidance by showing the shortest way to the nearest exit. More specifically, the system will have a total mapping of the all the internal and external spaces of the airport (for the trial purposes only building 2 of the STB will be mapped), it will be able to locate a particular user and will display the necessary part of the mapping in a scaled manner. The map will use a zoom scale in order to provide information of the user position and the nearest exit in the same screen. A green line will mark the best route for the user, so he can reach the nearest exit as fast as possible.

The application will work in a personalized manner taking into consideration various factors such as the user's mobility capabilities, age, health status, as well as the design of the physical space, any obstacles that might exist, the current occupancy, and the capacity of the evacuation routes. This kind of information can be gathered for each user from various sources for example the respective boarding pass or by setting the users preferences in the evacuation application. So, if special instructions are required, the application will be able to provide them during the evacuation process. A mock-up screen of the described functionality is shown in the figure below.

[5] https://www.samsung.com/uk/smartphones/galaxy-s10/galaxy-s10-5g/

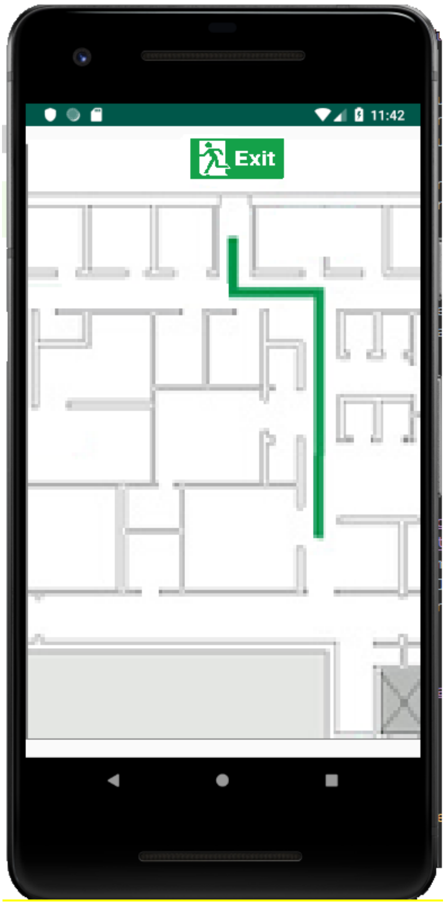


Figure 33. Evacuation application mock-up screen

3.3.3 Network Component/functions

In the Airport Evacuation use case, NOKIA-GR will provide the 4/5G radio coverage equipment (RAN) in the surrounding area of AIA, as highlighted in figure below:

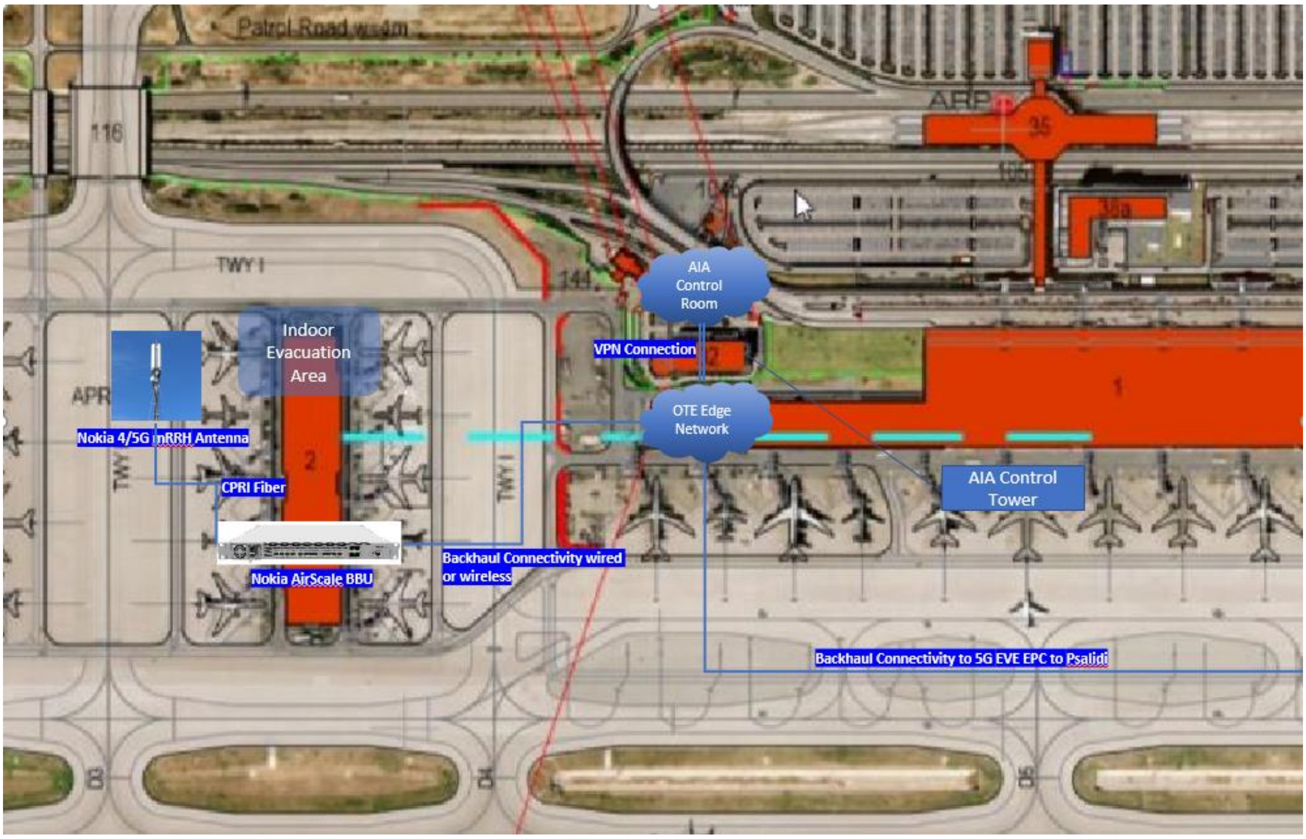


Figure 34. RAN coverage of AIA (logical view)

3.3.4 Trial description

The scenario to be implemented involves a suspicious person, an unattended item in the same area, and a simultaneous reception of an anonymous call, all of which result in the congregation of the Threat Evaluation Committee.

The area of departure Gates A37/A39 of the STB will be used to carry out the trial and scenarios. Athens airport STB is located south of the main terminal.. Terminals are connected by an underground tunnel equipped with a moving walkway as well as a ground walkway. Athens airport STB has two floors: ground level for arrivals and first level for departures.

3.4 UC13 – Excursion on an Augmented Reality (AR)/Virtual Reality (VR)-enhanced bus

Use case 13 aims to demonstrate the value offered by the use of 5G technology in cases when groups of people travel, e.g. on a bus, in order to visit a site of interest. The use case focuses particularly on the example of school students travelling to a destination of educational interest during a field trip or excursion, such as a group of up to 20-25 students from the school of Ellinogermaniki Agogi (EA) travel on a school bus to AIA to visit an exhibit that is hosted in one of the public spaces of the airport. The fast, reliable wireless connectivity offered by 5G and the smooth streaming of online content that can enable is utilized to generate good quality digital learning experiences both during the transportation to the destination and during the visit of the exhibit.

3.4.1 Use case description

In the morning of a typical working day in school year 2020-2021, a group of 20-25 students from the school of Ellinogermaniki Agogi (EA) travel on a school bus to AIA to visit an exhibit that is hosted in one of the public spaces of the airport.

The use of 5G-enabled AR and VR technologies enriches this school excursion with additional learning opportunities both during travel time and during the on-site visit. The digital content, media and applications used are combined with relevant conventional educational content and activities, complementing and extending them.

Figure 35. The 20-km bus route from the school (EA) to the airport (AIA)

The school bus transferring the students and their teacher starts from the premises of EA in the suburb of Pallini in the north east of Athens, heading towards the airport. During their bus transfer to the destination, students are presented with rich informational and educational content preparing them for the visit of the exhibit in the airport, through the use of VR technologies and 5G-enabled headsets. The high-quality rich content is delivered simultaneously to the 20-25 students riding the bus. The distribution of content to the students is personalized, in accordance with their preferences and requirements, their educational decisions and design made by their teacher. The content includes different objects (video, audio, 3D objects, etc.) and the student decides which object to interact with.

During the trials, the bus-based activities are implemented in an area of the airport which is selected by taking into account the availability of appropriate space and 5G coverage. An area with these characteristics that has been selected as the currently best candidate is the space consisting of parking areas and streets behind the Administration building (Building 17) of AIA. AIA grants the school bus and its passengers access to this area for the needs of the trials.

Subsequently, students reach the area in the airport where the exhibit can be visited. There, they use AR technologies to interact with digital content (in the form of text, images, videos, interactive 3D digital objects) blended with the exhibit and the surrounding environment. Approaching the exhibit, students use their 5G-enabled handheld devices to see and interact with relevant digital content projected on the physical world. This includes information on the exhibit and its wider cultural/historical/scientific context, visualizations of invisible processes or of extensions or analyses of the physical object, etc. The digital content also includes 3D items that the user will be able to interact with (e.g. by viewing and examining them from different angles and distances, etc.).

Additionally (or alternatively to the pre-visit bus-based VR experience), students are also presented with relevant content through VR while traveling back to school after they have completed the visit of the exhibit in the airport, in the context of wrap-up and follow-up learning activities.

While there can be flexibility about the selection of the thematic content of the learning experiences, current planning and decisions have prioritized the use of historical, cultural and scientific content relating to the "Myrtis, "Face to Face with the Past" exhibition[6] .The full physical version of this existing and very successful exhibition presents the results of an important interdisciplinary enterprise: the focal exhibit is the reconstructed face of an anonymous 11-year-old Athenian girl who was – along with Pericles – one of the tens of thousands of victims of typhoid fever in the year 430 BC. The girl is conventionally named Myrtis. Step by step, the exhibition describes the documentation process towards the full reconstruction of the girl's face based on the remains found during excavations in central Athens.

Figure 36. Myrtis as a physical exhibit in the "Myrtis, Face to Face with the Past" exhibition

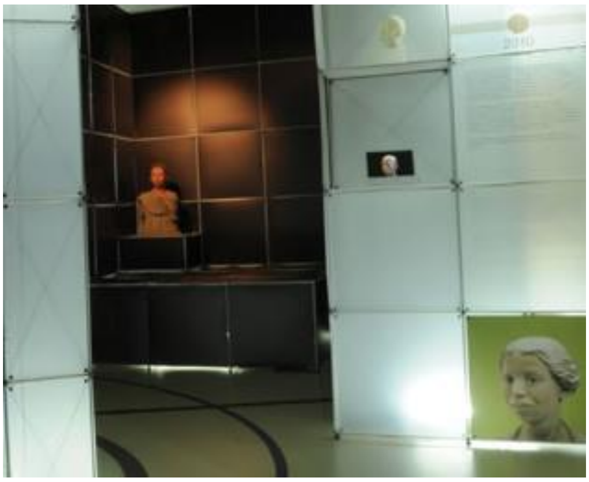


Figure 37. Myrtis as a physical exhibit in the "Myrtis, Face to Face with the Past" exhibition

In the present use case, the exhibit is an artistically designed surface in the form of a panel or banner or poster, hanging or standing in an appropriate area in the public spaces of the airport and inviting travellers to find out more about Myrtis, and through her, about ancient Athens and life in the ancient city. By pointing their smartphones or tablets to the exhibit, users (i.e. the visiting students, but also every airport user) get rich AR technology and content activated. They are invited and motivated to find out about and interact with various aspects of Myrtis' story and everyday life of people in the past, in the context of personalised experiences defined on the basis of users' needs and interests and a set of predefined interaction scenarios.

[6] http://www.myrtis.gr

Figure 38. Examples of public images of Myrtis, including from a previous event hosted by AIA, and an impression of her "getting alive" through AR on a handheld device

Possible locations for the exhibit include the permanent exhibition space of the Acropolis Museum in the departures area of the airport, or another appropriate space in the public space of the departures or arrivals areas.

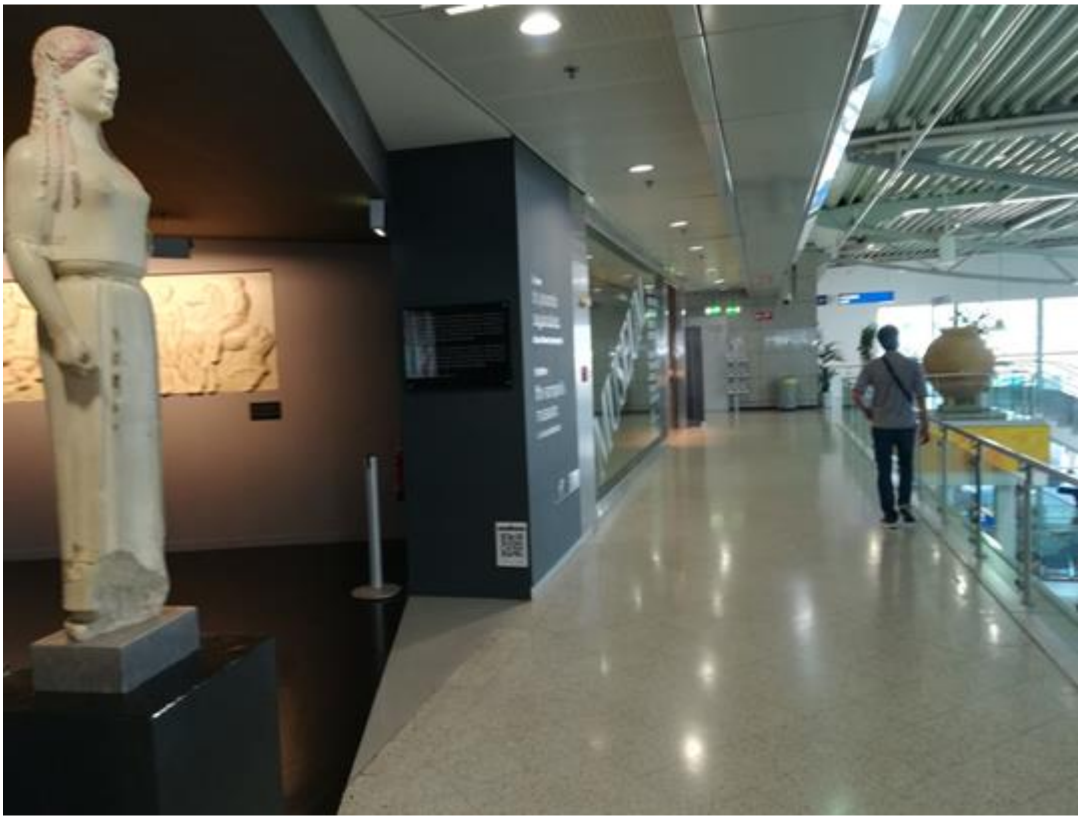


Figure 39. Views of the Acropolis Museum exhibition in the airport (AIA)

Figure 40. Views of the Acropolis Museum exhibition in the airport (AIA)

Figure 41. Views of the Acropolis Museum exhibition in the airport (AIA)

3.4.2 Vertical Components

3.4.2.1 Overall architecture of use case

The architecture of AR/VR bus excursion use case consists of two components:

1) AR and VR applications:
AR and VR applications will offer interactive and audio-visual factor to learning during the bus excursion.

2) Nokia 4/5G radio coverage equipment (RAN)

The 5G technology will offer the opportunity to AR and VR applications to be faster, with better throughput and mainly to be used in outdoor environment like the environment of this use case.

3.4.2.2 Platform

Platform defined in section 3.2.2.2.

3.4.2.3 Devices and gateways

The 5G-enabled hardware required includes VR/AR equipment to be used by each of the participating students. VR on the bus will be headset based and AR at the exhibit will we phone based. Samsung will provide Samsung GearVR headsets[7] and S10 devices-5G version[8] respectively.

[7] https://www.samsung.com/uk/wearables/gear-vr-r325/

[8] https://www.samsung.com/uk/smartphones/galaxy-s10/galaxy-s10-5g/

3.4.2.4 Application

The use case requires the development of the respective AR and VR applications. This will be carried out by ATOS in collaboration with EA, based on technological development and deployment offered by ATOS and educational and 3D digital content offered by EA.

In the development of the AR and VR applications, the following points will be taken into consideration:

- The content and design of the learning experiences is based on the consideration of relevant learning needs and objectives. The design process involves teachers as orchestrators of the learning experiences and in close collaboration with experts providing them with technological enablers and support.
- The aim of using Extended Reality (ER) (which is VR and AR) is to enhance the interaction between students and the learning content, making them more engaged and motivated to probe deep into the targeted area of learning.
- It is desirable that students participate in personalized experiences adapted to their characteristics, needs and interests and shaped according to their demands and decisions.
- Elements of gamification may be included in the design of the learning experiences, to increase user motivation for active participation and engagement with the learning through playful interaction with content and peers. For example, possible elements of this kind are the following:
  - Users may be playfully motivated to provide information about themselves so that the experience can be adjusted accordingly (e.g. through the use of a mini-game at the start).
  - Users may have the opportunity to collaborate with each other around and in relation to the exhibit and/or the theme of the excursion, e.g. by co-creating relevant digital content (e.g. collaborative drawing/painting), or by collaboratively solving a puzzle.
  - 'Treasure hunts' and searching for clues may be included in the design to motivate users to look for hidden information and gather points/tokens etc. that will allow them to advance though the gamified experience.

3.4.3 Network Component/functions

In the AR/VR bus excursion use case, Nokia-GR will provide the 4G/5G radio coverage equipment (RAN) in the surrounding area of AIA, as highlighted in Figure 42 below:

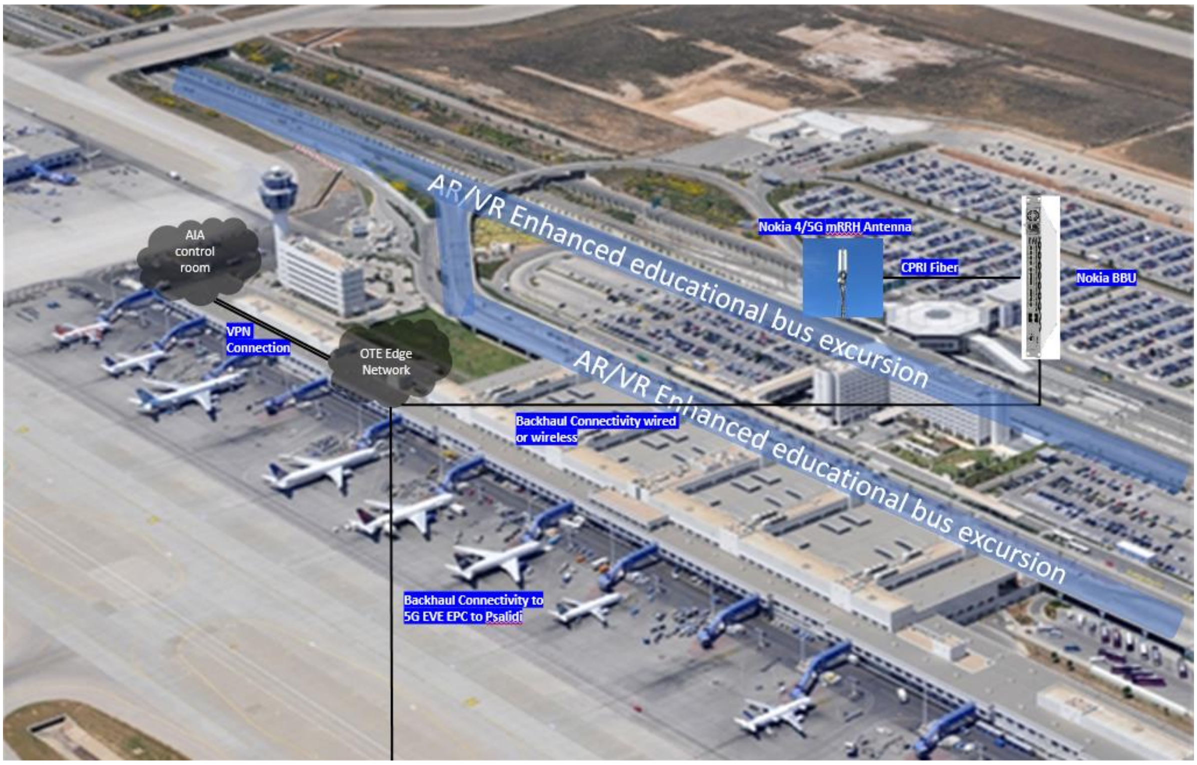


Figure 42. RAN coverage of AIA (logical view)

3.4.4 Trial description

The exact time for the visit of the student group to the airport will be defined by EA and AIA in collaboration, so as to secure that: a) the 5G digital learning experience during the outing will be relevant to the in-school learning experiences of the students, b) the preparation and setup of the exhibit and the development and deployment of the AR/VR has been carried out as required, and, last but not least, c) peak periods of traveller traffic at the airport (e.g. holidays, big events hosted, etc.) will be avoided.

EA and AIA will also collaborate closely to define the appropriate spaces for the realization of the trials, i.e. a space for the school bus to move within the area of 5G coverage and the public space where the exhibit will be hosted. Diligent attention will also be paid to all security, safety, privacy and data protection issues arising from the fact that a group of under-aged students will visit the airport premises for the purposes of the trials, in accordance with the ethics provisions and procedure of the project.

4 Athens node use cases technical requirement analysis and evaluation

4.1 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]. In our case, where four different main use cases have 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.

4.2 Use case 10- Smart airport parking management Technical Requirements analysis

The general vertical use case requirements for the use case 10 are shown in Table 2 . The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 43 .

Table 2. 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								

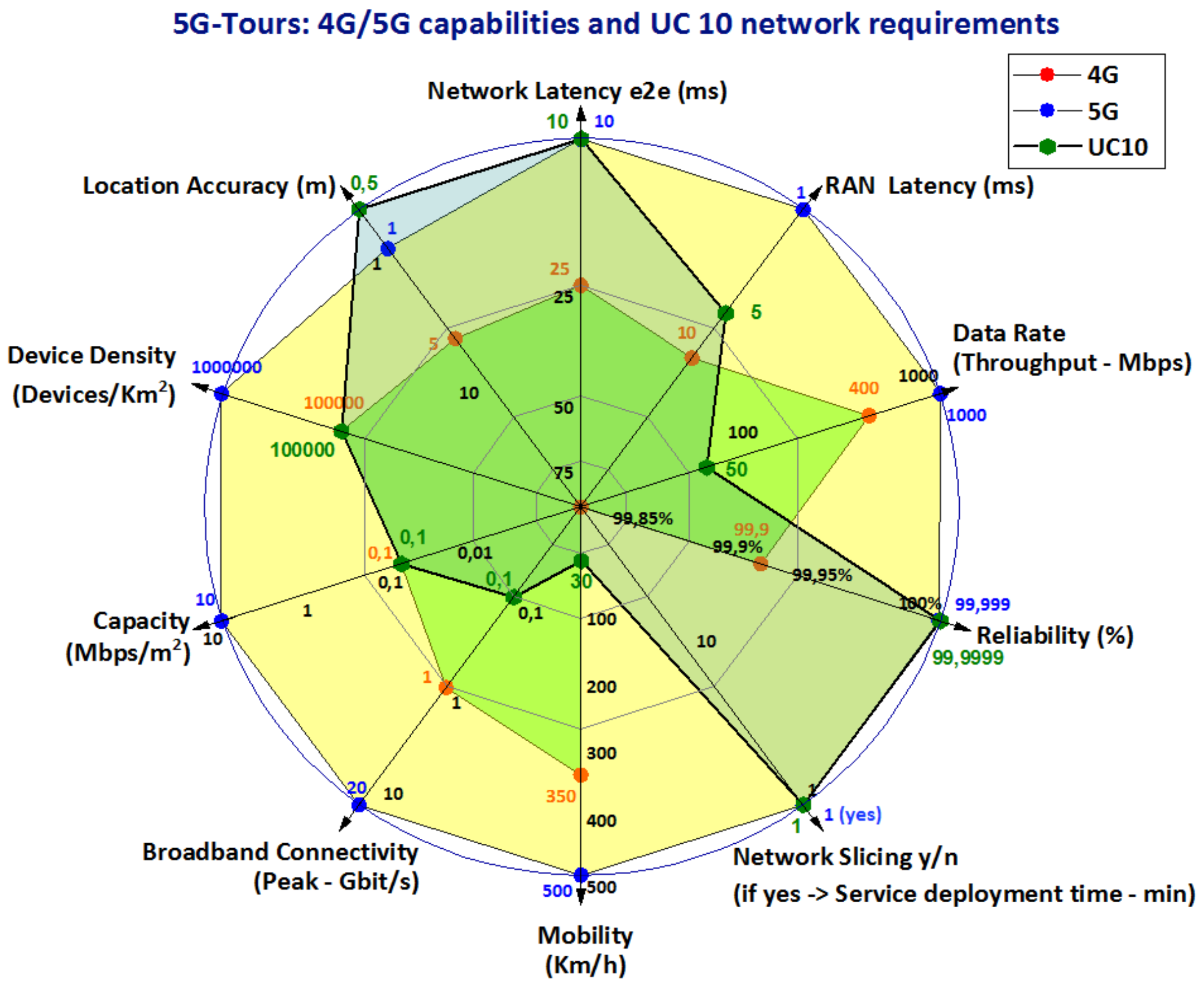
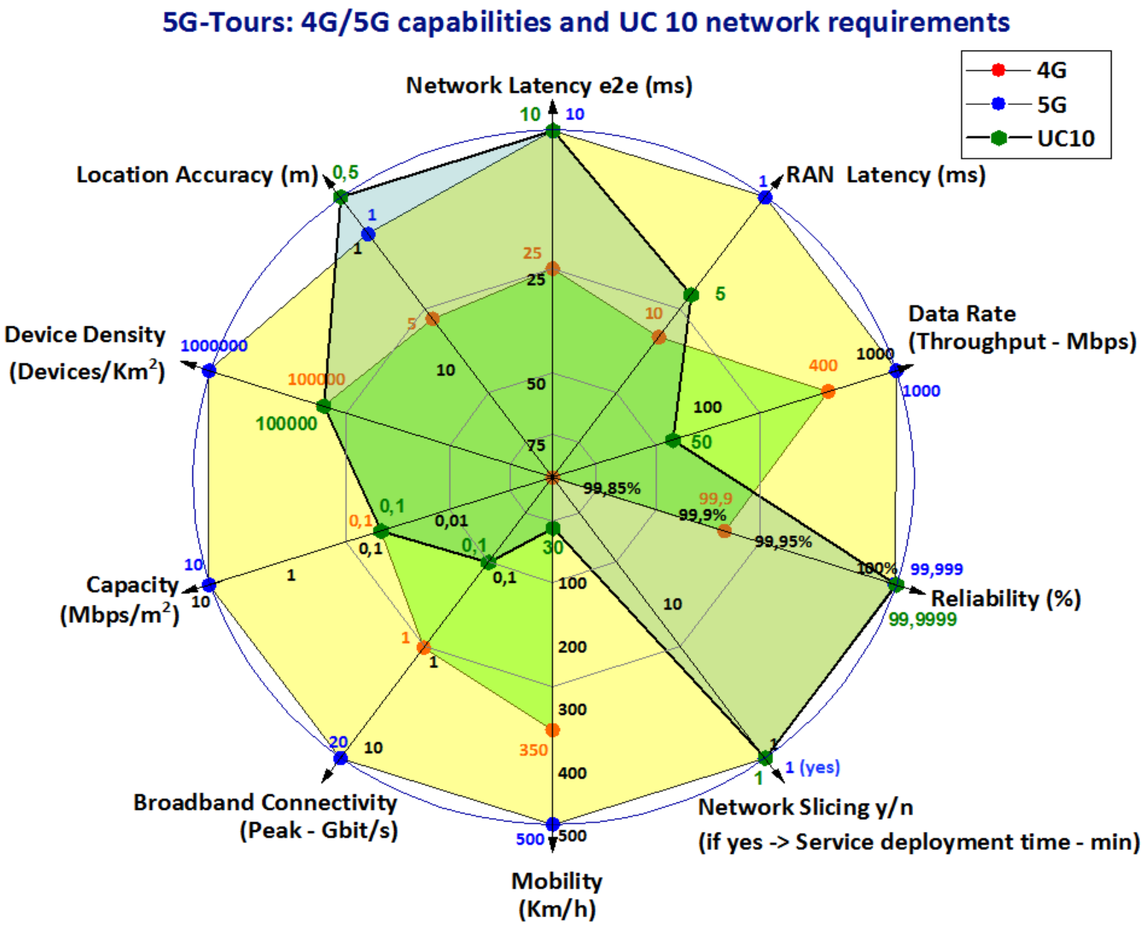


Figure 43. Radar graph for UC 10: Smart Parking management requirements



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),
- capacity and
- device density

the existing 4G/LTE and 4G+ technology/network will suffice, when it comes to

- reliability, slicing and
- RAN latency and network latency (E2E)

a 5G network is required.

Furthermore, for the case of the location Accuracy the UC-10 requirement stretch the limits of 5G networks. 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 Wi-Fi assisted / 5G network together will other modalities should be utilized in order to provide 0.5 meters location accuracy.

4.3 Use case 11 –Video enhanced ground based moving vehicles Technical Requirements analysis

The General vertical use case requirements for the use case 12 are shown in Table 3. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 44.

Table 3. Use Case 11 – 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

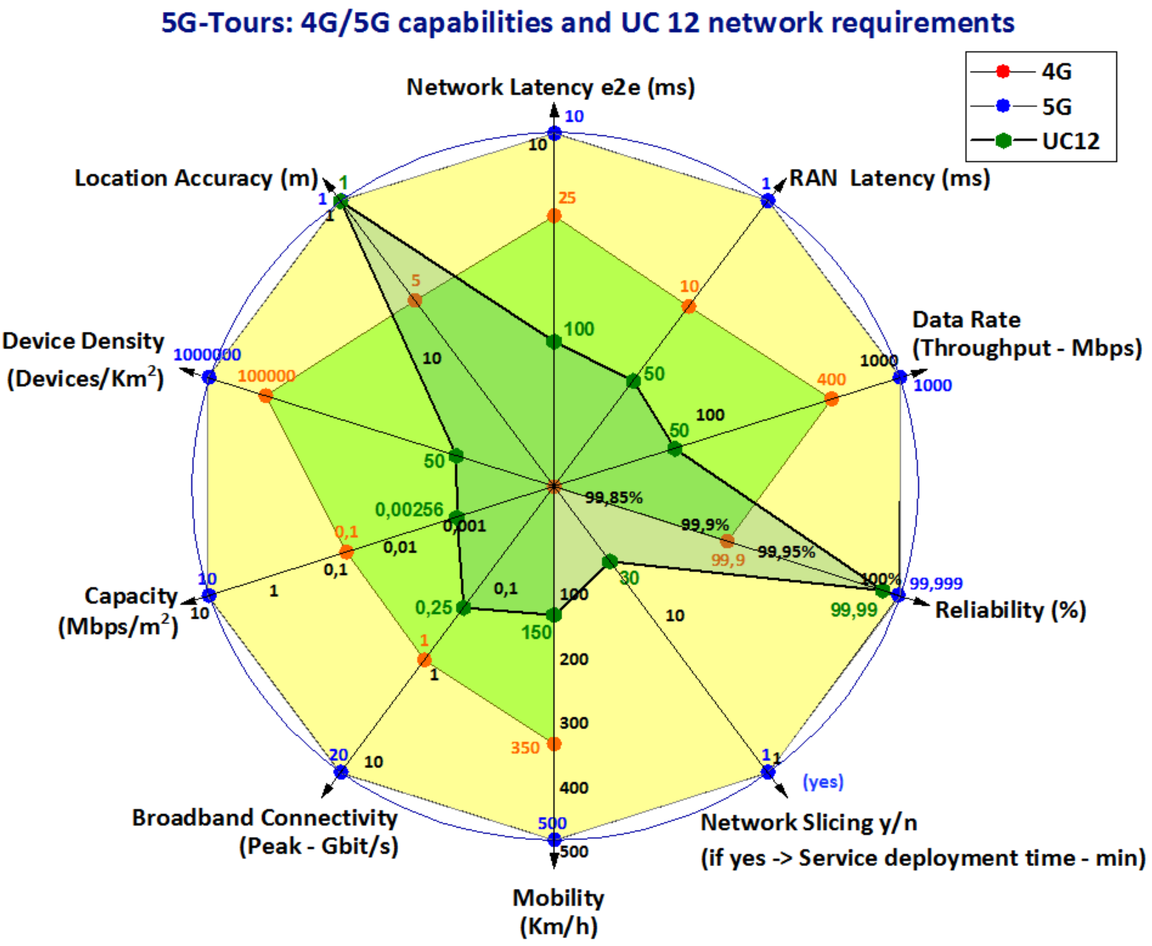


Figure 44. Radar graph for UC-11: Video enhanced ground based moving vehicles requirements

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 (3.1) can also be achieved by other means in outdoor environments, the only requirement that necessitates 5G technology is network slicing. This UC-12 can server as an example of a service that even though it does not strictly require 5G it will definitely benefit from such deployments.

4.4 Use case 12 –Emergency Airport Evacuation Technical Requirements analysis

The general vertical use case requirements for the use case 11 are shown in Table 4. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 45:

Table 4. Use Case 12 - 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

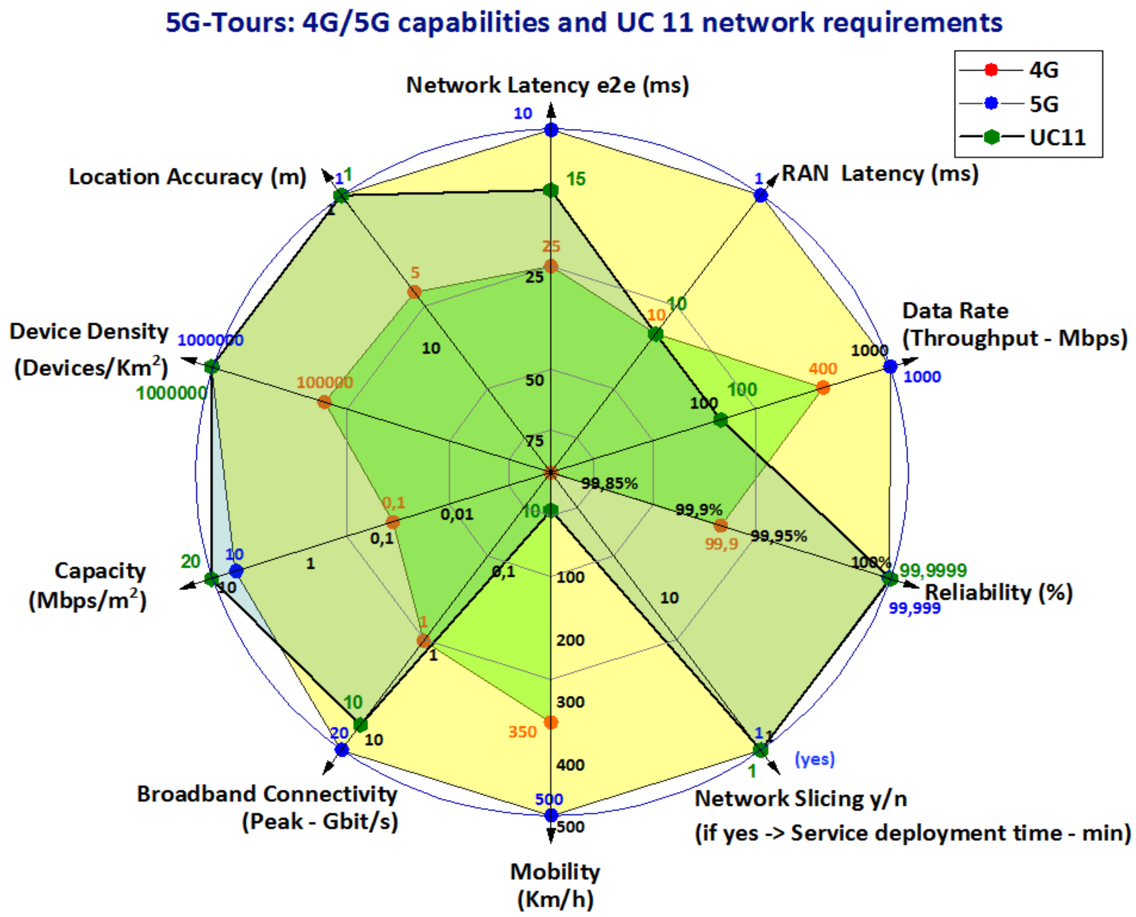


Figure 45. Radar graph for UC 12: Emergency Airport Evacuation requirements

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 their limit. Therefore, for a successful implementation of this UC careful planning of the 5G NR eNBs 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.

4.5 Use Case 13 – AR/VR bus excursion technical requirements analysis

The general vertical use case requirements for the use case 13 are shown in Table 5 below. The corresponding radar chart of general requirements against the 4G/5G networks capabilities is shown in Figure 46.

Table 5. 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

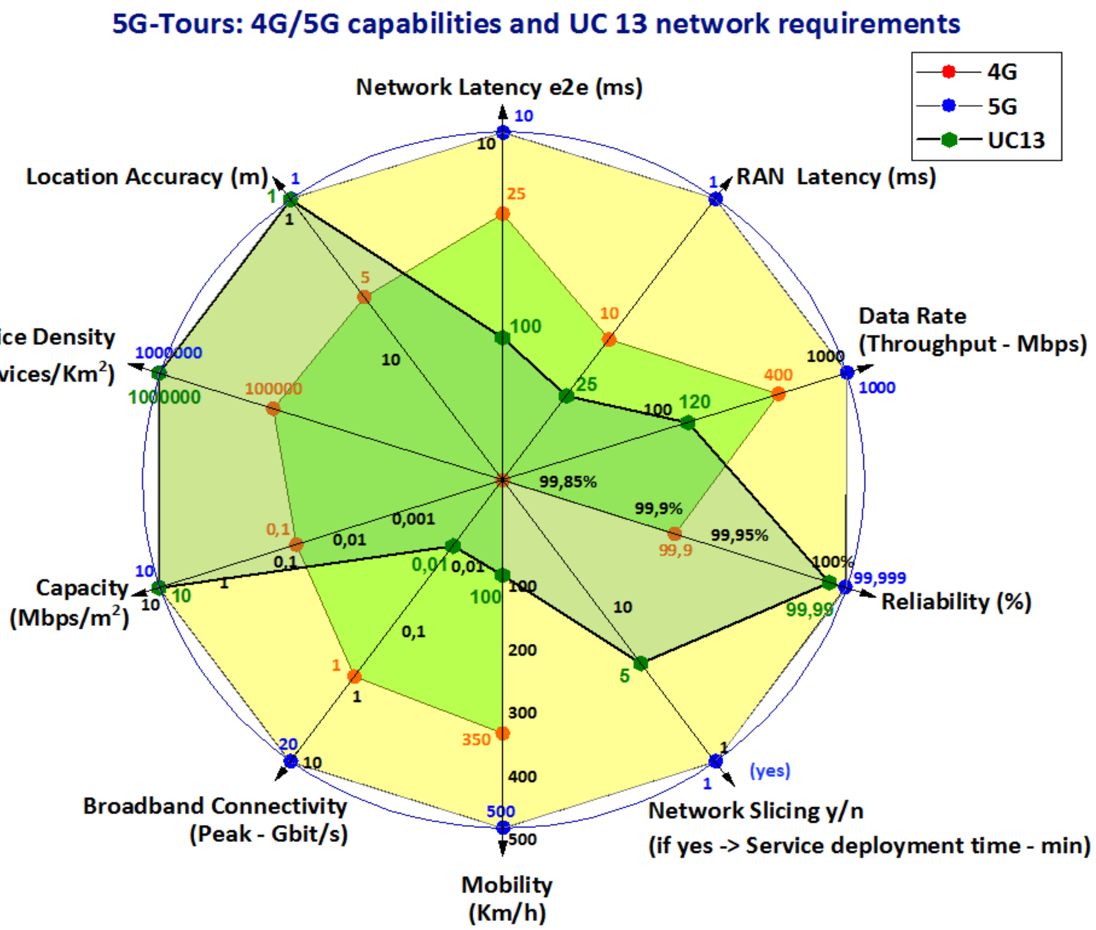


Figure 46. Radar graph for UC 13: Excursion on an AR/VR-enhanced bus requirements

Half of 5G-TOURS UC-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 be 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 Core 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.

4.6 Description of the evaluation methodology

There will be two KPI measurement platforms, to be used:

A. Multiple probe based, layer 2 & 3, active & passive KPIs continuous measurement (monitoring) platform.

Pass through probes, GE/10GE, connected at several points of the whole network:

- At the use case site, just after the terminal device: camera, IoT sensor or IoT gateway, 5G modem, etc.

- At the interface between the 5G antenna Base Station (BS) and before the backhauling equipment
- Between the EPC and the IP Core router
- At the input stage of the application servers (after the IP core router)

The probes will consist of two ports, either GE or 10GE technology. Typical probes are of the manufacturer Accedian. They will be synchronized either to a Precision Time Protocol (PTP) grand master clock, installed in the central site of the 5G network or through a local GPS device. They will be managed by the KPI validation platform (KVaP) of ACTA. Measurements will be collected and presented by the platform.

An indicative list of measured KPIs includes:

- packet Loss
- jitter
- frame loss
- delay
- packet size distribution
- utilization
- throughput

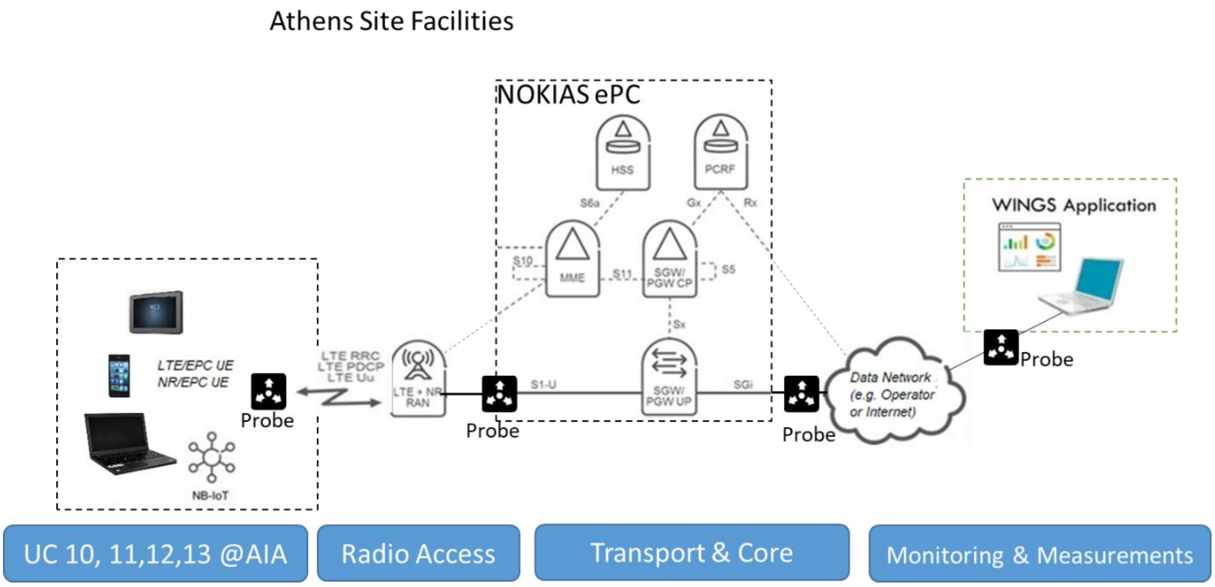


Figure 47. KPIs measurement platforms

Measurements will be performed both in L2 and L3 OSI layer.

Network Segmentation: An effort will be made to deploy as many probes as possible along the full E2E network, in order to evaluate separately the performance of all distinguished network segments (e.g. radio, backhaul, core, etc.).

Passive and active monitoring methodologies will be applied:

-Active monitoring: KPIs like delay, jitter, packet loss, etc. require one probe to transmit artificial/test traffic (test packets) towards the next probe (both being parts of a single network segment), within the exact traffic stream (e.g. VLAN) carrying the original use case traffic. The amount of this test traffic, in the unit of time, will be selected to be:

- Low enough so it will not affect the performance of the network, carrying the use case traffic

- High enough so the measurement accuracy & granularity, to be sufficient.

-Passive monitoring: KPIs like throughput, packet size distribution, etc., will be measured by just counting and classifying the use case original traffic packets, passing though the specific probe interface port.

B. Single Probe based, layer 3 & 4, passive KPIs continuous measurement (monitoring) platform.
A platform (Viavi Observer [7] or similar technology) will be connected at an interface (GE/10GE) in the core of the 5G network (perhaps through a mirror or a span port). This is an interface where all the network traffic is passing through. It will provide recording of the layer 3 & 4 (and above) signals using hardware and software filters. Accurate timestamping of the recorded signals will be performed.

A series of secondary KPIs (see below) will be evaluated & stored, separately per service & application running over the network.

Synchronized either to a PTP grand master clock, installed in the central site of the 5G network or through a local GPS device. This platform will be fed by a time-of-day signal, so high accuracy timestamping of the recorded signals will be possible.

This platform will be able to analyse traffic using some of the following filters:

- IP
- session
- type (DNS, DHCP, HTTP(S), RSTP, NTP, etc.)

An indicative list of secondary KPIs include:

- application delay (ms) client – server
- data bits/sec
- data bytes
- jitter
- loss rate
- network delay (ms) client – server
- network utilization
- retransmissions client – server
- utilization client – server
- video bits/sec
- video bytes
- video packets

The combination of the measurement results of both platforms in one single presentation GUI, is investigated considering the use of a common time axis.’

4.7 Milestones description

The Table 6 provides the time schedule of the use cases implementation, to be refined in the context of WP6 (application development), WP3 (network deployment) and WP7 (integration and evaluation).

Table 6: Trials summary Time Plan

	2019		2020				2021				2022	
	Q1 Y1	Q2 Y1	Q3 Y1	Q4 Y1	Q1 Y2	Q2 Y2	Q3 Y2	Q4 Y2	Q1 Y3	Q2 Y3	Q3 Y3	Q4 Y3
UC10			M1		M2		M3		M4		M5	
UC11			M1		M2		M3			M4	M5	
UC12			M1		M2		M3			M4	M5	
UC13			M1		M2		M3			M4	M5	

The achievements of the milestones are the following:

- M1: use case overall design, network and application requirements analysis;
- M2: use case first implementation tested in lab environment;
- M3: use case first implementation tested on initial network infrastructure;
- M4: use case first implementation evaluated on initial network infrastructure;
- M5: updates, optimization in infrastructure and use cases.

5 Conclusions

This deliverable has provided a detailed description of the high-level implementation plans for the four Use Cases (UCs) that will be demonstrated in the Athens node of 5G-TOURS. For each UC deployed, this deliverable presented the perspectives of the different stakeholders, the architecture design, the solutions to be deployed for the implementation of the pilots, the network elements, the devices to be used, the trials for the evaluation of the solutions according to the selected use cases and the expected KPIs. The main conclusions of the analysis performed by this deliverable are as follows:

- The UCs that will be implemented in the Athens node provide a high value to the different vertical stakeholders involved, namely the Athens International Airport (AIA) and the school Ellinogermaniki Agogi (EA), ultimately contributing to the project vision towards a mobility-efficient city, leveraging 5G to enhance the experience of travellers in different ways.
- In order to be able to run these UCs, very stringent network requirements need to be satisfied in terms of latency, throughput, reliability, location accuracy, etc. The analysis of such requirements performed in this deliverable show that the UCs could not be supported relying on 4G legacy technology, and 5G is needed for their implementation. Hence, 5G is required in order to achieve the ambition vision of 5G-TOURS.
- The various UCs require different pieces for their realisation, including applications, vertical equipment, network terminal components and network infrastructure deployment. As the far reaching vision of the project is not feasible with state of the art technology, many of these components are currently not available in the market and will require project-specific developments. By identifying all these components and providing a detailed implementation plan to develop and bring together all these components, this deliverable provides the basis for the work to be performed by WP6.
- From the network infrastructure site, 5G-TOURS relies on the mobile network platform and infrastructure provided by the 5G-EVE project. However, the current deployments of 5G-EVE do not cover all the needs of the UCs involved in the Athens node, and hence it is needed to expand the current deployments of the 5G-EVE infrastructure. This deliverable has presented the specific needs of 5G-TOURS, which will be addressed jointly with the 5G-EVE project.

With the above, this deliverable has clearly identified the objectives and functionality that needs to be met by the different UCs as well as the different pieces that need to be implemented to achieve these objectives. The analysis performed in this deliverable in terms of the implementation plans and timeline for implementing the use cases provides the basis for the work that will be performed in WP6.

In addition to the above, this deliverable also serves the purpose to synchronize the work of WP6 with WPs 2, 3 and 7: i) the different requirements of the various UCs have been aligned with WP2 which is focusing on the overall 5G-TOURS UCs and KPIs, ii) the needs from the network infrastructure will be addressed by the 5G-TOURS architecture jointly with WP3, and iii) the initial ideas on the tests that will be required to validate the UCs will be aligned with the evaluation methodology designed by WP7.

6 ANNEX: General use case technical requirements description

The explanation and definition of all general requirements ([3], [4]) included in Table 7 are provided next. Although a general definition is given, a more specific interpretation is also possible.

For example, end-to-end (E2E) latency for one UC can be the time it takes for the data to travel from a Smartphone to the server that runs a particular application (in the Cloud) and the time for the answer to be received back (on the smartphone).

For another UC, RAN latency (radio access network latency) might be the time for a location-information of a vehicle to be send to the 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 E2E Latency) - round trip: 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: 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: 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 7. 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., Wi-Fi, 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. ≤ 90 minutes (≤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 8. 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						

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. The relative position and angle of the axes is typically uninformative. A typical example of a radar chart is illustrated in Figure 48.

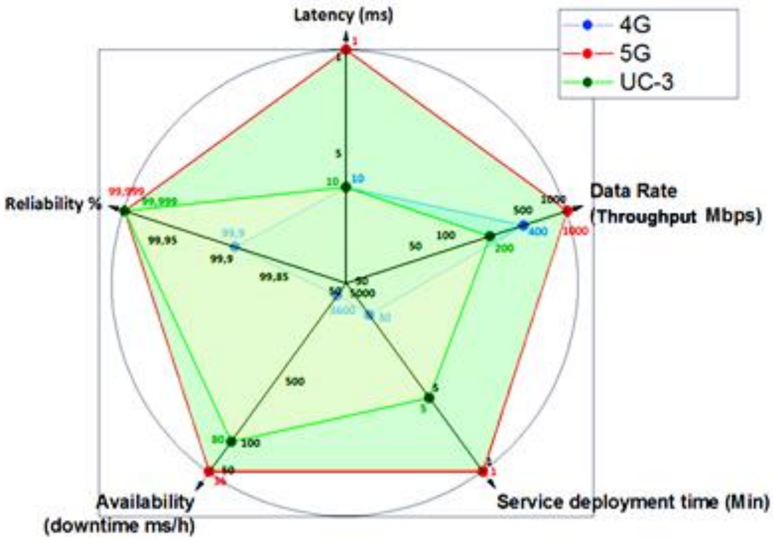


Figure 48. A typical multi-axis radar chart, that illustrates network requirements like latency, data rate, service deployment time, availability and reliability and a comparison with 4G/5G capabilities

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 availability and security requirement are not included in the charts and the subsequent analysis.

As a reference for the analysis a 4G vs. 5G capabilities radar graph is first created. The radar graph is based on Table 9 (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 9. 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 49- 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 area, 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.

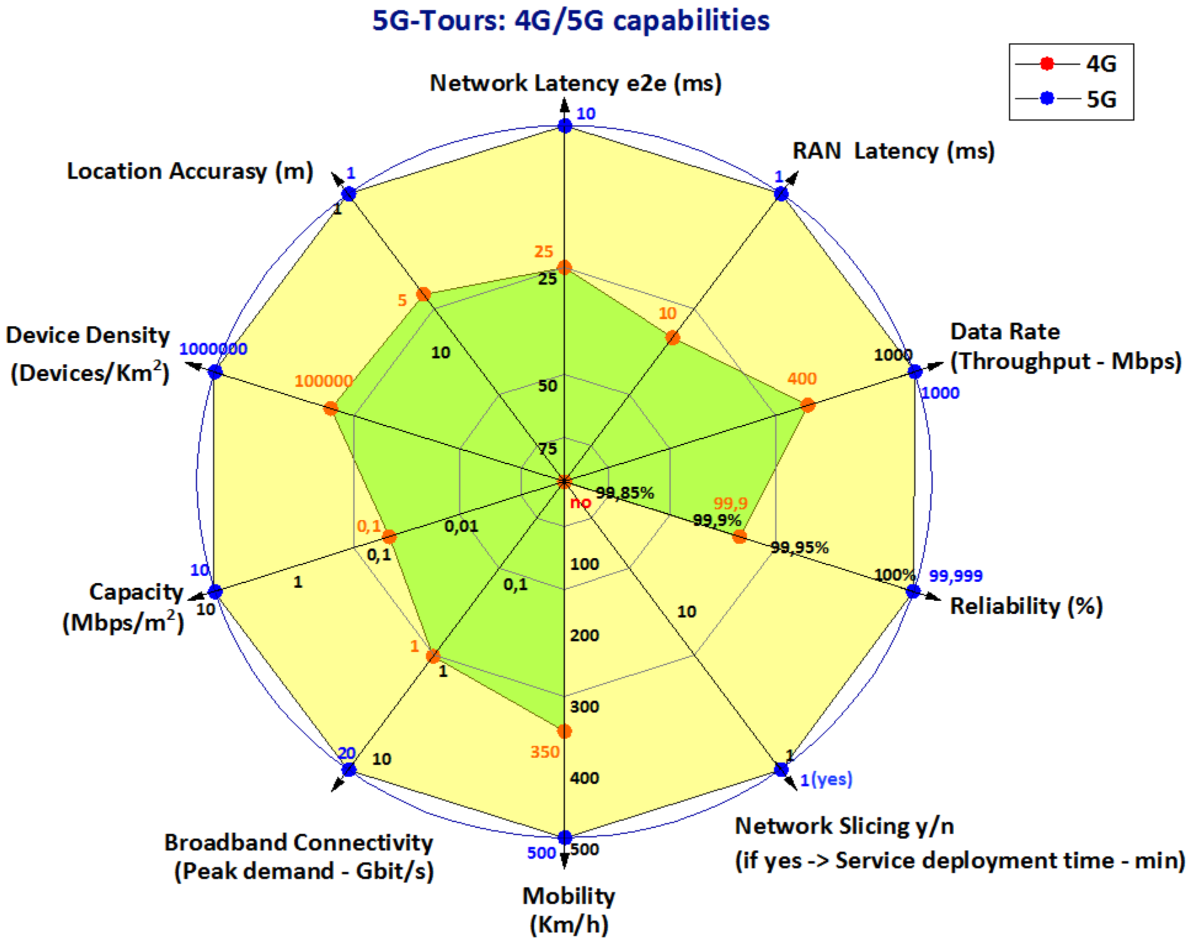


Figure 49. Radar graph for 4G/5G capabilities

The first radar chart which corresponds to Table 9 (above) will be subsequently used 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 Athens node use cases will be presented. With this graphical representation will become easily apparent if the requirements fall inside the capabilities of 4G/LTE networks, or need the enhanced capabilities of the 5G technologies or even need something better than that (we did encounter one of these instances but a remedy is also proposed).

Next, the compiled requirement tables and a basic analysis of the 4 use cases is presented.

Acknowledgment

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