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

Deliverable D6.2

First mobility efficient city use cases implementation results

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Contents

List of Acronyms and Abbreviations

Acronym	Description
3D	3 Dimensional
3GPP	Third Generation Partnership Project
5G	5th Generation mobile Wireless Communication System
5G PPP	5G Public Private Partnership
5GC	5G Core
AI	Artificial Intelligence
AIA	Athens International Airport
AMF	Access and Mobility Management Function
AMIS	Airside Monitoring Inspection Specialist
ANN	Artificial Neural Networks
API	Application Programming Interface
AR	Augmented Reality
ASOC	Airport Service Operations Center
BBU	Baseband Unit
BLE	Bluetooth Low Energy
CMM	Cloud Mobility Manager
DDNS	Dynamic DNS
DNS	Domain Name System
eMBB	enhanced Mobile Broadband
eMBMS	evolved Multimedia Broadcast Multicast Service
EPC	Evolved Packet Core
EPG	Evolved Packet Gateway
FDD	Frequency Division Duplex
FFmpeg	Fast Forward MPEG
FTP	File Transfer Protocol
gNB	5G Node B
HCAA	Hellenic Civil Aviation Administration
HLS	HTTP Live Streaming
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
ICMP	Internet Control Message Protocol
IGMP	Internet Group Management Protocol
IoT	Internet of Things
KPI	Key Performance Indicators
KVaP	KPI Validation Platform
KVaP	KPI Validation Platform
LTE	Long-Term Evolution
LTE-M	Long-Term Evolution for Machines
LWM2M	Lightweight M2M
MANO	Management and Orchestration
MEC	Multi-Access Edge Computing
mMTC	Massive Machine Type Communications
mmWave	Millimeter Wave
mRRH	micro Remote Radio Head
NB-IoT	Narrow Band IoT
NFV	Network Functions Virtualization
NR	New Radio
NRFs	Network Repository Function
NSA	Non-Standalone Access
NSSF	Network Slice Selection Function
NTP	Network Time Protocol
OSM	Open Source MANO
OSS	Operation Support Systems
P2P	Peer-to-Peer
PLMN	Public Land Mobile Network
PPPoE	Point-to-Point Protocol over Ethernet
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RSSI	Received Signal Strength Indicator
RTCP	Real-Time Tranport Control Protocol
RTMP	Real-Time Messaging Protocol
RTP	Real-Time Transport Protocol
RTSP	Real Time Streaming Protocol
SA	Standalone Access
SC	Small Cells
SMF	Session Management Function
SMTP	Simple Mail Transfer Protocol
SNMP	Simple Network Management Protocol
STB	Satellite Terminal Building
TCO	Total Cost of Ownership
TCP/IP	Transmission Control Protocol/Internet Protocol
TOA	Time of Arrival
UART	Universal Asynchronous Receiver/Transmitter
UC	Use Case
UDM	Unified Data Management
UDP	User Datagram Protocol
UE	User Equipment
UI	User Interface
UPnP	Universal Plug and Play

URLLC	Ultra-Reliable Low Latency Communication
USB	Universal Serial Bus
vEPC	Virtual Evolved Packet Core
VNF	Virtual Network Function
VNFC	Virtual Network Function Components
VOD	Video on Demand
VPN	Virtual Private Network
VR	Virtual Reality
WP	Work Package

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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 implementing a set of use cases that improve mobility-related experiences from various perspectives. These use cases revolve around the 5G EVE Athens site, including an extension to the Athens International Airport (AIA).

This deliverable serves as a reference to report on the first mobility efficient city use cases implementation results, as well as their connection to the 5G-TOURS platform which will be realized through the network that will be deployed at AIA as an extension to the 5G EVE Athens site.

The scope of this deliverable is to describe the progress in the implementation of the use cases in terms of network deployment and equipment that will be utilized, as well as from the application point of view and the terminal equipment components and interfaces. These interfaces will allow for the communication between the actors of each UC and the 5G-TOURS network infrastructure. Furthermore, a crucial part of this deliverable is to present the steps that have been taken in terms of integration and test in labs while also presenting results that have been produced both from these lab tests and in the field. The results will be analyzed and lessons learned will be identified in order to prepare for the validation trials. This deliverable will also present the risks identified for the UC implementation and trials execution due to the 2nd COVID-19 pandemic wave that has arisen.

Finally, this deliverable serves as a successor to deliverable D6.1 [1] and internal report IR6.1 and predecessor to the deliverable D6.3 produced within WP6 - Mobility-efficient city use cases implementation, which focus on the implementation of the use cases of the mobility-efficient city. In D6.1 the focus was on the use cases description, in the definition of a detailed work plan as well as to the architecture definition of each use case. The internal report IR6.1 focused more on the initial progress of the UC implementation as well as the progress on the network design part. This deliverable also serves as a reference with respect to the alignment of the work plan as presented in D6.1. More specifically, this deliverable describes the progress in terms of implementation for the following 4 UCs of the mobility-efficient city:

- **Use case 10** – Smart airport parking management: In this use case, parking users at the airport obtain real time information on available and occupied spaces through 5G-enabled parking sensors. They are able to locate available parking spaces directly through a mobile application and will be guided there via the optimal route. This use case involves mMTC communication, which represents an essential functionality of the 5G family technology.
- **Use case 11** – Video-Enhanced ground-based moving vehicles: This use case 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, thus improving day-to-day airport operations as well as response activities to emergencies. This use case involves very large throughputs as well as highly critical communications.
- **Use case 12** – Emergency airport evacuation: This use case 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. This use case focuses on the location accuracy part of 5G technology. The application relies on AR technology suitable for training exercises and simulations at the airport.
- **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 exhibition, involving large throughputs and low latencies in highly mobile environments.

1. Introduction

The **mobility-efficient city** aims at presenting a set of use cases (UCs) that improve mobility and travel-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) follow-me vehicles enhanced with high-quality video streaming capabilities, (iii) personalized evacuation procedure and (iv) efficient ways of entertaining/educating travelers/students going on an excursion on a smart bus.

This deliverable describes the progress so far for the mobility-efficient city UCs based on the implementation plan defined in D6.1, which was refined in IR6.1 in order to deal with the risks that were identified due to the 1st COVID-19 pandemic wave, that will run in the Athens node of the 5G-TOURS project. D6.2 is fully aligned with ongoing activities in other WPs as well as the previously submitted deliverables and the ongoing ones.

The four use cases concerning the mobility-efficient city are:

a) **Smart airport parking management:** This is a solution that relies on the mMTC functionality provided by 5G. Around 100 parking 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 life setting inside the AIA satellite terminal based on AR. The incorporation of AR technology in this particular use case will be useful for training and simulation exercises to be held in the airport. Furthermore, this use case focuses on the location accuracy part of 5G technology.

d) **Excursion on AR/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; such applications were not feasible before 5G.

The content of this deliverable is structured as follows.

In Chapter 2 the progress of UC10, smart parking management, is described. This chapter also contains the overall description of the infrastructure along with the UC10 description and implementation details, which makes the UC10 section longer. More specifically, the definition of all implementation details of the smart parking UC as well as the progress both on the network part and on the application deployment in terms of components and communication interfaces are given. Also, the preliminary results produced from the tests in lab environment and in the field (AIA B17 building parking area) are presented. More specifically, in UC10 there has been already a small scale deployment at AIA for testing in order to progress with the integration of the parking sensors with the WINGSPARK platform and mobile application. Some initial tests for the mobile application have been executed on site.

In Chapter 3 the progress of UC11, Video-enhanced ground-based vehicles, is described. More specifically, the definition of all implementation details of the UC11 as well as the progress both on the part of the network and on the part of the application deployment is given. Also, the preliminary results of the implementation are presented. In detail, the final equipment has been purchased and the setup of the infrastructure needed for the UC deployment has progressed. The probes have been defined and the connection between AIA and the 5G EVE node at Psalidi has been established. A media server has been setup at AIA and the first version of the web based interface for the AIA apron monitoring has been tested in lab environment.

In Chapter 4 the progress of UC12, Airport evacuation, is described. More specifically, the definition of all implementation details of the evacuation use case as well as the progress both on the part of the network and on the part of the application deployment is given. Also, the preliminary results of the implementation are presented. More specifically, the 3D model of the terminal that the use case will take place has been created. The 3D model has been integrated in the mobile application in order to test the functionality in a simulated way, as due to COVID-19 access to the terminal was not possible. The application and the optimal route to the exit have been tested in lab environment. From the network perspective the 3 indoor cells that will be used for this UC have been purchased and the installation process at AIA has started.

In Chapter 5 the progress of UC13, AR/VR bus excursion, is described. More specifically, the definition of all implementation details of the UC13 as well as the progress both on the part of the network and on the part of the application deployment is given. Also, the preliminary results of the implementation are presented. In summary, the content to be used in the AR applications of ATOS and WINGS and the VR application of SRUK has been decided. The equipment to be used in this use case has been ordered and received by the partners. The infrastructure to support the deployment of this use case has been set up at 5G EVE Athens node at Psalidi. Initial tests of the apps have been deployed in lab environment.

In Chapter 6 the innovations for each use case that will be trialed in the Athens node as well as the relationship with the overall 5G-TOURS architecture is presented.

In Chapter 7 a high-level work plan describing the implementation, testing and validation processes, is presented. Furthermore, the risk assessment as well as the impact of the 2nd COVID-19 pandemic wave is presented and contingency plans for the next months till MS3 are reported.

In summary, this document will further detail the implementation progress of the four different use cases that will be trialed in the Athens node of 5G-TOURS. Each of the use cases has been motivated by showing the usefulness for the corresponding vertical partners, highlighting the value for each partner. Furthermore, an analysis of the different components implemented to run the use cases has been performed, identifying the different applications and vertical equipment required in each case.

Beyond the vertical perspective, this deliverable has also analyzed the implementation of the network side of the UCs, describing the infrastructure already deployed or the infrastructure that will be deployed in the months to come, the refinement of the network level requirements involved in each use case, as well as the tests both in labs but also in the field (where available) that have been conducted. Thus, this document serves as a reference of the implementation progress of the use cases and will be updated as the implementation and tests in the network progresses further.

2.UC10 - Smart parking management

2.1 UC10 Overview

The AIA area accommodates three short and long-term parking lots for AIA visitors and travelers, altogether occupying an area of around 190 km^2. The parking process at AIA can be very time-consuming, and therefore stressful, especially when time until flight departure is limited. At the same time, purposeless and untargeted driving does not favor the environment from an emission perspective.

This use case will allow the AIA parking users to obtain real time information on available and occupied spaces. This will be achieved by the installation of around 100 5G-enabled (i.e., communicate using a 5G technology) parking sensors. This way the drivers will be able to locate the 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 free parking space.

Situation example: On a peak day for AIA, approximately 20 vehicles can become congested in the parking facility of the B17 building. It would appear that upon arrival to park within the facility, the vehicles begin to search for an adequate parking spot, ideally near the entrance. Unfortunately, with so many vehicles simultaneously in search of the ideal spot and rushing to park, this inevitably causes congestion. A vehicle driving in the wrong direction, by accident or to get a spot before another vehicle gets to it first, can end up colliding with the second vehicle which had been driving in the correct direction.

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 has been 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 entrance of the facility).

Partners involved: WINGS, SEQUANS, OTE, NOKIA-GR, AIA, ACTA

Location: AIA

2.2 UC10 implementation

The use case takes place in the B17 building parking facility of the AIA and involves the use of:

- A mobile application presents the available parking spots in real time, optimally routing to the selected parking spot, as well as historical data regarding each driver’s parking events. The app is powered by intelligent algorithms for choosing the optimal spot for each user by serving also concurrent requests and by spreading the drivers to the area of interest to minimize the cases where one driver gets the spot that was proposed for another driver. If that happens the algorithm also provides rerouting capabilities. Furthermore, the app leverages 3D graphics on the area of interest to provide the driver with an optimal user experience.
- A web dashboard to support the smart parking management staff that includes real time monitoring of the sensors installed in the facility as well as notifications regarding events of interests like a sensor that needs maintenance due to a low battery or due to a malfunction. Furthermore, the parking facility management staff can see useful statistics regarding the parking events and occupancy trends for different timeslots as well as access to historical data both at sensor level and for the parking facility as a whole, by providing various visualization services for the airport administrative user. Finally, the dashboard also provides access to statistical information based on predictive analytics about “busy” or “calm” days and times for the driver/parking user.

The real time monitoring is based on the deployment of a number of parking sensors on the AIA premises. WINGS sensor 2nd prototype has been developed and tested during the past few months. Currently, 5 sensors have been deployed: One at OTE premises for collecting data, one at WINGS Athens premises and 3 at AIA parking facility. A larger number of sensors is planned to be installed in the parking facility by January 2021.

The 2nd version of the dashboard containing enhancements regarding user and sensor management has been deployed since the summer 2020 and has been thoroughly tested. Currently the 3rd version of the dashboard is being developed. This version will contain enhancements regarding notifications events, parking events management, statistics in sensor level and access to historical data through various visualization services.

The second version of the mobile application has been developed and is currently being tested. This version contains 3D graphics to provide an optimal UI experience as well as User Account management. Integration with the routing component reported in D6.1 [1] and IR6.1 has been completed.

With respect to the network implementation it has been decided, for various reasons, to follow a two phases implementation approach. This decision has been reached based on the requirements that have been defined in D2.1 [2], the large area that needs to be covered in AIA, the time plan of each of the use cases, and, last but not least, the need of integration with the 5G EVE infrastructure (at the moment still under deployment). From the above it is clear that it would not be possible to deploy a network that would meet all these aspects already at its first implementation. However, it should be highlighted that this approach is still fully compliant to the scope of addressing the two main objectives of 5G-TOURS that are to validate the need of 5G (Objective 1) and to demonstrate the benefits of the 5G-TOURS innovations (Objective 2[1]).

More specifically, the AIA deployment for UC10 is designed to be done in two different phases. Phase 1 starts in June 2020 while the 2nd phase will start as soon as NOKIA-GR's experimental network is in place.

- **Phase 1**: During phase 1, a small number of parking sensors (e.g., 5 sensors) has been installed on the AIA staff parking. These sensors will use SIM cards provided by OTE and will communicate via NB-IoT connectivity with the WINGSPARK platform, through the commercial NB-IoT OTE network. The same network is also used for WINGS testing deployments during the development period. The app will use the commercial 4G+ network of OTE for testing purposes.
- **Phase 2**: During phase 2, a larger number of parking sensors will be installed in the AIA premises (around 100 sensors). The sensors that will be deployed during Phase 2 will also use SIM cards provided by OTE and will communicate via NB-IoT connectivity with the WINGSPARK platform, through the commercial NB-IoT OTE network. The app will run on the S10 and S20 smartphones provided by SRUK using the SIM cards provided by NOK-GR and will communicate with the platform through the 5G-TOURS network at AIA (integrated with 5G EVE infrastructure).

The sensors communication system constitutes an mMTC use case and, as described above, for both the 1st and the 2nd Phase NB-IoT connectivity will be utilized on the sensors side. The mMTC requirements (which continue to evolve with newly arising applications and use cases) have already been addressed as part of 3GPP Release 13/14 low power wide area (LPWA) technologies development, which includes NB-IoT. These technologies (which are also evolving in specification at each subsequent 3GPP Release, i.e., 15, 16 and 17, for improved performance such as better throughput, power consumption, etc.) have been confirmed to meet the 5G mMTC requirements that were set for IMT-2020 evaluation. With the rise of more diversified (in terms of requirements, e.g., more bandwidth and ultra-reliable low latency) mMTC-related scenarios, 5G Core deployment may be required. In that regard, it is worth noting that coexistence of the cellular IoT technologies (i.e. LTE-M and NB-IoT) with NR carrier is already there since 3GPP Release 13/14 (one of the deployment scenarios that is supported from the start of 5G NR work in 3GPP is to allow LTE-M/NB-IoT transmissions to be placed directly into a 5G NR frequency band [5]), while Release 16 is expected to make this coexistence more efficient as well as support the capability for connection to 5G core.

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

2.2.1 Network Deployment

During the most recent period of the project, for the better organization of the WP6 infrastructure designation and installation and in order to reach smoothly the MS2 (30/9/2020) and MS3 (31/3/2021), several online-meetings and on-site F2F meetings were organized and took place between OTE, COSMOTE[2] mobile team and NOKIA-GR, AIA, WINGS, ACTA and all the other WP6 partners. In those meetings, many decisions were taken concerning the following issues:

- The best architecture of the NOKIA-GR's network to support the four UCs.
- The final number of antennas and BBUs.
- The final locations where antennas will be installed (i.e., on which COSMOTE's poles) at the AIA facilities.
- The COSMOTE's data rooms and the server racks that will be used.
- The power supply needed.
- LTE Band 2600 MHz, with FDD B7 and 10 MHz Bandwidth will be implemented. We will start 5G-TOURS project deployment with NSA. 4G is still used in the core since it is NSA. As we move to SA, then only 5G will be available; SA is not yet ready.
- Responsible entity for the antenna licensing process at the airport.
- Responsibilities of each one of the teams OTE, COSMOTE, NOKIA-GR and AIA for the installations
- The PLMN ID that will be used.
- The type of SIM cards that will be provided by NOKIA-GR and by OTE (for the sensors).
- Where and how the interconnection of AIA with Psalidi will be done. At Psalidi area the 5G EVE infrastructure is installed and ready.
- Decision was taken by involved WP6 partners and the PM and TM of the project to proceed using the NB-IoT/LTE-M radio access for interconnecting the chipsets in sensors with the commercial COSMOTE 5G family network, while NOKIA-GR's SIM cards will be used for interconnecting the application part in smart devices to the trial NOKIA-GR's – OTE network.

All the above issues have been agreed for the deployment of the infrastructure (OTE, NOKIA-GR) and for the implementation of the four UCs of WP6. OTE, as a Site Manager, provides operator infrastructure at the AIA (data rooms, poles of antennas, racks, switches, routers, etc.), including a 10Gbps connection line with Psalidi (with existing 5G EVE infrastructure). Also, the OTE Academy's facilities (data centers, racks, servers, and internet access and telecommunication infrastructure) are used.

OTE obtained a temporary license from the Greek National Regulator Authority[3] (EETT) for using the 5G band frequencies 3.7-3.8 GHz for the needs of the first tests. In addition, AIA obtained a second license from CAA (Civil Aviation Authority) for installing antennas at the International Airport of Athens.

Since the frequency band 3.7-3.8 GHz could be utilized in Athens only for 2.5 months, a decision was taken from NOKIA-GR, OTE and the other partners to use new NOKIA-GR's 5G antennas transmitting in the new desired B42 (3.5–3.6 GHz) band, that belongs to OTE. The installation of new 5G antennas will take place in January.

The final interconnection diagram/architecture of Athens node for the needs of implementation of the mobility efficient city is depicted in Figure 1 below.

[2] COSMOTE is part of OTE group of companies
[3] https://www.eett.gr/opencms/opencms/EETT_EN/index.html

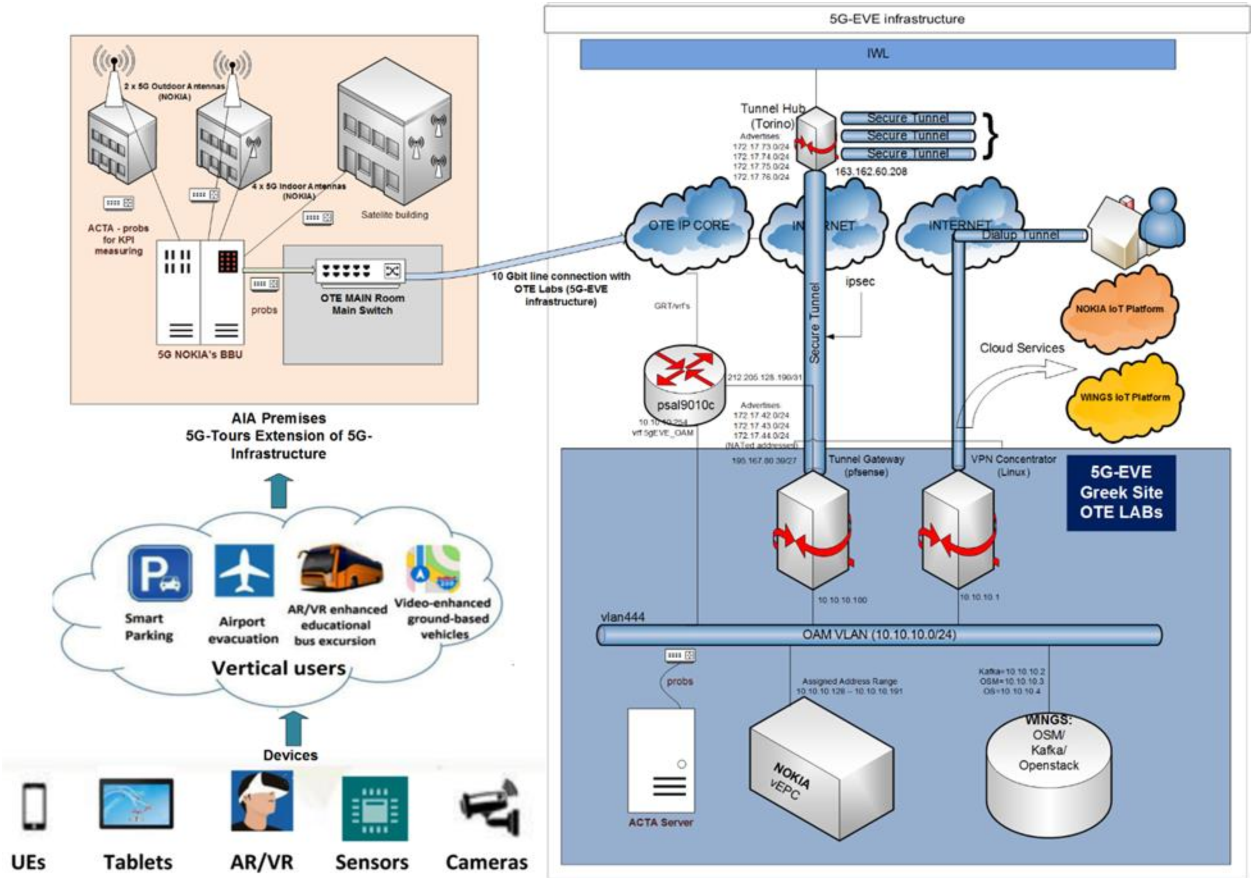


Figure 1. 5G-TOURS Athens node platform.

The mobility-efficient city aims at presenting a set of use cases that improve the tourism and tourism-related experiences from various perspectives. The implementation of the four UCs relies on 5G EVE Greek site infrastructure and on an extension that is implemented at the AIA premises during the 5G-TOURS project. The different network components of the Athens Node that have been implemented in 5G EVE project are the following (see Figure 1 above):

- A fully functional 5G network by NOKIA-GR is installed and configured and is operational;
- An Orchestrator (OSM) is installed and configured by WINGS and is also operational;
- The OSM is fully interconnected with the Interworking Layer (IWL) in Turin 5G EVE site through a secure tunnel;
- A Kafka bus server, for the needs of keeping the metrics of the KPIs, is installed and configured and the interconnection of the Kafka with the central Kafka server is under implementation;
- The interconnection of the NOKIA-GR's 5G platform with the orchestrator is in a final phase of implementation;
- There is an interconnection between the OSM and WINGS' IoT platform.

To support the needs of 5G-TOURS project and the implementation of the four UCs at the AIA premises to extend the existing 5G EVE Athens node, the following additional equipment will be installed:

- 2 outdoor and 4 indoor antennas. After the finalization of installations in January, the 5G antennas will utilize the spectrum band 3.5-3.6 GHz, while the 4G antennas the 2.5 GHz
- All the antennas will be connected through fiber optics to the NOKIA-GR's BBUs at the airport. Then, the data will be forwarded through an OTE switch which is connected to the OTE IP Core, using a 10 Gbit line, to interconnect to the 5G EVE Greek site infrastructure at OTE Labs in Psalidi.

- For the needs of implementation of the four UCs, smart devices are used and specific innovative applications are under development (mobiles, tablets, AR/VR headsets, cameras, chipsets, sensors, etc.). Initial versions of the applications have already been developed to be used in the first trials, but refinements and new features are being developed for the final trials according also to the overall WP6 time plan.
- Also, probes will be installed between antennas and BBUs and between BBUs and the OTE switch, as well as between NOKIA-GR's 5G platform and WINGS IoT platform at Psalidi. These probes will be used for measuring metrics in real time in order to validate the KPIs of the network.

Figure 2 below highlights the network deployment that will be applied to cover the Smart Parking use case.

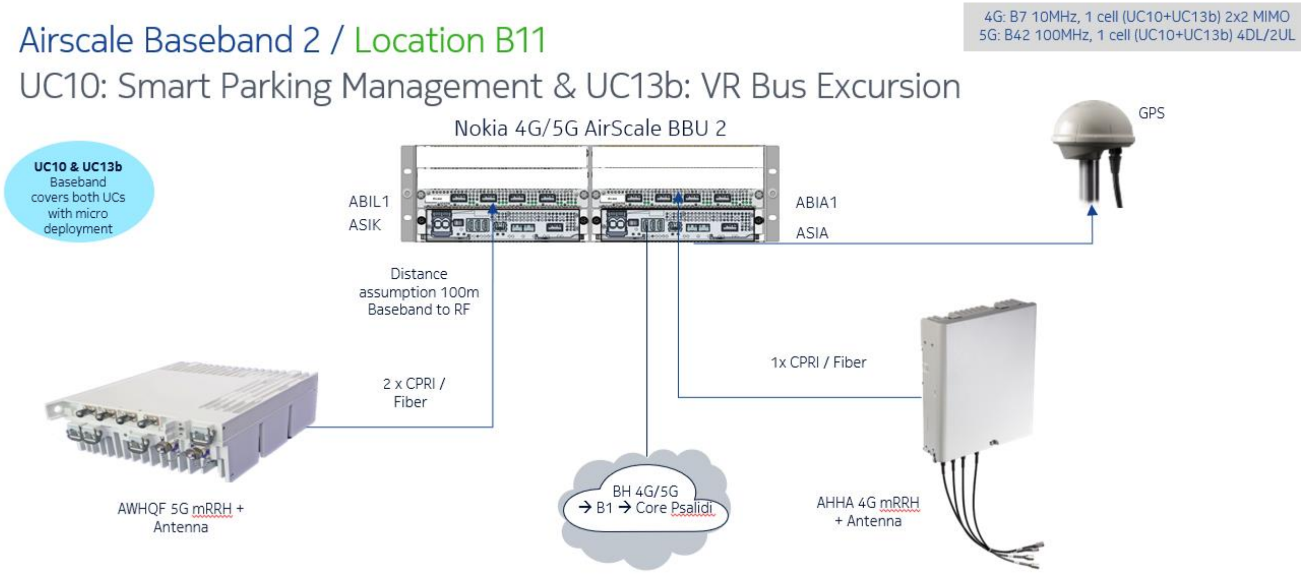


Figure 2. Smart parking management network deployment.

An Airscale BBU will be placed in the control room of building B11 in AIA. One pair of 4G/5G outdoor antennas (non-standalone deployment solution) will be placed on the roof-top of the same building. A backhaul connectivity will follow from B11 to the main control room of the airport (Building M2). From there, a 10Gbit Ethernet connection is already established to the Packet Core network. Figure 3 illustrates the control room of building B11 and the antenna mast at the rooftop of the same building.

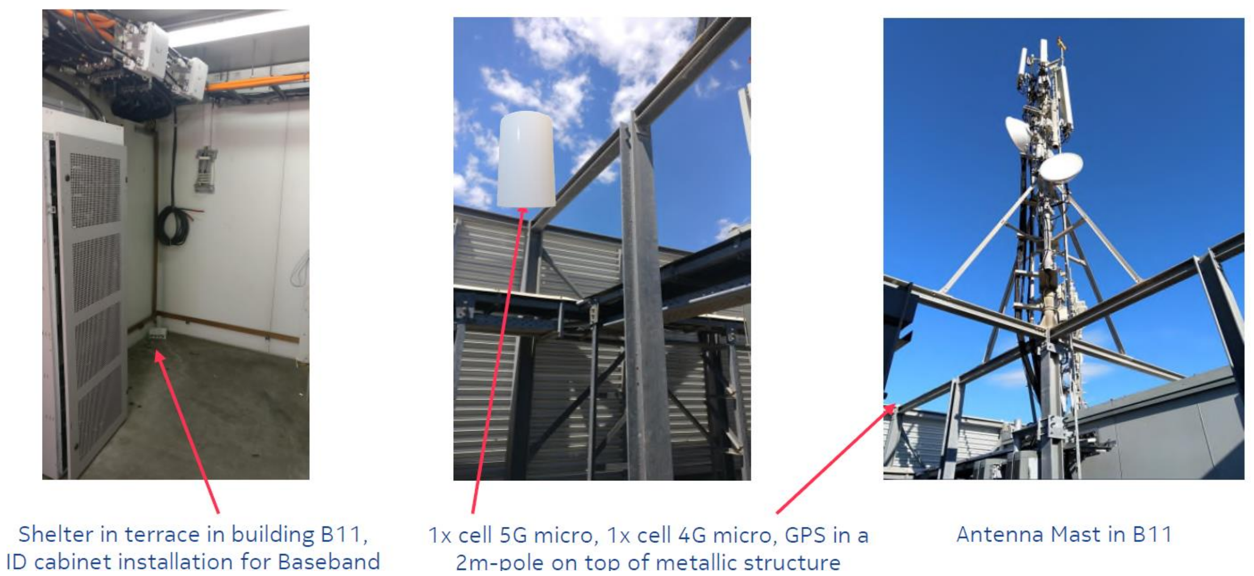


Figure 3. Control room of building B11 & the antenna mast.

Core Network of 5G EVE

The mobility efficient city network deployment will largely rely on the available Core Network infrastructure from 5G EVE Athens for the vertical trials. It relies on 4G (and eventually 5G) equipment provided by NOKIA-GR. The infrastructure consists of RAN, offering 5G NSA (Option 3X) support for phase 1 and 5G SA support for phase 2 of the 5G-TOURS project, vEPC Core Network (phase 01) and 5GC (phase 02) Core Network elements and tools for the management and orchestration of the NFV infrastructure. Functional behavior is the same as with non-virtualized nodes. CMM VNF is composed of multiple internal components (VNFCs).

5G-TOURS Core Network will reuse 5G EVE Core Network deployment for both phase 1 and phase 2. Regarding phase 1 deployment, vEPC Core Network will be used and connected with 5G NSA RAN as described in deliverables D3.1 [3], D3.2 [4] and shown in Figure 4. Note that vEPC is deployed at OTE premises in Psalidi, Attika.

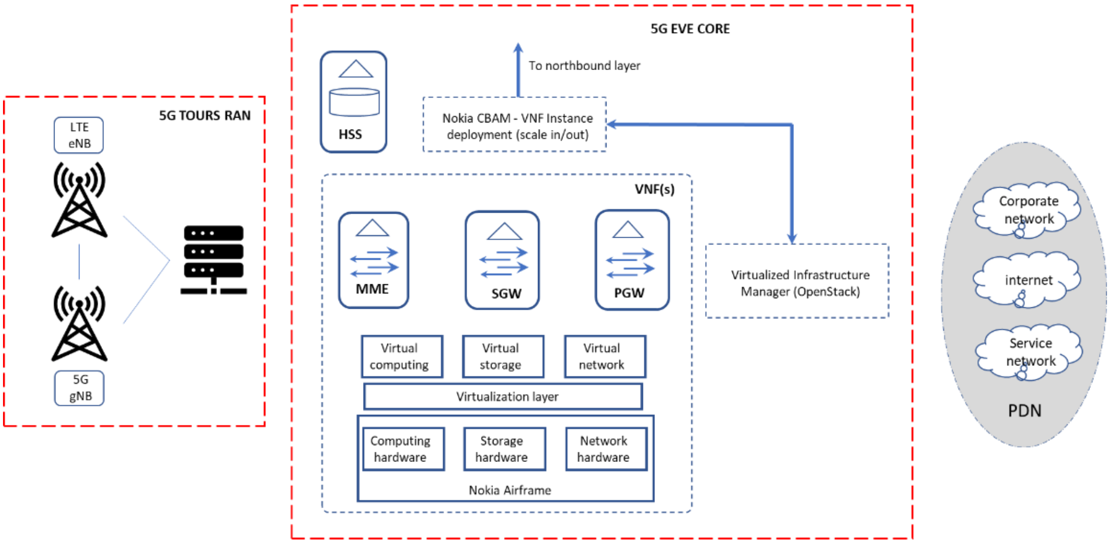


Figure 4. Current Core Network deployment for the Mobility-Efficient City.

Regarding phase 2 deployment, vEPC will be replaced by 5GC consisting of AMF, SMF, UDM, and possibly NSSF and NRF, as shown in Figure 5. The 5GC will be connected with 5G RAN acting in SA mode.

Currently, the modifications and enhancements needed in the Core Network infrastructure to extend the 5G EVE network from Psalidi to AIA are in progress. Regarding the RAN infrastructure, the installation of the antennas to be used in the context of 5G-TOURS in AIA is in progress.

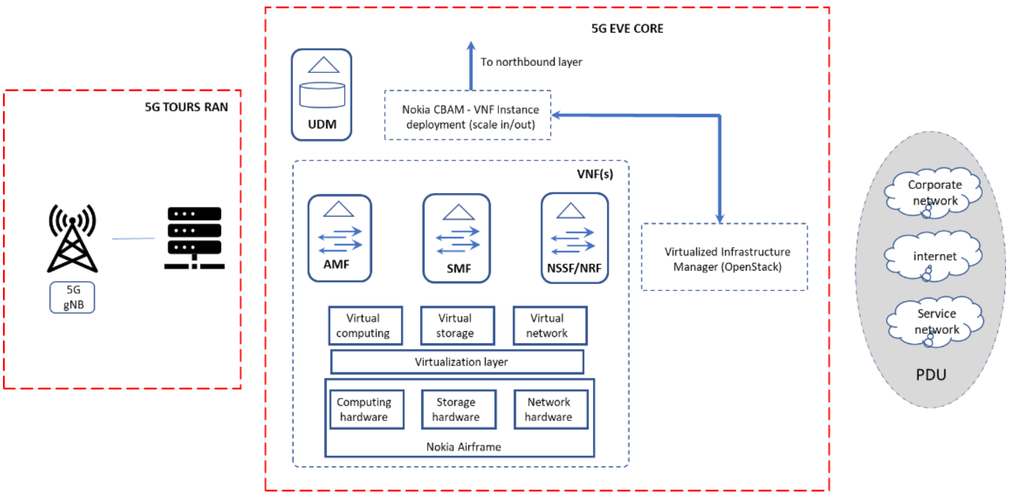


Figure 5. Phase 2 Core Network deployment for the Mobility-Efficient City.

2.2.2 Network Equipment

The proposed solution for the Smart Parking Use Case is a fully 3GPP gNB compliant small cell solution using NOKIA-GR's Flexi Zone platform. Key benefits of the proposed solution are as follows:

- Uniform user experience across the network through tight integration and feature parity with the macro network;
- Total cost of ownership (TCO) benefits due to macro parity, common NetAct OSS with macro, complemented with heterogeneous network features;
- Unrivalled small cell baseband capacity in the market;
- Enabled for evolution to Zone architecture for extremely high small cell cluster capacity and Multi-access Edge Computing (MEC) for local breakout additional services such as augmented reality.

Flexi Zone Small Cell future-proof product family and its most innovative small cell architecture provide new capabilities and versatile approach to address the varying deployment needs and business cases and fulfil the requirements of the UC in terms of density, latency, performance and throughput.

The solution selected consists of:

Baseband HW:

- AMIA AirScale Subrack
- ASIA Air Scale Common
- ASIK Air Scale Common
- ABIA Air Scale Capacity
- ABIL Air Scale Capacity

RF HW:

- AHHA Air Scale Micro 4T4R B7 20W
- AWHQF Air Scale Micro 4T4R n78 B42 40W

ANCILLARIES:

- FOSP Optical SFP P 1310nm 9.8Gb 10km SM
- FUFBH SM OD fiber LC OD-LC OD dual 100m
- FOTB Optical SFP+ 10GBase-LR 1310nm SM
- FMFA FLEXI MOUNTING KIT FLOOR/WALL/POLE
- AOQA Air Scale Optical QSFP Adapter
- OCTIS Plug Kit DC Power
- OCTIS Plug Kit SFP
- AMBA Air Scale Micro Bracket Assembly Kit
- AAQA Air Scale mRRH Dir Ant 3.5G
- AAHG Air Scale mRRH Dir Ant 2.2G 2.6G

GPS:

- FYMA GPS MOUNTING KIT
- FTSH GPS cable assembly 100m
- FYGC GNSS Receiver Antenna
- FTSF Sync Cable F

The aforementioned network equipment will be deployed in AIA surrounding area (Logical Network View) as highlighted in Figure 6.

Figure 6. RAN coverage of AIA (logical view).

2.2.3 Application Components

The service provided will be an extension in the functionality of the existing WINGS' STARLIT platform tailored to parking facilities, entitled WINGSPARK, and will consist of:

- A mobile application that will provide the user searching for parking with the aforementioned capabilities (i.e., 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.
- 5G-supporting occupancy sensors.

The 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 via NB-IoT connection the respective information of the state change 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 slots are visualized at client's device. Below, a schematic representation of the proposed architecture is shown (Figure 7):

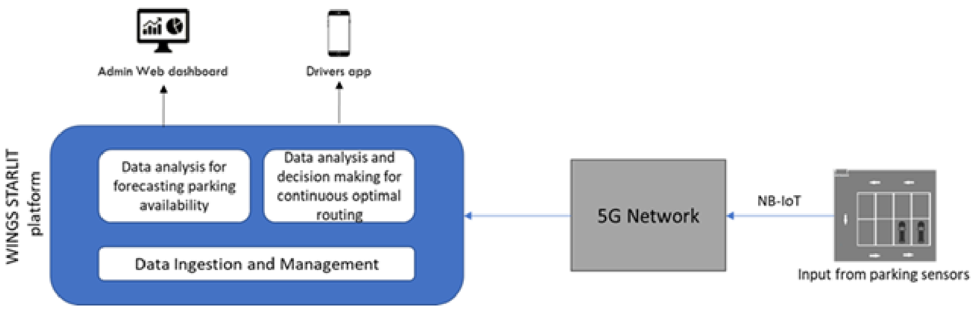


Figure 7. High level Smart parking system architecture.

2.2.3.1 The WINGSPARK driver's application

The mobile 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.

More 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, or
- To retrieve the available parking slot closest to the specified point of interest, as well as get the shortest navigation guideline towards it.

The figures below present the current version of the driver's application. Figure 8 depicts the login screen of the WINGSPARK driver's application. If the user has an account, he can input his/her username and password and in case these are correct the user will be redirected in the main application page (Figure 10 and Figure 11). If the user does not have an account, he/she can create one by pressing the link "*No account yet? Create one*". Then, the user will be redirected to the Register screen shown in Figure 9. When the user creates his/her account successfully then he/she will be redirected to the information screen of the application as shown in Figure 10, where he/she can find some basic information about the application. When the user presses the "*Continue*" button, the main screen of the app will load. The application can be viewed either in vertical (Figure 12) or in horizontal orientation (Figure 13).

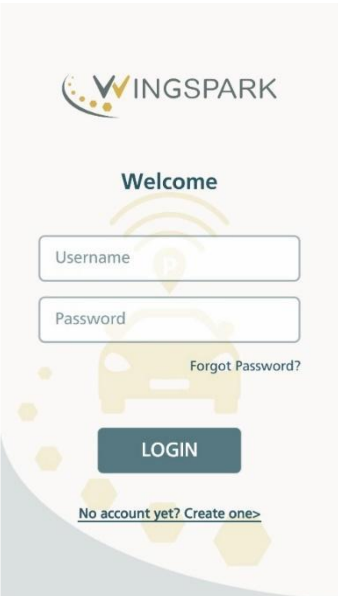


Figure 8. The login screen of the WINGSPARK driver's application.

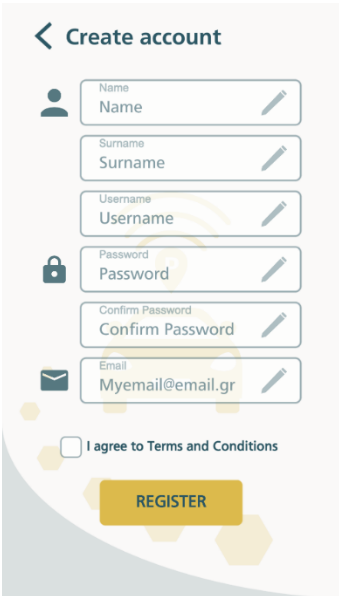


Figure 9. The create account screen of the WINGSPARK driver's application.

In the main screen, the user has various options. In the header of the application, he/she can change the application's language. Currently, the application is offered in two languages: Greek and English. The user can also see the current date and time. Below, the B17 building parking facility 3D version is loaded based on the user's location (Figure 13). There, he/she can see their relative location with respect to the parking slots. In the parking slots that are occupied, car graphics are loaded in order to give the user the information visually. The free parking slots are marked with yellow. Also, at the bottom of the screen, the user can have a look at B17 building parking facility top view, always according to his location.

When the user opens the application and his location is at the entrance of the parking facility, the system retrieves the available parking slot closest to the specified point of interest, as well as the shortest navigation guideline towards it. The user can also access the menu of the application from the bottom of the screen, where he can view and edit his profile (Figure 14) and vehicle information, view the current slot that he is parked in, as well as access historical information (Figure 15) regarding his parking events in the period of interest (Figure 16). For each parking event, he can see the data, the duration as well as the parking spot that he parked to. If he/she wants they can select a specific period of interest in order to see his parking events as shown in Figure 15 and Figure 16. Finally, they can also choose to log out of the application.

Figure 10. The information screen of the WINGSPARK driver's application.

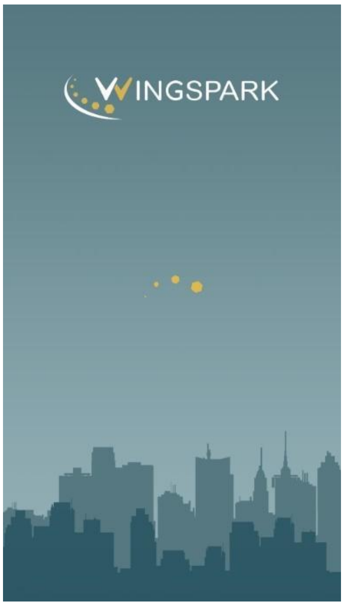


Figure 11. The loading screen of the WINGSPARK driver's application.

Figure 12. The main screen of the WINGSPARK driver's application in vertical orientation.

Figure 13. The main screen of the WINGSPARK driver's application in horizontal orientation.

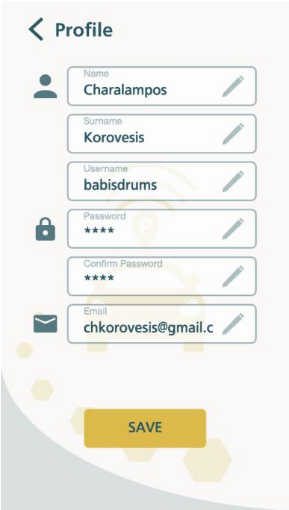


Figure 14. The edit profile screen of the WINGSPARK driver's application.

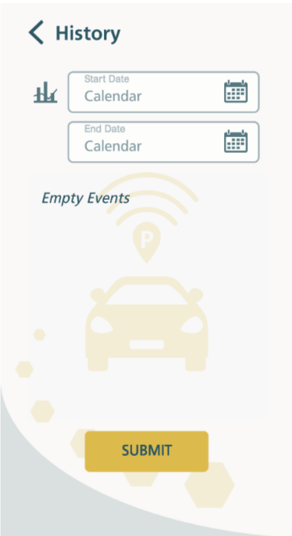


Figure 15. The view historical data screen.

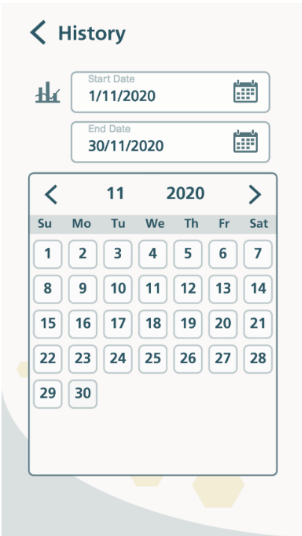


Figure 16. The user can select the dates of interest to see his parking events, as well as the duration and the parking spots that he parked to.

2.2.3.2 The WINGSPARK web dashboard

Also, a web dashboard is developed for the administrative user to keep track of the whole smart parking system (Figure 17). The dashboard provides 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 is also available presenting all the parking positions and their live status (Figure 18). Initially, the user is presented with the main page of the dashboard. This page consists of the following elements.

- A toolbar which on the rightmost side, a login icon is presented, where the user can login and manage his account.
- A sidebar on the left side, where the user can access the list of sensors and to view their location as well as their current status (occupied or not in real-time). The admin user can also have access to all the sensors' information in real time, like the sensors' status, their battery level, the particular slot where it is located and the coordinates of the slot (Figure 19). When the admin user selects an individual sensor, he has access in two different charts, one that demonstrates the daily occupancy for that spot and another one that demonstrates all the different parking events on a daily basis as well. This kind of information is also available in the form of raw data (Figure 20). The admin user has also the right to add, edit or delete an individual sensor (Figure 21, Figure 22).
- In the main panel, the user can see the current status of the parking area as the occupied sensors, the disabled ones, as well as the parking spot occupancy. The user can also see statistics for parking space availability in the form of parking events or occupancy. All statistics are available on a daily, monthly and yearly basis.
- In the main panel also a map is depicted, on which, various markers are spread, representing the position of each sensor (Figure 23). Upon clicking on a marker, the information of this sensor is presented on top of the map. The information depicted are the name of the slot, the sensor id as well as its location, its current status (occupied or free) and information whether the sensor is active or disabled.
- From the main panel the user can access the Notification Center, where he can see the notifications for each sensor as shown in Figure 24.
- Furthermore, from the Sensor Groups menu item, the administrator can view the existing groups and create a new one (Figure 25) and also edit the group and assign or unassign sensors to the selected group (Figure 26).

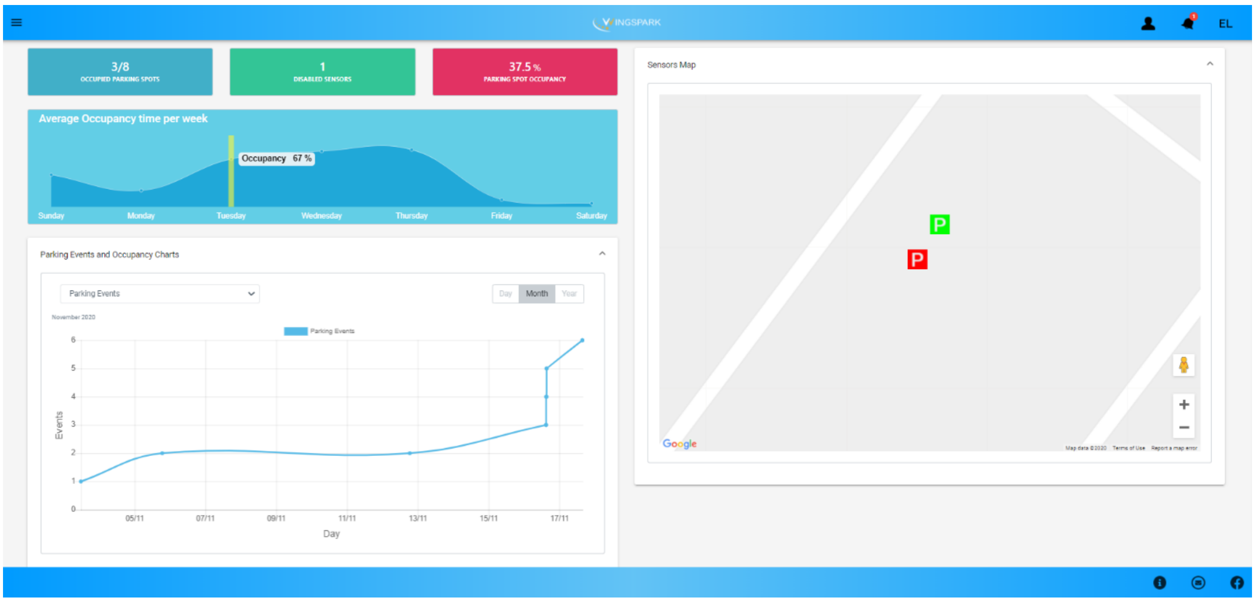


Figure 17. View of the Smart Parking management dashboard.

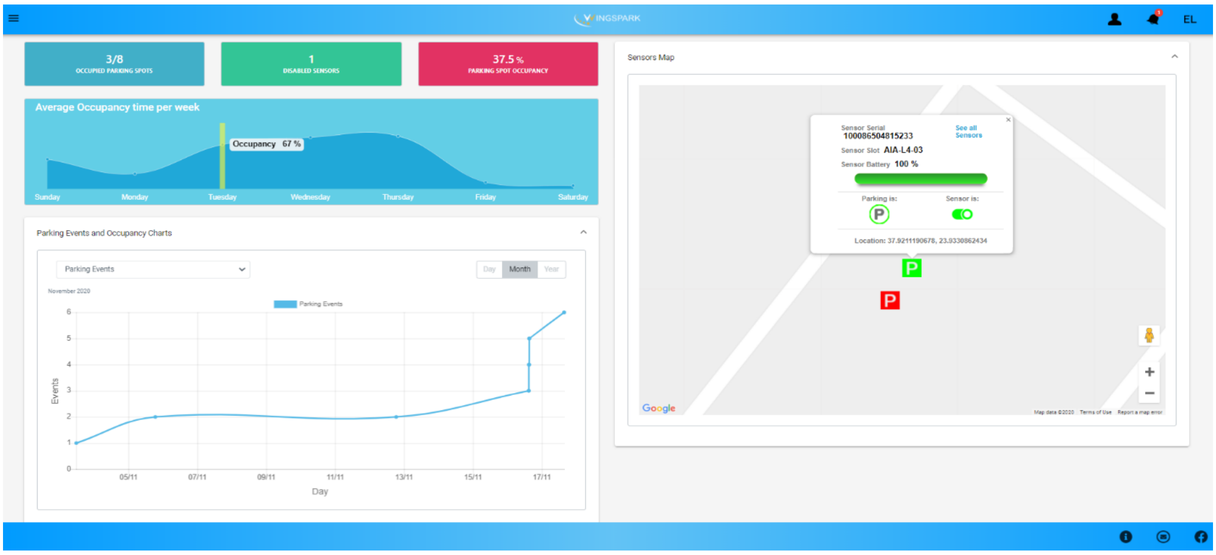


Figure 18. View of the Smart Parking management dashboard – Map view – Select Sensor.

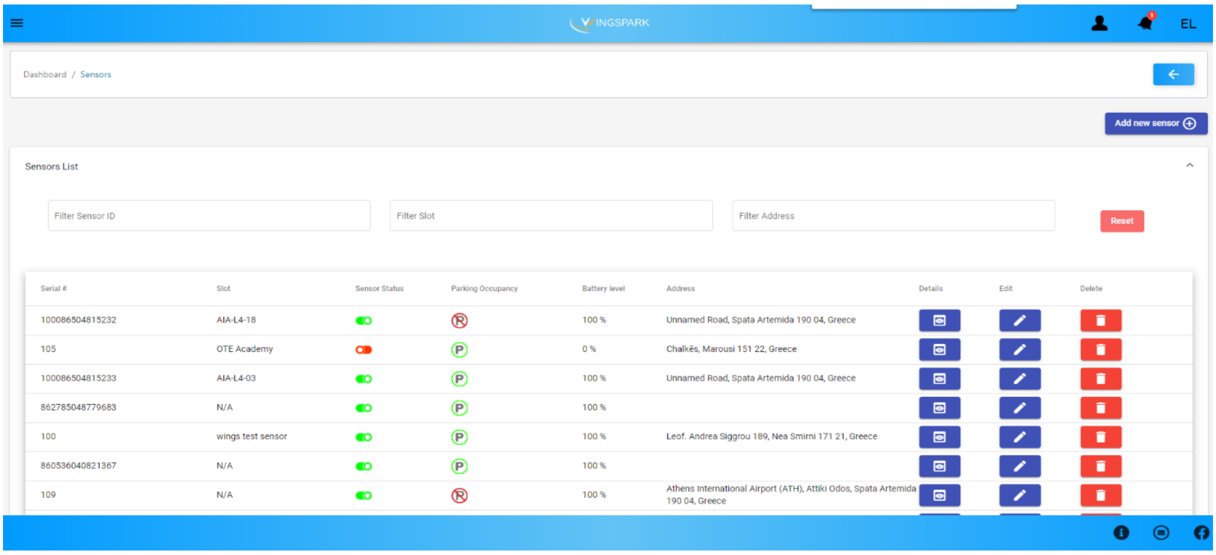


Figure 19. View of the Sensors panel.

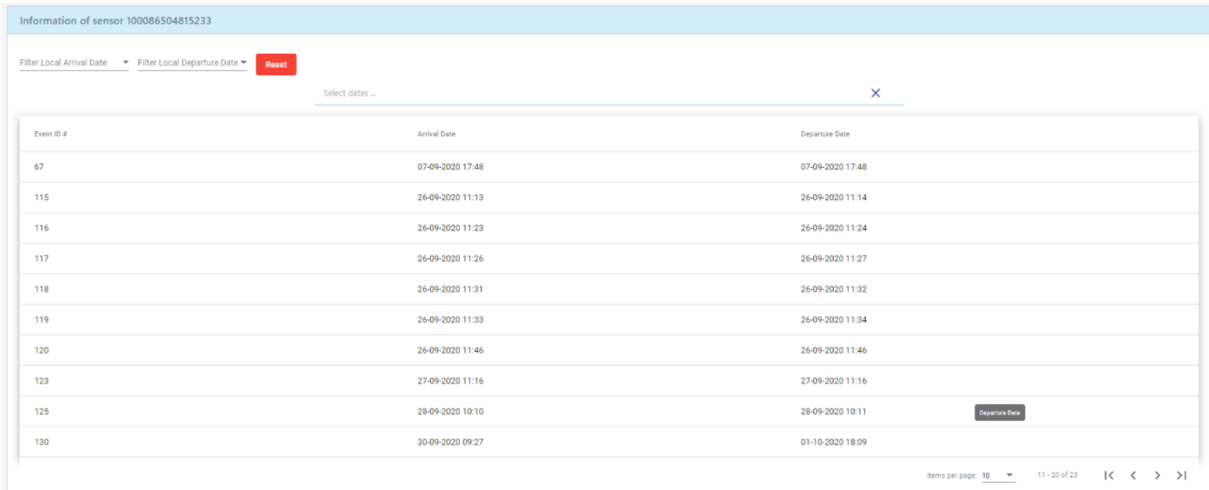


Figure 20. Raw data view for an individual sensor.

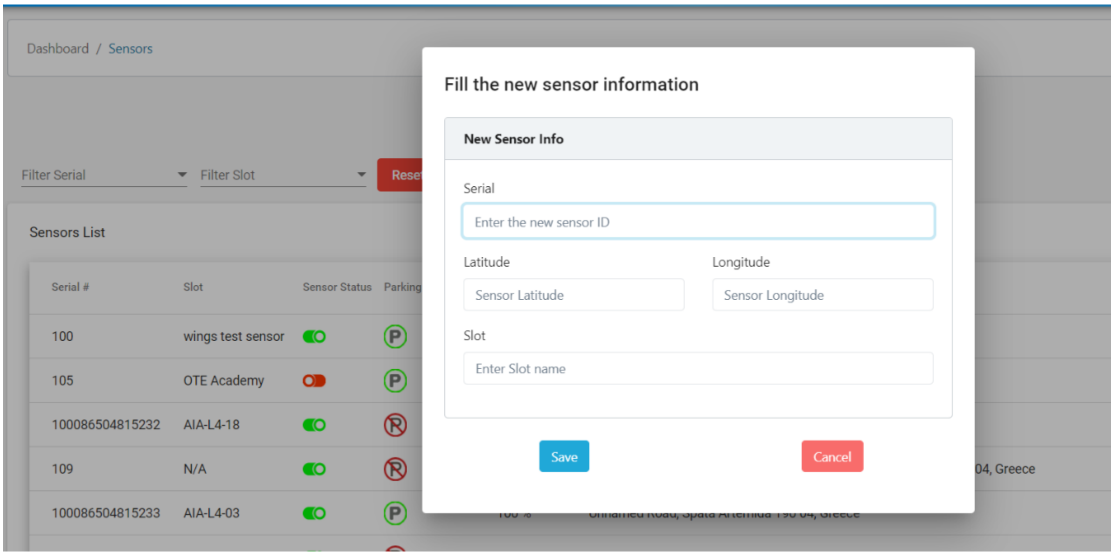


Figure 21. Add new sensor panel.

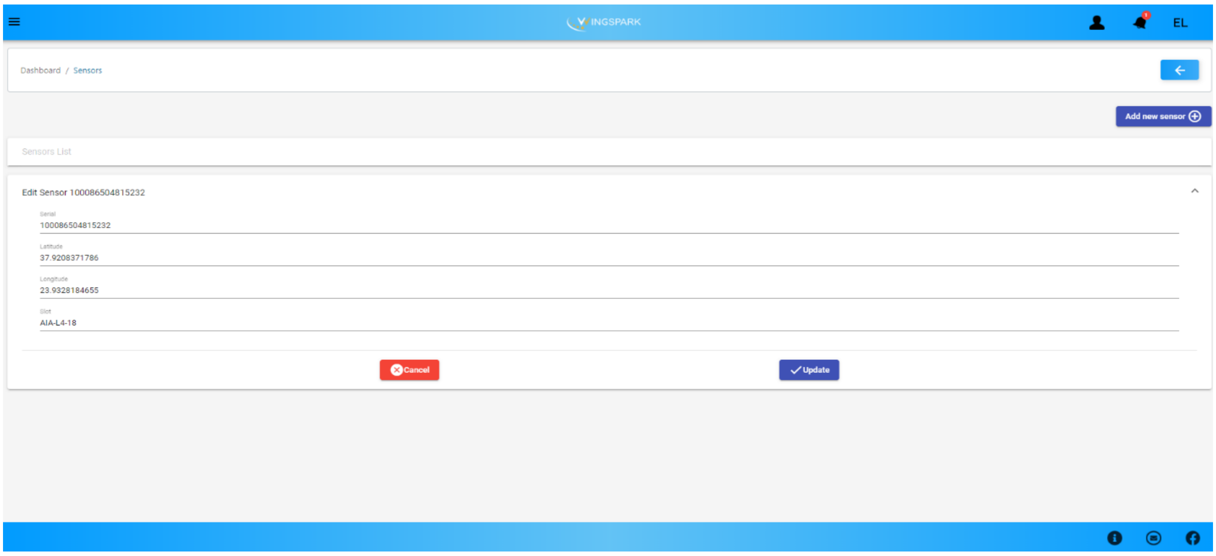


Figure 22. Edit sensor panel.

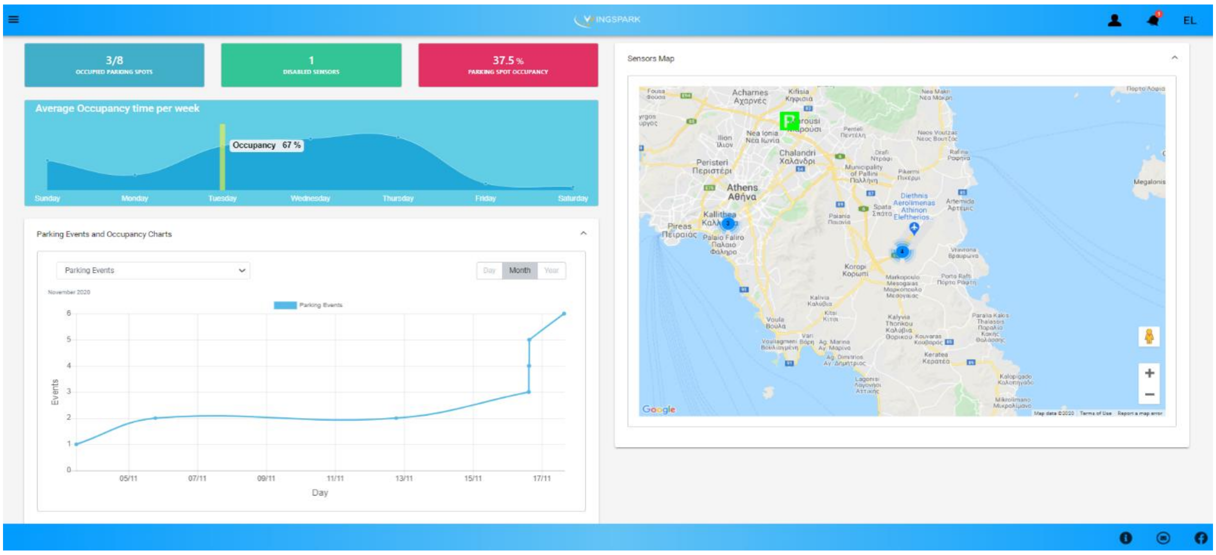


Figure 23. Sensors View on map.

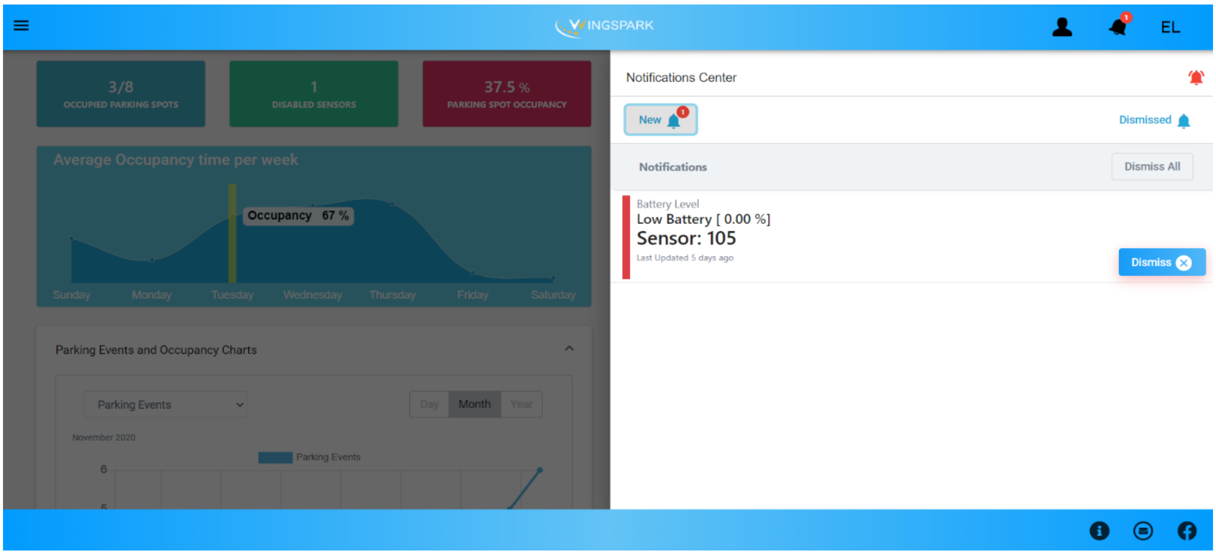


Figure 24. Notifications Center.

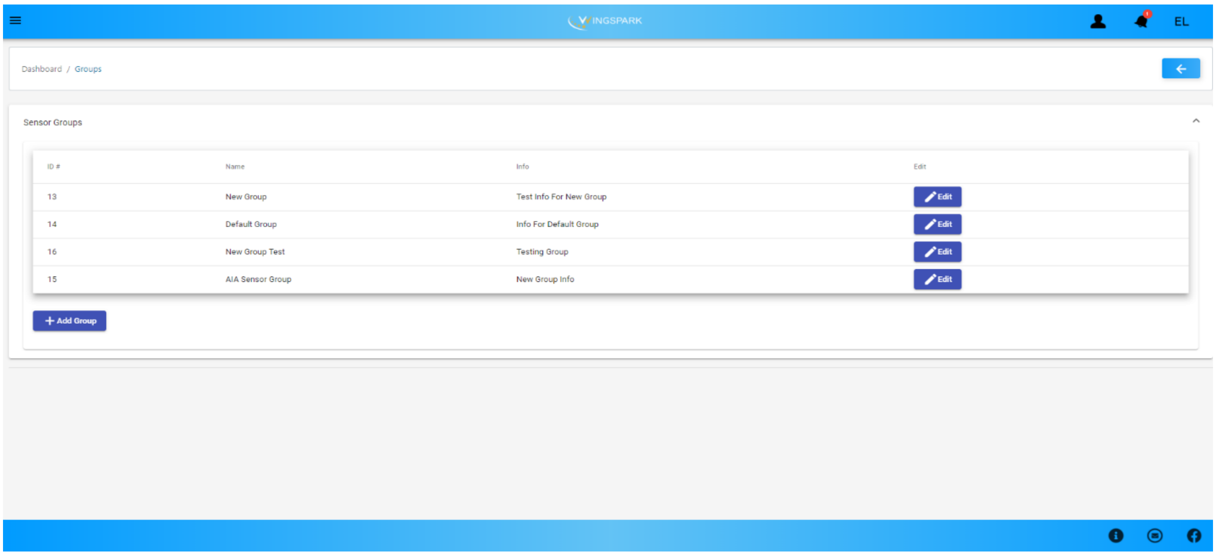


Figure 25. Sensor Groups.

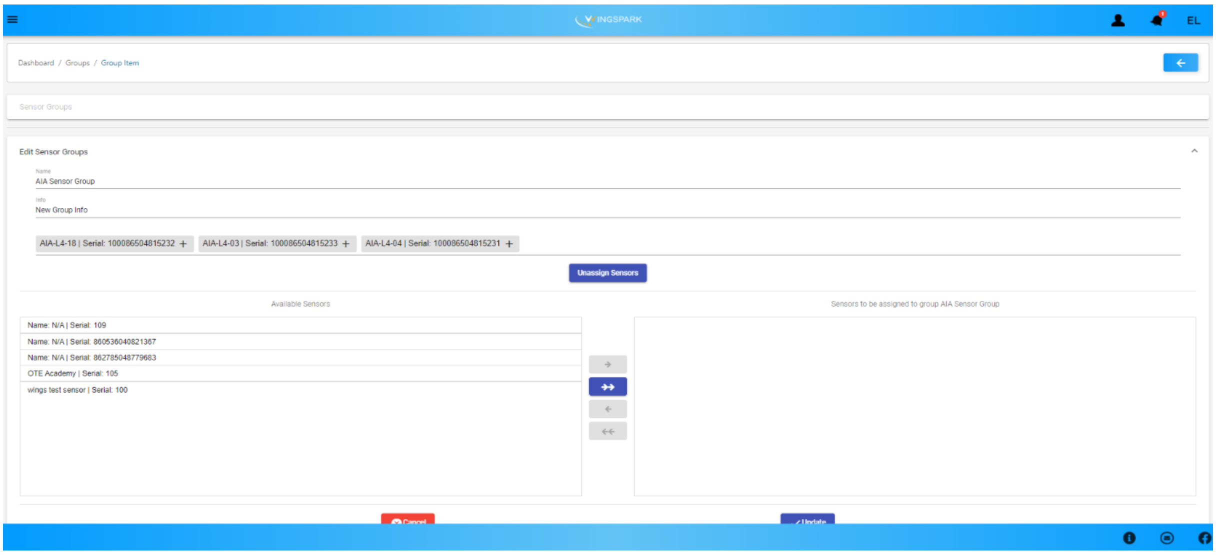


Figure 26. Sensor Allocation to group.

2.2.3.3 High level view of smart parking application

As mentioned above, the end user experience is divided into two user level applications: i) a mobile app, addressed to the parking user and ii) a web app, addressed to the parking administrator. A complete consolidated backend system is developed to support and serve these two applications in a way that the intercommunication between them is assured. A high-level view of the smart parking frontend and backend applications is shown in Figure 27.

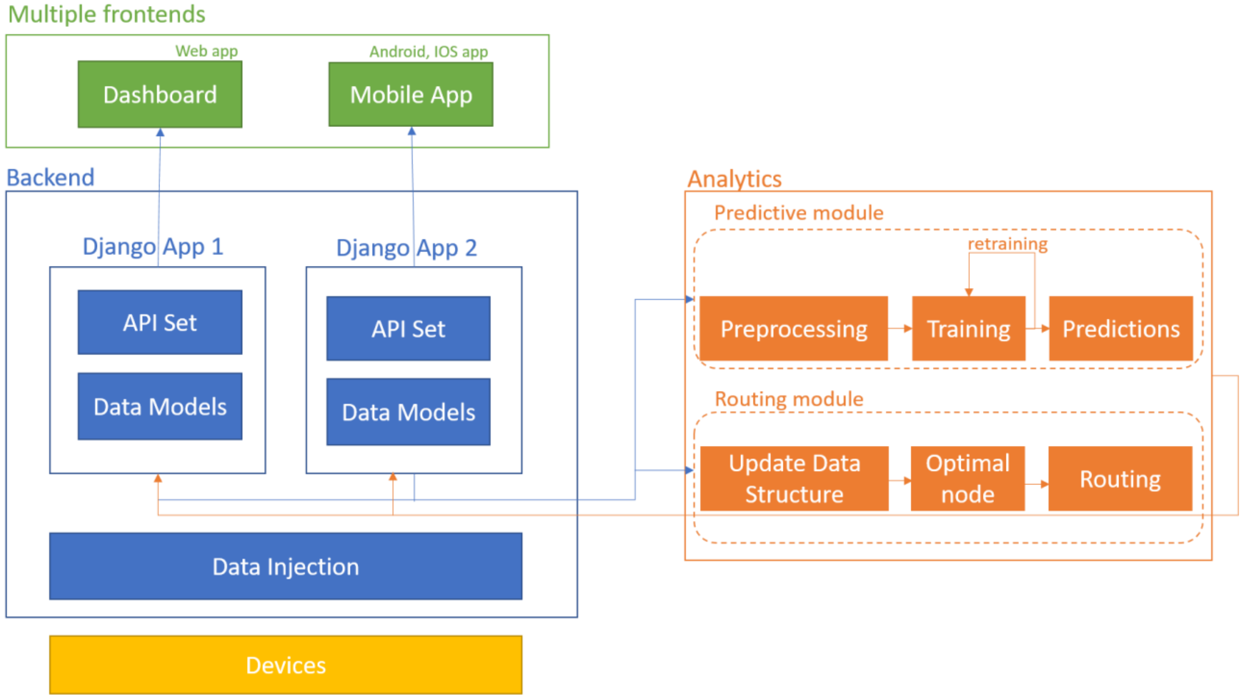


Figure 27. High level view of smart parking application.

2.2.4 Technical equipment components

The technical components required for this use case are:

- 95 parking WINGS prototype sensors each of which includes an NB-IoT connectivity module.
- 5 parking WINGS prototype sensors each of which includes an NB-IoT connectivity device, provided by SEQUANS (these prototypes complement the ones above, using the advanced communication devices developed by one of the project partners – SEQUANS).
- 5 smartphone/mobile devices for testing the mobile application during the trials, provided by SRUK.

The parking sensors both with Quectel and the SEQUANS communication module transmit data using the commercial COSMOTE NB-IoT network by using NB-IoT SIM cards provided by OTE (Phase 1 and Phase 2 of the UC).

The details for each technical equipment component that will be used in this use case are described below.

Mobile/smartphone:

To make use of the 5G network available, a 5G compatible phone is essential. Specifically, Samsung S10 5G will be used. Samsung provided 30 x S20 mobile devices for the needs of the trials. These devices have been configured with the specific PLMN ID, which is provided from OTE to NOKIA-GR’s trail network at AIA.

Samsung S10 5G [7]: is powered by a Snapdragon 855 5G processor (octa-core CPU at 2.84 GHz) and is equipped with 8GB RAM, enabling multitasking and fast switching between apps. S10 5G is built to take advantage of millimeter wave (mmWave) 5G networks at sub-6 GHz frequency bands, while being to automatically fall back to LTE when 5G service is not available. Although the smartphone can attain speed over 1Gbps via a mmWave small cell, it cannot exploit the low band 600 MHz FDD (frequency division duplex) 5G service. Finally, it is equipped with a non-removable Li-Ion 4500 mAh battery and supports super-fast charging with its 25-watt adapter.

NB-IoT connectivity device:

The low-rate, low-power device will be attached to the cellular network 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.

The device is a small size (34 x 29 mm mechanical form factor, 8 grams) embedded modem including a module from the SEQUANS Monarch family of solutions. Monarch is a single-chip LTE Cat-M1/Cat-NB1 solution 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 lightweight M2M (LWM2M) client for over-the-air device management, and a rich set of AT commands. The embedded modem features 1 U.FL port, connectivity via Serial UART or USB, and is pin-compatible - with a 20 pin interface - which enables easy integration with the parking occupancy sensor solution. Figure 28 depicts the device.

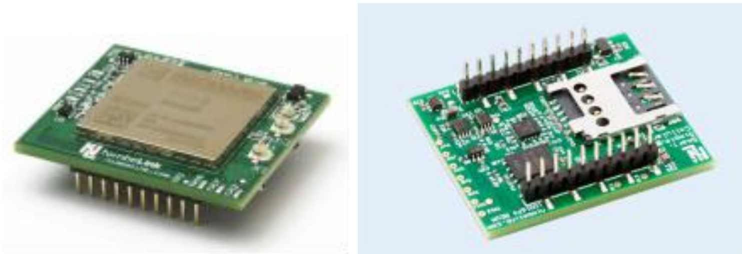


Figure 28. Embedded modem for NB-IoT connectivity.

The embedded modem features throughputs of 375 Kbps download and 375 Kbps upload, supports frequencies from 700 MHz to 2.2 GHz and includes a removable Micro-SIM card slot. SIM card provided by OTE is used to connect SEQUANS communication module in OTE NB-IoT public network operating at band 20 that corresponds to uplink 832 - 862 MHz and downlink 791 - 821 MHz.

For prototyping and developing the integration of the modem with WINGS Parking Occupancy sensor, SEQUANS also provides a development kit (Figure 29) which is compatible with the embedded modem and is specifically designed to help minimize the power requirement of the prototype solution. The development kit includes an adapter board which breaks out the serial UARTs for easier computer/laptop access to the mounted embedded modem via AT commands through PC terminal application. It also includes 1 SMA port and antenna, as well as power supply.

Figure 29. Development kit with mounted embedded modem.

Parking Occupancy Sensor:

The device detects the state of each parking spot, i.e., whether it is free or occupied. The device consists of a custom board designed by WINGS, an NB-IoT connectivity module, a magnetometer used for vehicle detection, which measures magnetic field in 3 axes and 4 to 6 Li-ion batteries. Data is transmitted through the OTE NB-IoT network. In Figure 30, the current version of the device is depicted.

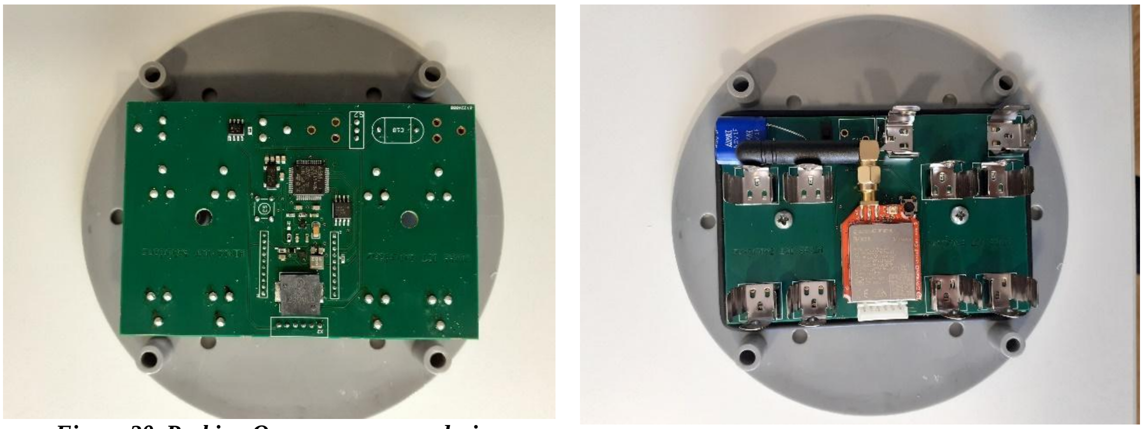


Figure 30. Parking Occupancy sensor device

The Smart Parking device case should support the specifications listed in Table 1.

Table 1. WINGS Smart Parking sensor characteristics

Characteristics	NB-IoT sensor values
Material	Polycarbonate
Protection class	IP67 / IP68
Load resistance	Up to 15 tons
Operating temperature	-30 ... +65°C
Storage temperature	-30 ... +65°C
Humidity range	0 to 95%
Height	40 mm
Diameter	220 mm

The current case prototype is depicted in Figure 31.

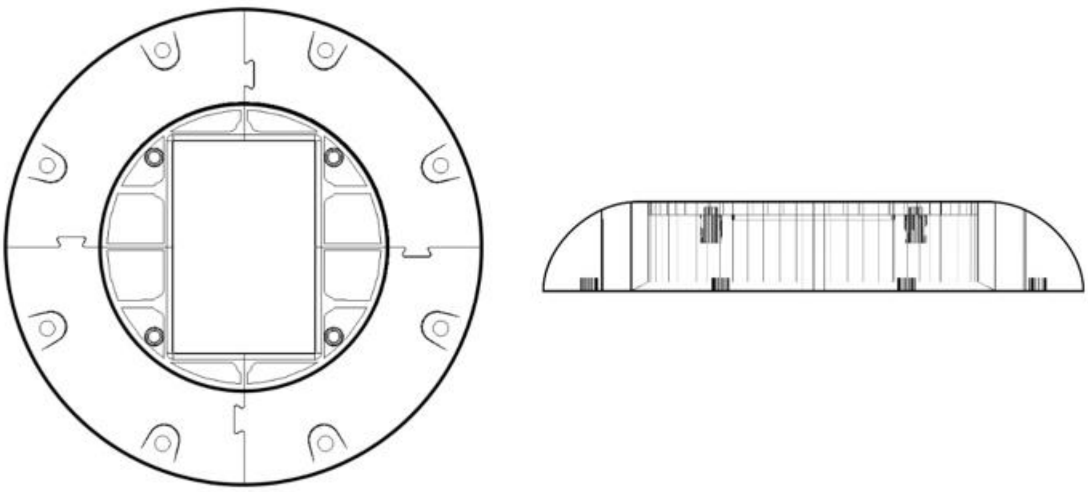


Figure 31. WINGS Smart Parking NB-IoT sensor prototype.

WINGS Smart Parking device is running with a 32 bit CPU STM32L476RET6 which processes all the data from the peripherals like the magnetometer. For the parking detection, we use a 3-axis magnetometer which is the lis2mdl [8] and a Quectel bg96 NB–IoT module [9] to connect to the network.

The device wakes up every 10 seconds and checks with the magnetometer if the parking slot is occupied. If a change is detected, for example an empty parking spot is occupied and vice versa, the device sends information to the UDP server. There is an ACK packet that ensures that all transmitted data is received in the server side. If the ACK packet is not received, then all the required information is re-transmitted from the device. When ACK packet is received, the device is put-on sleep mode, to achieve the minimum power consumption. The device currently uses 4 Saft 17500 Li-ion batteries. If the batteries power falls below a certain threshold, the sensor is disabled, and a notification is sent from the device to the dashboard.

2.2.1 Interfaces

The smart parking platform consists of a combination of different components and interfaces aiming to cover the needs and requirements that have been identified in the first phase of the project. A high-level view of the platform components is presented in Figure 32.

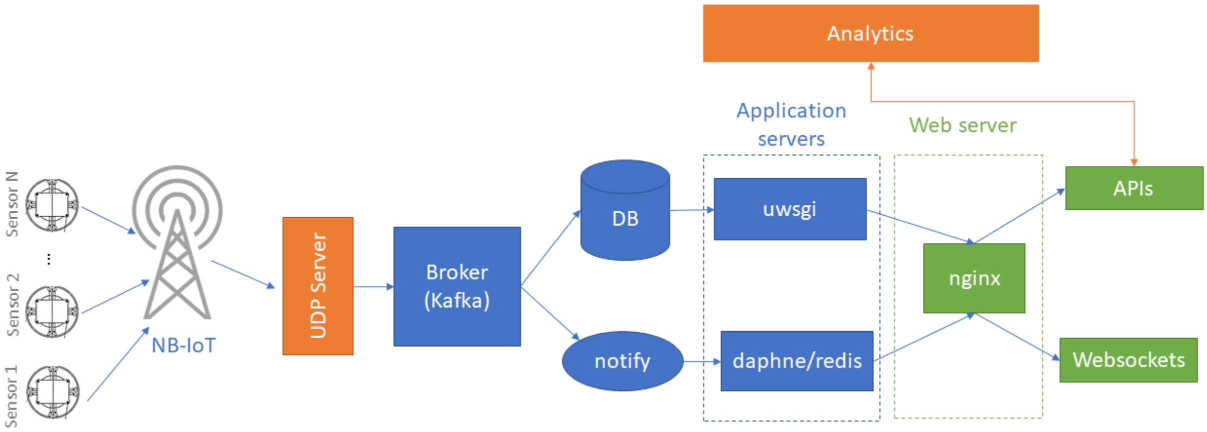


Figure 32. High level view of the platform components.

UDP Server [10]: The UDP packets, containing the sensor state measurements as well as the timestamp, cannot be written directly to the Kafka Broker, but requires transformation into a compatible format. Therefore, a lightweight Java (netty[4]) server is deployed in a Docker container and communicates with the Kafka container. After a UDP packet is received, the UDP server reads the packet body and feeds a Kafka producer that drops the information into a Kafka topic.

Kafka Broker[11]: Kafka uses a producer that collects the packet sent from the UDP server and stores it in a Kafka topic. Then a Kafka consumer retrieves that data from the topic and stores them in the Postgres database.

Django [12]: Django is the backed application of the platform. Django is deployed through two different application servers: **uwsgi** and **daphne/redis**. The uwsgi is responsible for the deployment of the REST API that the system uses to display the historical data (data stored in the database). The daphne/redis server is responsible for the deployment of the real time feed of the data through the web sockets. Django is also responsible for the creation of the data model. It also includes several different views and serializes in order to provide a set of APIs in a json format, filtered in the desired way, accessed through a REST framework. Django includes a number of notifiers in order to provide real time information to the web sockets.

Nginx [13]: is the Web server used for serving both uwsgi and daphne/redis application servers to the Web through ssl protocols.

[4] https://netty.io/

Frontend applications: An Angular [14] based web app supports the communication between the parking administrator user and the platform. An Android mobile app supports the communication between the driver/parking user and the platform.

Analytics: A python-based module consisting of a predictive component, which utilizes ANN and specifically **keras**[5], to predict the occupancy and a routing component based on graph implementation of the parking area's topology. For the purposes of the latest, the **networks** python library was utilized, representing the parking slots as the graph nodes and the corridors connecting the parking junctions, the slots and the entrances/exits of the area as the graph edges. On this base, several configurable options have been integrated, so that the implementation considers the exit/entrance that the car is approaching from or the user wishes to be nearest to, considers the current ongoing requests to best split the users uniformly around the desired area, etc. The output of the component is the optimal parking slot and the suggested route towards it, according to the specified criteria, encoded in **json** format.

2.3 Integration and results from tests in labs

A summary of the progress that has been made during the past months, based on the project's Gantt chart and the specific time plan created for each individual use case, is described below. Thus, regarding milestone 1 (M1- use case overall design, network and application requirements analysis), that ended in March 2020, the following tasks concerning the smart parking platform have been completed.

- Testing of early prototype device using Quectel module, as well as exploring integration with SEQUANS module and feeding data to WINGS cloud.
- Web dashboard development based on the early prototype device.
- Mobile application development.
- Mobile application testing.
- Web dashboard testing.

Moving on M2-use case first implementation tested in lab environment (ended on September 2020), the following tasks have been completed.

- Deploy one sensor at OTE premises.
- Deploy a small number of parking sensors at AIA premises.
- Testing of deployed parking sensors.
- Web dashboard testing and enhancements.
- Provide a stable version of the second version of the web dashboard.
- Mobile application testing and enhancements.

A more detailed description of the current state of the platform follows.

A WINGS prototype sensor is installed, deployed and monitored in three test locations, namely WINGS, OTE and AIA premises for the past few months. All the parking events are recorded in the database and all information about these events (sensor ID, timeframe of the event, sensor battery level etc.) are available through the platform's REST API.

For testing the functionality of the analytics component, several scenarios were studied, for each of which, different arrangements of occupied parking slots were considered. In Figure 33, two of these scenarios are depicted. For simulation purposes, a testing parking area consists of two parking sections, with each having 8 parking slots, i.e., 16 parking slots in total. The cars on the slots represent the occupied slots, as monitored by the respective sensors.

[5] https://keras.io/

User 1 approaches from the entrance located at the upper left part of the figure and have specified a desire to park as close as possible to the entrance located at the upper right part of the figure. The system finds the slot that is closest to the specified point of interest (POI) and provides the shortest route towards it (blue route) considering if the respective corridor has one-way or both-ways directionality. User 2 on the other hand, approaches from the entrance located at the middle right part of the figure, and desires to find an available slot closest to his entering point. The system again, finds the slot compatible with these criteria and provides the corresponding route (yellow route).

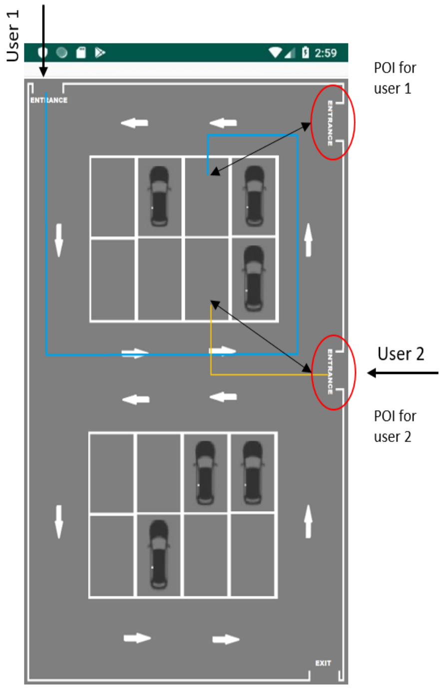


Figure 33. Simulation scenario for testing the analytics functionality.

Finally, to demonstrate how the algorithm models the traffic within a big parking facility, a simulation scenario was conducted based on the actual parking area of AIA. As depicted in Figure 34, several users (1,2,3,4) are approaching from the left – hand side entrance and want to park as close as possible to the administration building. The numbers indicate the chronological order of the requests. As User 4 arrives, just after the previous three users have been navigated by the service to the appropriate slots, the algorithm specifies the slot, from the available ones, closest to the entrance of the administration building (green slot). Although the shortest route towards this slot is from the left-hand side of the parking (dashed blue line), as were the routes of the previous requests, an alternative route (blue line) is suggested to avoid congesting the corridors of the parking. The algorithm achieves this by keeping record of the most recent requests and updating weights of the respective edges to simulate the traffic within the parking area. It should be noted here that the service also avoids sending users to slots that are adjacent to an occupied place. If the driver decides not to follow the slot proposed by the system, then the system will be able to take this into consideration in the next requests for parking from other users. In this case, the real-time information from sensors is used to propose a slot that is not taken.

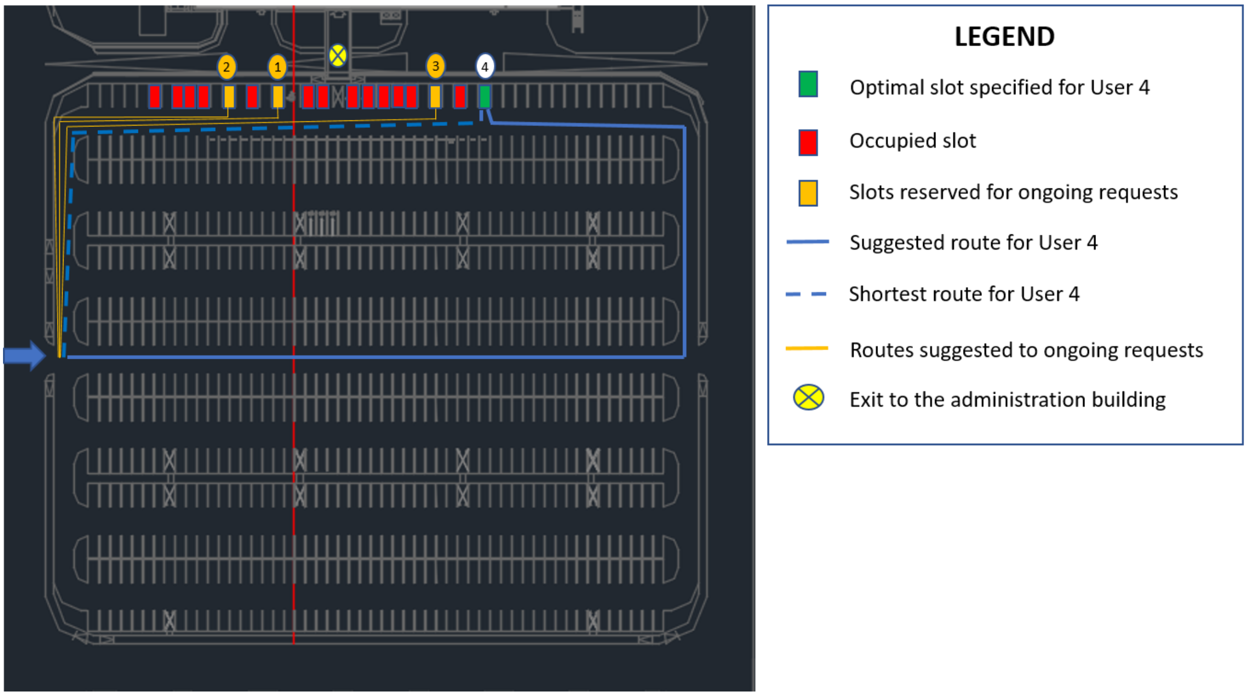


Figure 34. Simulation scenario implemented for the AIA's parking area.

2.4 Tests in the Network

During the deployment phase of the Network, various tests and measurements will be conducted (based the use of ICMP/ping and iPerf) in order to evaluate the optimal performance of the network and the involved platforms.

During the phase of the verticals' integration and during operation and demonstrations, other types of measurements will be performed. This is needed in order not to affect the network operation and influence the service delivery. These types of measurements will be based on network probes (software, hardware or both) that will be placed in key locations of the infrastructure and passively measure the required KPIs. The architecture and methodology of these measurements is described in the section that follows.

Network probes

ACTA will assist the implementation of the network, by measuring network KPIs and validating the level of performance achieved. These KPIs comprise metrics related to the service provided to the end-users (such as latency, data rate, etc.) as well as others related to the operation of the network (such as deployment time and scalability).

ACTA, together with NOKIA-GR and OTE, identified the network-elements and their interfaces for optimal measuring probe placement. A variety of probes (both hardware and software, open source and proprietary) were considered. ACTA based on prior expertise have selected and ordered different types of probes together with the central controller. ACTA also identified the probes' configuration, to match the interfaces & placement location with that of the network links and interfaces. The target is to achieve end to end measurement of KPI values. A Proof of Concept has been performed at ACTA Labs, as well as at OTE Labs premises, to gather real time measurements (using 4G connectivity).

ACTA's implementation is based on the use of Viavi[6] network probes (Figure 35), as well as on Accedian's[7] network probes (Figure 36). They will be managed via a proprietary controller or the in-house developed KPI Validation Platform (KVaP). The KPI metrics involve performance from the network links, nodes, services, physical & service ports, signal levels etc. The measurements are being transmitted to and stored on a cloud

[6] https://www.viavisolutions.com/en-us/product-category/network-test-certification/multi-protocol-field-test
[7] https://accedian.com/platform/software-hardware-l2-l4-testing/

server for further processing. Measurements are performed with sub-millisecond accuracy that is essential for validating the KPIs and performance of the 5G Network.

Figure 35. The Viavi MTS-5800 probe.

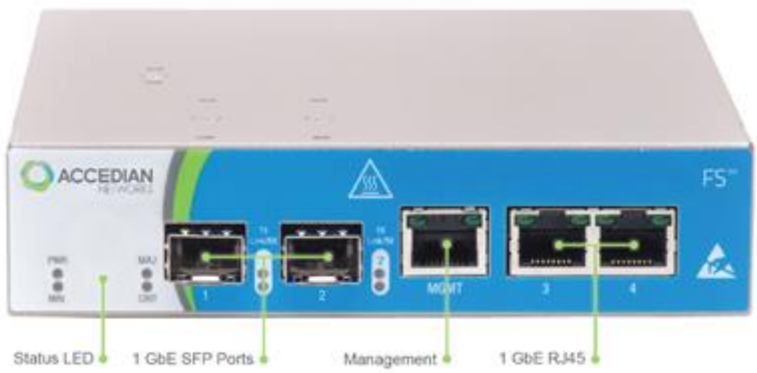


Figure 36. The Accedian FS network performance probe.

The system includes both the ability to monitor the traffic passing through the network (user traffic) and extracting important KPIs such as bandwidth utilization and transfer speeds per service, as well as active testing (test traffic) which provides packet loss, delay and jitter information for selected network paths.

The proposed KPIs to be measured are:

- Throughput – sustained demand
- Latency end-to-end
- RAN latency
- Jitter
- Packet Loss
- Max/Attainable/Min Bitrates (Data Rates)
- Utilization (as a time varying % of Max)
- Availability (= Uptime/ (Uptime + Downtime) x 100%)

The first probe will be connected via Ethernet through configuration between the NOKIA-GR’s Airscale BBU and the Backhaul of the telecom network at the AIA as shown in Figure 37. The second probe will be installed via Ethernet through configuration at the Backhaul of the telecom network in the OTE labs. Finally, a third probe will be placed via Ethernet through configuration between the Packet Core network at OTE labs and the WINGS Application Server.

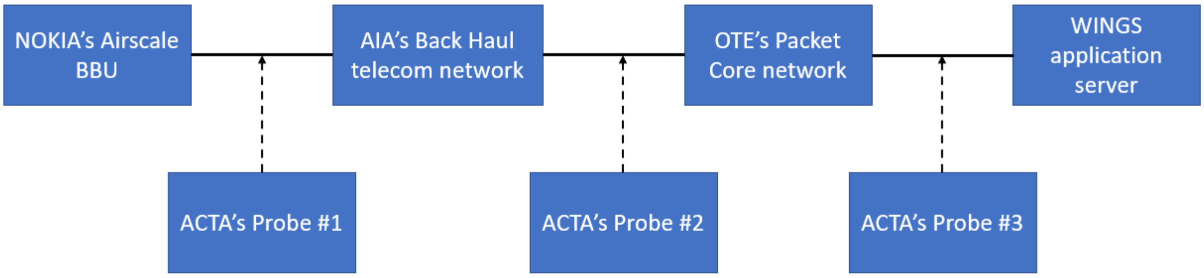


Figure 37. ACTA's probes topology in the network.

The NOKIA-GR BBU will be installed in room B2 of the Athens International Airport. The Backhaul network equipment is installed in the control room of building M2 of AIA. The Packet Core network is in OTE labs. The large amount of data will be analyzed and presented in a user-friendly format, to identify possible weak points of the network which will indicate the need to undertake corrective action for optimization and performance improvement. During this period, ACTA is also working on the preparation of several test measurements in cooperation with NOKIA-GR and OTE. Preliminary tests are being prepared in the 4G network of OTE using the Accedian probes that will allow further optimization of ACTA's KVaP platform.

For the needs of this UC and the corresponding test and trials, OTE as site manager provides all the telecommunication infrastructure at Psalidi (OTE Academy's facilities) and AIA (data rooms, poles for antenna mounting, racks, switches, routers, etc.) for the implementation of the UC in cooperation with NOKIA-GR, as well as for implementation of KPI validation in cooperation with ACTA. In addition, OTE, for the needs of the interconnection of AIA with Psalidi (5G EVE infrastructure) has established a 10 Gbit line.

The block diagram of the architecture where the KPI measurement probes and server for control and data collection and analysis is shown in Figure 38 below. The blue probes are the same to the ones indicated in Figure 37 and the green ones are new to be closer to the end-user and the Service Delivery Platforms.

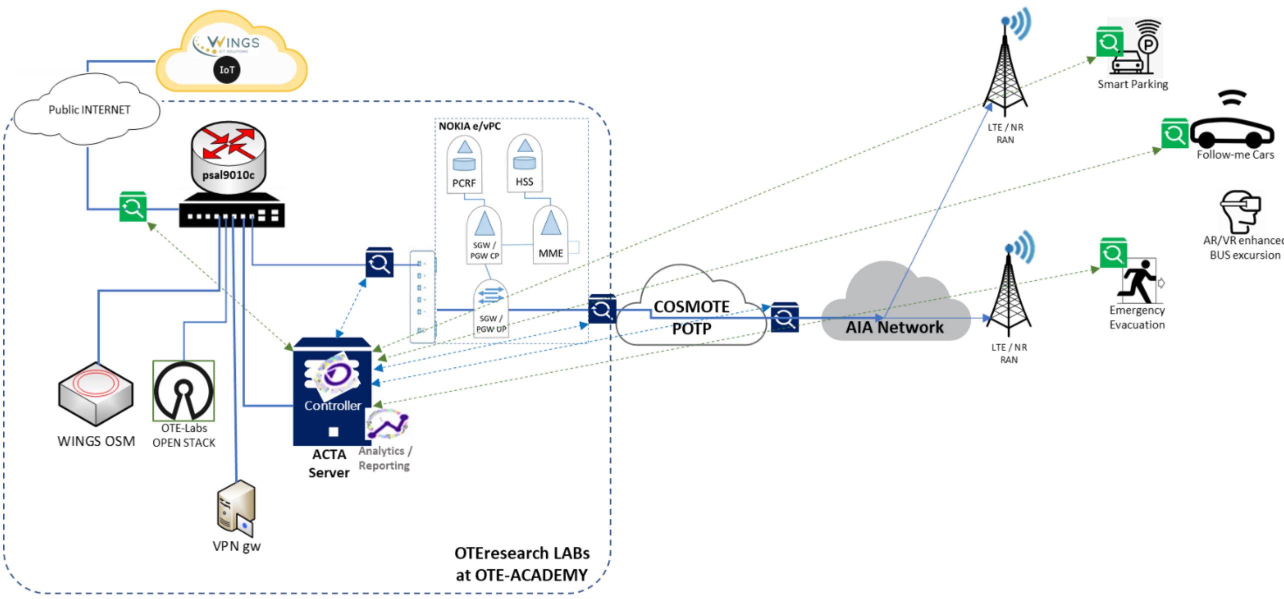


Figure 38. Overall network topology for the Athens 5G-TOURS site together with the KPI probes and server.

Two types of probes are considered: Passive and Active. The passive just monitors the network parameters while the active sends control data in order to measure time dependent parameters like latency, jitter and packet loss. The use of the improved TWAMP protocol will provide better accuracy compared to the widely used ICMP [18], [19] for the active measurements.

The use of real-time network and service KPI acquisition, together with the subsequent analysis of the measurements, allows for pre-emptive resolution of network and service delivery issues. This approach together with the AI based Orchestration for network resources is part of the innovation(s) suggested for the 5G-TOURS project implementation.

3.UC11 - Video-enhanced ground-based vehicles

3.1 UC11 Overview

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 misdemeanors, 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 will be utilized to transmit live video feeds from the area where the incident is taking place not only to ASOC, but also to other concerned third parties and stakeholders such as Police HQ, Civil Protection, HCAA[8], Fire Brigade operation centers, etc.. This will most certainly coordinate and expedite the response to needs and emergencies as they occur and will maintain the safety of the Apron area.

This use case will be implemented via the installation of high-definition cameras on the follow-me vehicles, which will feed live video feeds to the ASOC as well as to other concerned third parties and stakeholders. Enhancing the ground-based moving vehicles with technologies that 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.

Situation example: 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. 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 proceeds to promptly inform this employee that smoking is prohibited on the tarmac. During the peak morning hours at approximately 04:30 – 07:30, where there are several arrivals and departures that the AMIS must facilitate, thus the AMIS are unable to accommodate all arriving and departing aircrafts by inspecting their positions which results in aircraft departure delays. The late departure of aircrafts from Aircraft parking stands delays also, the arriving aircrafts as their parking position has not been vacated.

The follow-me vehicles also access on-demand service and provide the follow-me services for aircrafts, which lead aircraft to their parking position. 5G technologies will be used to provide, on-demand and/or live video streaming or upload recorded data later in order to monitor and oversee the activity at the airport airside area, and attend incidents, emergencies and critical events.

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.

Partners involved: WINGS, OTE, NOKIA-GR, ACTA, AIA

Location: AIA

[8] Hellenic Civil Aviation Administration

3.2 UC11 implementation

3.2.1 Network Deployment

As we mentioned in the previous chapter OTE and COSMOTE in co-operation with NOKIA-GR organized all the designation and implementation part of the infrastructure for the needs of the four UCs of the mobility efficient city. During the last period of the project for the better organization of the WP6 infrastructure designation and installation and in order to reach smoothly the MS3, many teleconferences or online-meetings and on site F2F meetings took place and organized between OTE, COSMOTE mobile team and NOKIA-GR, where many decisions were taken as they have been mentioned before. In section 2.2.1 we have described in detail the existing extended infrastructure of Athens node. Figure 39 highlights the network deployment which will be applied to cover the Video-enhanced ground-based vehicles use case.

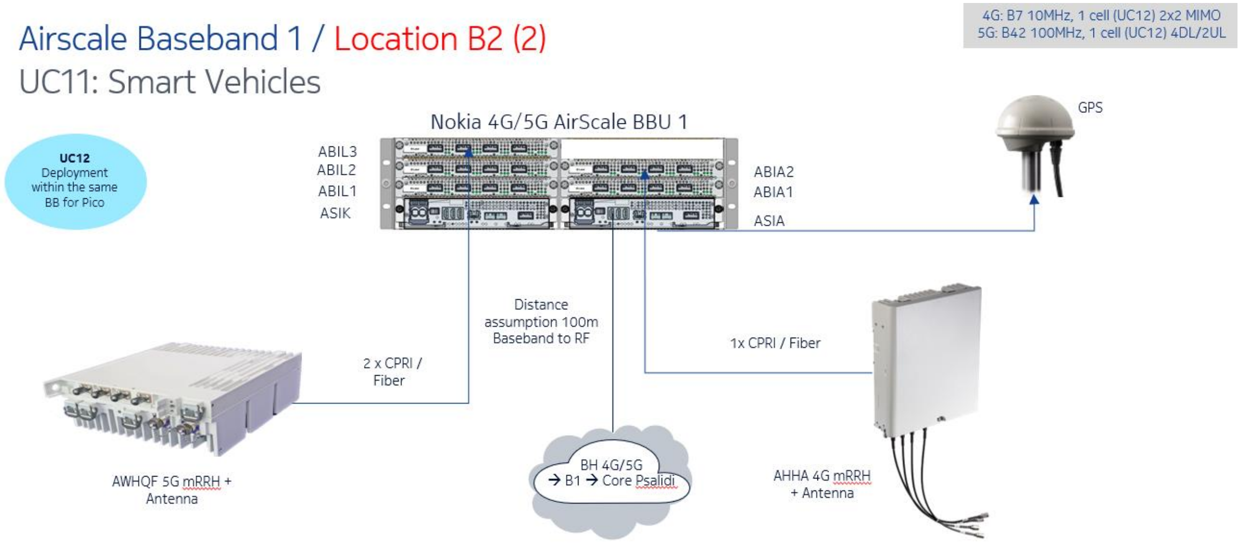


Figure 39. Network deployment for video-enhanced ground-based vehicles use case.

An air scale BBU will be placed in the control room of building B2 in AIA. One pair of 4G/5G outdoor antennas (non-standalone) will be placed on the rooftop of the same building. A back-hall connectivity will follow from B2 to the main control room of the airport (Building M2). From there a 10 Gbit Ethernet connection is already established to the Packet Core network.

Figure 40 illustrates the control room of building B2 and the antenna mast in the rooftop of building B2.

Figure 40. The control room of building B2 & the antenna mast.

For the Core Network of 5G EVE see section 2.2.1.

3.2.2 Network Equipment

The following network equipment will be used for Video Enhanced Ground Based Vehicles. It belongs to the same product "family" as the chosen equipment for Smart Parking UC and fulfils all the requirements and needs of the UC.

It consists of:

Baseband HW:

- ABIL AirScale Capacity
- 3x Accedian FS network performance probe
- 3x MikroTik RBLtAP-2HnD&R11e-LTE Router

RF HW:

- AHHA AirScale Micro 4T4R B7 20W
- AWHQF AirScale Micro 4T4R n78 B42 40W

ANCILLARIES:

- FOSP Optical SFP P 1310nm 9.8Gb 10km SM
- FUFBH SM OD fiber LC OD-LC OD dual 100m
- OCTIS Plug Kit DC Power
- OCTIS Plug Kit SFP
- AMBA AirScale Micro Bracket Assembly Kit
- AAQA AirScale mRRH Dir Ant 3.5G
- AAHG AirScale mRRH Dir Ant 2.2G 2.6G

The Network Equipment will be deployed in AIA surrounding area (Logical Network View) as Figure 41 highlights.

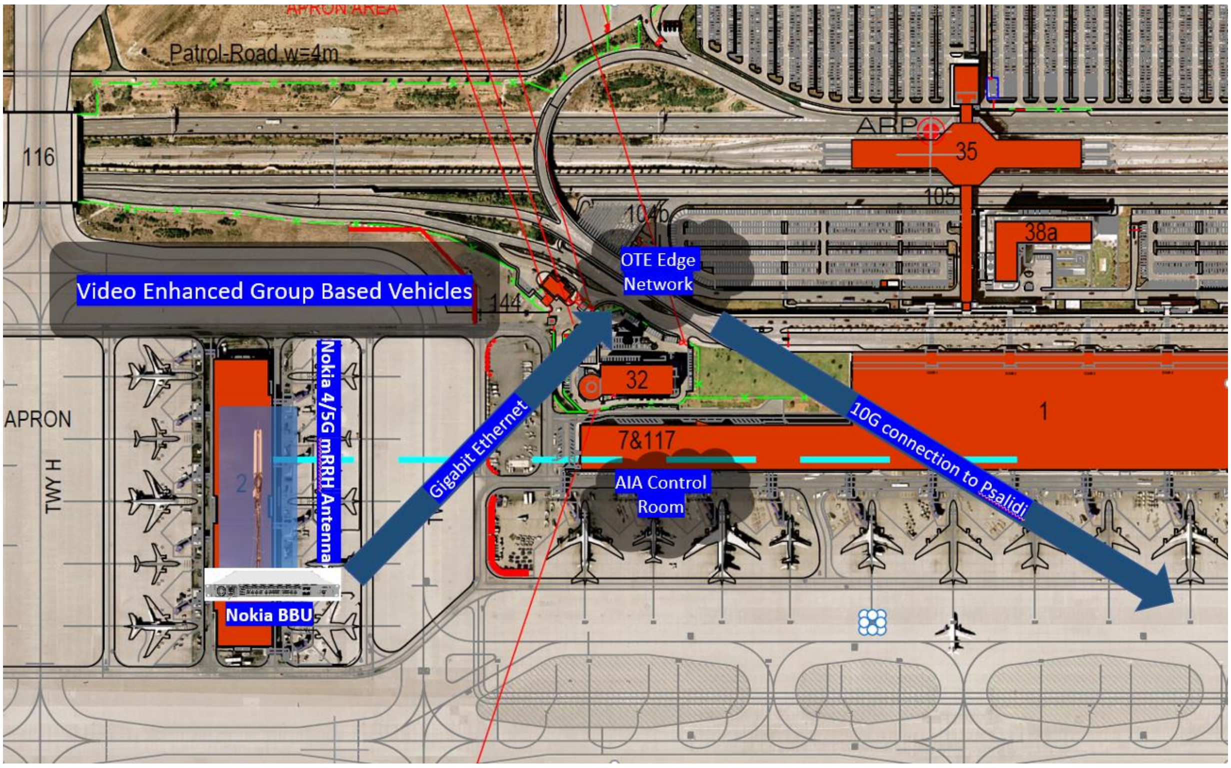


Figure 41. RAN coverage of AIA.

3.2.3 Application Components

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 deployment will be done on the media server provided by AIA. A mock-up screen of the described functionality is shown in Figure 42.

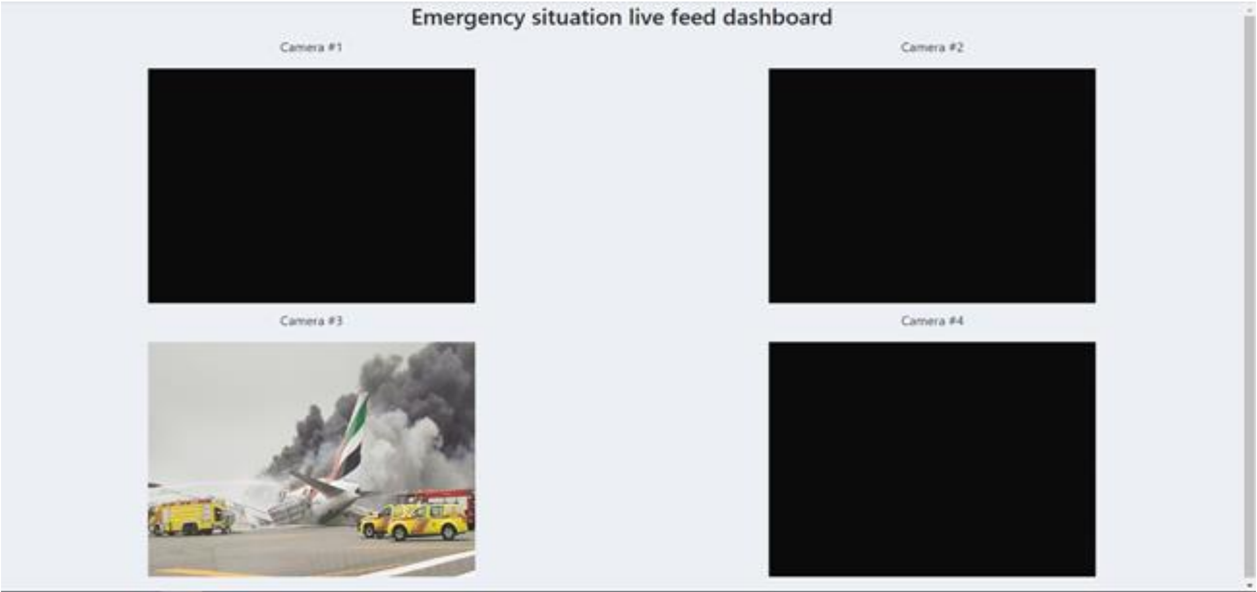


Figure 42. Situational awareness application mock-up screen.

The application provided for this use case comprises of:

- The Nginx web server [13], which is a free, open-source, high- performance HTTP server.
- FFmpeg[9], which is a software project consisting of a variety of libraries for handling video, audio and other multimedia files and streams.
- RTMP (Real-Time Messaging Protocol)[10], a TCP-based protocol which maintains persistent connections and allows low-latency communication.
- HLS (HTTP Live Streaming)[11], which is a streaming protocol, widely supported across multiple devices and platforms.
- Video JS player[12], a JavaScript-based video player that uses the HTML5 video functionality built into advanced browsers.

The live streaming application developed in the context of this use case receives video feed from multiple cameras and provides live video streaming on a one-page website. The feed from each camera is sent to different ports on the Nginx web server in RTMP format. This is achieved through the FFmpeg framework which encodes the feed and allows the setting of bitrate, resolution, quality and other video parameters. Then, each RTMP feed is converted to HLS, which delivers video files as small MPEG2-TS file downloads that are interpreted as a seamless stream. The conversion is done using the appropriate settings in the configuration file of the Nginx server. The live streaming process feeds a simple HTML page integrated with the Video.js player (Figure 43).

The initial testing was performed using two web cameras; however, the application can be expanded in order to support the original installation plan (three high-definition cameras).

[9] https://ffmpeg.org/
[10] http://www.adobe.com/devnet/rtmp.html
[11] https://developer.apple.com/streaming/
[12] https://videojs.com/

Figure 43. Current version of the live streaming application.

3.2.4 Terminal Equipment components

The technical components required for this use case are:

- 3 smartphone/mobile devices for testing the mobile application during the trials provided by SRUK.
- 3 5G routers for testing 5G capabilities provided by ACTA
- 3 IP Cameras for vehicles for testing live steaming through 5G network provided by AIA.
- VM Media Server for storing the video streaming provided by AIA
- 3 SIM cars for 5G routers provided by Cosmote

Mobile/smartphone:

To make use of the 5G network available, a 5G compatible phone is essential. Specifically, Samsung S10 5G will be used. More details can be found in section 2.2.4.

4G routers with Ethernet interfaces:

To make use of the 5G network available, a 5G compatible router is essential. ACTA will provide for the first phase of the use case a 4G router and then it will be replaced with a 5G.

MikroTik RBLtAP-2HnD&R11e-LTE Router (4G): has built-in cellular modem that supports 4G (LTE) connectivity. The 2.4 GHz 802.11b / g / n wireless capability provides secure access to the LTE network from your phone or any other wireless device with download speeds of up to 150 Mbps. It also has a Gigabit Ethernet LAN port for wired devices. There are many power options: DC socket, POE socket and automotive. The durable case with a special wall mounting kit is ideal for almost any challenge: from public transport, food trucks or logistics in harsh winters and stormy desert environments. LtAP can handle any temperature from -40 ° C to + 70 ° C. It is a perfect solution for real-time vehicle monitoring.

Hikvision Cameras:

To make use of the 5G network available, a **reliable** Mobile Network Camera is essential.

HIKVISION DS-2XM6522G0-I(D)(M)(/ND): has high quality imaging with 2 MP resolution, clear imaging against strong back light due to 120 dB true WDR technology, efficient H.265+ compression technology, is water and dust resistant (IP68) and vandal proof (IK10), has advanced streaming technology that enables smooth live view and data self-correcting in poor network and 3D DNR technology delivers clean and sharp images. Its video max. resolution is 1920x1080 and the power supply and consumption are 24VDC.

Media Server:

The video streaming will be transferred and stored to a VM Media Server on AIA premises. The virtual machine requirements are 4 core vCPUs and RAM 4GB. The operating system will be Linux or Microsoft Windows Server 2016.

3.2.5 Interfaces

The Video-enhanced ground-based vehicles platform consists of a combination of different interfaces:

- The end devices - IP cameras will transfer the live streaming to AIA's Media Server which will save the data.
- The web dashboard will take the appropriate data from the server and will visualize in parallel the live streaming from three different cameras.

The communication between the interfaces is depicted in Figure 44:

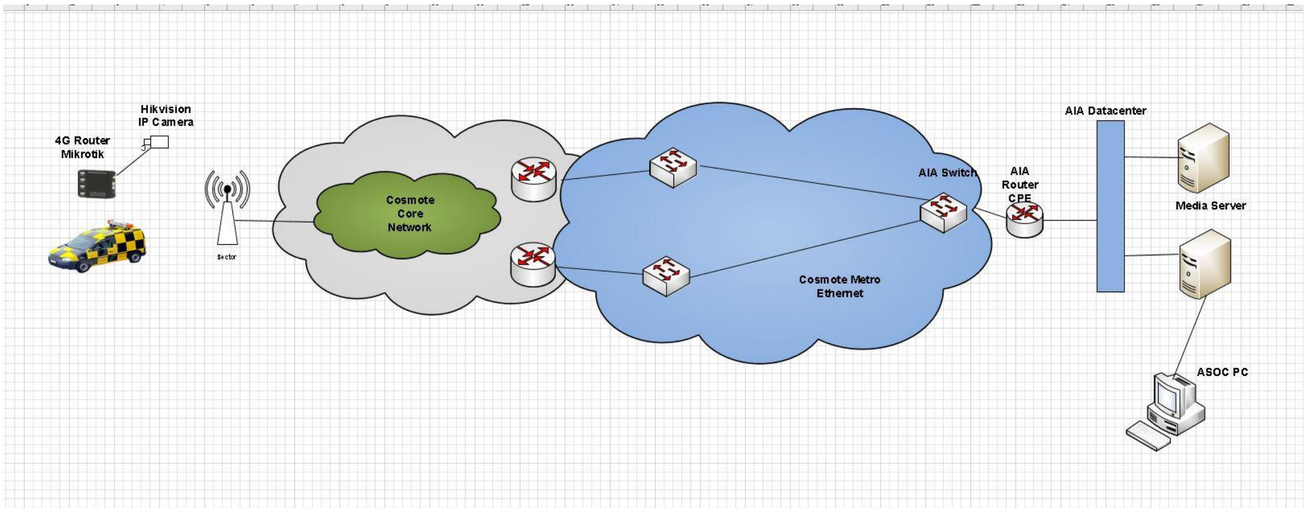


Figure 44. Network diagram for UC11.

The video streams are to be received by a NGINX open source webserver that provides load balancing, socket streaming and reverse proxy servers. The NGINX webserver has a variety of application modules that facilitate a multitude of options for video streaming, such as pushing the streams on a web media player, re-streaming the streams elsewhere, saving the video stream locally in various video formats, or playing video files later on demand (VOD). Using the NGINX Real-time Messaging Protocol (RTMP) module we receive the video streams on the NGINX server in RTMP format on the standard RTMP port (1935). The streams can be encoded to the HLS format using the FFMPEG library, with different bitrates and video quality for adaptive streaming. The FFMPEG library also allows for recording the streams in numerous video formats and compressions. The HLS streams are served to our platform, where users with access can see all 4 different streams played simultaneously.

3.3 Integration and results from tests in labs

A summary of the progress that had been made during the past months, based on the project's Gantt chart and the specific time plan created for each individual use case, is described below.

- The IP cameras have been purchased.
- The 4G router model has been decided.
- The installation and power supply of the router from the vehicle engine has been decided.
- The installation of ACTA probes on vehicles has been decided.
- The development of a Web dashboard showing 2 different camera streams has been completed.

3.4 Tests in the Network

This task will address the facilitation of the logistics processes at AIA. In particular, in the context of this use case, several emergency ground-based vehicles (also referred to as "follow-me" vehicles), which lead aircraft to parking positions, monitor and oversee the activity at the Airport Airside area, and attend incidents, emergencies and critical events, will be equipped with 5G-enabled video capturing devices, providing support both for day-to-day airport operations to the airport and response to emergencies.

The network probes described in UC10 will be also used in UC11 (see section 2.4).

In addition to that, one 4G router (Figure 45) will be placed by ACTA in each of the three AIA ground-based vehicles. The router will be connected to the 4G network of AIA for the phase 1 trials. When the 5G network in AIA will be fully available, the 4G routers will be replaced by 5G routers that are already under test at OTE labs. A fourth probe will be connected via an Ethernet port with the routers. This will allow the performance monitoring of the peripherals connected to the router of the vehicles.

Figure 45. MikroTik RBLtAP-2HnD&R11e-LTE Router.

With respect to 5G router testing and evaluation the following are being done at OTE research labs:

UC11 – 5G-router Trials/Prototypes

Each of the Ground-Based Vehicles (Follow-me cars) of the AIA will be equipped with a HD Camera that will stream the Driver View to the Control Center. The Camera will be connected to a 5G-Router via Ethernet Interface in order to achieve the IP connectivity with the Control Center. For the 5G router ACTA Ltd has started testing and evaluating different alternatives. Five (5) different manufactures of CPEs (Customer Premises Equipment were invited to supply samples. These were:

1. Huawei Hellas

2. ZTE Hellas
3. AVM Germany
4. Oxygen Broadband
5. Sercomm Taiwan

From those 2 have responded with prototypes (namely ZTE and Oxygen Broadband) and one (AVM) promised to supply sample on Q1 of 2021. The ZTE CPE can be seen in Figure 46 and is the model ZTE MC801.

Figure 46. ZTE 5G-Router/modem model MC801 that supports the 3,5-3,8 GHz frequency band.

Oxygen Broadband submitted a prototype based on Quectel RG500Q-EA and the prototype together with their IP router modem (HDI34201 (based on Realtek rtl8685 chipset) is shown in the picture bellow (Figure 47).

Figure 47. Oxygen Broadband 5G Router Prototype based on Quectel & Realteck Reference boards.

ACTA and OTE have run successful connectivity tests with both prototypes. Since there are no SIMs available for the NOKIA-GR 5G pilot installation, COSMOTE’s commercial 5G network was used. The results are not representative of what is expected from NOKIA-GR’s 5G network so at the present time connectivity and interoperability issued with the end devices (Cameras, Laptops, Acta Probes etc.) is being investigated.

Results that will represent the behavior and performance of the NOKIA-GR network can only be expected in mid-Q1 of 2021. ACTA and OTE continue to cooperate with the manufactures to have the 5G-router ready ahead of the field trials.

For the needs of this UC and for the Athens site OTE as site manager, provides all the telecommunication infrastructure at Psalidi (OTE Academy’s facilities) and AIA (data rooms, poles for antenna mounting, racks, switches, routers, etc.) for the implementation of the UC in co-operation with NOKIA-GR, as well as for implementation of KPI validation in cooperation with ACTA. In addition, OTE, for the needs of the interconnection of AIA with Psalidi (5G EVE infrastructure) has established a 10 Gbit line.

4.UC12 - Airport evacuation

4.1 UC12 Overview

The main goal of this use case is to exploit the 5G capabilities for assisting current evacuation plans in large crowded indoor public spaces and thus, reduce the possibility or magnitude of casualties. The idea of this scenario is to support occupants to be safely guided to the nearest exit, after an unattended item is left at Gate A36 of the STB and based on the current protocols an evacuation is deemed necessary.

The overall objective is to validate whether the 5G capabilities can complement existing processes and capabilities by providing automated guidance for the evacuation route to residents and regular users of the facility to visitors, travelers, and possible vulnerable people who are not aware of the facility. Real time data such as numbers of evacuees within an area, persons trapped, assistance to impaired people, visualization of real-time flows of people will be evaluated to assess the impact of 5G technology.

Evacuation of an Airport Terminal in case of an emergency is fundamental for ensuring the protection of human life and reducing as much as possible, the number of casualties. The elements of panic that may ensue during an evacuation process may result in unnecessary and severe repercussions. In previous incidents where evacuation procedures were initiated and handled with the use of simple technologies such as tetra and telephone, uncontrolled evacuees have been found scattered beyond the designated muster areas.

In respect to efficient and rapid evacuation in cases of 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. Evacuating in a quick and organized fashion such as that which the 5G will be provided by automated dynamic emergency routes from the affected area up to the muster areas, is of the utmost importance. The 5G provides the capability to obtain real-time data from the emergency environment which is to be evacuated, such as numbers of occupants within the area, persons trapped in isolated areas of the building and about the real-time flow management of the evacuees.

Furthermore, this use case can accommodate for incidents that have complex and dynamic evacuation requirements such as a fire spreading or a terrorist attack, that require dynamic information to be conveyed to evacuees.

Airport terminals are very large and complex public venues with a large number of travelers, visitors and employees. Airport evacuations in general, are currently based on pre-established plans and procedures to be executed during the emergency.

AIA is the main gateway to Athens and Greece in general. On a daily basis AIA serves approximately fifty to sixty thousand passengers travelling through the airport, while during the peak traffic days this number can reach approximately one hundred thousand or even more, including visitors and employees.

The Airport's objective is to process this crowd in an efficient and safe manner, while at the same time have in place the relevant plans, tools and processes required to mitigate any emergency. An 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.

This scenario describes 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. In the context of this use case, a section of AIA will be provided, and around 50-60 volunteers (actors) will participate in an evacuation exercise. Naturally, such an emergency situation will call for low latency communications with high reliability of being realized, which means that a URLLC slice will have to be allocated so as to ensure that all travelers and AIA personnel are notified and guided to the most appropriate exit immediately. A detailed 3D digital model of the section to be evacuated along with all objects contained therein, such as seats, desks and monitors, will be created and fed into the evacuation support system. Emergency exits will all be recorded and fed into the system supporting the evacuation procedure along with information on their exact location as well as their capacity, if they are accessible, etc.

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

Partners involved: AIA, KEMEA, WINGS, OTE, NOK-GR, ACTA

Location: AIA APRON

4.2 UC12 implementation

4.2.1 Network Deployment

For the implementation of UC12 OTE and COSMOTE in co-operation with NOKIA-GR organized all the designation and implementation part of the infrastructure for the needs of the four UCs of the mobility efficient city. During the last period of the project for the better organization of the WP6 infrastructure designation and installation and in order to reach smoothly the MS2, many teleconferences or online-meetings and on site F2F meetings took place and organized between OTE, COSMOTE mobile team and NOKIA-GR, where many decisions were taken as they have been mentioned before. In section 2.2.1 the existing extended infrastructure of Athens node is described in detail. Figure 48 (red square) highlights the network deployment which will be applied to cover the airport evacuation use case.

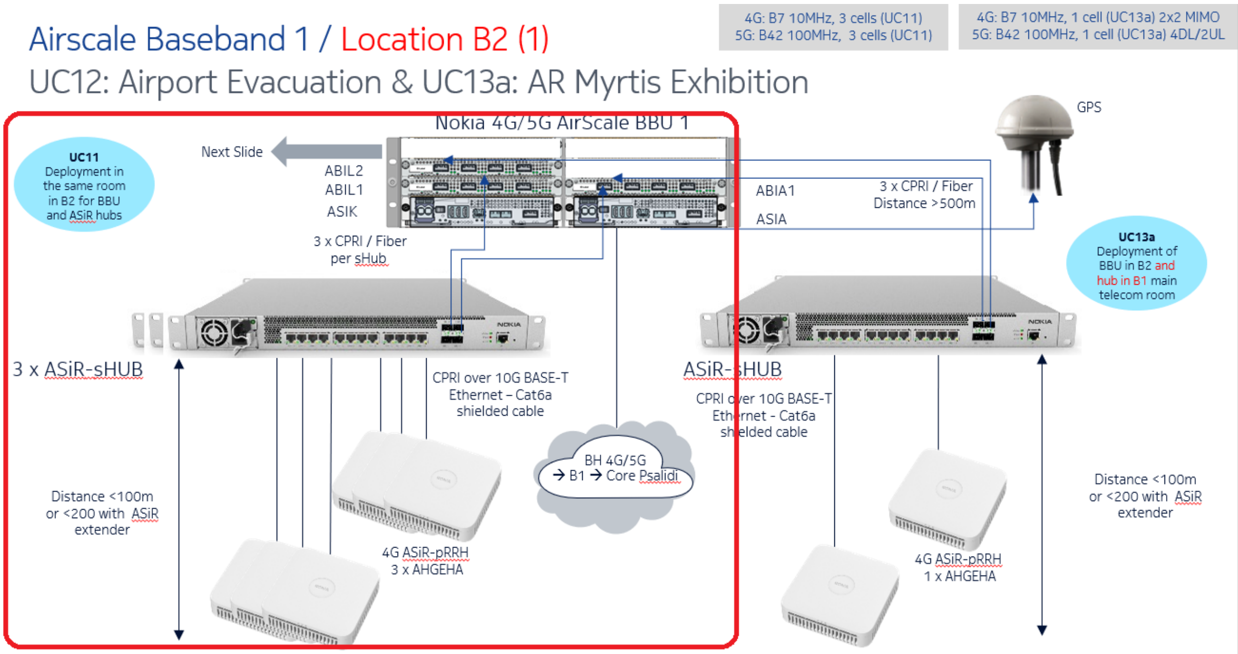


Figure 48. Network deployment for airport evacuation use case.

An AirScale BBU will be placed in the control room of building B2 in AIA (Figure 49). Three pairs of 4G/5G indoor antennas (non-standalone solution) will be placed on the second floor of the same building. A backhaul connectivity will follow from B2 to the main control room of the airport (Building M2). From there a 10 Gbit Ethernet connection is already established to the Packet Core network.

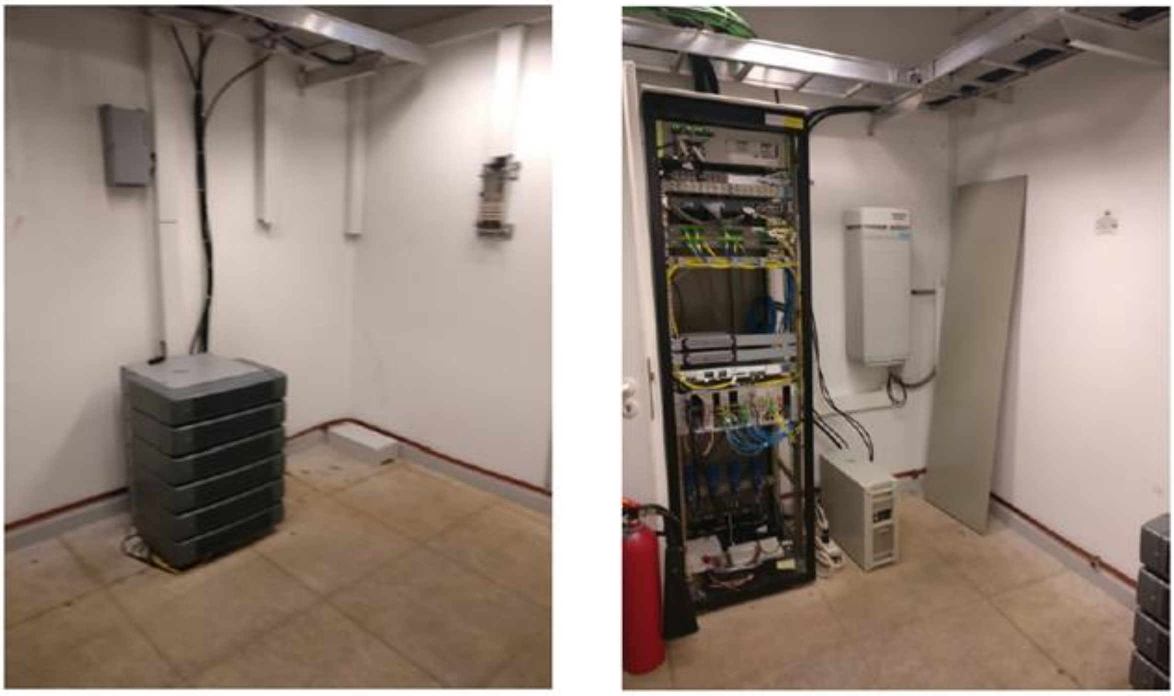


Figure 49. Control room of building B2. There is a space for BBU (floor installation) and ASiR HUBS (3X1 RU).

In Figure 50 we can see a 2D/3D model of the indoor area (second floor of building B2) where the evacuation scenario will take place. It can also be seen the location of small cells in the building.

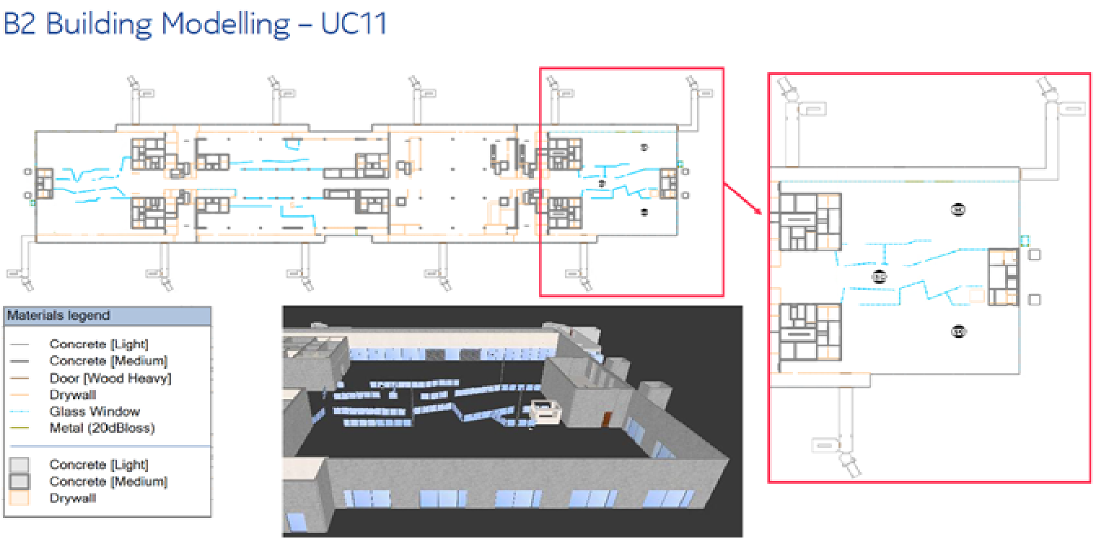


Figure 50. B2 building modelling.

For the Core Network of 5G EVE see section 2.2.1.

4.2.2 Network Equipment

The proposed solution for the Airport Evacuation Use Case is a fully 3GPP gNB compliant indoor small cell solution using NOKIA-GR's Flexi Zone platform. Key benefits of the proposed solution are as follows:

- Centralized flexible architecture enabling graceful 5G insertion.
- Best performance vs. size.
- High capacity.
- Carrier-grade software quality (macro parity).
- Proven plug & play for light touch install.
- Enhanced scaling via SFN.

Flexi Zone Small Cell future-proof product family and its most innovative small cell architecture provide new capabilities and versatile approach to address the varying deployment needs and business cases and fulfil the requirements of the UC in terms of density, latency, reliability, mobility and throughput.

The solution selected consists of:

Baseband HW:

- AMIA AirScale Subrack
- ASIA AirScale Common
- ASIK AirScale Common
- ABIA AirScale Capacity
- ABIL AirScale Capacity

ASIR HUB:

- APHA ASiR-HUB 12-port

RF HW:

- AHGEHA ASiR-pRRH B1 + B3 + B7
- AWHQB ASiR-pRRH n78 B42

ANCILLARIES:

- FOSO Optical SFP O 1310nm 9.8Gb 1,4km SM
- FUFBG SM OD fiber LC OD-LC OD dual 10m
- FOTB Optical SFP+ 10GBase-LR 1310nm SM
- ASiR Dual port power extender
- FMFA FLEXI MOUNTING KIT FLOOR/WALL/POLE
- AOQA AirScale Optical QSFP Adapter

GPS:

- FYMA GPS MOUNTING KIT
- FTSH GPS cable assembly 100m
- FYGC GNSS Receiver Antenna
- FTSF Sync Cable F

Performance HW:

- 3x Accedian FS network performance probe

The aforementioned Network Equipment will be deployed in AIA surrounding area (Logical Network View) as Figure 51 highlights.

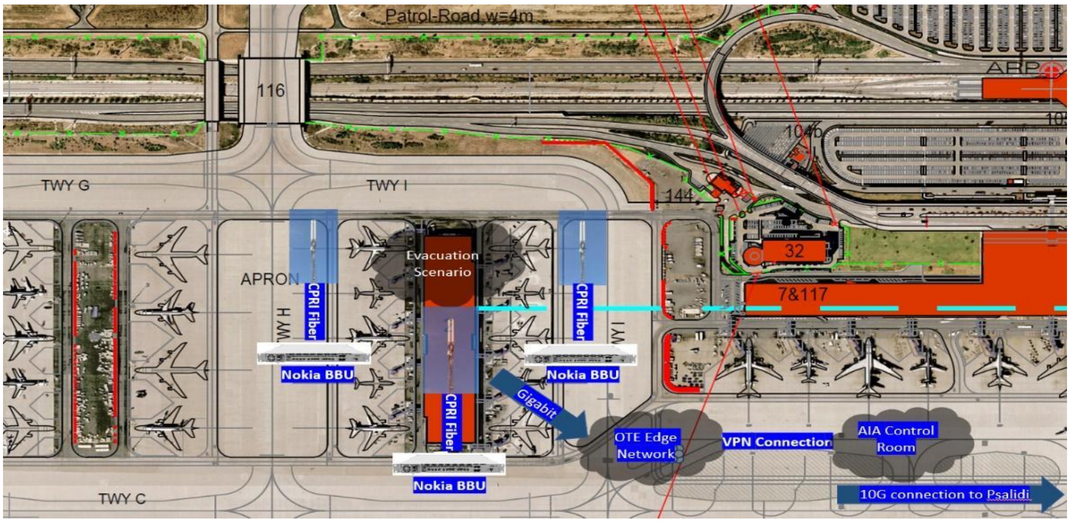


Figure 51. The RAN coverage of AIA.

4.2.3 Application Components

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, three indoor 5G micro cells provided by NOKIA-GR will be installed in order to calculate each user's location accurately as will be analyzed in section 4.3. 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 (it will be explained in the coming section 4.3). A schematic representation of the proposed architecture is shown in Figure 52:

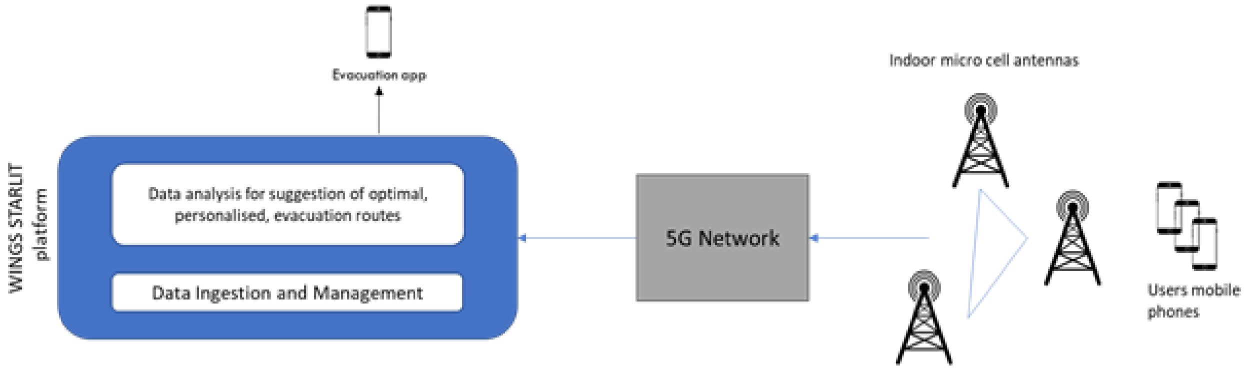


Figure 52. High level architecture of the evacuation system.

As far as the application is concerned, the key components needed are:

- The server/cloud component, responsible for processing the data received from the respective end-user device. This component is responsible to implement the graph-based approach followed for selecting the preferred exit, as well as providing the optimal route towards it.
- The end-user device and namely the respective mobile application, responsible for sending the appropriate data to the cloud for further processing, as well as for the visualization scheme/augmented reality environment. The appropriate data consists of the relative location of the user, defined in the appropriate indoor environment reference system, e.g., in which part/room/area of the building is the user currently, as well as the personalized options/preferences of the user, if any.

4.2.4 Terminal Equipment components

The technical components required for this use case are:

- smartphone/mobile devices for testing the mobile application during the trials provided by SRUK.
- SIM cars for 5G routers provided by Cosmote.

Mobile/smartphone:

To make use of the 5G network available, a 5G compatible phone is essential. Specifically, Samsung S10 5G will be used. For more information please see section 2.2.4.

4.2.5 Interfaces

Backend server: A python REST framework as the central backend system responsible for orchestrating the user requests and the analytics component and for delivering the information to the end user.

Unity/Vuforia modelling: The framework responsible for modelling the space and environment of the test site as well as managing the AR components. This will be integrated into the End-user device application/Dashboard.

End-user device application/Dashboard: The end-user device/devices responsible for delivering the appropriate information (current location and status, preferred destination, etc.) to the backend server in json format for further processing and visualizing the relevant information (routing, estimated arrival time, etc.) in an AR environment.

Analytics: A python-based module responsible for calculating the optimal exit and the optimal path towards it, using a graph-based approach.

4.3 Integration and results from tests in labs

For the current simulation scenario, a top view of a section of AIA was used and for testing purposes a part of this area was considered. This top view, as well as the area under consideration for the testing purposes, can be seen in Figure 53 below:

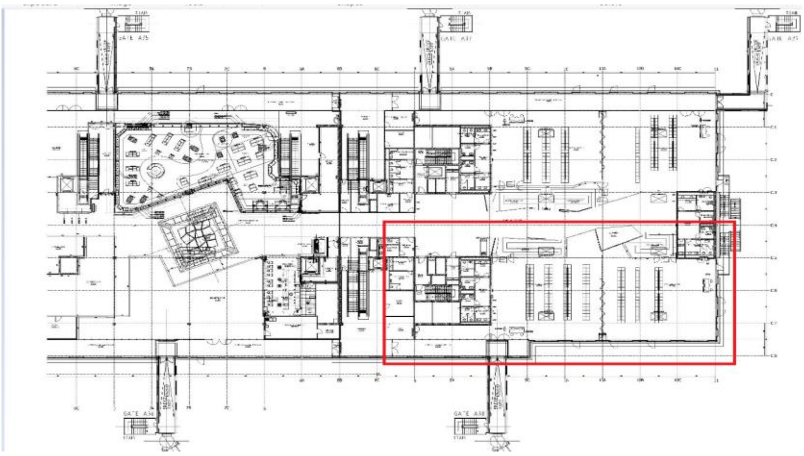


Figure 53. Top view of an AIA's section and the area considered for the purposes of the simulation scenario, denoted with red.

For modelling the indoor geometry into a corresponding graph, an abstraction of the indoor topology was conducted, meaning that the room-level topology details were omitted, and the rooms were considered empty. The reason for this, is that the purpose of the service is to provide an indicative room level guidance providing instructions to which room/section to move towards, rather than how exactly to move within the room/section. The graph to model the possible navigation of the user within the area is shown in Figure 54Figure 54, on top of the AIA's top view. More specifically, the top view of the AIA's area considered for the simulation with the corresponding graph which models the possible movements of the users. The division of the area into the sections A,B and C was arbitrary to organize the nodes of the graph into groups for p.

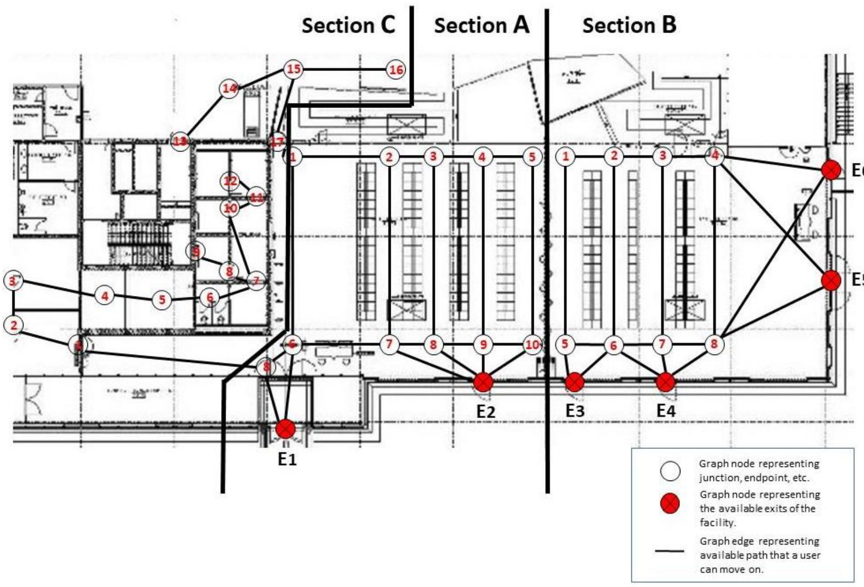


Figure 54. Navigation graph based on AIA's area.

A simulation scenario, consisting of two users asking for routing towards the closest exit is shown in Figure 55. The users located at the respective pins, request navigation to the closest exit and the algorithm specifies the closest one for each user and provides the shortest path towards it. It should be noted here that the algorithm takes into account the latest requests, in order to split the users towards the available exits, as uniformly as possible, to avoid crowding in a specific section. The study area, with the available exits indicated with the red arrows, the end users located at the respective pins and the provided routes towards the optimal -according to the specified criteria- exit (in this case the criterion is closeness to the exit). In the future dynamic management of the exits will be considered to cover potential terrorist scenarios where the terrorists are on the move and as such specific exits may be out of reach.

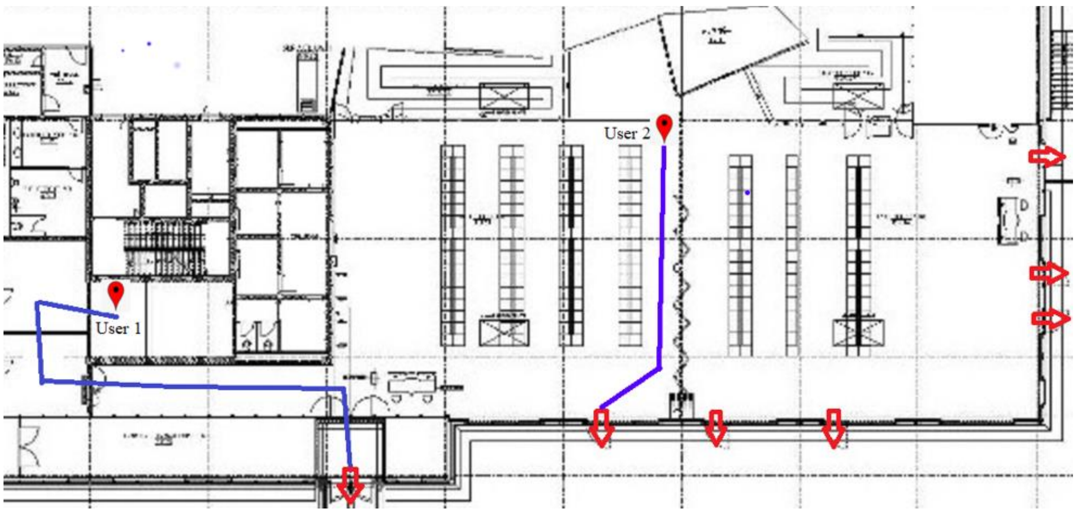


Figure 55. Simulation scenario for routing towards the closest exit.

The next step in the process of integrating the provided solution to a complete and easily perceptible to the user system, is incorporating the provided route in a unified AR environment application, which will accurately guide the user based on the route calculated. In the section below, a brief overview of this AR environment is provided.

The first step is to create a digital 3D model of the area being studied. To create the digital three-dimensional structure of the evacuation space, the airport's architectural plans will be used for the basic structure of the building (floors, walls, doors, partitions, exits, corridors, stairs, columns, windows). Then, all the objects that constitute fixed constructions in the space (offices, screens, shops and more generally objects that cannot be moved will be placed in it. The large objects that are inside the space and may be moved to other places (sliding doors, chairs, space bans) will be constructed. This way we will have a digital capture of the airport in its basic features. Then, this digital model will be utilized by **Unity** game engine, which allows a virtual navigation within the model. This, in combination with **Vuforia**, will enable augmenting the real space with digital information, which in this case is directions towards the selected exits through the optimal path, identified by the algorithm described above.

Indicatively, in the Figure 56 one can see, an actual scene from the airport, the corresponding digital model created to enable the virtual navigation in Unity and the scene augmented with easily perceived directions.

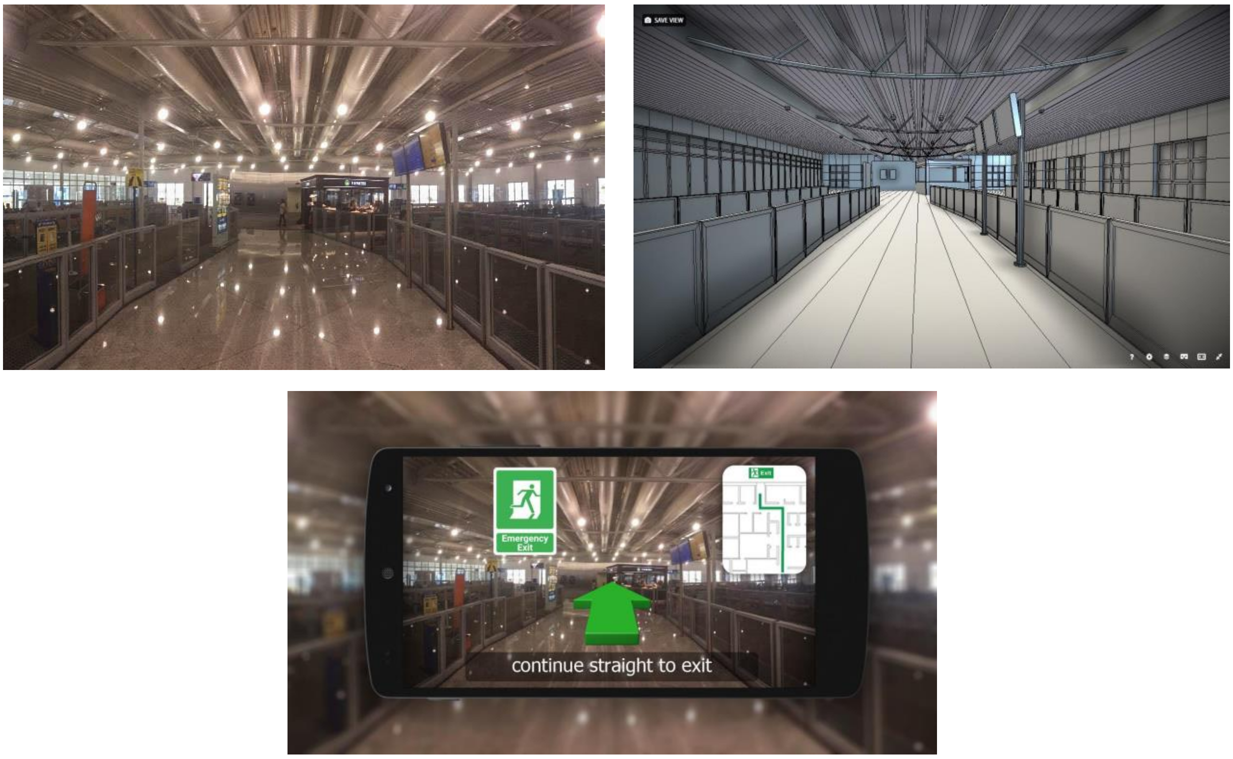


Figure 56. a) The actual scene from a section of AIA, b) the corresponding digital model c) augmented directions, as well as a top view of the suggested route towards the optimal exit.

The AIA top view cad files have been utilized for the virtual 3D model creation as shown in the figures below (Figure 57, Figure 58, Figure 59 and Figure 60).

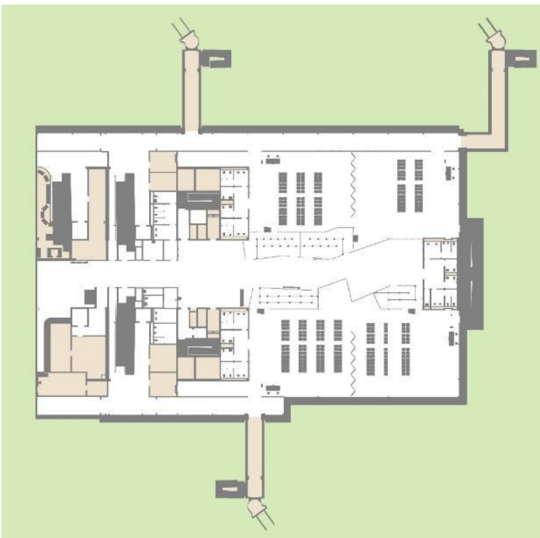


Figure 57. The AIA top level view.

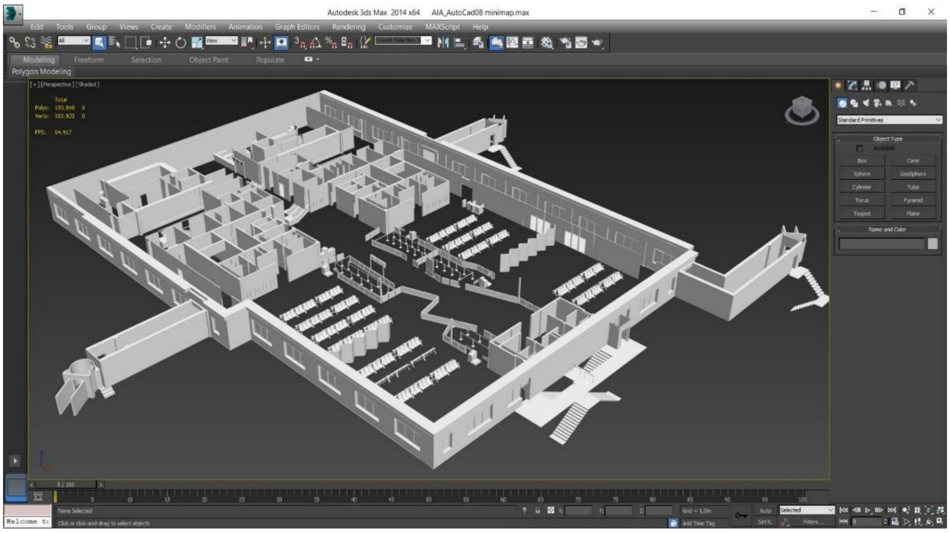


Figure 58. The constructed 3D model in Unity based on the top view.

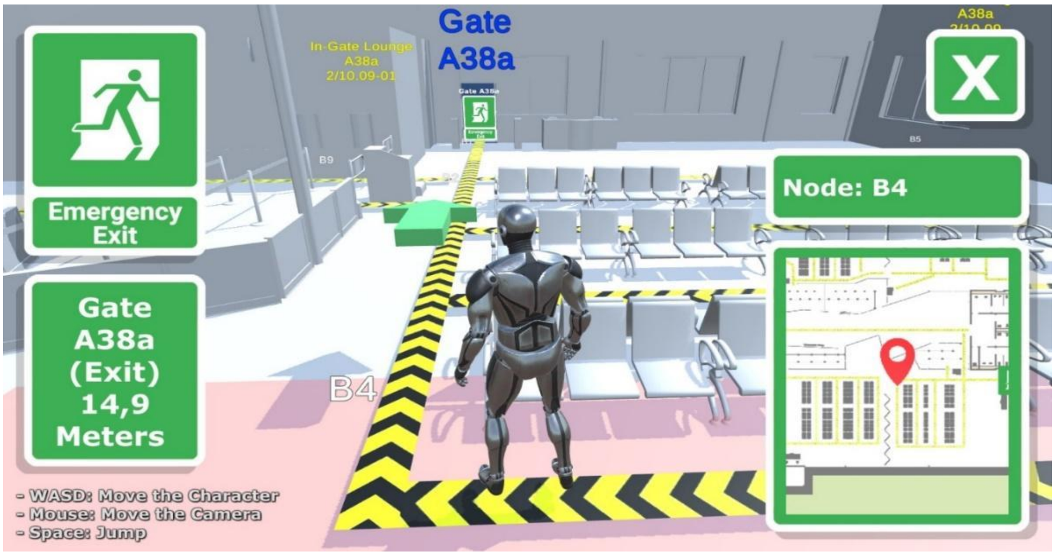


Figure 59. Integration of 3D model in the Unity environment.

Figure 60. Virtual navigation of the user within the modelled area.

Regarding the indoor localization component, there are several approaches that have been studied recently. The most prominent categories to which the various algorithms can be divided to, that have been also utilized at commercial level are listed below:

- Time of arrival (TOA)
- Angle of arrival
- Arrival time delay
- Received signal strength Indicator (RSSI)
- Hybrid systems (mix of different physical principles related metrics)

According to the State-of-the-Art studies, calculating the TOA using Ultra Wideband Positioning can provide some of the most promising results in terms of accuracy [15]. As the lower bound of the variance of TOA measurements is dependent on the signal bandwidth [16], the exploitation of the higher bandwidths that 5G networks offer could be of great benefit, to reach sub-meter accuracies that would enable accurate room-level localization, which is crucial for the evacuation case study. Nevertheless, there have been studies showing that the RSSI algorithms can achieve comparably high accuracies, while offering scalability of the size of the network and enabling hundreds of devices to connect, without any interference. It should be noted that regardless of the method the final accuracy perceived by the end user, is dependent on the indoor test site environment and the complexity of the configuration, obstacles and extends of the area [17]. This task will be addressed at the end of milestone 2 (end of September) when the experimental network will be deployed by NOKIA-GR at the AIA.

4.4 Tests in the Network

A mobility-efficient framework is also targeted by means of the airport evacuation use case leveraging advanced 5G capabilities, especially in relevance to low latency and enhanced reliability to ensure the timely notification of travelers being part of a hazardous situation.

The network probes described in UC10 will be also used in UC12 (see section 2.4).

For the needs of the Airport Evacuation UC and the corresponding test and trials OTE as site manager provides all the telecommunication infrastructure at Psalidi (OTE Academy’s facilities) and AIA (data rooms, poles for antenna mounting, racks, switches, routers, etc.) for the implementation of the UC in cooperation with NOKIA-GR, as well as for implementation of KPI validation in cooperation with ACTA. In addition, OTE, for the needs of the interconnection of AIA with Psalidi (5G EVE infrastructure) has established a 10 Gbit line.

5.UC13 - AR/VR bus excursion

5.1 UC13 Overview

The main goal of this use case is to demonstrate the value offered using 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. In the trials, a group of 20-25 students from the school of Ellinogermaniki Agogi (EA) will travel on a school bus to AIA to visit an exhibit that will be hosted in a public space of the airport. The fast, reliable wireless connectivity offered by 5G and the smooth streaming of online content that it can enable will be utilized to generate good quality digital learning experiences both during the transportation to and from the destination, and during the visit of the exhibit.

Situation example: 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 (Figure 61). 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, using VR technologies and 5G-enabled smartphones and headsets. The high-quality rich content is delivered simultaneously to the 20-25 students riding the bus. At the destination, students interact with the exhibit using AR technologies on their 5G-enabled smartphones. Finally, during their return to school on the bus after the visit, they participate in educational wrap-up and follow up activities embedded in VR experiences supported by each student's 5G-enabled smartphone and headset. Overall, the distribution of content to the students is personalized, in accordance with their preferences and requirements, as well as the 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.

The different phases of the trials of UC13 are presented below in further detail.

Figure 61. The 20-km bus route from the school (EA) to the airport (AIA).

Partners involved: EA, ATOS, SRUK, ACTA, WINGS

Location: school bus, AIA

UC13.a Students travelling to the Athens Airport: the VR-enhanced pre-visit experience

On a school bus, EA's school students will be traveling to the AIA, where they will visit an exhibit in the arrivals area introducing Myrtis to the travelers arriving in Athens. Myrtis is the result of renowned interdisciplinary research led by Professor Manolis Papagrigorakis of the University of Athens and his team, based on archaeological skeletal material excavated in modern-day Athens. 'Myrtis' is the fictional name given to the reconstructed face of an 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.

This part of the trials will be implemented on the school bus while it is moving in a small area of the airport with 5G coverage (a parking area and surrounding roads behind Building 17).

- *Interface:* Students will use the 5G Smartphone to enter a 3D VR space, where they will be able to explore the environment and select to interact with various digital assets.
- *Duration of the pre-visit VR experience:* 5-10 minutes
- *Scenario and content:* EA will provide the structure and script of the VR experience, as well as the digital assets, which will be implemented in a 3D VR space by SRUK.

The parts VR-enhanced pre-visit experience is comprised of the following parts:

UC13.a.i Profiling mini-game

The purpose of the profiling mini-game is to enable offering personalized experiences to each student.

Each student will be asked 3-4 questions, which will be disguised in a mini game. The answers the user will give will affect the way the app will work for that user.

The questions asked refer to language, age/educational level, etc.

UC13.a.ii Video introducing the experience

The students will watch a 3-5-minute video which will introduce them to what they will see and learn about during their visit to the Myrtis exhibit.

EA will create a relevant high definition 2D video of a size appropriate to test the system, using and editing existing video material on Myrtis.

UC13.a.iii Video introducing the gamified aspects

In a short, 1-2-minute video, students will be informed that after the visit, during their bus journey back to school, they will participate in game-based testing of what they have noted and learned during their trip to the exhibit.

The video will explain the purpose and rules of the game. It will encourage the students to be careful to collect information and evidence during the visit, so that they can later prove their achievements and win relevant prizes/emblems.

EA will design the gamification and will create a high definition 2D video of a size appropriate to test the system.

UC13.b Students in the Athens Airport: the AR-enhanced visit experience

The students will enter the public area of the arrivals hall in the Athens Airport. They will stand in front of the exhibit, i.e., a large banner introducing Myrtis to the travelers arriving in Athens. The accompanying teacher will talk to them briefly about the purpose and procedure of the visit, including information on how to use the AR application to enhance the learning experience and its game-like feeling.

- *Interface:* Students will use the 5G Smartphone to point to different parts of the banner and so trigger AR content on their screens. They will explore the different items represented on the banner and the information they will be hiding, and they will be free to select to interact with any of the available digital assets.
- *Personalization:* The AR content offered to each user will be personalized on the basis of the input the user will have provided in the profiling mini-game (UC13.a.i).

- *Duration of the AR experience:* 10-15 minutes
- *Scenario and content:* EA will provide the structure and script of the AR experience, as well as various digital assets, which will be implemented in the AR environment by ATOS. EA will also design, produce and set up the banner exhibit, collaborating with AIA for its appropriate integration in the environment of the airport. In addition, WINGS developed further AR experiences on related themes to provide even richer opportunities for students' and the public's interaction with Myrtis' messages through 5G.

The AR-enhanced visit experience is comprised of the following parts:

UC13.b.i Rich information on Myrtis and Athens through AR

A number of different areas with short texts and other visual elements will appear on the exhibit banner. Some of these items will act as triggers of AR experience, popping up a panel with additional information when looked through the end-user device.

The central item will be an image of Myrtis (e.g., a close-up of the back of her head, with atmospheric background light around it), which will trigger a video revealing her face and conveying the main message of the experience: a warm welcome to her city and an encouragement to users to explore the content.

Around the central image, diagrammatically, three areas of short text and images will trigger AR content on three corresponding thematic areas: a) Everyday life in Ancient Athens through a child's eyes; b) The perils of war and a pandemic crisis that devastated Ancient Athens; and c) the reconstruction of Myrtis' face and its science.

Each one of approximately ten active visual items on the banner will trigger a different line of XR experience (approximately three items per thematic area, plus the central item).

UC13.b.ii Gamified AR experience

"Note this": While exploring the exhibit, at times students will receive alerts in the AR environment encouraging them to pay attention to some details or trivia that they will later find useful in a knowledge quiz (in the post-visit experience, cf. UC13.c).

The treasure hunt: The AR application will also organize a hunting game, in which the students will be asked to find certain items by following tips that will be given. Once a student finds the object, they will point their device to it, the app will recognize it, and register it on the student's list. This will unlock the next tip leading to the next object. Once an object is captured, the student can further explore it in detail later. The game will give more tips if the student cannot find an item. The targets will be provided to the students randomly, so that they cannot just follow what the others are doing.

UC13.b.iii Additional AR experiences

While exploring the exhibit in the Airport, as well as independently of that in any other location with 5G coverage, students and other members of the public can interact with Myrtis' messages through additional AR experiences developed by WINGS. This involves virtual exhibits with which users interact through AR. The content is diverse covering: a) ways in which ancient Greek art becomes a source of information for modern historical descriptions; b) Myrtis' story and the journey of knowledge that this research has generated; c) information on the site where Myrtis' skull was found in excavations; d) the DNA analysis involved in the Myrtis research, which revealed the cause of her death; e) the 3D model of Myrtis; f) representations of Myrtis, such as on a recent collection coin; g) more information on the classical period of Ancient Athens, in which Myrtis lived.

UC13.c Students travelling back from the Athens Airport: the VR-enhanced post-visit experience

On the school bus once again, school students will be traveling back to their school after their visit to the exhibit in the airport.

This part of the trials will be implemented on the school bus while it is moving in a small area of the airport with 5G coverage (a parking area and surrounding roads behind Building 17).

- *Interface:* Students will use the end-user devices to enter a 3D VR space, where they will be able to explore the environment and select to interact with various digital assets.

- *Duration of the post-visit VR experience:* 5-10 minutes
- *Scenario and content:* EA will provide the structure and script of the VR experience, as well as the digital assets, which will be implemented in a 3D VR space by SRUK.

The parts VR-enhanced post-visit experience is comprised of the following parts:

UC13.c.i The knowledge quiz

In the VR environment, students will participate in game-based testing of what they have noted and learned during their trip to the exhibit. This will be a knowledge quiz in the form of a "Who wants to be a millionaire?" game. Using the information and evidence they will have collected during the visit (including the trivia and hunted items from the AR experience, cf. UC13.b.ii), they will provide their answers to multiple-choice questions. To answer some of the questions, students will have to interact with digital assets, e.g. by exploring details of a 3D model or watching a short video.

UC13.c.ii Recognition of achievements

After the completion of the knowledge quiz, the VR application will present each student with their achievements during the whole experience, in the form of prizes, badges, other emblems, etc. Some of those will be easy to achieve, so that every student will receive at least a few. Examples of achievement include awards for having answered all questions, for having hunted most of the items, for taking less than a certain amount of time in the treasure hunt, etc.

5.2 UC13 implementation

5.2.1 Network Deployment

The Athens site will also support the implementation of the UC AR/VR student bus excursion. Toward this need OTE and COSMOTE in cooperation with NOKIA-GR organized all the designation and implementation part of the infrastructure for the needs of the four UCs of the mobility efficient city. During the last period of the project for the better organization of the WP6 infrastructure designation and installation and to reach smoothly the MS2, many teleconferences or online-meetings and on site F2F meetings took place and organized between OTE, COSMOTE mobile team and NOKIA-GR, where many decisions were taken as they have been mentioned before. In chapter 2.2.1 all the needed existing of Athens node is described in detail.

This Use case is a combination of an indoor and outdoor scenario. Network deployment for the indoor scenario can be seen in the Figure 62 (red square). The outdoor scenario is going to be implemented by using the radio equipment defined for UC10.

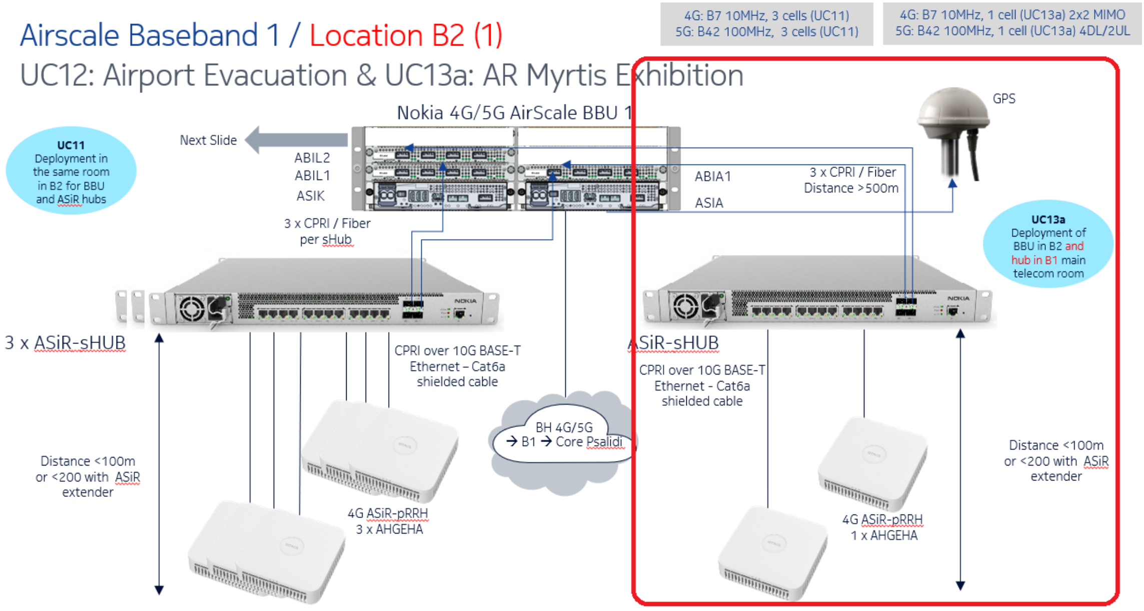


Figure 62. Network deployment for the AR/VS bus excursion use case (indoor).

An ASiR-sHUB will be installed in the control room of airport's main terminal building (M2) as shown in Figure 63.

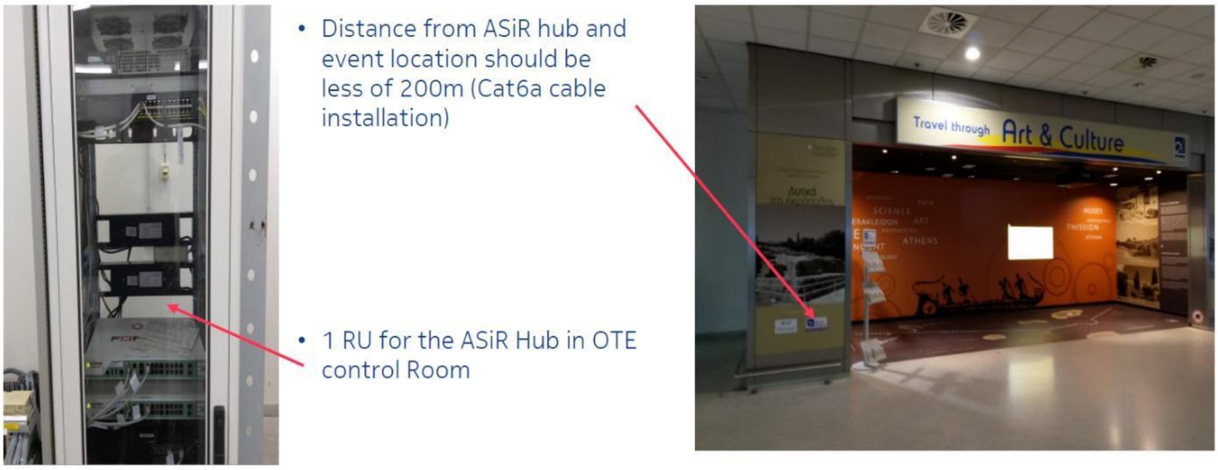


Figure 63. Illustration of the Rack where NOKIA-GR's Hub will be installed.

One pair of 4G/5G indoor antennas (non-standalone solution) are connected to the Hub and from there connected to NOKIA-GR's AirScale BBU. BBU resides in a satellite building, it is the low budget terminal of the airport, building B2.

In Figure 64a 2D/3D illustration of the indoor area, where the Myrtis exhibition will take place, is highlighted.

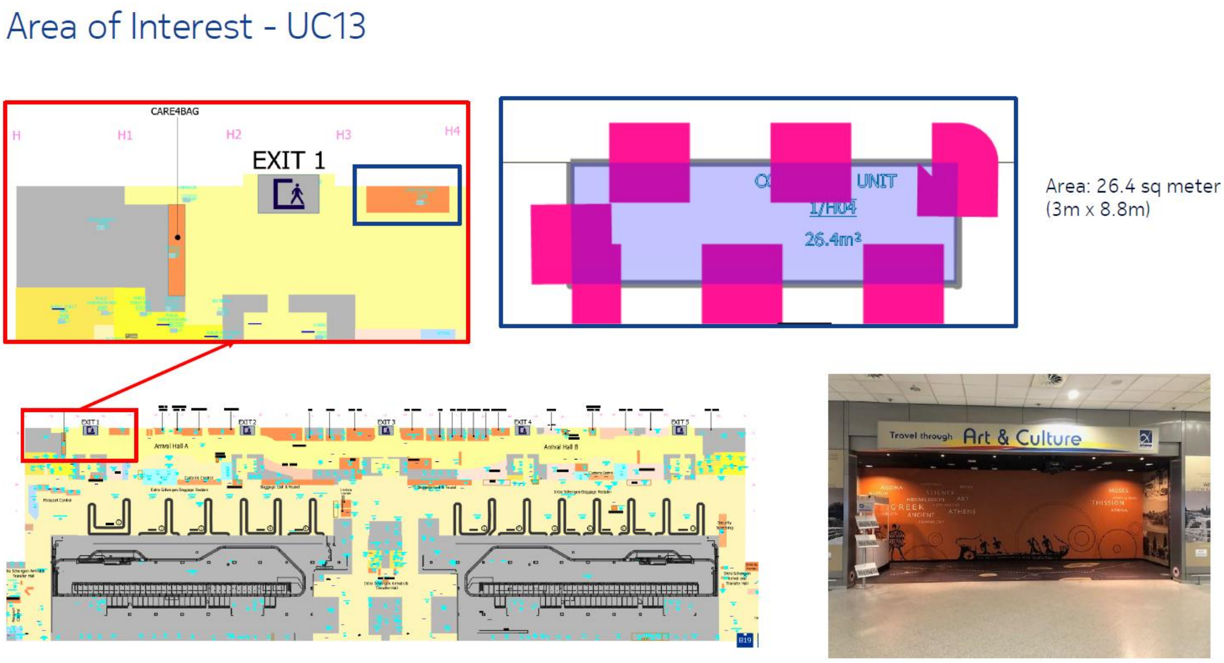


Figure 64. Illustration of the indoor area.

Network deployment for the outdoor scenario (Bus Excursion) is shown in Figure 65:

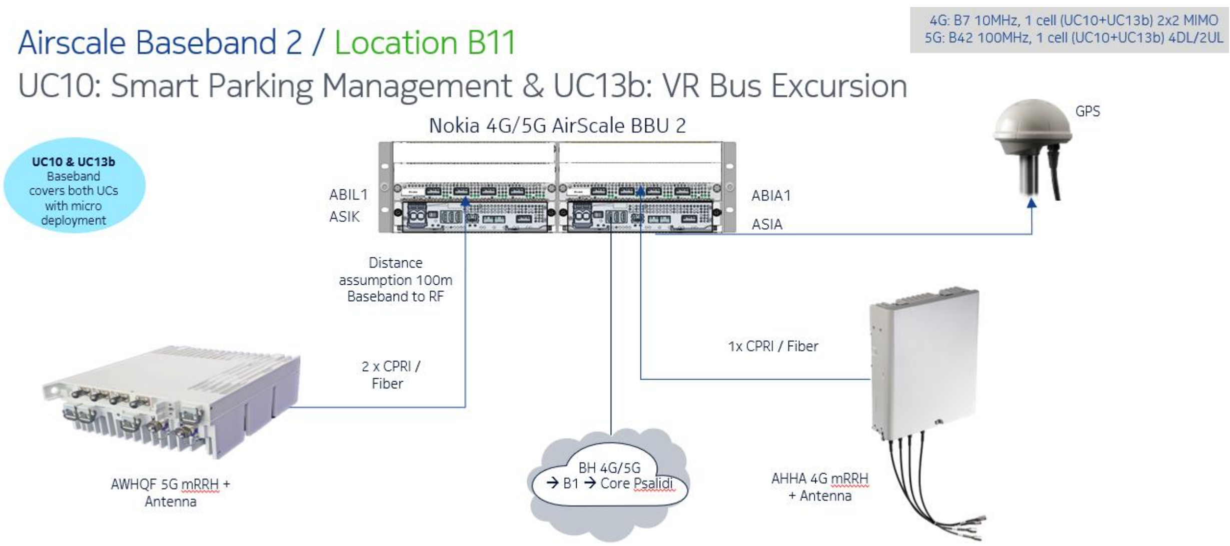


Figure 65. Network deployment for the AR/VS bus excursion use case (outdoor).

An Airscale BBU will be placed in the control room of building B11 in AIA (Figure 66). One pair of 4G/5G outdoor antennas (non-standalone solution) will be placed in the rooftop of the same building. A backhaul connectivity will follow from B11 to the main control room of the airport (Building M2). From there a 10 Gbit Ethernet connection is already established to Packet Core network.

Figure 66. The control room of building B2 & the antenna mast.

For the Core Network of 5G EVE see section 2.2.1.

5.2.2 Network Equipment

The following network equipment will be used for the indoor scenario, Myrtis Exhibition, of the AR/VR bus excursion use case. It belongs to the same product “family” as the chosen equipment for Evacuation UC and fulfils all the requirements and needs of the Use Case:

It consists of:

ASIR HUB:

- APHA ASiR-HUB 12-port

RF HW:

- AHGEHA ASiR-pRRH B1 + B3 + B7
- AWHQB ASiR-pRRH n78 B42

ANCILLARIES:

- FOSO Optical SFP O 1310nm 9.8Gb 1,4km SM
- ASiR Dual port power extender

Network equipment for outdoor scenario of AR/VR bus excursion use case:

RF HW:

- AHHA AirScale Micro 4T4R B7 20W
- AWHQF AirScale Micro 4T4R n78 B42 40W

ANCILLARIES:

- FOSP Optical SFP P 1310nm 9.8Gb 10km SM
- FUFBH SM OD fiber LC OD-LC OD dual 100m
- OCTIS Plug Kit DC Power
- OCTIS Plug Kit SFP
- AMBA AirScale Micro Bracket Assembly Kit
- AAQA AirScale mRRH Dir Ant 3.5G
- AAHG AirScale mRRH Dir Ant 2.2G 2.6G

Performance HW:

- 3x Accedian FS network performance probe

The Network Equipment will be deployed in AIA surrounding area (Logical Network View) as the Figure 67 and Figure 68 highlight:

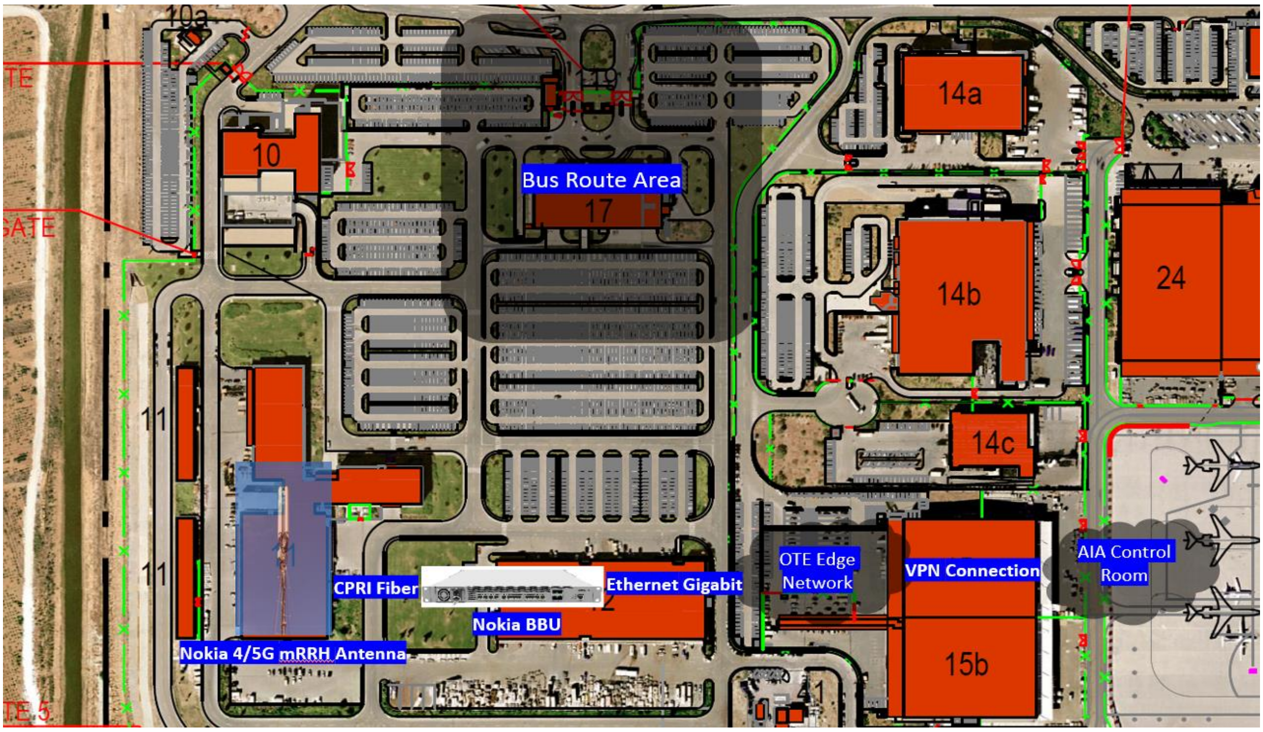


Figure 67. The RAN coverage of AIA for the AR/VR Bus Excursion use case.

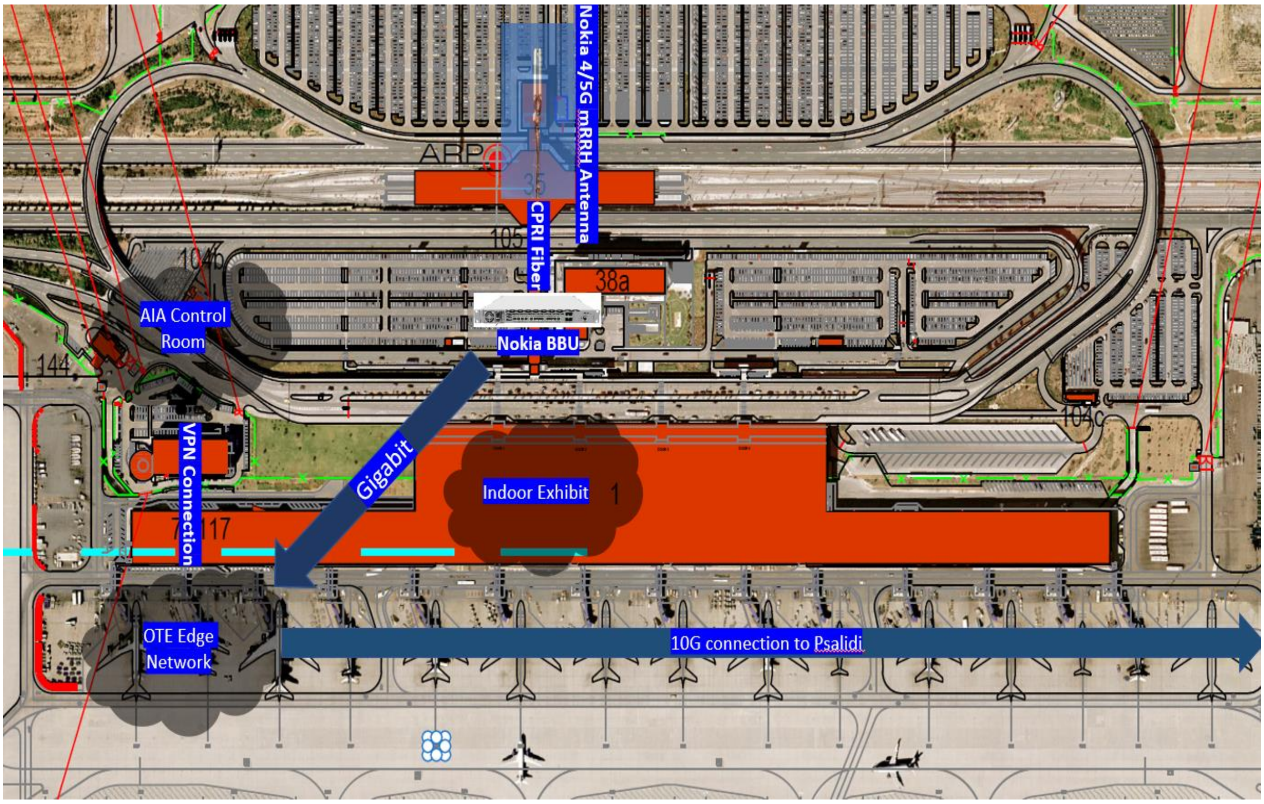


Figure 68. The RAN coverage of AIA for the Myrtis Exhibition use case.

5.2.3 Application Components

Technical features of the AR application

For the AR application ATOS has defined the following technical features:

- The API will be served using a Node backend and exposed using Swagger. That will allow SRUK to access ATOS's API easily. SRUK will need to access the API for saving the results of the preliminary test, for getting the questions of the quiz or getting which emblems has each student won, for example.
- Database: mongo DB
- If possible, one would use different docker containers for every module and deploy them easily to production.
- The client will be an AR Android app developed using Unity and Vuforia.
- The static assets will be served using Nginx.

"Developed in Node, the backend has been deployed in the VM provided by OTE. It provides several endpoints, exposed and fully documented using swagger, that are fundamental to the UC. It makes possible data sharing between the AR and VR sides, and adds functionality to support the hunting and quiz games, emblems calculation, user management, etc. As the project goes on, more features will be added to it, to support any of the client app needs".

The suggested architecture is presented in the following diagram (Figure 69).

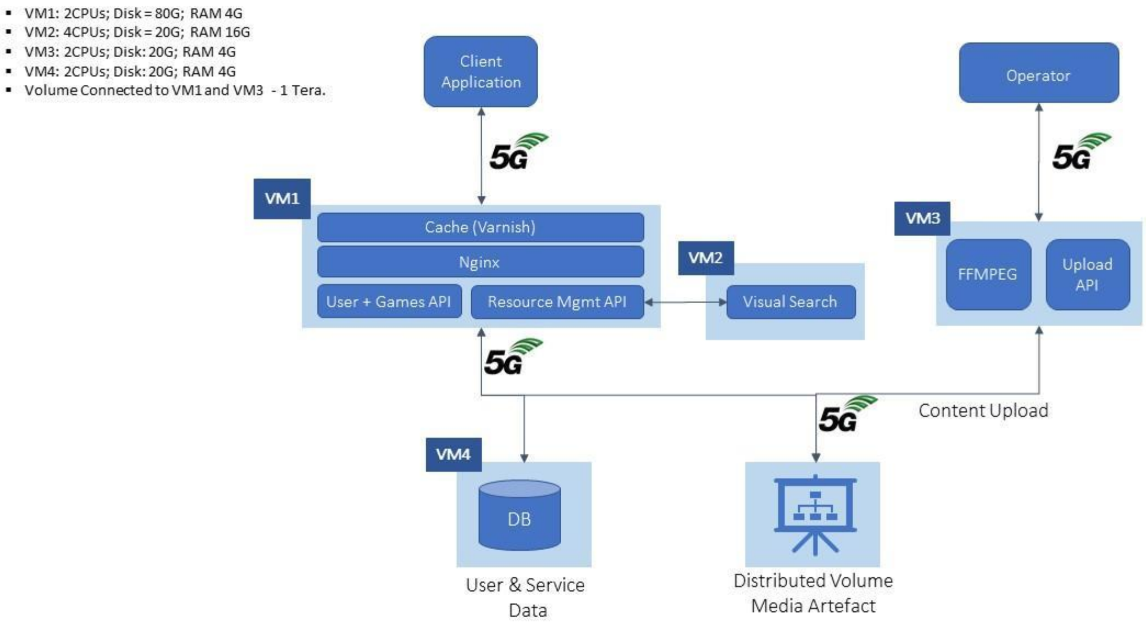


Figure 69. Architecture diagram of the AR application.

Technical features of the VR application

SRUK will be using the WebXR API, allowing it to use the application on Android, iOS, Windows, MacOS, and headsets of the Oculus, HTC Vive, Windows Mixed Reality and Cardboard variations.

The 3D assets will be of GLTF extension, guaranteeing that they are optimized for transmission.

SRUK will save and consume information through web-friendly endpoints exposed by ATOS.

For the needs of installing the back-end content of the AR/VR applications OTE provided a VM server at their facilities at OTE Labs Psalidi (where the infrastructure of 5G EVE exists) and a VPN connection to this server. ATOS has already installed the back-end content and a lot of interconnection tests were tried.

UC13.b.iii Additional AR experiences implementation details

As mentioned also in the UC13 overview the purpose of this application, is to represent the story of the Athenian girl from the 5th century B.C. named Myrtis and the scientific reconstruction of the scull and her facial characteristics. It is a modern digital museum presenting virtual exhibits, based on the technology of AR and the interaction with the user through predefined buttons and touch-screen hand gestures. The story telling consists of target images, which are recognized from the user's mobile camera and augmented by 3D virtual objects with visual and sound information about them. All the sources about the story of Myrtis were found in the official site[13].

If we can put a series in the events of the application we would say that we start with a general description of the way in which ancient Greek art is a source of information for modern historical descriptions. An important ancient Greek burial vessel "Lykithos" and its painting is the first 3D target. As we continue the tour, we describe in a few words the story of Myrtis and the journey of knowledge that has come through this research. The new upcoming 5-euro coin consists of the second 3D model target. After that we quote information about the excavation that took part in Keramikos, in 1994-5. A slideshow of photographs from this excavation is the third AR target of our story.

One of the most important aspects of this research about Myrtis is the DNA analysis to find the cause of her death. Thus, we represent a 4th target of a 3D DNA helix model. Modern technologies, such as 3D printing, have helped the scientists to create an identical copy of Myrtis skull, to avoid damaging the fragile original one. Therefore, we present a 3D model of a human skull as the 5th AR target. The most important one is the

[13] www.myrtis.gr.

actual reconstruction and representation of Myrtis (3D model of Myrtis as 6th target). Analyzing her characteristics and the knowledge that we have got know about this Greek era. Finally, we quote information about the ancient Greek classical period, as we present the 7th and last 3D model of Parthenon, the great architectural monument that has similar age to our character Myrtis.

Technical Information and 3D Modelling implementation details

The application itself has a horizontal "locked" orientation easy to understand. When the user opens the application there are intuitive messages that guide the user on how to use the app as shown in Figure 70.

Figure 70. User guidance in using the app.

In the beginning, there is a language option (there could be more options than "English" and "Greek", including audio clips and subtitles). There are two options such as "credits" and "exit" that can be used anytime. The 3D models have been created with 3Ds Max and Pixologic ZBrush as modeling tools, Photoshop Quixel as texturing tool, 3D Coat as an unwrapping tool and Photoshop as fine detail tool. All these models are described below:

1) Ancient Greek art is a great general source of information. At this point, a classical-period burial vessel (such as those made in the era Myrtis lived) was constructed to show a painting of a vessel presenting a girl's face. Since realistic representations often show images of war, while the application is being seen by young children, the following vessel Lykithos was selected, which is located in the National Archaeological Museum of Athens and presents a mythical Harpy, with a girl's face and a hawk's body (The image shows the vase in the Acropolis Museum - Figure 71 and its three-dimensional representation-Figure 72). Figure 73 shows the model integration within the mobile app.

Figure 71. The Lykithos vessel selected.

Figure 72. The 3D model constructed using the Lykithos vessel.

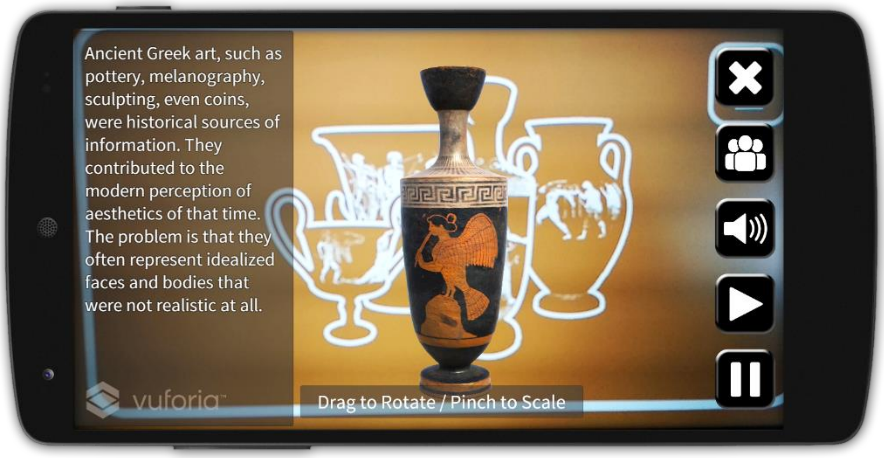


Figure 73. Model integration in the AR application.

2) Introduction with Myrtis. Since her publication, she traveled the world and told us her story. At this point, her stamp is presented in a travel envelope as well as the collector's colored coin of 5 euros as shown in Figure 74 (the coin will be released in 2020). From the information we have known, it has been constructed the 3D object of the following image (Figure 75 and Figure 76).

Figure 74. The Myrtis collector's colored coin of 5 euros.

Figure 75. The 3D model constructed using the collector's colored coin.

Figure 76. 3D Model integration in the AR application.

3) The excavation of Myrtis took place in Keramikos, Athens, in 1994-5. In this discovery a mass grave of 150 people who lived in the 5th century B.C. were found. Among them young children. A collection of photographic images of the excavation site (Figure 77) is presented in the form of a slideshow and useful information about them (Figure 78).

Figure 77. The slideshow used from the Myrtis excavation.

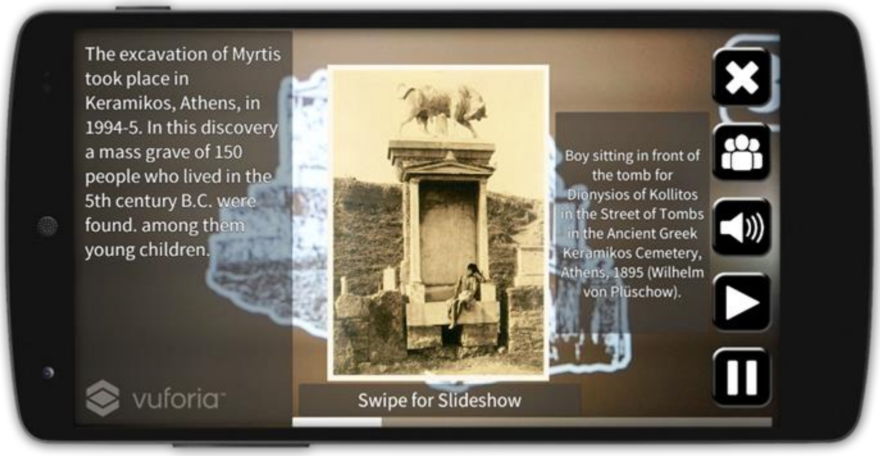


Figure 78. Slideshow integration in the AR app.

4) One of the most important aspects of the research about Myrtis was to find the cause of her death. A DNA analysis was performed for that reason. The geneticists concluded that the cause of her death was “Salmonella Typhi”. This was a very important finding as it has been the cause of the sickness known as the Plague of Athens. It was an epidemic that devastated the city-state of Athens in ancient Greece during the second year of the Peloponnesian War (430 BC). The plague killed an estimated 75,000 to 100,000 people including Pericles. At this point a DNA helix (Figure 79) is represented as a simplified 3D object (Figure 80 and Figure 81).

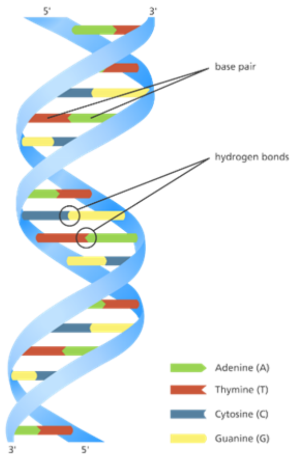


Figure 79. The DNA helix used for the 3D model creation.

Figure 80. The 3D model constructed using the helix.

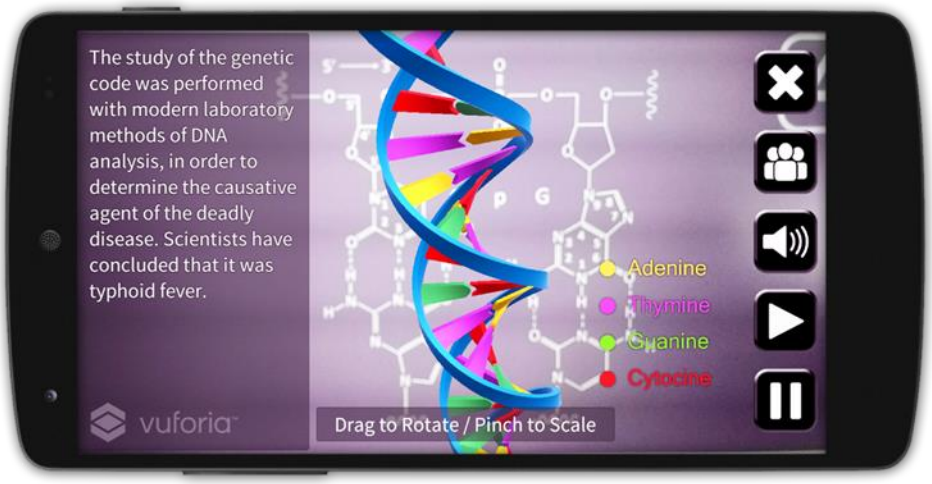


Figure 81. 3D Model integration in the AR application.

5) Modern technologies, such as three-dimensional reconstruction and printing, have helped the scientists to create an identical copy of the Myrtis skull, in order to avoid damaging the fragile original one. Therefore, we present a 3D model (Figure 83, Figure 84) based on a medical atlas (Figure 82), which represents a 12-year-old girl's skull.

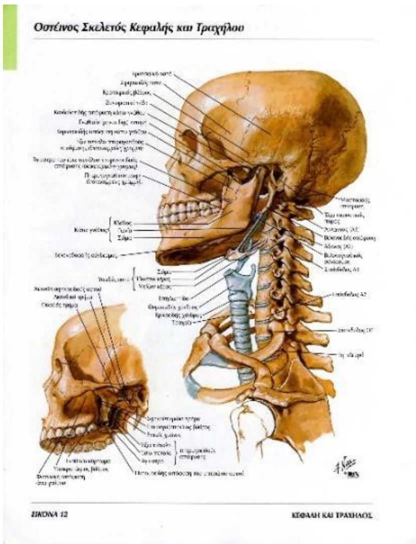


Figure 82. The medical atlas.

Figure 83. The constructed 3D model based on the medical atlas.

Figure 84. 3D Model integration in the AR application.

6) Representation of Myrtis. At this point we present a 3D model of Myrtis originally constructed by Mr. Maravelakis (Figure 85) with a few changes for the needs of a mobile application (Figure 86) (less polygons, better unwrapped model and textures). Figure 87 show the integrated model in the mobile application.

Figure 85. The scanned model of Myrtis.

Figure 86. The 3D model constructed.

Figure 87. Myrtis 3D Model integration in the AR application.

7) At this point we present an architectural 3D model of the Parthenon and the way it looked when first constructed (Figure 88). The Parthenon is the temple the Athenian Acropolis, dedicated to the goddess Athena (Figure 89). Construction began in 447 BC when the Athenian Empire was at the peak of its power. It was completed in 438 BC, although decoration of the building continued until 432 BC. It is the most important surviving building of Classical Greece. The ancient Greek historian Thucydides describes the situation of that era. Athens around 430 B.C. was in the period of the Peloponnesian War. At the same time, the Plague of Athens broke out, killing 50,000 people, including Myrtis and Pericles. Figure 90 shows the 3D model of Parthenon in the AR application.

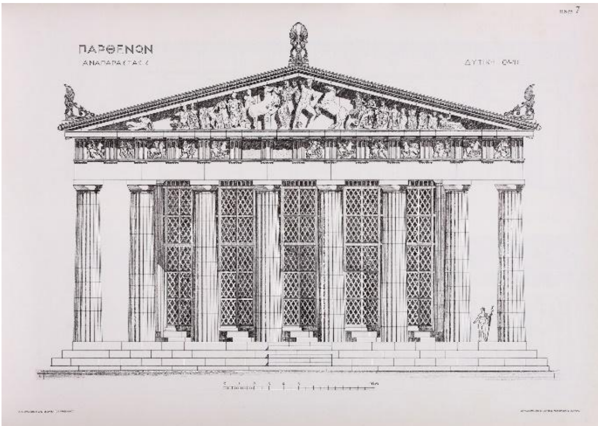


Figure 88. The Parthenon architectural design.

Figure 89. The 3D model constructed.

Figure 90. Parthenon 3D Model integration in the AR application.

5.2.4 Terminal Equipment components

The application will run and be tested on Samsung S20 5G devices for the AR part, mounted on DESTEK V5 VR headsets for the VR part. This will provide the connectivity needed on the mobile clients.

5.2.5 Interfaces

The UC13 platform consists of a VR client, an AR client, and a backend that provides them information and process the feedback given by the students.

The backend is a very lightweight node server deployed using Kubernetes that will provide load balancing across 2 machines.

Both clients will connect to it to retrieve information about the exhibit, the quiz questions, etc. Also, it will serve the multimedia content using a NGINX server.

The AR client, developed in Unity, will play the different activities inside the exhibit room.

The AR client, developed as a web app, will play the different activities while the students are in the bus.

5.3 Integration and results from tests in labs

All the endpoints provided by the backend will be available through an API rest. The endpoints will be documented using swagger, so it will be possible to check the calls and test them in live.

5.4 Tests in the Network

This task will present an *AR/VR enhanced experience within a school bus*, transferring students to and from the destination of their excursion, in this case the AIA. This use case will give the opportunity to present how 5G connectivity behaves while demanding content in terms of network resources is being served inside a moving vehicle. The network probes described in UC10 will be also used in UC13 (see section 2.4).

For the needs of the AR/VR bus excursion UC and the corresponding test and trials OTE as site manager provides all the telecommunication infrastructure at Psalidi (OTE Academy's facilities) and AIA (data rooms, poles for antenna mounting, racks, switches, routers, etc.) for the implementation of the UC in co-operation with NOKIA-GR, as well as for implementation of KPI validation in cooperation with ACTA. In addition, OTE, for the needs of the interconnection of AIA with Psalidi (5G EVE infrastructure) has established a 10 Gbit line. Also, a lot of interconnection test between ATOS and OTE's labs took place for the needs of installing the backend content server.

6. Use cases innovations and relationship with the overall 5G-TOURS architecture

5G-TOURS architecture will provide an improved responsiveness for real-time consumer applications and provide a faster service to users. At the airport with real-time access to sensor data from 100 sensors and in the future with the capability of having more than 3000 sensors for all parking spots, intelligent infrastructure and 5G networks are in need. Indeed, one of the objectives of mMTC for 5G is to support very dense sensor deployments, such as the one that we have in UC10 – Smart airport parking management. The orchestration of the VNFs with the help of AI will provide scalability, network slicing, independence from the service type (mMTC in the Smart Parking use case) or network technology of the sensors devices and users that access the application. This will allow to deploy a network slice whose performance is not compromised by the other slices and whose features are tailored to the needs for the dense sensor deployments that we have in this UC. Thus, one of the key technologies that will be used for UC10 is network slicing.

Automatic and optimized deployments will intelligently fix any key issues per use case. Since Athens airport has more than 4 million people per month traveling and moving at and from the airport area, the orchestration will optimize the deployment of applications networks and services to better support overcrowded areas. Algorithms running at OSM's embedded AI will analyze the requirements received from verticals (i.e., UC 10 – Smart airport parking management and UC12- Airport evacuation) and with various performance indicator and measurements acquired from deployed VNFs, OSM will intelligently decide the optimal resources and deployment for each service. Furthermore, orchestration will allow verticals' services to be re-deployed, scaled in, scaled out or relocated from the cloud to the edge (e.g. closer to the users), improving the quality of user experience whenever is needed in an automatic, fast and uninterrupted way. Thus, another technology used in the use cases of the Greek node will be orchestration.

For the implementation of the four Athens node UCs the existing infrastructure of 5G EVE Greek site with the OTE-NOKIA-GR's vEPC will be used with an extension of NOKIA-GR's antennas and BBUs at the AIA facilities. This implementation will follow two phases. During the first phase, the start/stop or enable of the Smart Parking service will run with direct connection to the 5G EVE infrastructure at Psalidi (5G EVE Greek site). During the second phase the start/stop or enable of the service will run using blueprints and the Portal of 5G EVE (see Table 2).

Table 2. WP6 UCs mapping (use of blueprints in phase 2).

UC	Phase 1				Phase 2				
WP6	**Reference Network**	**Service Accessibility**	**Objectives**	**Availability target dates**	**Reference Network**	**Service Accessibility**	**Objectives**	**PoC/Additional development**	**Availability target dates**
UC10	Outdoor extended 5G EVE NOKIA-GR / OTE infrastructure	Direct request*	Obj1	MS3 (31/03/2021)	Outdoor extended 5G EVE NOKIA-GR / OTE infrastructure	5G EVE portal / Direct request	Obj1+ Obj2	Addition of AI-based intelligence in the Greek site orchestrator	MS4 (31/09/2021)
UC11	Outdoor extended 5G EVE NOKIA-GR / OTE infrastructure	Direct request*	Obj1	MS3 (31/03/2021)	Outdoor extended 5G EVE NOKIA-GR / OTE infrastructure	5G EVE portal / Direct request	Obj1+ Obj2	Real-time KPIs measurements and validation using probes	MS4 (31/12/2021)
UC12	Indoor extended 5G EVE NOKIA-GR / OTE infrastructure	Direct request*	Obj1	MS3 (31/03/2021)	Indoor extended 5G EVE NOKIA-GR / OTE infrastructure	5G EVE portal / Direct request	Obj1+ Obj2	Addition of AI-based intelligence in the Greek site orchestrator	MS4 (31/12/2021)
UC13	Indoor extended 5G EVE NOKIA-GR / OTE infrastructure	Direct request*	Obj1	MS3 (31/03/2021)	Indoor extended 5G EVE NOKIA-GR / OTE infrastructure	5G EVE portal / Direct request	Obj1+ Obj2	Real-time KPIs measurements and validation using probes	MS4 (31/12/2021)
	* Portal usage is not precluded								
	Obj1: Validate the need of 5G networks								
	Obj2: Demonstrate the benefits of 5G-TOURS innovations								

According to Table 2 all the mobility efficient city UCs will run using blueprints in a second phase. Moreover, UC10 Smart Parking management will be demonstrated during the mid-term review of the project. A demo/video was prepared toward this need. According to Table 3:

- UC10 requires a very high accuracy and a very low latency. To provide this service, 5G-TOURS architecture will be instantiated to deploy network slices meeting these requirements.
- UC11 requires a very large throughput and a very high reliability level. To provide this service, 5G-TOURS architecture will be instantiated to deploy network slices meeting these requirements.
- UC12 requires a very high accuracy for the location of the end-users as well as a very high level of reliability. 5G-TOURS architecture will be instantiated to deploy a network slice meeting this service requirements.
- UC13 requires a large throughput and a very low latency. Moreover, edge computing technology may be leveraged to bring the AR/VR server close to the end-users. 5G-TOURS architecture will be employed to deploy a network slice customized to the needs of this service.

Table 3. Service types/slices for mobility efficient city UCs.

Areas	Use cases	URLLC	mMTC	eMBB
Mobility-efficient city	Smart airport parking management		X	
	Video enhanced ground-based moving vehicles			X
	Emergency airport evacuation	X	X	
	AR/VR enhanced bus excursion			X

Two types of innovations have been decided for the mobility efficient city (see Table 4)

- To add smartness AI-enhanced MANO to OSM (5G EVE orchestrator) and a diagnostics module (by WINGS). UC10 and UC12 have been selected to showcase this innovation.
- To implement Real-time (Active or Service Performance) measurements while the 5G-TOURS Use Cases are active and running (by ACTA). UC11 and UC13 have been selected to showcase this innovation.

Table 4. Mobility efficient city network innovations.

Network Innovations	WP6
Service Layer	Active performance measurements while service is running (UC11 and UC13 will be used for demonstration). AI-based enhanced MANO and the diagnostics component of the 5G-TOURS Service Layer (UC10 and UC12 will be used for demonstration).
AI-based enhanced MANO	Resource allocation, deployment and migration of network services in an automatic and optimized way using various metrics (infrastructure, VNFs, Applications etc.) and verticals requirements (through 5G EVE OSM upgrade) - UC10 and UC12 will be used for demonstration.
AI-based data analytics	Real-time feed of KPI values, for better AI-based decision making (UC11 and UC13 will be used for demonstration). Network monitoring for anomaly detection, performance degradation and root cause analysis of these problems, will be provided by the diagnostics component of the AI-based enhanced MANO (UC10 and UC12 will be used for demonstration).
Other	Correlation of the user QoE (WP7) with active service KPIs to identify relations between network performance, Quantitative service KPIs and QoE (UC11 and UC13 will be used for demonstration).

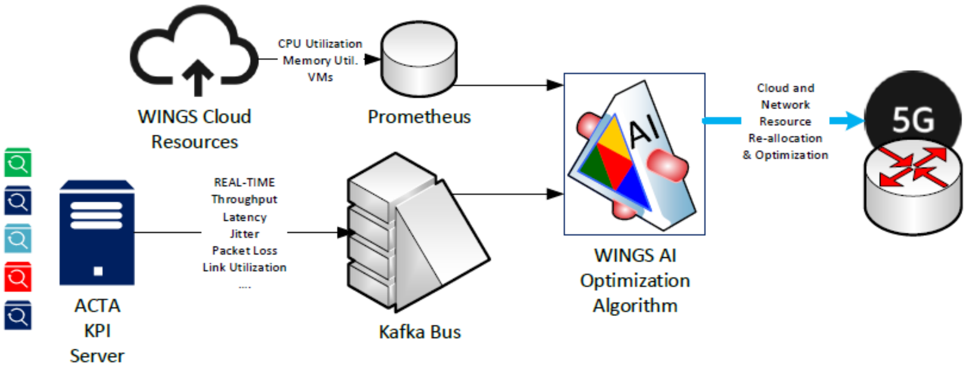


Figure 91. 5G-TOURS network innovations high level view.

AI-enhanced MANO (Orchestration)

Problem:

- Configuration for deployment of network functions and applications is fixed for the whole lifecycle.
- Changes in deployment of a network function or applications are difficult, time consuming and cause excessive expenditures or service outages.
- Information about the availability of resources in the infrastructure is not known.
- Metrics from applications, VNFs, infrastructure are not considered after the deployment of a service.

Solution:

- Automated operations such as deciding the deployment location of a NS and resource utilization in a highly heterogeneous cloud infrastructure.
- Automated and optimized network resource utilization, monitoring of SLA under 5G network.
- Automated and fast deployments and reallocations of network functions and applications in emergency situations.
- Real-time monitoring and collection of various metrics for multiple attribute decision making.

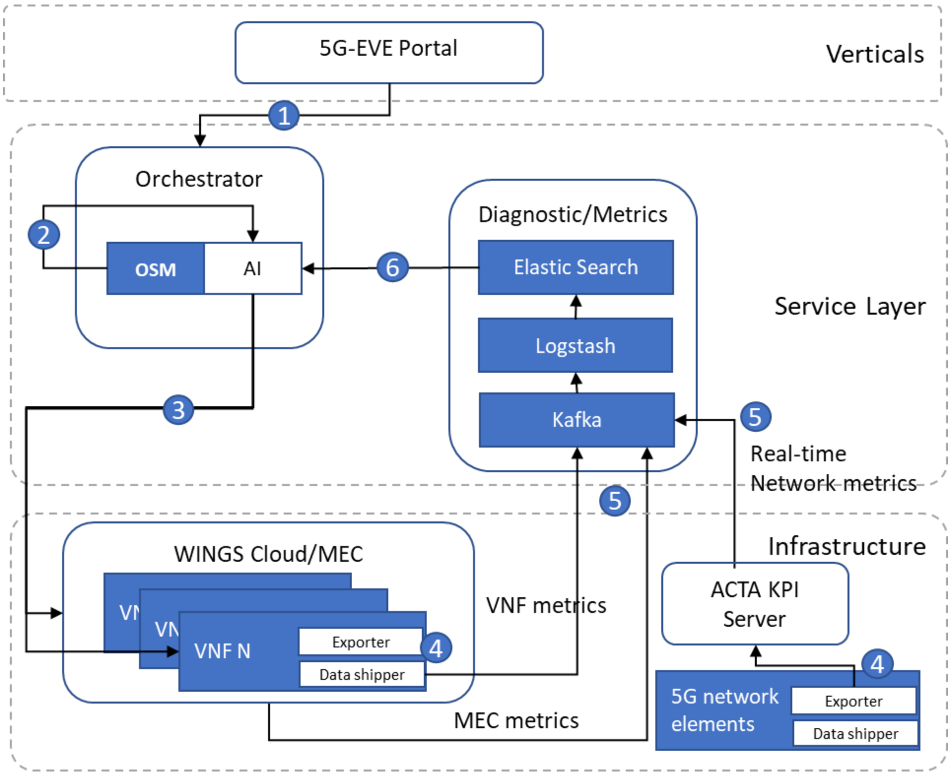


Figure 92. 5G-TOURS network innovations detailed view.

Figure 92 illustrates the steps and processes that AI-enhanced MANO component is able to retrieve metrics from MECs, VNFs in real time and evaluate them in order to make any migration decisions. Some of the steps are:

1. NS, VNF unique IDs and other critical info is exported from the OSM and fed to the AI module.
2. The AI component triggers the metrics exporters/ shippers of the MEC platform and the MEC's VNF instances, to evaluate the metrics in real time
3. The metrics (network metrics, MEC metrics, VNF metrics) are shipped to the Kafka broker
4. The collected metrics are then pushed to the Elastic Search platform using Logstash. The Diagnostic component gets the metrics data from the Elastic Search module.
5. The Diagnostics component communicates with the AI component to provide the diagnosis results.

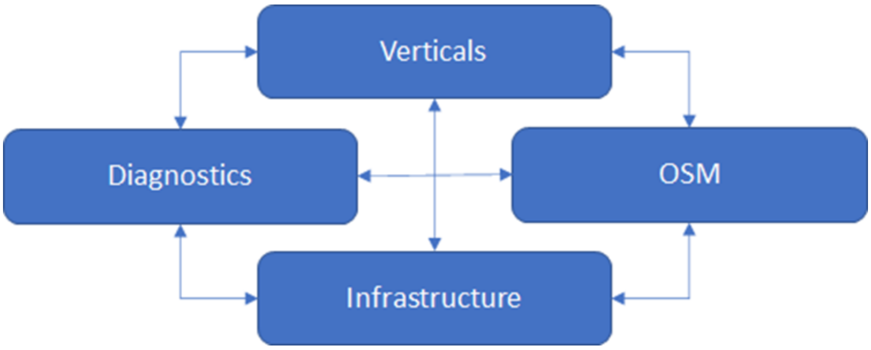


Figure 93. Enhancements on Interfaces.

New Interfaces are designed and being developed to support AI at the OSM level (Figure 93).

- Interface with Verticals
- Interface with Infrastructure
- Interface with Vertical Applications
- Interface with Diagnostic component

Performance diagnostics module

The performance diagnosis module is responsible to realize two critical tasks: Anomaly detection and Root Cause Analysis (RCA). During the anomaly detection task, Machine Learning algorithms are used to identify any anomalies in the collected metrics that need to be considered further. The core of the performance diagnosis mechanism is the RCA module. The RCA module is responsible to predict and localize faults and service degradations, so that in a next step the engineers and technicians can take decisions on how to improve the system or mitigate the possible faults. The RCA module uses diverse information including correlated network/service events and E2E service graphs. By correlated network or applications events, we mean events generated by different sources that can be related e.g., in a temporal or spatial way. In addition, service graphs are used as additional knowledge for the RCA algorithms in order to correlate nodes or link along a network path.

Two RCA algorithms will be realized that will be operated in a real time manner. The first is using statistical learning and it is characterized by low complexity and high speed in finding the root cause. The second algorithm is using machine learning approaches (Self Organizing Maps - SOMs) and it is characterized by medium complexity and the requirement of a long training data set.

The developed module will be based on the 5G EVE performance diagnosis module [5G EVE D5.5], appropriately extended in order to: a) operate in a real time manner as explained below; b) communicate with the AI enhanced MANO module in order the decisions of performance diagnosis module to be realized and optimised in the actual development using the OSM.

Real-Time KPIs monitoring

In the context of 5G-TOURS ACTA proposes the use of real-time KPI measurements (in addition to the offline measurements that are used currently in the 5G EVE Athens site).

Offline (also referred to as Activation) measurements are usually performed using iPerf and Ping/ICMP based tools. They are very good in measuring network KPIs / metrics during and after the implementation phase and prior to Service Delivery. Currently they are used and are very well suited in assessing the infrastructure's readiness (in this case the 5G EVE network instance) to deliver a Service.

Real-time measurements (also referred to as Active), can monitor the KPIs after Service Activation and while the Service is being delivered (sometimes they are referred to as service performance measurements).

The innovation we suggest here is to implement Real-time (Active or Service Performance) measurements while the 5G-TOURS Use Cases are active and running. Analysis of the collected measurement will also provide a better insight with respect to the network and other components (servers, devices) behavior while the Services are running.

These include TWAMP (two-way active measurement protocol) that is better than the ICMP protocol [1] & [20] as well as non-invasive (passive) throughput traffic measurements. They are implemented using properly placed network probes of three different categories:

a) Software based on open source tools
b) Hardware SFP based for network elements and
c) Commercial software based ones.

The acquired data can be fed and analyzed in real time to improve the stability and performance of the aforementioned innovation (by WINGS) with respect to the improved (AI based) orchestration.

In a simplified manner, the real-time active KPI measurement and acquisition can be thought as a feedback loop for the Management and Orchestration of the overall Network and Service delivery platform. This concept is shown in Figure 94:

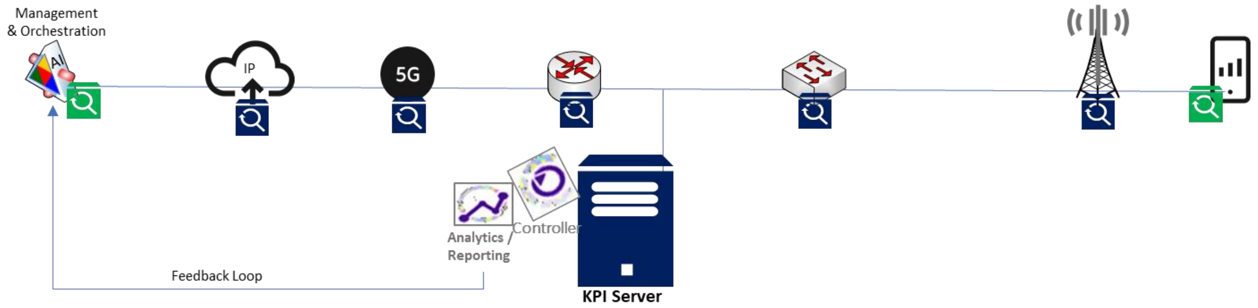


Figure 94. 5G-TOURS innovation concept of Real-Time KPI monitoring and Analysis.

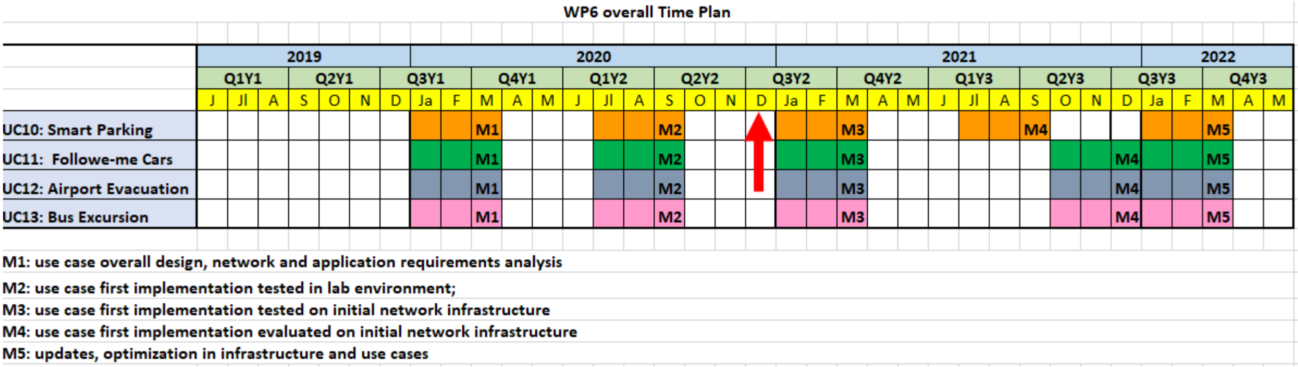
Summarizing the suggested innovations, these include the following aspects (in conjunction with the innovation that is presented in the previous section).

- Real-time monitoring of network KPIs (plus some Service KPIs) in parallel
- Utilization of both active and passive monitoring tools
- Integration of existing (legacy) as well as new / open-source tools for measurement acquisition
- Continuous feed of the measurements for analysis and decision making (i.e., deploy a new slice, or establish a new VNF to the edge-cloud etc.)
- Extension of the above approach even to end-user-devices/CPEs like smartphones & APP servers

The two proposed innovations will not be combined as a complete system/feedback control in any of the 5G-TOURS UCs, since this is beyond the scope of the 5G-TOURS project. They can though, serve as basis for further investigation and research.

7. WP Workplan

The overall time plan for the implementation of WP6 is illustrated below:



WP6 team has already finalized the overall design of network and application requirements analysis (MS1), has already installed the 4G antennas, backbone network, fiber optics, 10Gbit interconnection line and has made a lot of tests in the lab environment (MS2). Currently, the team is progressing towards the MS3 (31/3/2021) where the first implementation and tests will take place in the initial network environment, which is the first phase of implementation. A slight delay is expected with respect to MS5, but still the team will be able to achieve the project goals by the end of the project.

In order to reach smoothly the MS3 and fully achieve the project objectives concerning the WP6 the following actions have been planned for the next 3 months:

- 5G antennas have been ordered. Installations at AIA for the six (6) 5G Antennas will take place in mid of January.
- Although a 10Gbps line for the interconnection between AIA and OTE's labs at Psalidi (5G EVE NOKIA-GR's Platform) is established, vlans and IPs will have to be configured after the installation of the antennas.
- Till the end of February installations of the applications of the 4 UCs to 15 out of 30 of the Samsung S20 mobile devices will have been finalized, for the needs of first trials.
- For UC10, more sensors have to be installed at AIA area and a lot of network and application tests will run using the mobile devices. Also, this UC will be demonstrated during the first year review in February.
- For UC11, in phase 1 (MS3) Samsung mobiles S20 will be used as external cameras and for the MS4 real 4K cameras. Also, a VM machine is needed for the installation of the application. Interconnection of the Streaming server and app server will take place till end of January. Network and application tests will run during the February.
- For UC12, the finalize of the localization and navigation algorithms of the application will take place during February. A lot of Network and application tests will run during the February.
- For UC13, after the installation of the antennas tests will take place using the mobile devices Samsung S20 and gear VR sets, for debugging the AR/VR applications as well as the interconnection with the NOKIA-GR's network.
- Probes will be installed till the end of the February and real measurements will be collected to the ACTA's server. ACTA for installing probes and Real-time measurement server.
- Finally, during the March 2021 the first implementation will be tested for all UCs in the initial network infrastructure.

7.1 Deviation from work plan and Risks

In WP6 there may be some delays depending on how much this difficult period of the 2nd COVID-19 wave continues to impact the partners' work. All the functions of the UCs will be implemented; however, the scope of the trials may be affected by the current situation. Due to the lock down AIA had to cancel a lot of services;

however, this would not have serious impact for the antennas installations provided that it is arranged on time. For the rest of the partners the majority of the work is done remotely. As a consequence, there is a limited access to external site(s) and workplaces/labs. However, in terms of the antennas design/radio planning and installation at AIA the work progresses well. The same goes for the implementation of Greek site 5G EVE infrastructure, which is in a very good progress.

The only deviation from the first plan in WP6 is the time of 5G antennas installation. This deviation arised from the fact that the 5G frequencies that had been selected and reserved for the project, namely the 3.7-3.8GHz, could be used only for 2.5 months due to the end of the licensing period. Currently, all 5G frequencies in Greece are under the licensing process from the Hellenic Telecommunications and Post Commission and this affects the license period and frequencies obtained. OTE decided to change its strategy and will try to obtain other frequency bands. This had an impact on 5G antennas installation (and not on 4G pairs and network backbone), since the already bought antennas should be changed. Now all equipment that concerns only 4G antennas, backbone, fiber optics, power supplies is installed, and only the new 5G antennas will be installed in January 2021.

8. Conclusion

This document, deliverable D6.2 “First mobility efficient city use cases implementation results ”, has provided a detailed description of the current status of the design and implementation for the four UCs that will be demonstrated in the extension of 5G EVE Athens node that will be deployed in the AIA for the 5G-TOURS trials realization.

For each UC, this document presented the status of the architecture design, the network design and respective equipment to be deployed for the implementation of the pilots, the terminal equipment to be used as well as the application development progress for each one of the trials for the evaluation of the solutions according to the expected KPIs, by milestone MS2. Furthermore, this deliverable serves as a basis for the evaluation of the progress made in comparison to the agreed UC implementation time plan presented in deliverable D6.1. This deliverable has a closed relationship, on several levels, with almost all the WPs of the project in defining use cases, selecting the suitable technologies, and evaluating the impact on the techno-economic level.

For UC 10, smart parking management, there has been already a small scale deployment at AIA for testing in order to progress with the integration of the parking sensors with the WINGSPARK platform and mobile application. Some initial tests for the mobile application have been executed on site. The next steps till MS3 have been also defined and target a larger scale deployment. With respect to the evaluation the KPIs to be measured have been defined and the first results will be reported till the end of March 2021.

For UC11, the final equipment has been purchased and the setup of the infrastructure needed for the UC deployment has progressed. The probes have been defined and the connection between AIA and the 5G EVE node at Psalidi has been established through a 10 Gbit line. A media server has been setup at AIA and the first version of the web based interface for the AIA apron monitoring has been tested in lab environment. Till MS3 it is planned to test also on AIA premises using the experimental network to be installed by NOKIA-GR.

For UC12, airport evacuation, the definition of all implementation details as well as the progress both on the part of the network and on the part of the application deployment has been described along with some preliminary results of the implementation. Currently, a 3D model of the airport terminal has been created as access to the terminal was not possible due to COVID-19. The application and the optimal route to the exit have been tested in lab environment. From the network perspective the 3 indoor cells that will be used for this UC have been purchased and the installation process at AIA has started. Till MS3 the has been planned to test the use case at AIA premises using the experimental network to be installed by NOKIA-GR.

For UC13, AR/VR bus excursion, the definition of all implementation details of the UC13 as well as the progress both on the part of the network and on the part of the application deployment has been described. In summary, the content to be used in the AR applications of ATOS and WINGS and the VR application of SRUK has been decided. The equipment to be used in this use case has been ordered and received by the partners. The infrastructure to support the deployment of this use case has been setup at 5G EVE Athens node at Psalidi. Initial tests of the apps have been deployed in lab environment. As far as the next steps are concerned the plan is to test the current versions of the 3 applications using the experimental network to be installed by NOKIA-GR.

Furthermore, the innovations for each use case that will be trialed in the Athens node as well as the relationship with the overall 5G-TOURS architecture has been presented. More, specifically the innovation concerning the AI-based intelligence to be added in the Greek node orchestrator, the diagnostics module (part of the 5G-TOURS service layer) as well as the real time KPIs monitoring have been added. More specifically, the orchestration of the VNFs with the help of AI will provide scalability, network slicing, independence from the service type or network technology of the sensors devices and users that access the application. The performance diagnosis module is responsible for performing anomaly detection and Root Cause Analysis (RCA) in the collected metrics using Machine Learning algorithms. The RCA module is responsible to predict and localize faults and service degradations, so that in a next step the engineers and technicians can take decisions on how to improve the system or mitigate the possible faults.

With the above, this document has clearly identified the functionalities already implemented by the different UCs as well as the different pieces that still need to be implemented to achieve these objectives by milestone MS3. The analysis performed in this document in terms of the implementation plans and timeline for implementing the use cases as well as the impact from COVID-19 will serve as a reference for the work that will be performed in WP6.

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