DEDICAT 6G: Dynamic coverage Extension and Distributed Intelligence for human Centric Applications with assured security, privacy and Trust: from 5G to 6G

Deliverable D2.3
Revised scenario description and requirements

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List of Acronyms and Abbreviations

Acronym/Abbreviation	Definition
3D	Three-Dimensional
3GPP	Third Generation Partnership Project
a.k.a.	Also known as
AGV	Automated Guided Vehicle
AI	Artificial Intelligence
AP	Access Point
API	Application Programming Interface
AR	Augmented Reality
B5G	Beyond 5G
BLE	Bluetooth Low Energy
BMSC	Broadcast Multicast Service Centre
BS	Base Station
BT	Bluetooth
CCTV	Closed Circuit Television
CE	Coverage Extension
CEDM	Coverage Extension Decision Management
CEaaS	Coverage Extension as a Service
COVID-19	Coronavirus Disease 2019
CPU	Central Processing Unit
DC	Design Constraint
DU	Distributed Unit
DoA	Description of Action
EC	Edge Computing
EE	Execution Environment
EN	Edge Node
FC	Functional Component
FREQ	Functional Requirements
GDPR	General Data Protection Regulation
gNB	Next Generation Node B
GPS	Global Positioning System
HD	High Definition
H/M/L	High/Medium/Low

HMI	Human Machine Interaction
ICT	Information and Communications Technologies
ID	Intelligence Distribution
IDaaS	Intelligence Distribution as a Service
IDDM	Intelligence Distribution Decision Making
IM	Intelligence Management
IoT	Internet of Things
KPI	Key Performance Indicator
LDM	Local Dynamic Map
LE	Low Energy
LiDAR	Light Detection and Ranging
MA	Mobile Assets
MAP	Mobile Access Point
MAS	Multi-Agent System
MC-PTT	Mission Critical Push to Talk
MCS	Mission Critical Services
MEC	Multi-Access Edge Computing
ML	Machine Learning
MPLS	Multi-Protocol Label Switching
MQTT	Message Queuing Telemetry Transport
µS	Micro-Service
n/a	Not Available
NAT	Network Address Translation
NFREQ	Non-Functional Requirements
NODM	Network Operation Decision Making
NS-3	Network Simulator 3
OBU	On-Board Unit
PC	Personal Computer
POP	Point Of Presence
PoV	Point of View
PS	Physical System
QoE	Quality of Experience
QoS	Quality of Service
QR	Quick Response

RAM	Random Access Memory
RAN	Radio Access Network
RAT	Radio Access Technology
REST	Representational State Transfer
RF	Radio Frequency
RSU	Road Side Unit
SLA	Service Level Agreement
SLAM	Simultaneous Localization and Mapping
SOTA	State Of The Art
UC	Use case
UE	User Equipment
UNI	Unified Requirement
UML	Unified Modeling Language
UPS	Uninterruptible Power Supply
V2X	Vehicle to Everything
VR	Virtual Reality
VRU	Vulnerable Road User
vs.	versus
w.r.t.	With Respect To
WYSIWIS	What You See Is What I See

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Executive Summary

This document is an incremental update of the deliverable D2.1 - Initial Scenario Description and Requirements [1], which introduced the outcomes of the initial use cases description and requirements elicitation work carried out in the H2020 DEDICAT 6G project. The goal of this deliverable is to bring up to date use case stories and requirements, as well as to introduce a functional decomposition of the use cases.

These use cases are designed to validate the main objectives of DEDICAT 6G, which is to design a smart connectivity platform that is green, highly adaptable, ultra-fast and dependable/resilient for securely supporting innovative, human-centric applications. A detailed definition of the four use cases is given, introducing multiple stories to illustrate the expected workflow using the DEDICAT 6G platform, and to remark on the technical, social, and financial perspectives which are all relevant in each use case.

Four use cases are proposed in DEDICAT 6G:

1. **Smart warehousing:** It covers the trustworthy automated real-time monitoring, surveillance, and optimized operation of a warehouse;
2. **Enhanced experience:** It provides live streaming applications that use enhanced data overlay in 360°, *Augmented Reality (AR)* applications and *Virtual Reality (VR)*;
3. **Public safety (Public Protection and Disaster Relief, PPDR)**: This aims to showcase how resilience of critical communications can be enforced through DEDICAT 6G solutions and how human security can be protected in extreme situations;
4. **Smart highway:** It describes how connected and autonomous mobility can benefit from *Beyond 5G (B5G)* and 6G connectivity.

DEDICAT 6G use cases are presented from the standpoint of several relevant actors, contextualized in selected use case business field. Gaps are identified, and a set of requirements considering existing technologies and trends are extracted. A relationship is made between the context view and the functional view of the project and finally, proposals on how to fill these gaps are discussed, envisioning the expected functionalities of the DEDICAT 6G platform.

This deliverable focuses on the design and implementation of technical innovation work to provide a basis for multiple work packages: WP2 where the architecture is detailed and WP3, WP4, WP5 where technical enablers of DEDICAT 6G are designed and developed, and WP6 where demonstrations will be carried out to evaluate performance and validate DEDICAT 6G architecture and solutions.

1 Introduction

This document is an incremental version of D2.1 [1]. As such, this introductory section is quite similar as D2.1 but updated according to the project's progress. DEDICAT 6G focuses on four *Use Cases (UC)*:

1. **Smart warehousing:** It encompasses real-time automated tracking, monitoring and optimised operation of a warehouse using *Automated Guided Vehicles (AGV)* in a trusted way to improve operations such as picking sequence and product quality assessment. It places particular emphasis on real-time human-machine interaction, intelligence offloading and security;
2. **Enhanced experience:** It brings live streaming applications that use enhanced data overlay in 360° and AR-enabled applications, as well as more complex data sets in VR, with the necessary hard requirements in terms of bandwidth and compute capabilities for massive video processing and distribution. This use case is centered on distributed intelligence, compute offloading and caching, and dynamic *Coverage Extension (CE)*;
3. **Public safety (Public Protection and Disaster Relief - PPDR)**: The objective is to show how the resilience of critical communications can be strengthened through DEDICAT 6G solutions and how human security can be protected in extreme situations, such as natural disasters or terrorist attacks, through the use of various assets (drones, AGVs, etc.). This use case focuses on *Intelligence Distribution (ID)*, dynamic coverage extension, security assurance and human presence in the loop;
4. **Smart highway:** It outlines the benefits that connected and autonomous mobility can benefit from connectivity B5G and 6G, especially in the area of efficiently delivering the lowest possible delay and ultra-reliability. It is related to distributed intelligence, computation and cache offload, dynamic coverage extension, security and human-in-the-loop.

In this second and last iteration of the scenario description and requirements document, we continue the investigation on the project use cases specific performance, security and scenario operation aspects that can be improved leveraging the DEDICAT 6G architecture presented in D2.2 [2] and its secure smart connectivity services. Based on the pooling of the interests of the consortium members throughout the project with the participation in the mentioned use cases, and accompanied by the description of the use cases, including prerequisites, assumptions and specific infrastructure and needs, the DEDICAT 6G use cases are described to update the relevant stories and derive and create new requirements for the second iteration of the platform architecture.

Hence, the purposes of this second iteration comprise:

- Update and upgrade the D2.1 [1] content in general, focused on the UCs in general from an architecture and functional point of view;
- Showcase how the UC scenarios can leverage the D2.2 [2] DEDICAT platform architecture to perform their related tasks. This work is represented by adding a new subsection in each UC section where the functional interactions between the vertical side and the DEDICAT 6G platform are presented as *Unified Modeling Language (UML)* models;
- Update the UC scenarios according to the work done in other WPs of this project to be aligned with the UML models;
- Revise the requirements in each UC to represent the changes in the UC descriptions. Such a set of new functional and non-functional requirements will be used to feed the

future deliverables D2.4 and D2.5, where newer versions of the DEDICAT 6G architecture will be presented;

Use case scenarios and requirements identified in this deliverable represent a consolidated though comprehensive description of what the DEDICAT 6G architecture is expected to address in its next iteration. Use cases are being further refined and improved during the execution of the project, through a process of agile continuous improvement, which aims to consider any new or improved requirements that may emerge as planned.

This document is structured as follows. First, Section 1 provides a general introduction of this document. Section 2 highlights the main contributions and major updates presented in this deliverable with respect deliverable D2.1 [1]. Then, Section 3 explains the methodology followed in the UML design, and exposes the common points assumed in all UCs. Sections 4-7 provide detailed descriptions of the use cases and corresponding derived requirements, scenarios and UML models for Smart Warehousing, Enhanced Experiences, Public Safety and Smart Highway. Finally, Section 8 presents the main conclusions of this work and a brief summary of the key points.

2 Introduction to delta content with regards to D2.1

Deliverable D2.1 [1] was released in M3 (March 2021) as the first document presenting and describing the use cases and listing a preliminary set of functional and non-functional requirements from an architectural perspective. This deliverable D2.3 should be seen as the evolution of D2.1 [1], where the main outcomes of the effort invested in the context of WP2 in relation to the functional specification of the DEDICAT 6G use cases after eleven months are collected. This section is about highlighting the changes and novelty of this D2.3 with respect to its previous iteration in D2.1 [1].

The first obvious difference to the structure of D2.1 [1] is this current section. Here we outline the main evolutions and changes in this second and final iteration of the set of scenario and requirements description documents. This section is essential to elucidate the novelty, impact and evolution of the work presented herein. Even though the overall document contents have been revised, some parts of the document remain unchanged as no update was needed due to the huge effort invested in D2.1. In addition, it is worth mentioning that section 3 of the former D2.1 [1], "Introduction to requirements engineering", has been removed in this deliverable to avoid redundancy, while further details can be found in deliverable D2.2 [2]. Similarly, the COVID-19 Contingency Plan subsection in all UCs shown in D2.1 have been removed in this D2.3. Moreover, the content and the format of the document has been thoroughly revised, typos, issues with tables, figures or references have been identified and solved, and some parts of the document have been improved or rewritten.

With regards to the WP2 effort, the release of the deliverable D2.2 – Initial System Architecture [2] in M9 (September 2021) constituted a (non-official) intermediate milestone for this document. It enabled evolving the use case definition by using a common DEDICAT 6G architecture, especially relevant to the functional view, which has been leveraged to create the most remarkable novelty in this D2.3, the UC functional decompositions. Each UC description now has its own sub-section (4.5, 5.5, 6.5 and 7.5) to define its functional behaviour in different scenarios especially focusing on the roles to be played by the DEDICAT 6G platform and the interactions of the system with the specific *Functional Components (FC)*. These actions are modelled in UML diagrams, the design of which is a major improvement and is one of the main outputs of this document with considerable effort put into the definition of the models. With the aim of unifying the criteria in the UML models and for the sake of clarity, here we added a new Section 3 (General Introduction to UML diagrams) where we explain the methodology followed plus a set of assumptions common to all diagrams.

The work done in the previous activity enabled the rethinking of some parts in the definition of the UCs with respect to the presented content in D2.1 [1]. Thus, in this second iteration functional and non-functional requirements were revisited and amended as necessary for all UCs. In order to highlight the changes, the new requirements are represented in their corresponding tables in green while the modified ones are shown in yellow. This reconsideration of the UCs has also entailed a review of some UC scenarios, where, taking a similar approach to the requirements, some of them have been modified and new UC scenarios have been included in this document. It is also worth pointing out that a new actor has been considered in UC4.

Moreover, the content provided in this document will feed the next WP2 deliverable, D2.4, where the new set of UC requirements will be considered for merging with existing unified requirements, potentially creating new ones to be added to the DEDICAT 6G VOLERE template [3]. It will be used as well to update and enhance the second version of the DEDICAT 6G architecture. Finally, the new definition of the UC scenarios and UML models will be consulted in WP6 work to assess the implementation works within each UC context under a common project umbrella.

3 General Introduction to the UC UML diagrams

In this introductory section we provide some explanations and elements of methodology that help to understand on one hand the purpose of the UML diagrams introduced within the four next sections (one for each UC) and on the other hand the common approach (notation, rules and structuring) followed in the UML models for the four UCs (see in sub-sections X.5 "Relation to the functional decomposition" of each UC main section).

Before digging into technical details, it is worth noting that the purpose of this UML modelling exercise is to go one step beyond the work already achieved in the context View of D2.2 [2]. In D2.2 the various UCs were described from their actors' points of view trying to elucidate as clearly as possible the actions and subsequent interactions taking place with the platform without focusing on the platform actual content (a.k.a. black box approach).

On the contrary, in this D2.3 we open the box and illustrate how the FCs stemming from the functional decomposition can be exploited to implement these interactions and expected features and services.

As a final note, while following these common rules drastically enhances the readability of the UML diagrams, it also provides a high level of soundness among the 4 UCs. One of the main benefits is that it also becomes much easier to relate these UCs which each other.

We explain hereafter this common approach:

- For a given UC section, the first diagram, in their corresponding UCs functional decomposition sections, are always about service and system set-up, meaning here the preliminary actions towards the platform are depicted. These include creating an account and logging in order to be known from the platform and able to go further in the scenario steps, e.g., requesting a service. Then several actions follow:
  1. Service request: a vertical can request for Intelligence Distribution only as a service (IDaaS) or a request for *Coverage Extension (CE) as a Service (CEaaS)* that may involve Intelligence Distribution as well. In the first case, the request will address the *Intelligence Distribution Decision Making (IDDM)* FC and in the second case it will address primarily the *Coverage Extension Decision Management (CEDM)* FC which it-self relies on the IDDM for complementary actions/tasks. In order for the CEDM or IDDM to be able to grant a service, some input parameters are necessary:
     a. IDDM: the list of Edge Nodes (and characteristics) provided by the vertical, the list of *micro-Services (µS)* (and computing requirements) the vertical will instruct DEDICAT 6G for dynamic deployment, a deployment policy for these µSs (which may be empty) with regard to provided edge nodes;
     b. CEDM: the requested capacity, QoS per UE, a location where CE is expected (GPS coordinates e.g.), if the CE is expected to be ground or aerial based (a certain number of options are available for each). It falls under the CEDM duties to assess the needed number of MAPs and their nature (if it is not provided) based on the request parameters;
  2. When the initial request is a CEaaS request, the CEDM FC will rely on the IDDM FC to assess the feasibility of the combined CE/IM (Intelligence Management) request (if additional IM is requested). Since the MAPs are also Edge Nodes it may then rely on these nodes for additional µS/FC deployments. It is also worth noting that for the sake of load balancing, and other DEDICAT 6G core functionalities, the use of a vertical's edge node for µS deployment implies the automatic deployment of some dedicated

sensing Agent FCs which are used to aggregate a context. This context is used by the different levels of decision making;

3. A simple protocol, ContractNet[1], takes place between the two parties concerned following the service request. This protocol is typically used in *Multi-Agent Systems (MAS)* for task allocation in the context of cooperative work. When the initial request is eventually agreed upon (after or without counter proposal) some additional steps are implemented;
4. The *Service Level Agreement (SLA)* that follows the negotiation must be stored in the SLA Factory FC so that it can be enforced during service delivery;
5. µS images and metadata/descriptions must be uploaded to the µS/FC Repository FC and µS/FC Registry respectively;
6. Their characteristics and requirements (CPU, RAM, storage…) must be stored in the µS/FC Repository FC for further use by decision making;
7. A preliminary set-up policy is also uploaded by vertical operators to the *Edge Computing (EC)* Policy FC and will be used by the Service Orchestrator FC in particular when dynamic intelligence migration or scaling up takes place;
8. The verticals *Edge Node (EN)* characteristics (e.g., computational capacity) need to be uploaded to the EN Registry FC, for the IDDM FC to use;

- The second UML diagram is always about deployment and shows where the different vertical µSs and requested FCs are deployed. The Service Orchestrator FC is responsible for this deployment and is ultimately instructed by the IDDM FC (eventually via the CEDM FC in case of a dual CE/ID request);
- The following UML diagrams are usually used for illustrating the normal operation during the UC stories at run-time. The arrows show interactions taking place between the various components and often link to actions initiated by some actors, either by managers of some sort or simply by users (event attendees, drivers, workers etc.);
- Finally, the last diagram usually illustrates some migration/scaling-up scenarios involving both the Load Balancing FC and Service Orchestrator FC via the IDDM FC which collects constantly compiled contexts in order to take decision, like optimizing the execution of the various FC among the Edge Node in order to enforce and maintained the contractual QoS (w.r.t to the negotiated SLA).

A few additional important remarks:

- In order to keep the UML diagrams readable, some DEDICAT 6G FCs are sometimes omitted. For example, when using Status Agent FCs (there are quite a few of different types depending on the kind of information they are capturing and reporting), the corresponding Awareness FC may be omitted; Awareness FCs are meant to aggregate status agent information into a context which is used by *Decision Making (DM)* FC. In such cases a direct arrow from the agent to the corresponding xy*DM* FC is depicted (e.g., from a µS/FC Status Agent FC towards the IDDM FC), without explicitly mentioning the intermediary µS/FC Awareness FC;

[1] https://en.wikipedia.org/wiki/Contract_Net_Protocol

- For the same reason, the way security components regulate (and are enforced) component-to-component interactions is not explicitly shown. As a matter of fact every time an interaction takes place between -say a µS and a FC- 1/ the interaction is intercepted by the Data Market Place (either it is REST based or using a Message Bus like MQTT or sockets-based etc.), 2/ both parties are authenticated, 3/ it is checked whether the party initiating the interaction is authorized to do so, 4/ the interaction is granted or denied, 5/ the interaction is kept track of by the Logging FC and finally, 6/ a transaction is stored in the block chain for non-repudiation purpose;
- A *Physical System (PS)* is shown using the package pictogram. PS are meant to represent one or several computational systems with virtualization capabilities (containing more than one *Execution Environment (EE)*) where the FCs and µSs are deployed and run. When a Load Balancing FC points towards the PS, it is meant that it is balancing the load between and within the EEs/containers involved;
- On several occasions, PSs or even FCs/µSs are followed by an asterisk *. It means then, that several occurrences of these entities exist in the context of the UC. In general, not more than one instance of a same entity is represented unless a component migration is illustrated from one PS to another PS (which can be from a different nature, e.g., a µS migrating from a Car to a *Road Side Unit (RSU)* in UC4);
- In general, most of the mechanisms that occur in the background at the platform level are omitted when these mechanisms either are invisible from the UC point of view or do not affect the UC directly. For example, in order to take their decisions, the DM FCs (IDDM, NODM and CEDM FCs) are using large amounts of information coming from various sources and involving many FCs. Listing exhaustively all FCs involved would result in unreadable figures and would not serve appropriately the purpose of these UML diagrams. It is one of the main aims of D2.4 to go into the details of these aspects, elucidating them in particular using UML Sequence Diagrams;
- Finally, a colour coding is used to differentiate visually, deployed µSs (light green) from deployed FCs (deep green). Native FCs residing in the cloud remain yellow; Native services part of a vertical PS are also represented in yellow as being not deployed by the platform.

4 "Smart Warehousing" (UC1)

Upgrading or improving the digitization of relevant industry processes and embracing ICT and connectivity to increase productivity and efficiency is a key societal challenge and an economic target. This use case intends to demonstrate the feasibility and value of applying the distributed intelligence and computation offloading concepts in a Smart Warehousing context. Research studies have shown that smart warehousing processes (as part of Industrial *Internet of Things - IoT*) can be improved (efficiency in resource utilization, safety and security and overall automation performance) with AI, edge processing, and blockchain for improved trust [4] [5]. Human-robot interaction in smart warehousing is one of the main research topics from a technological and societal point of view [6].

The DEDICAT 6G Smart Warehousing use case will progress the current state of the art and also validate its main conclusions by applying DEDICAT 6G technological concepts (B5G/6G connectivity, enhanced through coverage extension, jointly with the computation offloading) for:

- optimizing warehousing operations with increased performance and improved efficiency;
- assisting training of new warehouse workers and maintenance of warehouse systems through application of 3D augmented reality;
- promoting human-robot interaction with 3D video-driven solutions;
- enhancing safety of personnel and goods;
- enabling remote inspection and diagnostics;
- identification and tracking of goods.

This will be achieved through an integrated state-of-the-art operational system based on AGVs and IoT systems with edge computation capabilities supporting deployment of DEDICAT 6G enablers.

4.1 Use case objectives and relation to project objectives

The main objective of this use case is to demonstrate how the application of the DEDICAT 6G technology in the smart warehousing context can boost performance of warehouse processes, improve their efficiency, enhance user (personnel) experience and ensure their safety. Overall, the scenario addresses project objectives #5 and #6 with other objectives addressed with specific use case goals. The following goals are set for this use case:

- To automate and remotely assist AGVs operation in the context of smart warehousing activities, using *High Definition (HD)* video and AR/VR functionality to enable human interaction.
    - Target innovation: Intelligence distribution and *Multi-Access Edge Computing (MEC)* could help reduce response time to perform certain actions as well as enable near real-time human intervention. This can also include advanced AGV operations enabled by B5G connectivity in conjunction with computation offloading in order to realize obstacle/human avoidance as well as human-robot and robot-robot interaction to perform a collaborative task;
    - Relation with project objectives: objectives #1 and #4.
- To enhance warehouse automation towards significant increase of operational efficiency and use of resources".
    - Target innovation: Predictive analytics by distributed AI and data analytics functionalities combined with cloud, edge, and roof computing capabilities. Utilization of DEDICAT 6G coverage and connectivity extension solutions for

ensuring low latency and reliable data exchange necessary for high performance decision making;
    - Relation with project objectives: objectives #1, #2, and #3.
- To enhance safety and security in warehouses – collision avoidance, social distancing, employee's wellbeing monitoring, environmental conditions, safety geo-fencing, and notifications/alerts.
    - Target innovation: Facilitation of adherence to social distancing (as long as it is applicable), monitoring the wellbeing of employees as well as monitoring the environmental conditions within the warehouse (e.g., through indoor air quality monitoring sensors mounted on the AGVs). Mobile computing nodes combined with IoT and communication infrastructure will facilitate decision making based on distributed computing;
    - Relation with project objectives: objectives #1, #3 and #4
- To enable remote surveillance and monitoring of processes with real time decision making for corrective and preventing actions.
    - Target innovation: MEC and distributed intelligence can act as an enabler in this use case as the aforementioned operations could greatly benefit from computation offloading aimed at reducing time to action. Operation and movement of AGVs requires low latency. The use of MEC could also speed up the decision-making process;
    - Relation with project objectives: objectives #1, #2, #3 and #4.
- To enhance coverage within the warehouse, through connectivity extensions in the context of dynamic obstacles in a typical warehouse (shipments of goods can be stored differently resulting in unforeseen obstacles for communication channels).
    - Target innovation: Utilization of deployed AGVs, drones, and IoT controllers for opportunistic networking, capacity and coverage extensions based on the operational context of a warehouse. All mobile nodes can provide range extension and IoT controllers act as communication/protocol gateways towards core network.
    - Relation with project objectives: Objective #3

4.2 General context and set-up

The Smart Warehousing UC will be deployed and validated in a warehouse provided by the project partner DIA. DEDICAT 6G enabling technologies and resources provided by participating partners will be integrated with the existing warehouse infrastructure (electrical network, network infrastructure, deployed sensing and automation systems) and include on-site personnel in the actual experiments.

4.2.1 Overview

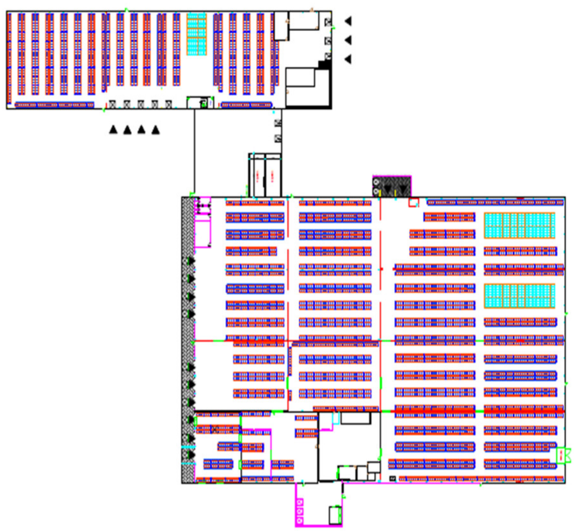
The DIA Warehouse "Imeros Topos" is located in NW Attica, 27 km from Athens city center (see Figure 1). The Warehouse is easily reachable via highway. Corresponding Google map coordinates:

- Longitude: 23°37'35.51";
- Latitude: 38° 3'51.74".

Figure 1: Warehouse "Imeros Topos" location

The following Table 1 provides a description of the warehouse in terms of the spatial/floor plan, data related to capacities, infrastructure, and equipment as well as indicative photos of the Warehouse.

Table 1: Warehouse "Imeros Topos" Information

<table>
<tr><th>Plan</th><th>Resources</th></tr>
<tr><td></td><td>

Height 11m; total storage area of 18.270 m²
Temperature Controlled Areas
Storage Capacity of 21.825 Pallets
Inbound & Outbound through 25 Ramps
Alarm and CCTV system
External > 2m fence
24/7 Guard and Additional Patrol during the night
Fire Protection (sprinklers) System according to Greek Fire Standards
UPS, 2 Electrical Generators
Solar panels
Wired and wireless network Infrastructure
Electrical pallet movers, forklifts
GPS monitoring and sealing shipping containers/trucks
</td></tr>
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4.2.2 Actors involved

Table 2 presents the "Warehouse ecosystem" in terms of the actors/roles and interrelationships reflecting the current conditions and operational procedures.

Table 2: The Warehouse "ecosystem".

Actor	Role	Relationship(s)
Warehouse Manager	Overall management	Coordinates Technical Manager, Safety Manager and Warehouse Supervisors.
Technical Manager	Equipment monitoring and maintenance	Coordinates Warehouse Supervisors for everyday operations; interacts with Technology, Network and Equipment Providers for after sales tasks.
Safety Manager	Training, conformance to safety measures/standards etc.	Coordinates Warehouse Supervisors for everyday safety tasks.
Robot/AGV(s)	New actor to be included in the context of warehouse enhancement.	This can act as a *Mobile Access Point (MAP)* providing dynamic coverage extension. It can also act as an edge node with computation capabilities. Finally, it can assist in warehouse operations such as quality assurance or transporting products.
Warehouse Supervisor(s)	Supervision of flows and processes within the warehouse	Coordinates specific team(s) of workers, Forklift/Machine Operators and Packaging Personnel
Warehouse Workers	Implementing warehouse processes e.g., picking, packing, checking, loading/unloading.	Implement certain procedures and follow Warehouse Supervisor's guidelines
Forklift/Machine Operators	Operation of forklift/machines in the context of warehouse processes.	Implement certain procedures and follow Warehouse Supervisor's guidelines

The above-described roles and interrelations are depicted in the following Figure 2. In this:

- Equipment, Technology and Network Provider(s) are not participating in everyday operations in real time;
- DEDICAT 6G System needs to be linked to the existing roles;
- Robots/AGV(s) needs to be linked to the existing roles.

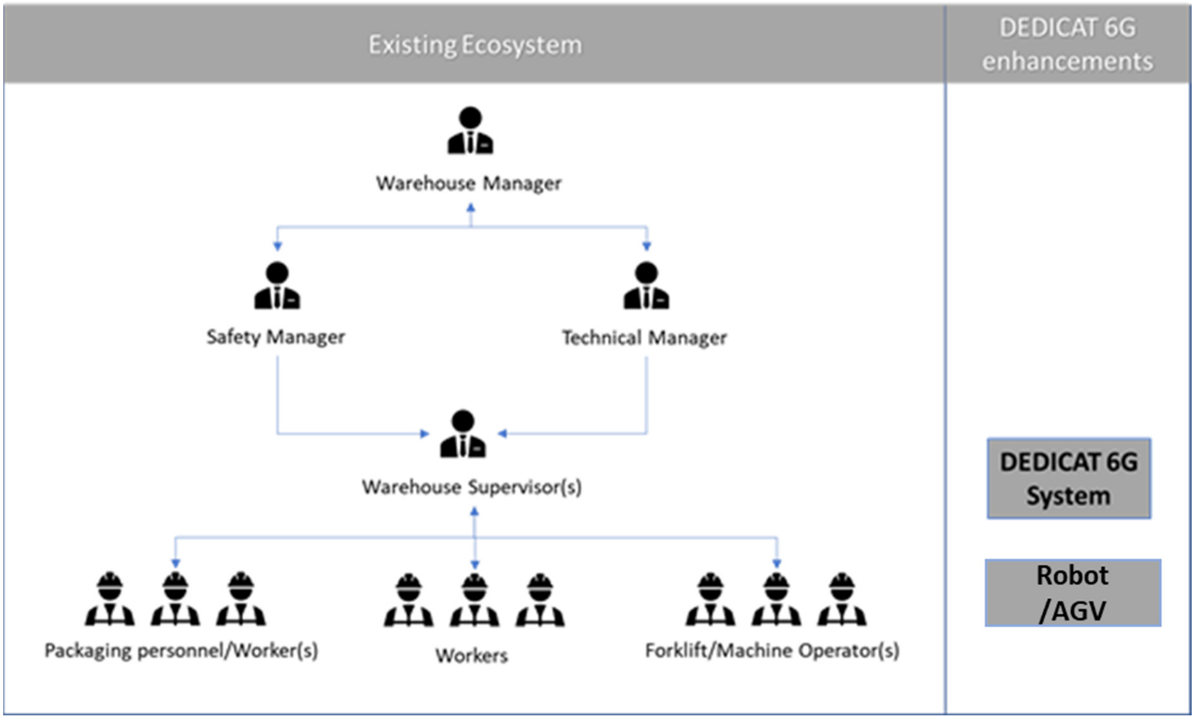

Figure 2: Smart Warehousing "ecosystem".

4.2.3 Set-up plan

The setup shown in Figure 3 is considered at this time for realization of the Smart Warehousing use case. This set-up considers the following:

- AGVs are deployed and configured to perform smart warehousing tasks;
- Smart warehousing IoT system deployed and configured to perform smart warehousing tasks;
- Bluetooth Low Energy (BLE) beacons are provided for Mobile Assets (MA);
- IoT system for access control is connected to electric locks;
- Environmental sensors are connected to the IoT system;
- Personnel are authorized and registered;
- Smart warehousing layout/plan is digitalized;
- DEDICAT 6G mobile app is installed on personnel mobile devices;
- DEDICAT 6G web dashboard is provided to the Warehouse Manager;
- DEDICAT 6G solutions for distributed computing, opportunistic networking and trust/security management are deployed and configured.

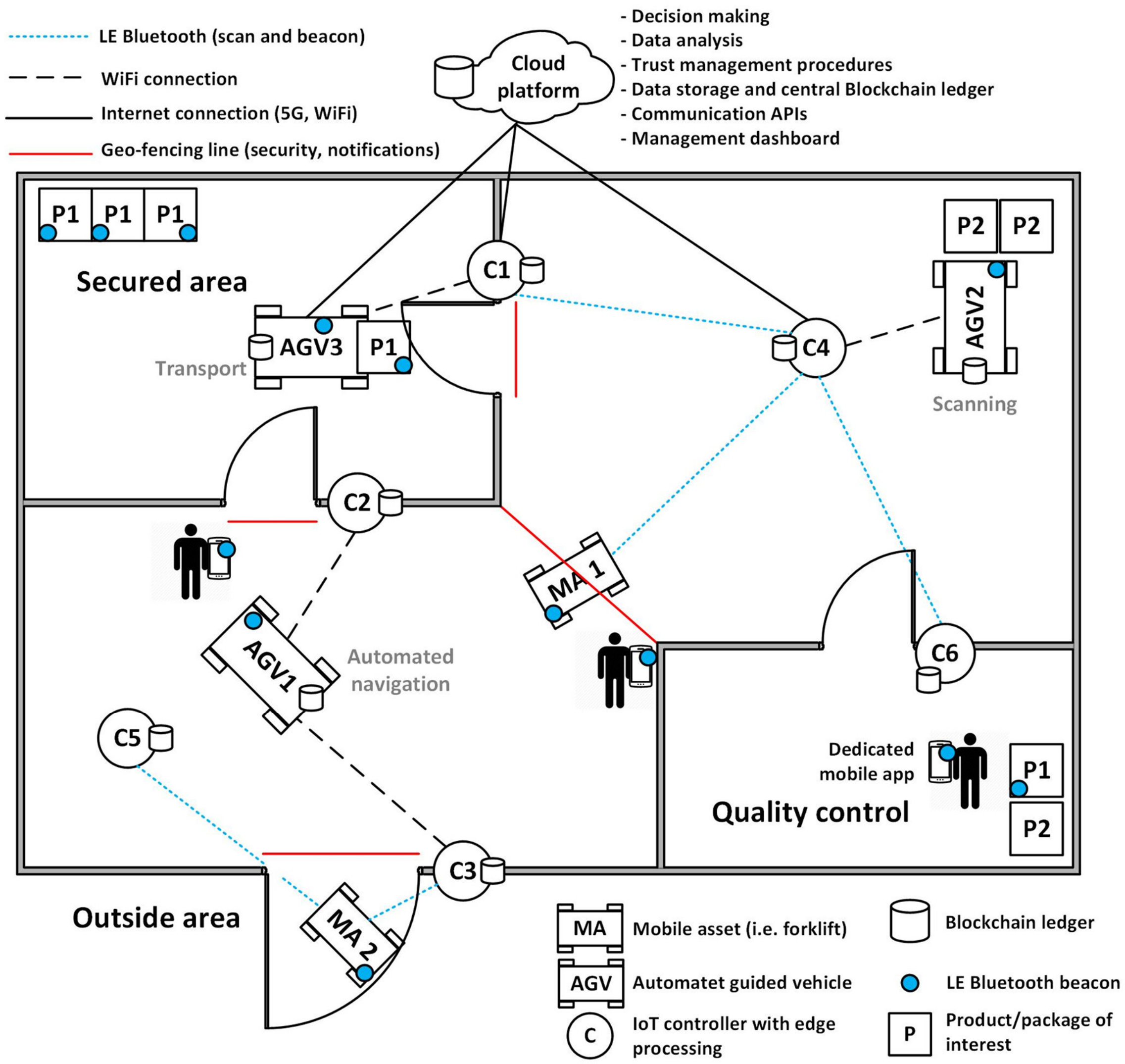

Figure 3: Smart warehousing use case setup plan

4.3 Pre-requisites and Assumptions

The main assumption for this scenario is that a Warehouse Manager seeks technological/IT solutions that will improve efficiency, boost performance and fortify safety of personnel and goods. Assumptions for the warehouse are the following:

- Performance and efficiency of the warehousing processes can be improved with advanced AI and communication methods and mobile equipment for process automation;
- Experience of personnel can be improved with IT based tools and smart user interface technologies;
- Safety of personnel and stored goods can be improved with AI-based decision making and advanced monitoring systems;
- Layout of the warehouse might be changed (depending on organization of stored goods) and AI-based management systems should adapt to the changed context.

The main pre-requisite for the scenario is that the DEDICAT 6G enablers and technologies provided by participating partners are integrated with existing warehouse infrastructure addressing the assumed requirements and smart warehousing goals. A more detailed list of pre-requisites includes:

- Pre-requisite 1: DEDICAT 6G platform interface and edge components deployed;
- Pre-requisite 2: Warehouse processes, infrastructure layout and floor plan digitalized – digital representation to be used by deployed smart systems;
- Pre-requisite 3: AGVs deployed and configured for intelligence distribution, smart warehousing processes and robot-human interactions;
- Pre-requisite 4: Communication network configured and enhanced to support advanced networking methods provided by DEDICAT 6G technology;
- Pre-requisite 5: IoT edge nodes and sensors deployed to closely monitor conditions in the warehouse and perform smart actuation with the help of AI-based decision making;
- Pre-requisite 6: location BLE beacons deployed on key mobile resources (AGVs, forklifts, etc.) and provided to personnel;
- Pre-requisite 7: DEDICAT 6G Mobile app for personnel installed on smartphones or tablets, providing the interface with the deployed system (notifications, configuration parameters, monitoring widgets, AR functionalities);
- Pre-requisite 8: DEDICAT 6G dashboard provided for warehouse administrators/ managers allowing them to manage all integrated processes, monitor performance, configure and send notifications and alerts to personnel;
- Pre-requisite 9: Smart warehouse remote control center for monitoring and remotely managing multiple warehouses – possibility for integration with the DEDICAT 6G dashboard.

4.4 Stories

Some of the main actors in the smart warehousing scenario are warehouse workers focusing on their daily tasks and warehouse managers/administrators focused on improving overall efficiency, performance, and safety by applying new processes, organizing personnel and resources and remotely monitoring deployed systems. These main actors will interface with the deployed DEDICAT 6G systems and new technology in different ways. This is why the perspective of 1) a warehouse manager and 2) a typical warehouse worker is described in the two stories.

The main services in the warehouse are:

- **Receiving:**
    - Receipt of goods from customs office, airport, production site, etc.
    - Unloading directly to the appropriate storage areas;
    - Quantitative and qualitative - macroscopic – control;
- **Storage:**
    - Storage of goods accommodating product specifications:
        - Controlled temperature;
        - High security materials;
        - Controlled substances;
    - Sorting and tracking of stock by material code, per lot / batch number and expiration date;
    - Storage control and inventorying in dedicated software and through *Radio Frequency (RF)* scanners;
- **Picking & Packing:**
    - Checking of all orders through RF scanners;
    - Loading of orders through RF scanners on distribution vehicles.

Notably, the primary operations within the warehouse include picking, forklift operation and loading; such operations are targeted as subject to optimization using the DEDICAT 6G envisaged system. More specifically reducing the actual movement of workers inside the

warehouse and automation of moving and transport for storing are expected to result in increasing productivity in the warehouse and labour cost optimization.
As presented in Section 4.1 the goal of this use case is to improve efficiency of these services by applying DEDICAT 6G solutions for distributed/edge computing, opportunistic networking and distributed trust management together utilizing deployed resources like IoT system and AGVs. To this aim, we present two different stories in UC1.

4.4.1 Story 1: Remote monitoring and configuration of smart warehouse by a warehouse manager

Short description

This story focuses on a warehouse manager who is responsible for setting up the strategy for improving performance, efficiency and safety of personnel and stored goods. This person also performs monitoring of the deployed resources and configured processes in order to assess overall performance and derive necessary updates. Finally, a warehouse manager is also responsible for interaction of the smart warehouse systems with the outside world including the wider supply chain. The assumption is that a warehouse manager monitors the operations from a dedicated location/office which may or may not be at the same location as the warehouse itself.

Story line

The Smart warehouse manager uses DEDICAT 6G system and provided management dashboard to configure smart warehousing processes and perform monitoring of achieved performance, efficiency and overall safety.

1. The warehouse manager is authorized on the DEDICAT 6G web dashboard and performs the following tasks:
    a. The manager utilizes the dashboard to configure daily tasks for the fleet of AGVs including product quality monitoring parameters, interaction rules with warehouse personnel and product offloading/loading schedule;
    b. The manager configures environmental parameters for storing different goods;
    c. The manager configures daily safety rules for workers including social distancing and safety zones with configurable geo-fencing zones for different time periods and in line with offloading or loading schedule;
    d. The manager configures authorization levels for workers with respect to warehouse areas.
2. AGVs receive configuration parameters and perform daily tasks:
    a. The AGV performs processing necessary for navigation in line with tasks and conditions in the warehouse. The AGV automatically adapts to changing layout as a result of goods being stored;
    b. The AGV maintains uninterrupted connection with smart warehousing systems;
    c. The AGV provides connectivity for IoT system and mobile devices running the DEDICAT 6G mobile application;
    d. The AGV reports its status and task completion to the warehouse management system.
3. Based on the manager's configuration parameters, indoor positioning of the mobile assets and personnel is performed through BLE beacons, environmental conditions in the warehouse are monitored and access to warehouse areas is managed with specific authorization rules:

a. The Smart Warehousing IoT system provides alerts to workers and the warehouse manager when social distancing rules are breached (many workers in a small area);
b. The IoT system provides alerts to workers and the manager when safety zones are breached;
c. The IoT system opens doors for authorized personnel to access areas with strict access control rules defined by the manager and the manager is notified about personnel accessing a restricted area. These areas include storage rooms for pharmaceutical products;
d. The IoT system collects and analyses data from environmental sensors (temperature and humidity) and provides alerts to the manager if strict environmental conditions are not met in certain areas of the warehouse;
e. The IoT edge controllers maintain communication channels with AGVs and among themselves in mesh networking mode so that uninterrupted access towards the smart warehousing systems is ensured.

4. The warehouse manager monitors smart warehouse processes through a web-based dashboard:
   a. The manager receives notifications when configured triggers are met;
   b. The manager can remotely configure and employ additional AGVs;
   c. The manager can remotely re-configure or turn off AGVs when needed;
   d. The manager can remotely revoke access rights for previously authorized personnel;
   e. The manager can access the camera feed on AGVs.
   f. The manager can get precise location of key mobile assets;
   g. The manager can direct personnel towards an area of interest or an asset;
   h. The manager can direct AGV towards an area or an asset of interest.

4.4.2 Story 2: Automated operation and production in smart warehouse

Short description

This story emphasizes how a typical warehouse worker utilizes deployed technologies to perform daily tasks (goods inventorying, goods shipment, training of a new worker, warehouse maintenance, etc.) more efficiently and safely. Warehouse workers are these who directly interact with the deployed AGVs, goods and other warehousing infrastructure. They are performing all their activities within the perimeter of the warehouse.

Story line

A smart warehouse worker interacts directly with deployed AGVs and IoT systems through provided control interfaces and with the DEDICAT 6G mobile application deployed on the worker's smartphone or tablet (which might be used for standard inventorying, communication and other warehouse operations).

1. Worker X works in the warehouse for some time and utilizes the DEDICAT 6G system in daily tasks. Worker Y is an intern who needs to go through the smart warehouse training process;
2. X logs in to the DEDICAT 6G mobile app and receives a list of daily tasks as specified by the warehouse manager. Y installs the DEDICAT 6G mobile App, registers and is authorized as an intern;
3. X inspects status reports of AGV#1 and AGV#2 and directs AGV#1 towards a product that needs to be moved to the loading bay while AGV#2 is directed to check the product status on the conveyor belt. X provides Y with instructions on how to utilize the

AR interface of the mobile app to navigate the warehouse. Y is instructed to escort AGV#1 to the loading bay;

4. X receives a notification to check AGV#3 in the restricted area where pharmaceutical products are stored. X has the required authorization level to enter the area using the Smart Access IoT system guarding the door. X sees that the AGV has turned over on its side. X notifies Y that he needs help to put the AGV#3 in the upright position. X requests temporary authorization for Y to access the area. The manager grants one-time access. Y uses the AR interface of the DEDICAT 6G application to navigate to the area of interest and is authorized to open the door. X and Y fix the AGV#3 and are back to the non-restricted area;
5. Y goes back to monitor AGV#1 operation and performs product inventorying (e.g., counting boxes) in the prepared shipment using the AR capability of the mobile application. A new shipment is being offloaded in the nearby loading bay and it contains heavy products. Y receives a notification that dangerous goods are being offloaded by forklifts and to stay away from the area. After finishing the status check of AGV#1, Y by mistake crosses the geo-fencing line configured by the manager and receives notification about entering the danger zone. Y continues on the same path and AGV#1 intervenes and alerts Y to go back;
6. AGV#2 reports that it has identified an issue with a product on conveyor belt based on the configured quality check procedure. The conveyor belt is stopped. X receives a notification and accesses the camera feed from AGV#2 to check the status of the product. The package appears to be damaged, or the smart label suggests that the product was not stored properly. X instructs AGV#2 to remove the product from the line. The conveyor belt is restarted. AGV#2 brings the damaged product to the inspection area while AGV#4 automatically takes over the conveyor belt inspection role;
7. X and Y go to the common personnel area and receive an alert that there are too many people already there and social distancing cannot be followed;
8. X and Y return to their tasks.

4.5 Relation to the functional decomposition

Here, we exposed the relation to the functional decomposition and must be seen as a link between the actions in performed in D2.2 context view UML diagrams for UC1 and the set of FCs defined in the DEDICAT 6G architecture.

4.5.1 CE Management Setup

The first UC1 UML diagram (Figure 4) starts with the Technical Manager setting up, through the cloud dashboard, the IDaaS parameters and request. In order to do so, the starting activity includes creating an account and logging in to the platform in order to request the service and upload all necessary services whenever the service negotiation process succeeds.

This first diagram is common to all UCs with still some variants depending on -for instance- whether the requested service is "Coverage Extension as a Service" or "Intelligence Distribution as a Service". It is extensively described at the beginning of Section 3.

In UC1, the requested service is IDaaS, therefore the set of parameters passed to the IDDM FC as first step of the ContractNet protocol, focuses on µSs and Edge Nodes only (along with deployment policy if any). Then, following the registration/login phase and after the terms of the service request negotiation have been agreed upon, the µS images together with their metadata (description) are uploaded to the µS/FC Repository FC and µS/FC Registry, respectively. A deployment policy is also uploaded to the EC Policy FC and the terms of the SLA are encoded and stored within the SLA factory FC where they will be enforced. Finally, the Vertical *Edge Node (EN)* characteristics are uploaded to the EN Registry FC.

Again, all these steps are achieved by the Technical manager, via the cloud Dashboard FC, even if for the sake of clarity, the latest steps in Figure 4 are materialized with straight arrows towards the *in fine* targeted platform FCs.

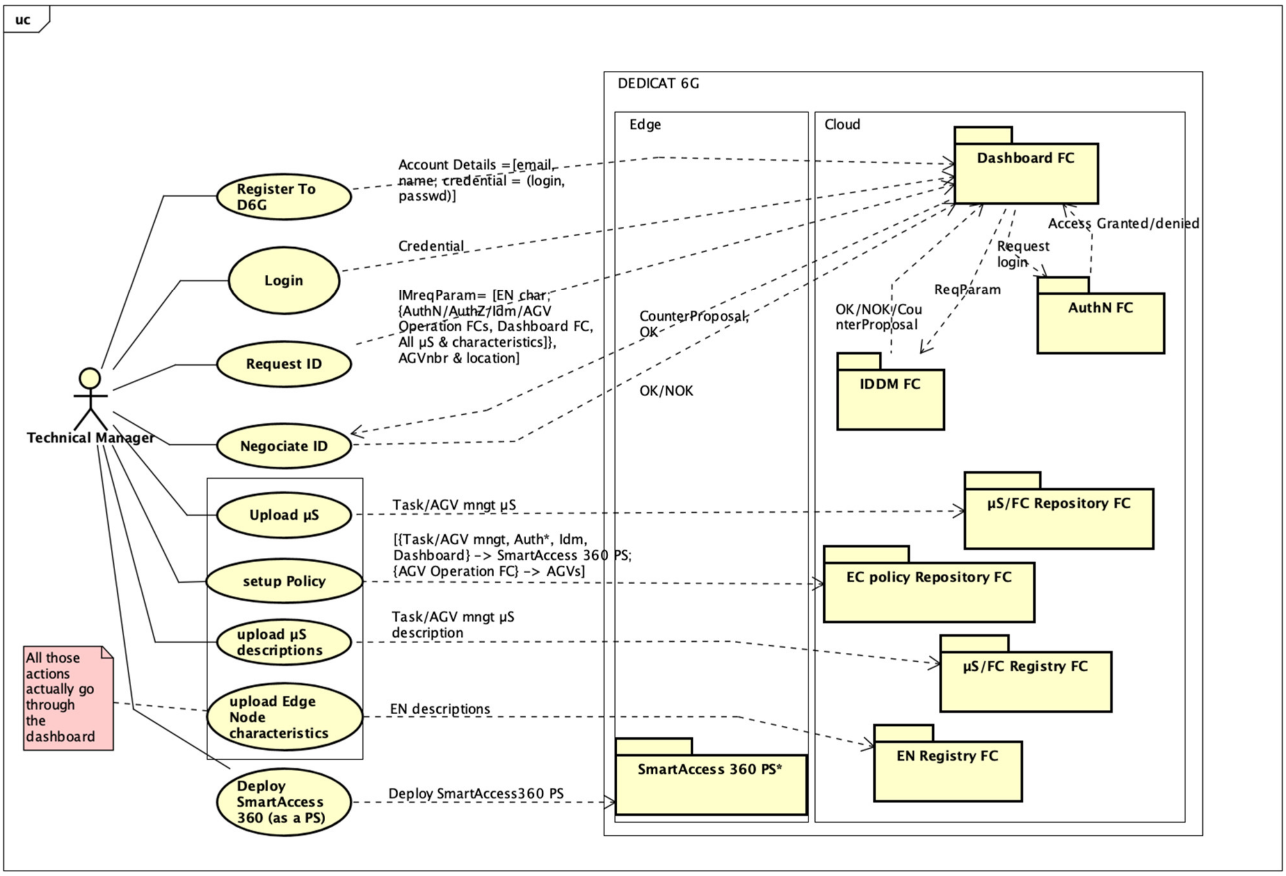

Figure 4: Smart Warehouse ID management set-up UML

4.5.2 AGV Deployment

Following the agreed contract set-up in the previous UML diagram, Figure 5 shows how the platform accomplishes the needed µSs and FCs deployment based on the parameters passed during the previous negotiation phase (beginning of ContractNet). The µSs to be deployed are therefore already known from the DEDICAT 6G platform, and along this set of µSs, some additional FCs need also being deployed so that the authentication and access control can be achieved locally in a SmartAccess360 physical system. This PS is physically deployed at the Warehouse (bottom part of the figure) by the Technical Manager.

The main workflow shows the IDDM FC taking the lead of this deployment task and instructing the Service Orchestrator FC to deploy the need FCs and µSs toward the Edge, within a designated SmartAccess360 PS.

The deployed FCs are the AuthN, AuthZ and IdM FCs, complemented by the Threat Analysis & Trust FC which performs threat detection in edge processing nodes. The three first FCs are involved as mentioned earlier in authentication and access control.

SmartAccess360 will be physically deployed at the doors/gates side and run some dynamically deployed DEDICAT 6G FCs (as edge FCs). Smart Actuation performs access control based on the AuthN/AuthZ/IdM FCs.

The three tasks shown in the diagram, involves 1/ deploying AGV at the warehouse (a DEDICAT 6G staff member physically bring the AGVs on site and perform some set-up activities which are not in the scope of this scenario) 2/ get notified when the deployment is successfully performed (this does not require any active action from the Technical manager of the warehouse) and 3/ (as already mentioned) performing the deployment of the SmartAccess360's within the warehouse. Of course, the deployment of FCs and µSs can only be achieved after the AGVs and other PSs have been deployed.

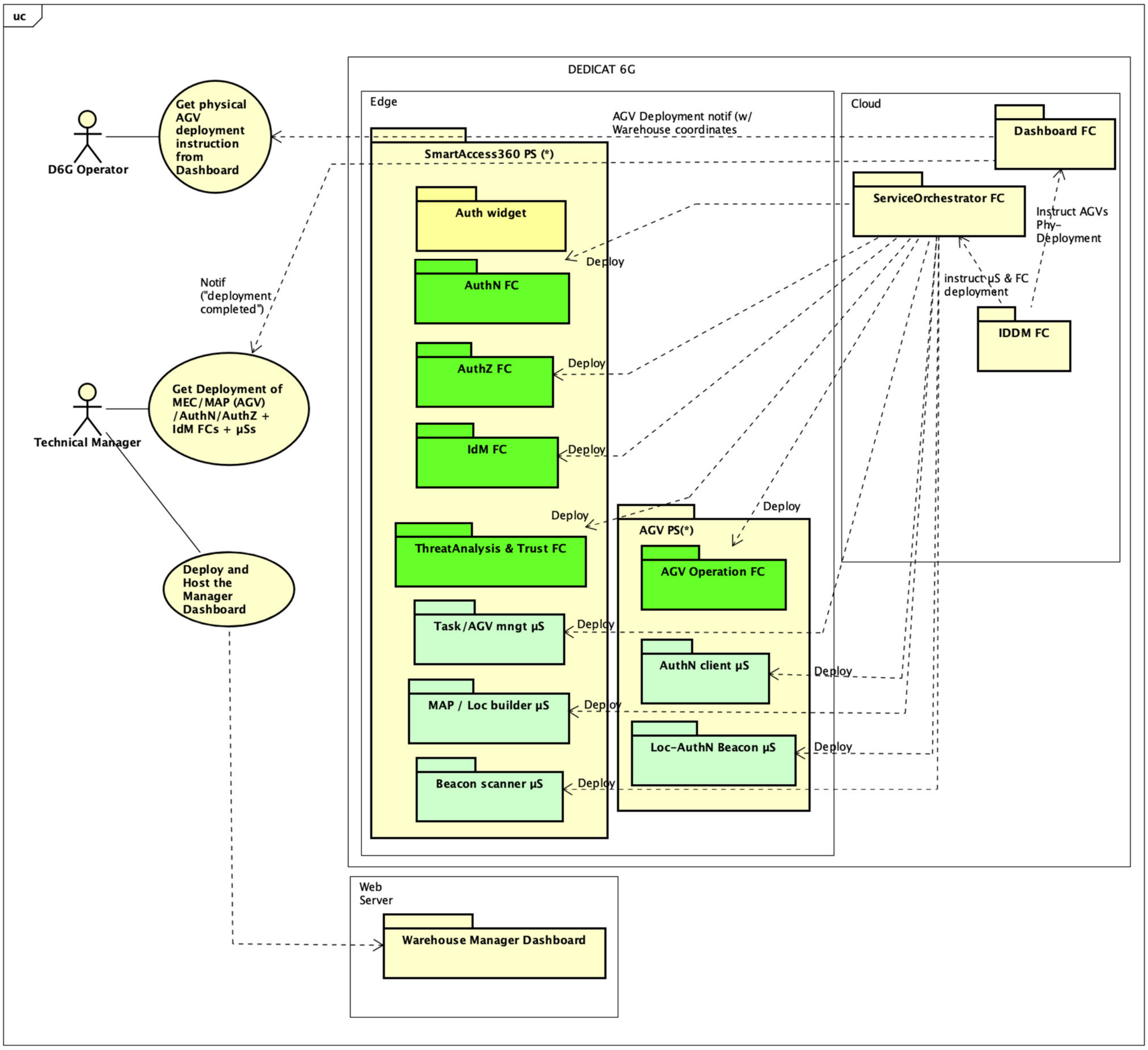

Figure 5: Smart Warehouse AGV deployment UML

4.5.3 Smart Warehouse Worker Setup

In Figure 6 we identify the actions related to the warehouse manager, worker and AGVs focusing on the warehouse pre-operation set-up. The manager utilizes the Manager Dashboard and configures daily safety rules for workers, including social distancing and safety zones with configurable geo-fencing zones for different time periods and in line with offloading or loading schedule. Also, the manager configures authorization levels for workers with respect to warehouse areas.

Smart Access 360 controller opens doors for authorized personnel to access areas with strict access control rules defined by the manager. The manager in turns gets notified about personnel accessing restricted area. This IoT system provides workers and manager with alerts whenever safety zones are breached.

A warehouse worker interacts indirectly with deployed AGVs and IoT systems through provided control interfaces and with the UC1-specific mobile application deployed on the worker's smartphone or tablet. The device can be used for standard inventory, communication and other warehouse operations.

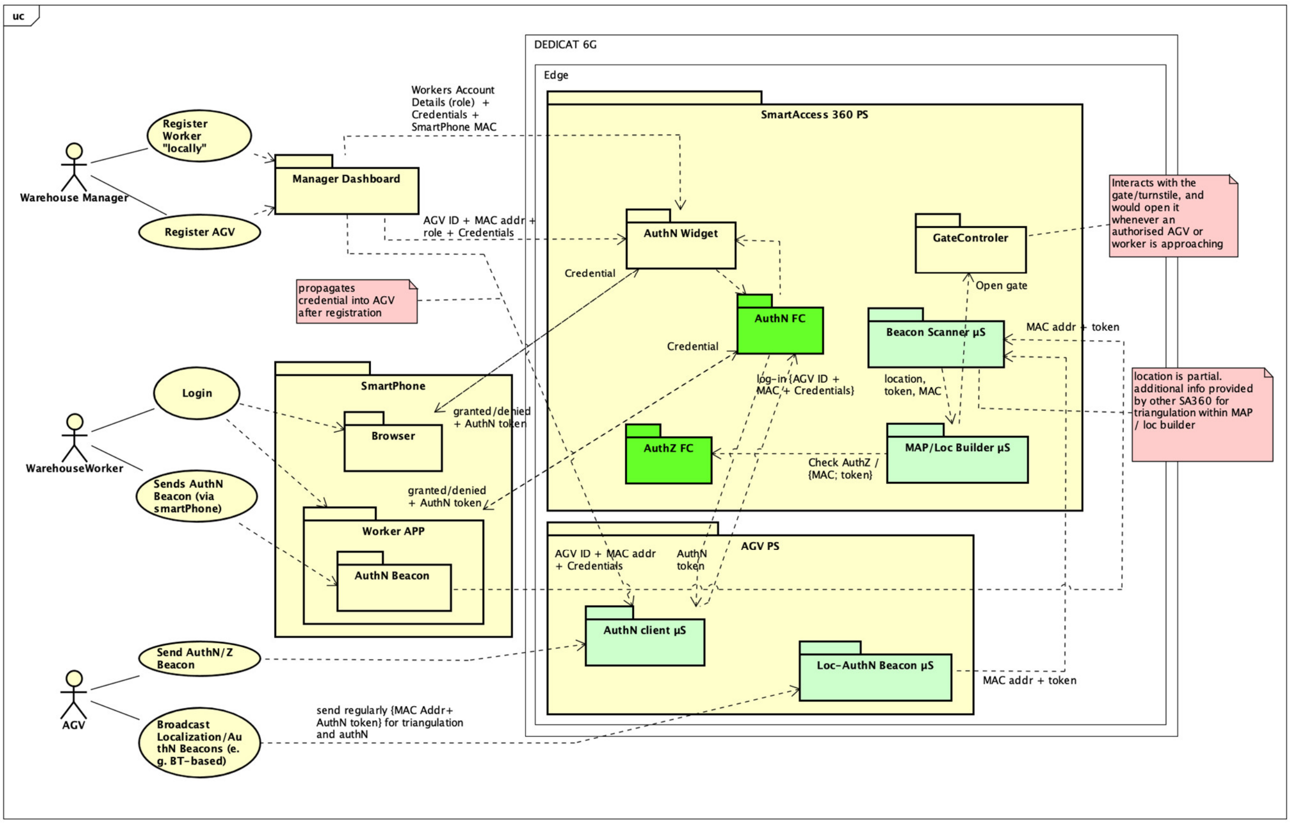

Figure 6: Smart Warehouse worker set-up UML

4.5.4 AGV Management

Figure 7 focuses on pre-operation Worker and AGV task configuration and management. Through the *Manager Dashboard* (bottom left of Figure 7), the warehouse manager can configure:

- daily tasks for the fleet of AGVs including product quality monitoring parameters, interaction rules with warehouse personnel and product offloading/loading schedule;
- daily tasks for workers, which can be accessed via the worker APP (see Figure 8);
- environmental parameters for storing different goods;
- daily safety rules for workers including social distancing and safety zones with configurable geo-fencing zones for different time periods and in line with offloading or loading schedule;
- authorization levels for workers with respect to warehouse areas.

The Manager Dashboard also allows to view the overall status and processes of the warehouse through dedicated cameras, view notifications e.g., on completed tasks, view precise location of key assets, direct personnel or AGVs towards an area of interest or an asset, view

AGV camera feeds, view real time data from the robots such as their status, battery level, availability and other statistical and historical data.

Figure 7 focuses on the configuration of, on the one hand, workers' task schedule and on the other hand, AGVs task schedule plus time/space constraints and rules. The SmartAccess360 hosts the Task/AGV Management (Mngt) µS that in addition to configuring and maintaining a worker's task list, keeps track of a complex AGV task plan that relies on AGV capabilities (named RobotCap µS in the UML diagram). For example a complex AGV task can be "automated quality check" which consists of a robot being able to identify and pick up a product, interact with image analysis and depending on the result transfer the product to the corresponding warehouse area. More detail on how capabilities relate to the AGV Operation FC is available in the following section.

As mentioned, the same component -Task/AGV Mngt µS- is responsible for describing and assigning tasks to both warehouse workers and AGVs

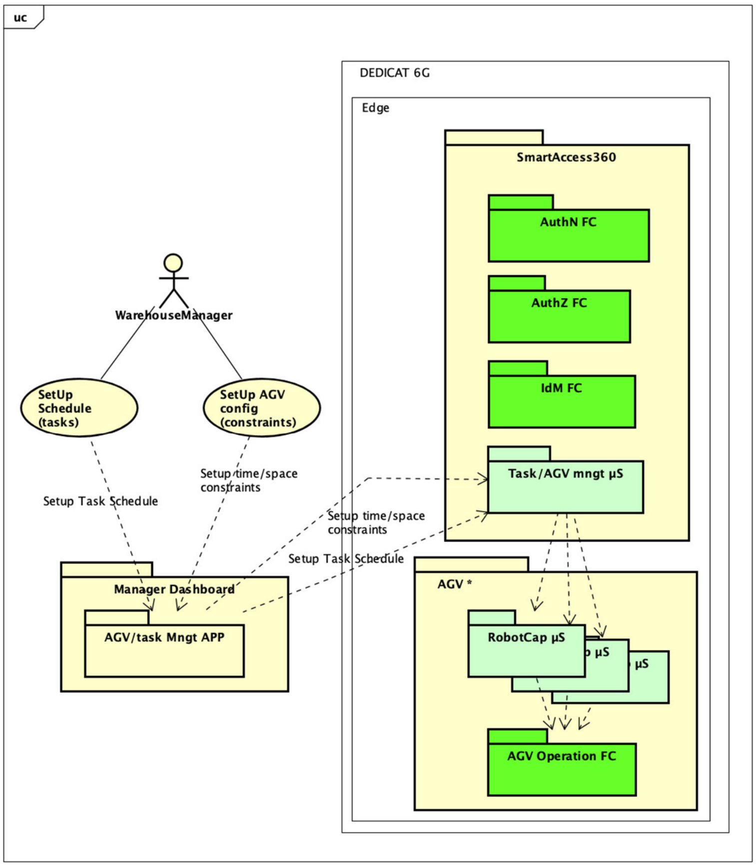

Figure 7: Smart warehouse AGV management UML

4.5.5 Smart Warehouse Worker Workflow

Smart Warehouse worker workflow is presented in Figure 8. The worker in the warehouse utilizes the DEDICAT 6G system in daily tasks, logs in to the mobile app and receives a list of tasks as specified by the warehouse manager from the Task/AGV Mngt µS that centralizes task plan for the AGV and task to-do-lists for the workers. Workers register and (as authorized users) receive tasks and AGV-related notifications.

As it can be seen in the figure, a worker, - navigating his Worker APP- can be notified new tasks (as specified and assigned by the Warehouse manager in previous figure), can access tasks descriptions, can report a task as completed and can also be notified various alerts.

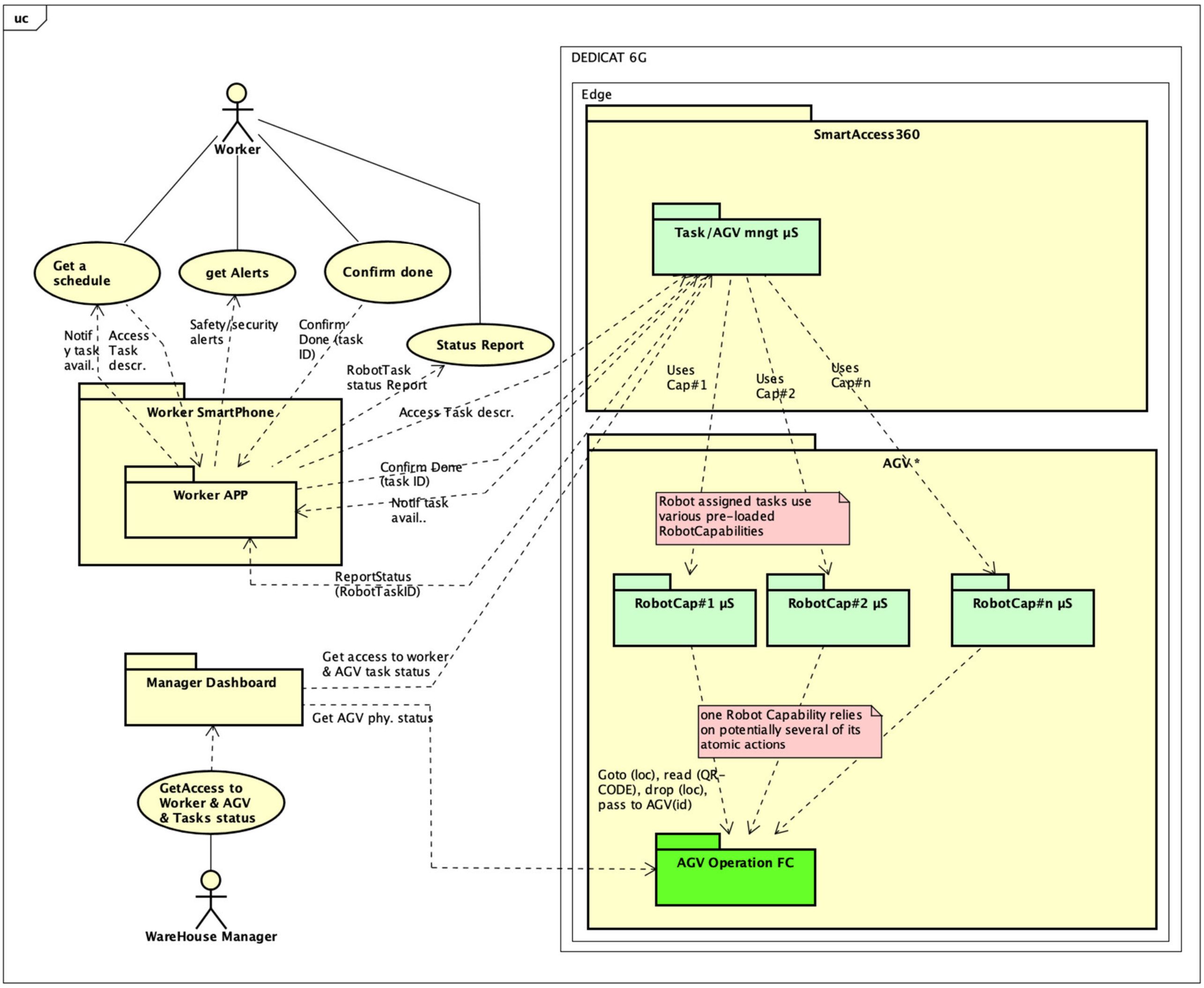

Figure 8: Smart Warehouse worker workflow UML

From the AGV point of view, a task is seen as an "orchestration" of high-level capabilities (RobotCap#i in the following picture). These capabilities exploit the basic actions a robot can perform, e.g., raise a robotic-arm, grasp an object, move to a pre-defined location, identify a parcel based on a QR-code, etc. as provided by the AGV Operation FC.

In order to remain efficient, µS related to an AGV should be executed sat a certain performance level. Would this level drop, the efficiency of the AGV would be jeopardized and would require entering into an Intelligence Distribution scenario, where capabilities need to be transferred to another AGV that would eventually take over the initial AGV for the remaining of its allocated tasks.

Beside these atomic actions an AGV can perform, the AGV Operation FC also provides access to information about the AGV status (Battery level, on/off and deployment-related information) for EN management purpose (like docking for battery charging).

Since an AGV task is monitored and orchestrated end-to-end by the Task / AGV Mngt µS, this component knows whenever a robot task has been either completed successfully, aborted or ongoing. The story is different when it comes to workers' tasks; in that case that µS needs explicit notification from the worker ("Confirm Done" action and arrow) through the worker's APP.

While the worker APP running on the worker's tablet/smartphone is meant to offer the necessary GUI to deal with her daily work (i.e., accomplishing a list of pre-determined/assigned tasks), the Warehouse Manager can check and follow-up on the progress of both workers and AGVs tasks via the Manager Dashboard which communicates directly with the Task/AGV Mngt µS.

The same dashboard is used for other actions like setting tasks up as explained in previous figures. Finally, the manager can also check the physical status of the AGVs (i.e., "get AGV phy. Status" action).

4.5.6 Capability Migration

This last UML diagram (Figure 9) elucidates one case of µS migration from one AGV to another AGV, and more precisely a set of AGV capabilities (#3, #7) from AGV#1 to AGV#6. We do not come back here on the rationale and criteria for such intelligent distribution which is already explained in previous Section 4.5.5.

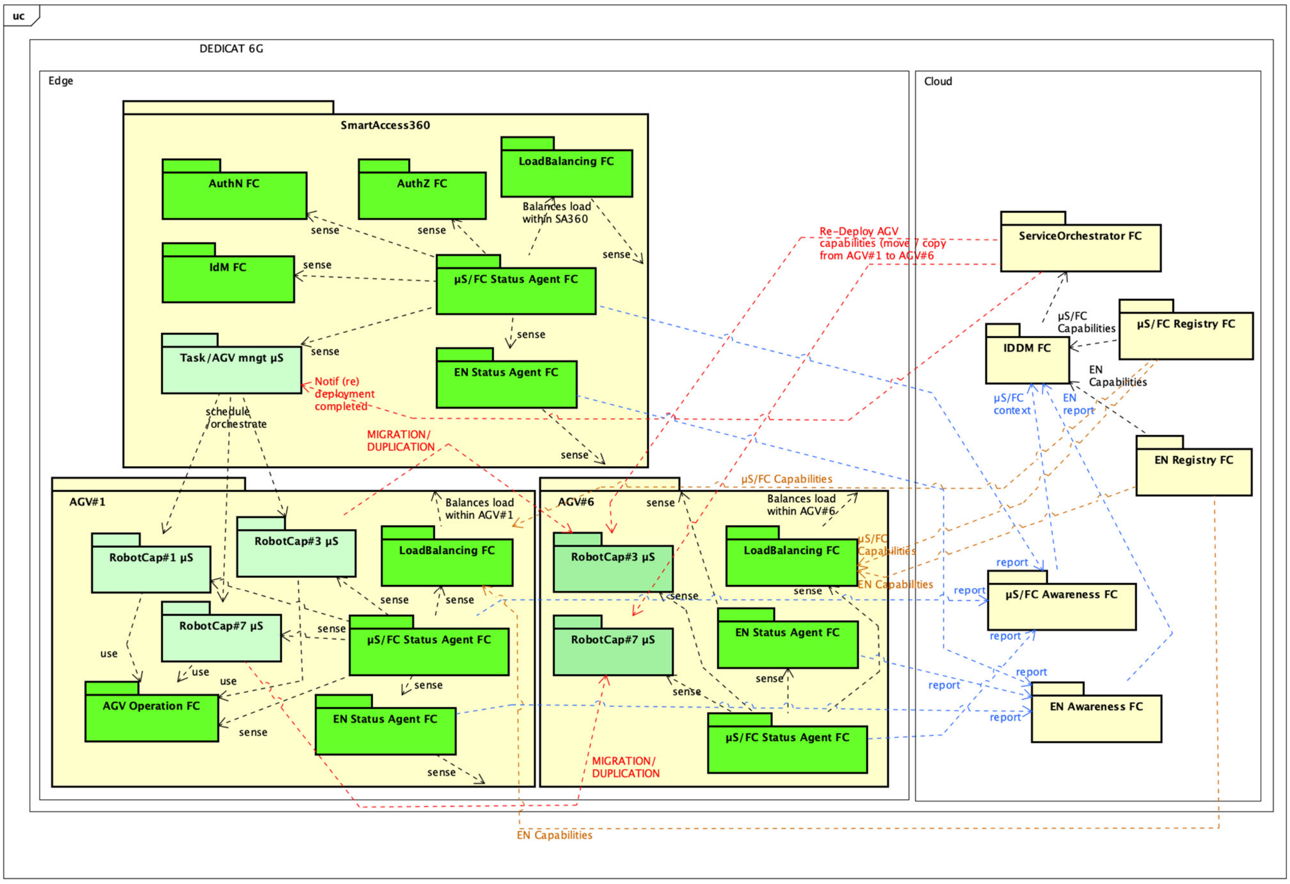

Figure 9: Smart Warehouse Capability Migration UML

Before the actual µS migration can take place, several actions occur in the background: lot of agents and awareness native DEDICAT 6G components are at work, collecting information about the execution status of the deployed FCs and µSs on the one hand and about the Edge Node status (i.e., the AGV) on the other hand.

Based on this information Load Balancing takes place within each Robot (locally to one PS then). It may happen however that the Load Balancing FC alone can't maintain good enough execution performance for some of the embedded µSs resulting in overall degraded AGV operation or overall vertical application (in this case Smart warehousing) performance in terms of latency, energy efficiency and business operation (some of these are captured within specific KPIs).

In that case (and that is what Figure 9 shows) the overall task - as currently assigned to AGV#1 in the Task / AGV Mngt µS - needs being reallocated to another robot, say AGV#6 with the proper set of capabilities needed to accomplish the needed tasks. Which AGV becomes the target of the capability migration is under the responsibility of the IDDM FC. It is to be noted that when deciding to instantiate these two capabilities in AGV#6, the IDDM FC takes into account existing dependencies between the capabilities in order not to disrupt or jeopardize their proper execution in AGV#6. As a result, more µSs than just #3 and #7 may be eventually instantiated in AGV#6. Also, the Task /AGV Mngt µS gets notified about these resulting actions so that replacement of AGV#1 by AGV#6 can be considered for the remaining tasks.

4.6 Requirements

The following two tables, Table 3 and Table 4 respectively, give the list of 1) functional and 2) non-functional (e.g., business or societal) & non-technical requirements pertaining to the Smart Warehouse UC only. As exposed in Section 2, for the sake of clarity, the modified requirements are presented in yellow and the new ones in green colour.

4.6.1 Functional requirements

Table 3: "Smart Warehousing" list of functional requirements

ID	Type	Category	Description	Priority	Rationale	Fit Criterion
1	FREQ	Security	Distributed identity management. Ability to identify and authorize devices/equipment and actors without access to central identity provider.	H	The edge computing system must be able to perform identity and trust management autonomously in emergency situations	Check - Identity provided and verified with and without access to centralized identity provider
2	FREQ	Monitoring	Collecting performance logs from edge computing and communication nodes and systems in the backend. Local edge computing systems must be able to log performance of processes and resource utilization in every operational context.	H	Locally deployed computation and communication systems must be able to perform monitoring of established emergency processes and act on collected information in line with a pre-defined set of rules. Collected data is sent to the central platform for performance analysis and updates for local decision-making models. Exact performance metrics will be defined within the project.	Access and completeness analysis of collected logs.
3	FREQ	Interfacing	DEDICAT 6G mobile app for configuring and utilizing the deployed solution instance. Used by warehouse personnel and management.	H	Mobile app to be developed to support smart warehousing use case. It will be the main interface through which end users interact with the system.	Mobile app published and tested in experimental setups.
4	FREQ	Interfacing	DEDICAT 6G web dashboard for administration of the system instances and monitoring performance metrics of DEDICAT 6G resources and services (metrics to be specified within project)	H	Web dashboard to be provided for administrating the overall DEDICAT 6G system, performance monitoring and maintenance. It can be specialized for specific stakeholders of the project use cases.	Web dashboard available on URL and tested in experimental setups.

5	FREQ	Security	Configurable authorization levels for the deployed DEDICAT 6G systems	H	Accessible functionalities in smart warehousing setup should depend on predefined authorization levels: DEDICAT 6G admin, warehouse manager, warehouse personnel, test user	Configurable authorization levels implemented and tested.
6	FREQ	Replicability	Solution must be replicable to different types of warehouses	H	It is important that processes configured for one smart warehouse can be applied (with minimal reconfigurations) to different warehouse setups. This will ensure high exploitation potential of the solution.	Emulation of a new smart warehouse layout and check the base set of DEDICAT 6G operations in a new context.
7	FREQ	Trustworthiness	Trustworthiness assessment for each device participating in distributed computing and opportunistic networking based on predefined trust metrics as part of the DEDICAT 6G trust management system	H	Devices and services must establish and confirm trust before engaging in data exchange. Trustworthiness will be assessed with trust metrics (for devices, interfaces, users, processes, decisions, etc.) to be implemented within DEDICAT 6G trust management system.	Trust metrics calculated and tested in experimental setups.
8	FREQ	Trustworthiness	Trustworthiness assessment for each process initiated through distributed computing and based on trust metrics defined in the project and use case and implemented within DEDICAT 6G trust management system.	H	Devices and services must establish and confirm trust before engaging in data exchange. Trustworthiness will be assessed with trust metrics (for devices, interfaces, users, processes, decisions etc.) to be implemented within DEDICAT 6G trust management system.	Trust metrics calculated and tested in experimental setups.
9	FREQ	Edge processing	AGV performs edge processing for self-navigation and interaction with personnel and warehouse systems	H	AGV will act as a mobile computing node capable of analysing collected information and making decisions in context of smart warehouse operation and DEDICAT 6G system operation	Software developed and deployed. Data analysis and decision-making algorithms implemented in code as part of AGV firmware/subsystem.
10	FREQ	Edge processing	IoT controllers perform edge processing and decision making for indoor positioning and monitoring of environmental parameters	H	Deployed IoT system should include edge IoT controllers capable of performing data analysis and decision making in context of smart warehouse operation and DEDICAT 6G system operation. Edge IoT controllers will allow smart warehousing operation to be performed with and without support or access to the server side processes.	Software developed and deployed. Data analysis and decision-making algorithms implemented in code as part of IoT controller's firmware/subsystem.

11	FREQ	Edge processing	DEDICAT 6G mobile app performs processing necessary for AR interface	M	DEDICAT 6G mobile app should be able to perform data analysis processes and decision making by using computing and data storage resources of mobile devices (smartphone or tablet) on which it is deployed. This way the AR features can be supported with and without access to centralized services.	Check in experimental setup. Mobile app installed on a mobile device and check that it is capable of performing implemented ML tasks required for AR functionality.
12	FREQ	Communication	AGVs directly exchange information among themselves, with IoT system and personnel mobile devices	H	DEDICAT 6G system must enable flow of data between different participating nodes, within the scope of a smart warehouse, through direct communication channels. This way data from a source (e.g., sensor) can reach its destination in different paths comprising communication channels between different deployed communication and processing nodes. This will ensure uninterrupted services, data exchange and decision-making capabilities performed over locally deployed resources.	Check that data can be sent between any pair of deployed devices (IoT controller, AGV, mobile device, sensor).
13	FREQ	Communication	IoT controllers are able to reach servers/cloud system through auxiliary communication paths	M	If a direct communication channel (wired or wireless) between IoT controller and IoT system server/cloud is disabled or overloaded, the controller should be able to utilize local wireless communication network to reach a node with access to the Internet/cloud services.	Disconnect/ disable primary interface and observe that IoT controller is able to connect with the cloud system.
14	FREQ	Security	On demand incident report	L	The DEDICAT 6G system must be able to provide incident reports or any other report on demand through the web dashboard.	Trigger reporting procedure, receive test report and check its content.
15	FREQ	Security, privacy and trust	Local resources and private data stored in the devices and nodes used for coverage extension and intelligence distribution should be protected.	H	This needs to be enabled so that data obtained from a field node cannot be used in malicious manner.	Check that data in local storage is encrypted with selected method.
16	FREQ	Data - Virtual entity	Digital representation of a warehouse (floor plan, system layout) is supplied to the decision-making system	H	Most of the smart warehousing decision making processes require digital representation of the warehouse context	Process for creating warehouse virtual entity

					(systems, layout, mobility paths, personnel etc.).	implemented and tested through emulations.
17	FREQ	Security, privacy and trust	A device or node shall not be used for dynamic coverage extension or intelligence distribution without the approval of the user/owner/operator of the device/node.	H	Node/resource owners must be able to make decisions about their resources and devices being utilized in local ad-hoc networks with devices belonging to other users.	Approve two out of three nodes and trigger coverage extension or intelligence redistribution and observe which nodes are involved in ad-hoc networks.
18	FREQ	User interface	AR interface for smart warehouse use case for mobile apps	H	Smart warehouse use case scenarios require AR interface for realization of the objectives. This interface will be part of DEDICAT 6G mobile application.	AR interface implemented as part of DEDICAT 6G mobile app and tested in experimental setups.
19	FREQ	Sensing	Environmental sensing system deployed and configured to interface with IoT system	H	It is important to monitor environmental conditions (temperature and humidity) to make sure that product storing requirements are met.	Check that the IoT system collects and transfers sensory readings to DEDICAT 6G AI models and decision-making processes.
20	FREQ	Notification	DEDICAT 6G smart warehousing procedures can send push notifications to managers and personnel	H	Push notifications provide information on daily tasks, alerts and status of the DEDICAT 6G resources.	Check that push notifications are delivered to DEDICAT 6G mobile application
21	FREQ	Safety	Configurable safety zones and parameters	H	IoT system needs to support configurable safety zones through web dashboard interface where digitalized warehouse layout is provided. These zones need to be configured by warehouse manager in line with operating context (e.g., offloading of dangerous products).	DEDICAT 6G web dashboard provides interface for safety zone configuration. IoT system monitors location/movement of mobile assets and personnel and sends triggers when a mobile asset or personnel member enters safety zone.
22	FREQ	Machine learning	High precision indoor positioning performed with edge computing and utilizing fixed, mobile nodes and BLE beacons	H	The indoor positioning will be used for tracking mobile assets and for triggering safety rules based on proximity of tracked assets and personnel.	DEDICAT 6G web dashboard displays precise location of tracked assets and personnel and their BLE beacons on the warehouse layout. Location precision is in a radius of 1 meter.
23	FREQ	Machine learning	AGV route adapts to changes in warehouse layout	M	AGVs need to adapt to changes in warehouse layout as result of offloading and	Set mobility route (point A to point B) for AGV, put

					placement of products – dynamic obstacles.	obstacle on the route and monitor AGV ability to reach destination without manual reconfiguration.
24	FREQ	Machine learning	Decision making based on monitored environmental parameters (temperature, humidity)	M	DEDICAT 6G system needs to be able to provide decisions/alerts/ notifications based on results of analysis of collected environmental sensor readings.	Emulate sensory data out of predefined range and observe decision making algorithms result in triggering event.
25	FREQ	Networking/ Machine learning	Decision making for coverage extension	H	DEDICAT 6G system must run algorithms for coverage extension decision making in order to enable uninterrupted access to key resources and services by all participating nodes and with specific focus on mobile nodes like AGVs.	Move AGV in warehouse area without fixed wireless network (the main network used within warehouse) coverage and observe other communication nodes establish communication link towards the AGV. AGV maintains access to core services.
26	FREQ	Coverage/networking	The system shall be able to make decisions on the creation, reconfiguration and termination of an ad hoc coverage extension network.	H	DEDICAT 6G system in smart warehousing scenario must be able to automatically decide on creation, update and termination of ad-hoc networks for coverage extension and for auxiliary communication paths for critical system elements.	Check based on experimental setup. We need a project-level fit criterion for this requirement.
27	FREQ	Load balancing	The system shall be able to make decisions on how intelligence should be distributed among nodes	H	DEDICAT 6G system in smart warehousing setup must be able to decide when it is required to perform distribution of intelligence processes (AI/DA/ML), which nodes should be used, which functions should be distributed to which nodes, etc.	Check based on experimental setup. We need a project-level fit criterion for this requirement.
28	FREQ	Security, privacy, trust	Communication between all nodes shall be realized in a secure and trusted manner.	H	Data protection must follow best practice standards in communication channel encryption.	Check based on experimental setup. We need project-level fit criterion for this requirement.
29	FREQ	Remote management	AGVs can be shut down remotely	M	Warehouse managers need to be able to remotely shut down AGV in case it is faulty in any way or in case energy needs to be reserved.	Trigger AGV shutdown through web dashboard and observe AGV ceasing all operation.

30	FREQ	Coverage/Net-working	AGVs/Robots, Drones and other devices should be able to communicate with each other and with the "central" net-work infrastructure.	H	This is required for setting up an ad hoc network where an AGV/robot or drone may be playing the role of a mobile ac-cess point (MAP).	Check data propagation between end points (ping messages between points).
31	FREQ	Coverage/Net-working	Relaying shall be supported by central nodes or by edge nodes.	M	This will allow forwarding of data and con-trol signalling in the scope of dynamic coverage extension through an ad hoc network.	Move AGV in area without fixed wireless network (the main network used within warehouse) coverage and observe other communica-tion nodes establish com-munication link towards the AGV. AGV maintains access to core services.
32	FREQ	Coverage/net-working	It shall be possible to identify the need for a dynamic coverage extension.	H	DEDICAT 6G system in context of smart warehousing needs to be capable of identifying coverage extension needs and opportunities while relying on AGVs and deployed IoT system.	Check that trigger is properly recognized. We need project level fit-crite-rion for identifying the need for coverage extension.
33	FREQ	Coverage/Net-working/ Load balancing	It shall be possible to identify the need for (re-)distribution of intelligence.	H	DEDICAT 6G system in context of smart warehousing needs to be capable of identifying (re)distributed intelligence needs and opportunities while relying on AGVs, mobile devices with DEDICAT 6G app and deployed IoT controllers.	Check that trigger is properly recognized. We need project level fit-crite-rion for identifying the need for redistribution of intelli-gence.
34	FREQ	Coverage/Net-working	Device and infrastructure capable of set-ting up a connection	H	A device in an ad hoc coverage exten-sion network shall be able to set up a con-nection with the central infrastructure. The infrastructure shall be able to trigger a de-vice in an ad hoc coverage extension network to set up a connection.	Check that a device in an ad-hoc network can ping the central infrastructure. Check that the infrastruc-ture can trigger the device to set up a connection with other devices.
35	FREQ	Coverage/net-working	More than one coverage extension net-works shall be supported at the same time.	H	Different ad-hoc networks established across shared nodes and in close vicinity must minimize mutual interference and share resources.	Setup two ad-hoc networks and monitor communica-tion performance metrics (delay, packet drop rate, throughput).

36	FREQ	Load balancing	It shall be possible to dynamically distribute computation between central and edge nodes	H	Intelligence can be distributed across central and edge nodes based on the needs of the operational context.	Check that process for data analysis can run on central and at least two edge nodes in a federated manner.
37	FREQ	Coverage/Networking Load balancing	The system shall be context aware.	H	The system shall be able to obtain information on application, service and network goals and objectives to be achieved, as well as potential policies. The system shall be able to obtain information on capabilities of network elements, MAPs and edge devices in terms of communication networking (e.g., *Radio Access Technologies* (RATs) and spectrum, capacity, and coverage), physical movement, the type of the MAP, computation capabilities, storage capabilities and available power. The system should maintain information and knowledge on the context that has to be addressed in terms of computation tasks, power consumption requirements, a set of mobile nodes that need coverage, mobility and traffic profiles of the different nodes, radio quality experienced by client nodes, options for connecting to wide area networks, the locations of docking and charging stations for drone and robot MAPs and the current locations of the terminals and MAPs' elements.	Check based on defined experiments. Check that the system is able to infer the current system context/situation.
38	NFREQ	Usability	The user perceived quality of service/quality of experience shall not be negatively affected by the dynamic coverage extension and intelligence distribution.	H	The coverage extensions and distributed intelligence must improve or maintain perceived QoE and QoS in order to justify the creation of ad-hoc opportunistic systems.	We need project level fit criterion for user QoS and QoE assessment

4.6.2 Non-functional and non-technical requirements

Table 4: "Smart Warehousing" list of non-functional and non-technical requirements

ID	Type	Category	Description	Priority	Rationale	Fit Criterion
1	NFREQ	Interoperability	New resources and systems can be configured to interoperate with the deployed DEDICAT 6G resources	M	Deployed DEDICAT 6G smart warehousing solution should be scalable in a sense that additional systems and resources can be integrated and made interoperable.	Emulate addition of a new IoT system and test interoperability.
2	NFREQ	Safety	Ensure wellbeing of personnel through environmental monitoring	M	Warehouses bring certain risks for personnel wellbeing because of dangerous goods, strict environmental conditions under which goods need to be stored (e.g., freezing temperature or low humidity) and especially in context of COVID-19 pandemic it might be challenging to maintain social distancing. DEDICAT 6G AI systems can help to minimize risks associated with personnel wellbeing by providing alerts if danger/safety risk is identified.	Emulation of risk/dangerous situations by putting data values outside defined ranges and observing that DEDICAT 6G system performs predefined actions – sends alerts and notifications.
3	NFREQ	Productivity	Efficient training of personnel using AR tools	H	DEDICAT 6G system should support realization of advanced AR interfaces as part of mobile application. AR must help personnel to speed the learning curve (learn warehouse layout, processes and rules). Trainers and managers can provide points of interest for trainees through the AR interface.	Check AR performance and acceptance with warehouse personnel. Assess ease of use and collect feedback. It is important that usage of AR does not interfere with the overall safety of the personnel.
4	NFREQ	Efficiency	Warehouse automation improves energy efficiency	M	Certain automation processes might result in improved energy efficiency. Lights can be turned off in an area of the warehouse without personnel. AGVs can operate in conditions which are less energy demanding (in dark, sub-optimal temperature etc.).	Assess with warehouse operator which processes can be subject to energy saving and under what conditions AGVs can be left to work without on-site supervision. This strategy can be translated into monthly energy bill reduction by assessing current energy

						consumption of employed resources.
5	NFREQ	Cost reduction	Edge computing offloads server processes and reduces cloud costs	L	Cloud/server capacities can be lowered if most of the procedures are performed on the edge. Cloud can be responsible for data storing and strategic decision making.	Compare processing tasks performed on the cloud/central server with and without processing on edge devices like IoT controller and AGVs.
6	NFREQ	Cost reduction	Reduce internet bandwidth consumption	L	Edge computing reduces internet bandwidth usage since most data are analysed locally.	Check internet bandwidth usage of outbound channel with and without edge processing.
7	NFREQ	Cost reduction	Management of multiple warehouses through one control center	M	Remote AGV and IoT system monitoring and management in real time must be supported from the central management office in order to ensure cost effective management of multiple warehouses. It can also create opportunities for outsourcing smart warehouse management to specialized 3rd parties.	Emulating multiple warehouses.
8	NFREQ	Networking	Remote access to deployed DEDICAT 6G resources and equipment must be enabled	H	Warehouse managers must be able to manage deployed resources (AGVs, IoT system) remotely with minimal latency.	Warehouse manager sends command (e.g., make sound signal) to AGV through web dashboard accessed over Internet. Warehouse manager can trigger onboard relays of IoT controllers remotely – door opens.
9	NFREQ	Scalability	The system should work with other models of AGVs and IoT equipment	L	It should be enabled that DEDICAT 6G system can with minimal adaptations include 3rd party AGVs and IoT systems to be on-board. These new systems will have to host DEDICAT 6G logic.	We would need 3rd party open platform devices to test this portability.
10	NFREQ	Ethical	The system shall follow appropriate health and safety procedures conforming to relevant local/national/EU guidelines/legislation in order to protect the environment and people.	H	Health and safety procedures need to be translated into system automation and decision-making processes provided by DEDICAT 6G system.	Translate selected regulations into a specific set of automation and decision-making rules. Confirm completeness.

11	NFREQ	Ethical	The system should keep a log of places, moments and trajectories where personal data is compiled, transferred, stored, deleted, anonymized (or pseudonymized) or processed in any other way.	M	This is important for privacy and data protection audits that can be requested by the warehouse manager or regulatory bodies.	Setup logging procedure, generate logs and check their completeness in different experimental setups.
12	NFREQ	Business	Labour optimization through reduction of warehouse personnel moving within the warehouse	M	The system will rely on AGVs and IoT systems to minimize the need for personnel to have to walk to certain areas in order to check the status of a process/key asset.	Enable step count app (can be 3rd party) on personnel mobile devices and compare step counts with and without DEDICAT 6G solution
13	NFREQ	Business	Productivity increase through automation of picking/packing operations	H	DEDICAT 6G smart warehousing resources will automate the product handling operations – AGVs will be able to move products and perform quality inspection with camera and other sensors.	Check that AGV is able to perform package handling operation with experimental setup.
14	NFREQ	Interfacing/Interoperability	DEDICAT 6G should be able to interface with selected systems already deployed in locations where use cases are realized	M	Interfacing can be done through existing APIs, control points, databases etc. Interoperability with key services and resources already deployed in a warehouse is needed.	Integration completed and tested with message exchanges between end points.
15	NFREQ	Replicability	Solution can be deployed and configured for different types of warehouses	H	It is important that solutions developed for one smart warehouse deployment can be applied to other smart warehouses with minimum re-configurations.	Emulating different smart warehouse setups and monitoring system performance
16	NFREQ	Privacy	Privacy sensitive information from personnel must be anonymized when stored and processed	H	Privacy protection must be ensured with best practice approaches for anonymization of identifiable personal information when transferred and stored.	Check data collected at source (personal data) and check data when stored in database – confirm that data is anonymized.
17	NFREQ	Data protection	Business sensitive data should not be stored outside of smart warehouse logical perimeter	M	Warehouse managers can select data that need to remain within warehouse logical perimeter and not transferred to 3rd parties.	Check that data is stored only in the local database.
18	NFREQ	Usability	End-users shall not be involved in the processes for dynamic coverage extension,	H	The system complexity should be hidden from the user.	Check that coverage extension and intelligence redistribution is performed

			intelligence distribution and security, privacy and trust assurance.			automatically without user intervention and that these processes are transparent to the user.
19	NFREQ	Usability	The user perceived quality of service/quality of experience shall not be negatively affected by the dynamic coverage extension and intelligence distribution.	H	The coverage extensions and distributed intelligence must improve or maintain perceived QoE and QoS in order to justify creation of ad-hoc opportunistic systems.	We need project level fit criterion for user QoS and QoE assessment

5 "Enhanced Experience" (UC2)

The Enhanced Experience use case focuses on live public events that are characterized by a dense number of local users (participants) as well as remote participants enabling virtual attendance. In such a use case, the underlying mobile network will be stressed by the users accessing their devices and even through live streaming from the site [7] [8]. As a consequence, a large audience is vying for the same network resources within a small area [9]. In addition, large crowds would move from one venue to another depending on the time and places (e.g., multiple stages attract varying sizes of audience). In this case, dynamic network coverage is needed to provide increased seamless connectivity [10], [11]. The DEDICAT 6G solution for Enhanced Experience focuses on these issues and strives to provide richer quality of experience to local spectators as well as delivering enhanced live experience to remote users using B5G/6G networking.

5.1 Use case objectives and relation to project objectives

The scenario objective precisely follows most of the project objectives #1, #2, #4, #5, #6, #7. The aim is to develop adaptive, dynamic solutions for human-centric applications that are not only efficient in terms of energy and time, but also enhance the experienced quality of service. A solution for dynamic distributed edge intelligence will be provided in order to improve task execution time and response to B5G/6G support for innovative, low-latency applications. Improved coverage will have dynamic expansion for people anywhere, anytime for enhanced real-time experiences. Furthermore, human-centric user applications between humans and digital systems will showcase the novel interaction developed in DEDICAT 6G. The showcases and demonstrations in real operational environments will emphasize the value and novelty of the Enhanced Experience UC.

5.2 General context and set-up

5.2.1 Overview

Public mass events tend to have a large audience with different roles. We consider the selected on-site users, who are vying for the same mobile network resources amongst other local users using the network for their tasks. The other users in the audience are considered as mobile traffic generators.

5.2.2 Actors involved

- On-site users (audience): The selected users who have access to DEDICAT 6G solutions and / or platform. These users have sophisticated B5G devices accessing the privileged modes on the network infrastructure. These users can also have the opportunity to use enhanced smart video streaming applications and smart glasses;
- Remote users: These users are located out of the event area; in homes, parks, or other remote places with access to mobile networks. They could have virtual participation with improved quality of experience. They possess DEDICAT 6G software for the video playback application;
- Event organizers: Their role is to provide access for the DEDICAT 6G group for the area, permission to perform experiments, and to provide multimedia content.

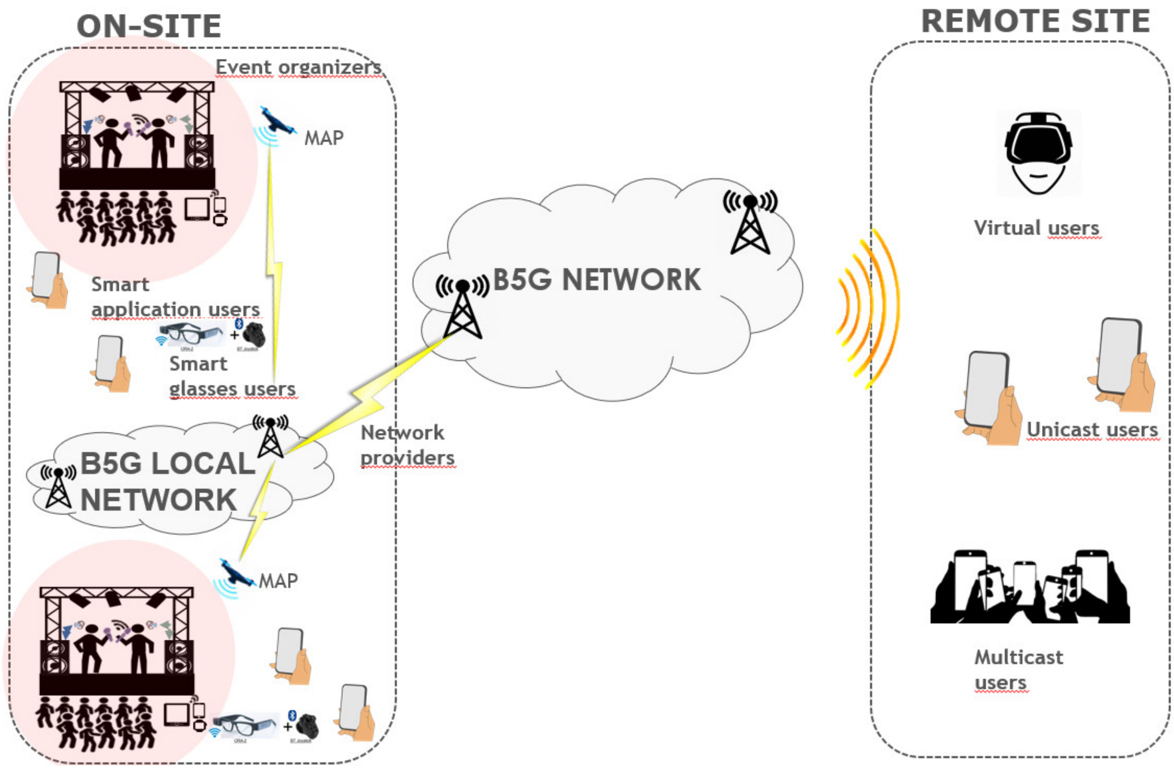

Figure 10: The set-up in the Enhance Experience use case.

5.2.3 Set-up plan

The site set-up includes ultra-high-definition video cameras, mobile devices, smart glasses and a B5G capable mobile network. The hidden network infrastructure contains dynamic intelligence implemented via enhanced AI algorithms, routing, and computation processing. In addition, *Mobile Access Points* (MAPs) are included to provide dynamic coverage.

5.3 Pre-requisites and Assumptions

- Mobile communication B5G network supports the technology developed in DEDICAT 6G (e.g., multicast support, smart glasses connectivity);
- The live streaming supports streaming over *Network Address Translations (NATs)*;
- Local users are equipped with mobile devices with the selected video streaming software and B5G mobile connectivity. The selected users can also be equipped with smart glasses and / or smart applications for enhanced experience and easier navigation;
- Remote users are equipped with mobile devices (smartphones or tablets) with the middleware and application enabled to receive unicast or multicast streams.

5.4 Stories

The three stories planned for the Enhanced Experience use case take place in two locations: On-site (public venue such as music concert) and in a remote location (user's home etc.) considered as a means for virtual participation. The stories focus on providing a more efficient DEDICAT 6G technology for on-site participants as well as narrowing the border between physical and virtual presence for such public events. To be precise, Story 1 concentrates on improving the on-site experience, Story 2 enhances the virtual experience remotely and Story 3 combines the previous stories a via live service for remote users.

5.4.1 Story 1: On-site participant at public event

This story takes place in a public organized event, which can be a music concert, sports event, etc. In this story we take the music concert as an example.

Short description

"You are participating in a live public event, such as a live music concert with multiple stages, and you are glancing at the event brochure thinking about which artist to see next. Suddenly your mobile phone alerts you and you receive a live video stream from your friend who has found a great position close to the stage of the artist you are also interested in. You begin the navigation according to the stream and find yourself quickly with your friend to watch your favourite band. After a while, you remember that some of your friends are not participating in the concert at all, and you decide to invite your friends. Since you are connected to a smart mobile network cell, which is enabled with the sophisticated DEDICAT 6G technology, you can easily launch a mobile video streaming service with your modern smartphone and high-definition camera even if there is a number of other mobile users competing for the same network resources."

"From the brochure, you find that each event is scheduled on a different stage. Viewing the event-stage mapping information, you can move to the target stage and find places to watch the event. Since the network adopting the DEDICAT 6G technology will provide dynamic coverage for connectivity extension, you can connect to the network to share/send video streaming content from anywhere in the event venue."

Story line

1. Local user X notifies local user Y of an interesting artist starting the performance via notification, text message, or direct link within the dedicated application;
2. Local user Y accesses the link via a dedicated software application using the existing B5G mobile network connection;
3. Local user Y can navigate to X by using the stream as a guide;
4. Local user X / Y launches live streaming from the dedicated software application visible to remote users. It can be either a private unicast access link or a broadcast stream;
5. Imperceptible to the remote user Y, smart edge processing and caching is taking place in the network via dedicated algorithms;
6. Local user X can move to at different stage and can access the network for video streaming data transmission;
7. Imperceptible to local user X, network connectivity between MAPs and users is established dynamically via intelligent algorithms.

5.4.2 Story 2: Remote participant for online streaming

This story takes place in a user's home premises, but it can also be located outside a live event area.

Short description

"You are staying at home when your friend contacts you via mobile and live streams real-time video from a concert. You live through an enhanced remote experience as if you were amongst the members in the audience by using virtual presence through VR glasses. At some point you receive another stream notification from the event organizers, which is yet another access link to a live stream from the concert."

Thus, the high-quality content from static cameras is distributed to a large audience for virtual participation in the event. COVID-19 is an excellent example of such a use case, where the event organizers are not necessarily postponing the event, but instead are live streaming the performances to paid users.

Story line

1. User X provides the access to a live video stream from the concert to remote user Y's mobile phone. It can be e.g., a notification, txt message or direct link via a dedicated application;
2. Remote user Y accesses the link via a mobile device using his mobile B5G connection. User Y is location independent;
3. Remote user Y can switch from one stream to another within the app in order to have the ability to experience varying viewing angles e.g., from different concert stages;
4. Imperceptible to remote user Y, smart edge processing and caching is taking place in the network via dedicated algorithms.

5.4.3 Story 3: "Massive" Video streaming on Facebook Live

This story takes place in the user's home premises, but it can also be located outside a live event area.

Short description

This story takes place during a concert in an area (stadium, concert park, etc.) where the concert attendees gather and enjoy the shows (different scenes feature various bands and music styles). Then they engage in live streaming activities. Two actors are involved: the main actor –say user X- is a music concert enthusiast who attends a concert, and the second (category of) actor is one of X's FaceBook™ live followers. A so-called Connected Car has been deployed at the beginning of the concert in order to increase radio capacity as the event is expected to be the first massive Facebook Live event over 6G.

Story line

1. User X sets up a Facebook Live on FaceBook and offers live streaming from the event he is attending. Doing so, he is aligned with the public streaming rules from the concert organizer;
2. Using his last generation Android™[2] smartphone, he easily set a private Wi-Fi hotspot up;
3. X then connects his SmartGlass to his Android phone. Doing so, he can use the embedded camera of his SmartGlass in order to live stream what he sees and listens to from the concert (a.k.a. WYSIWIS); Maximum resolution is chosen so that the Facebook Live followers can enjoy an enhanced high-quality and smooth (near-zero latency) video streaming experience;

[2] Android is a trademark of Google LLC.

4. In order to increase the radio capacity, a connected car is provisioned by the Event Organizer when negotiating and setting-up the Coverage Extension service with DEDICAT 6G;
5. The concerts starts and despite the pouring rain, tens of people, just like X, start video streaming to their own Facebook Live account. As a group they are able to cover the totality of the featured bands simultaneously and offer a unique experience to their followers;
6. On the other side of the Internet, thousands of followers can enjoy a one-of-a-kind experience of high resolution "multi-stage" video streaming, on the HD TV in the comfort of their homes.

5.5 Relation to the functional decomposition

The Enhanced Experience use case (briefly UC2) identified several actors with their main actions in D2.2 [2], which are now refined in this section with their relation to FCs. The rough division for actions is done between the actions comprising the necessary deployment set-up basically to DEDICAT 6G platform and actions performed by the use case attendees in the actual event. The first one contains pre-actions that are necessary to be done before the dedicated use case related actions are launched.

5.5.1 Service set-up

Figure 11 presents how the event organizer can initiate a Coverage Extension service request towards the DEDICAT 6G platform and provide all needed material for its implementation. The interactions between the Event organizer (registration, login, service set-up, uploads, etc.) and the platform are covered by the Dashboard FC through its GUI.

First the organizer registers into the platform by providing the account details including email address and name against the set username and password, which follows the normal user authentication procedure into the platform in the login phase.

AuthN FC (authentication) as a background process in the platform handles this action, relayed by the Dashboard FC. In the UC2 it is essential to request CE in the area where mobile users are vying from the network resources and are possibly in the limitations of signal reception. Since UC2 is targeting public events such as outdoor concerts, limitations for MAP usage exists i.e., drones are not allowed to fly over the area. This means that coverage extension will be ensured through the deployment of a terrestrial i.e., a Connected Car.

Such a CEaaS request comes with some essential request parameters: event site coordinates (GPS) used for Connected Car deployment, QoS level for each UE, and capacity in terms of the number of users. Furthermore, the µSs description to be deployed in the platform as well as deployment policy (which can be empty) is also informed to the system, because they are important criteria to be taken into by the CEDM FC and IDDM FC during the DM process.

When the negotiation phase has been successfully completed further steps are achieved as explain in Section 3: the deployable µS images together with their descriptions are uploaded to the DEDICAT 6G service repository (respectively µS/FC Repository FC and µS/FC Registry FC) alongside the possible policy for further deployment and load balancing purposes (EC Policy Repository FC). The DEDICAT 6G functionality and description of the CEDM & IDDM co-operation is explained at the beginning of Section 3 as it is part of the common approach.

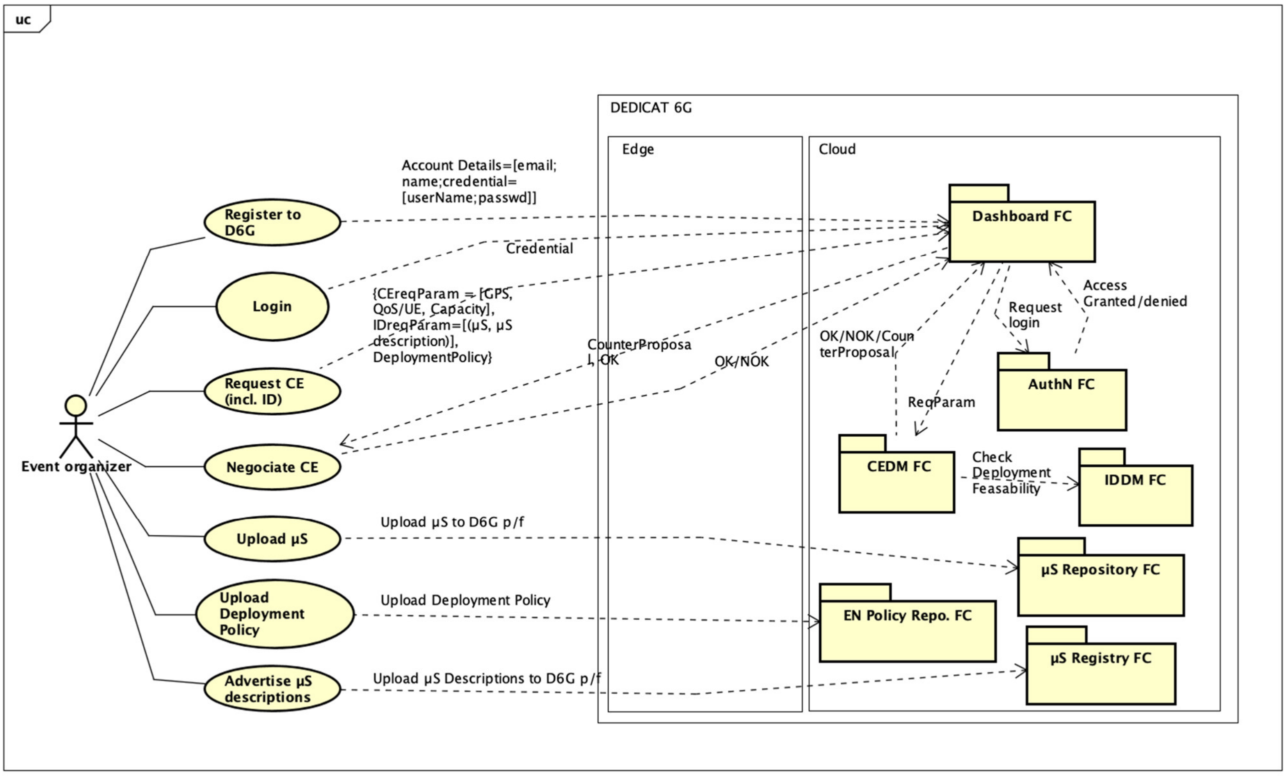

Figure 11: Enhanced Experience CE Management set-up UML

5.5.2 Deployment setup

Figure 12 presents the application deployment where needed FCs and μSs are actually deployed at the edge within the different PSs (Connected Cars). The deployment is initiated by the IDDM FC which instructs the Service Orchestrator FC to deploy the needed FCs and μSs according to the optimal Task/Edge node allocation that results from the IDDM decision making process. Whenever more than one Connected Car are deployed on site, the various FCs and μSs will be spread among them according to that Task/Edge node allocation.

Going a bit more in the detail of UC2 μSs, Enhanced Experience deploys two main components into the edge: mobile multicast service (namely as Multicast/Unicast) and video streaming service (Video Streaming p/f). These can be located either in a dedicated edge/MEC or as a distributed architecture where the services are decentralized to different physical edge locations e.g., for decreasing the service latency (improving QoS, bringing service closer to end users).

Multicast service comprises two components, the actual mobile multicast streamer (Multicast/Broadcast) and the service controller responsible for selecting either mobile unicast or multicast channel for the delivery e.g., according to the number of online users. Video streaming service contains the origin database for live streams as well as video transcoder, which can conduct multiple representations of the same stream for unique client devices.

As depicted earlier at the beginning of Section 3, the Service Orchestrator also deploys and keeps track of these services by updating the edge node and μS/FC repositories regarding their status of deployment.

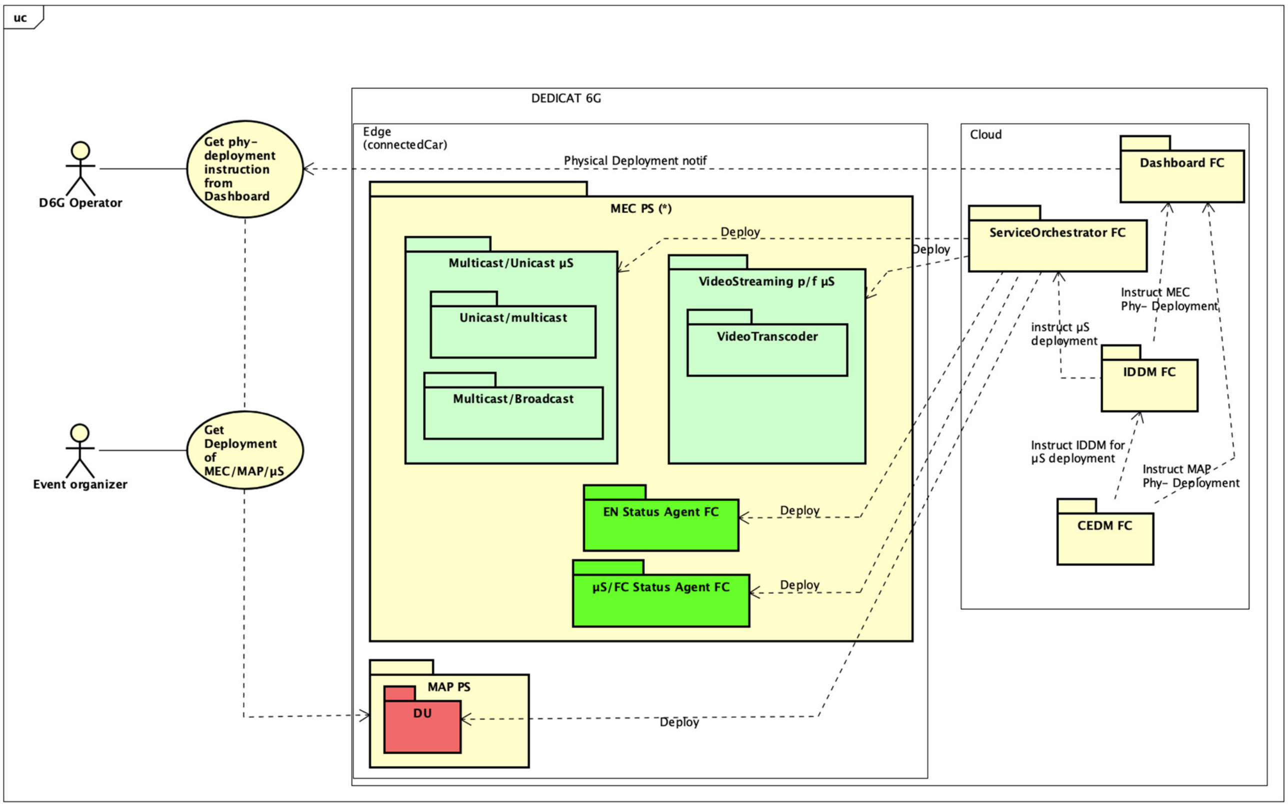

Figure 12: Enhanced Experience application deployment UML

5.5.3 Event participant - actor interactions

Next, we proceed to run-time actions and functionalities invoked by the users of the Enhanced Experience use case. As depicted in Figure 13, in this use case the event attendee can play either role as content producer or consumer. Here, the event attendee's role refers to the on-site users defined in Section 5.2.2. First, we take a look at the producer role in which the attendee possesses either Smart Glasses, Smartphone, or both. We concentrate primarily on using mobile B5G networking for delivering the live content into MEC for a wider video audience. Smart Glasses rely on mobile Wi-Fi hotspot for the network connection, which is initialized by its user during the configuration phase and then paired between the Smartphone and Smart Glasses. WPA2 authentication will be used for protecting the dedicated hotspot connection from other users. In the configuration phase, the video parameters (e.g., bitrate, resolution) according to the QoS (possible network limitations)/QoE (user exceptions) requirements are set.

Once the configuration is done the attendee can start "live" streaming to the edge/MEC server either by using direct connection from the Smart Glasses (via the network connection of the SmartPhone) or from the SmartPhone app. The next node in the streaming path is a Video Streaming platform, which can be a dedicated microservice in the edge/MEC or a third-party legacy system Facebook Live. Either way, the fundamental functions of both platforms are to transcode the video stream ensuring it becomes suitable for different end devices and available for content distribution.

As mentioned in earlier sub-section, the dedicated MEC services will be selected through decision making components in order to gain the most suitable PS location that optimizes the selected KPIs (e.g., latency, energy efficiency).

The *Distribution Unit (DU)* is connected both to UE devices as well as to edge/MEC platform for providing the B5G connectivity. The Video Streaming platform is feeding also the content for the mobile Multicast service, which currently requires stream-specific parameters in order to have correct timing and scheduling for the actual service. The multicast service alongside the multicast controller will interconnect with the DU in the MAP and schedule the service either via unicast or multicast depending on the number of users as well as service availability. These parameters are gained from the Network Performance Analytics FC, which on the other hand will feed the visualization unit. Naturally, Logging FC will handle and output the logs from the micro services so that performance metrics can be inferred.

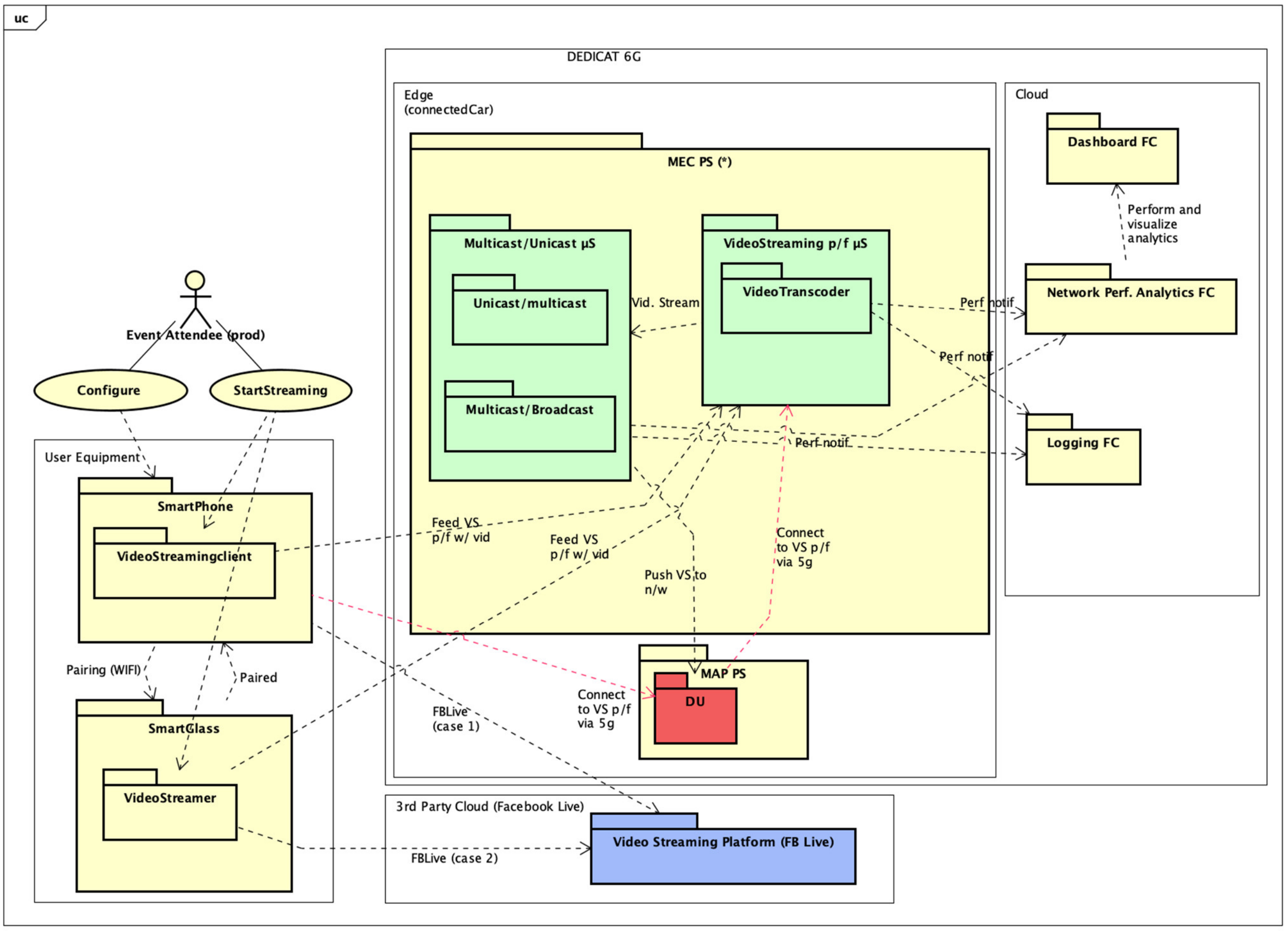

Figure 13: Local attendee – user interactions for content production UML

The next UML diagram, Figure 14, represents a similar diagram as Figure 13, but focuses now on the content consumption role. In this diagram the role of Event Attendee assumes both on-site and remote users. Video players are playing a key role in this scenario. First the user, who can be located physically in the event area or at a remote location such as at home, needs first to agree to the terms of service before accessing the playback service. Two aspects are valid: generally, the user must accept the terms of using playback application, as well as allow push notifications to the device. These notifications originate from the video service platforms as well as multicast service for announcing live content is available. Similarly, as in Figure 13, the SmartPhone and multicast services are connected to the DU.

After the user launches the video playback either from the advertised link or from the secured URL, Network Performance Analytics FC retrieves the information statistics of the connected client alongside the essential network KPIs.

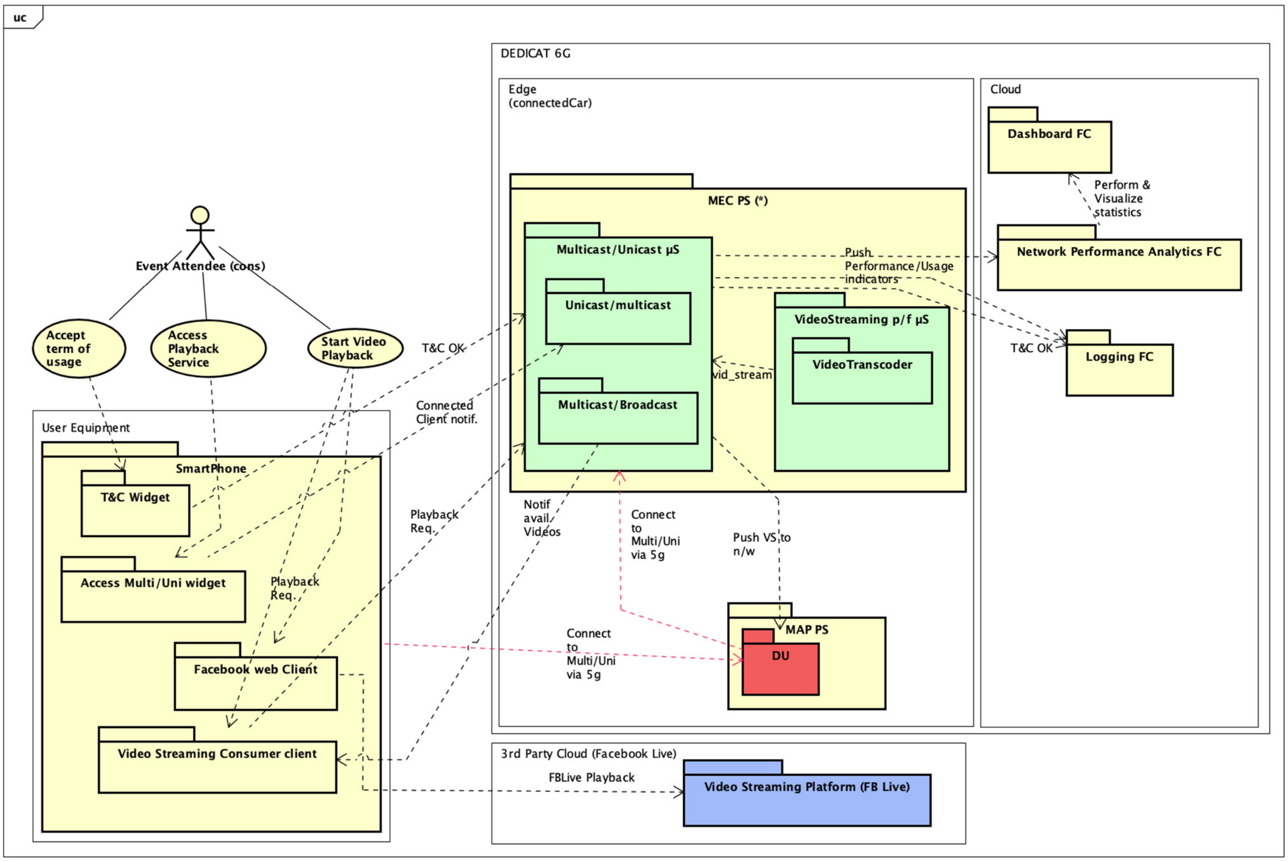

Figure 14: Local and remote attendee – user interactions for content consumption UML

5.5.4 Load Balancing Scenario

Figure 15 illustrates a scenario of Load Balancing relying on IDDM FC (for the decision part) and the Service Orchestrator FC (for the decision implementation part). This is done basically in the background in DEDICAT 6G, beyond the reach of the event organizers. The Load Balancing functionality is important in this use case since it can distribute the load more evenly, or even precisely for specific MEC servers capable of processing the heavy computing tasks. In order to relocate or scale a specific µS or FC up, the IDDM FC needs a precise picture of both Edge Node and running µSs and FCs. This information is provided by µS/FC status agent FC and EN status agents FC that aim at collecting performance and resource usage indicators. In our use case, the Video Transcoder is a typical µS which can be placed (migrated/duplicated, even virtually) to different locations depending on the need. Such offloading can decrease the load from the nearby MECs towards the edge closer to users, which on the other hand, can even decrease the downlink latency.

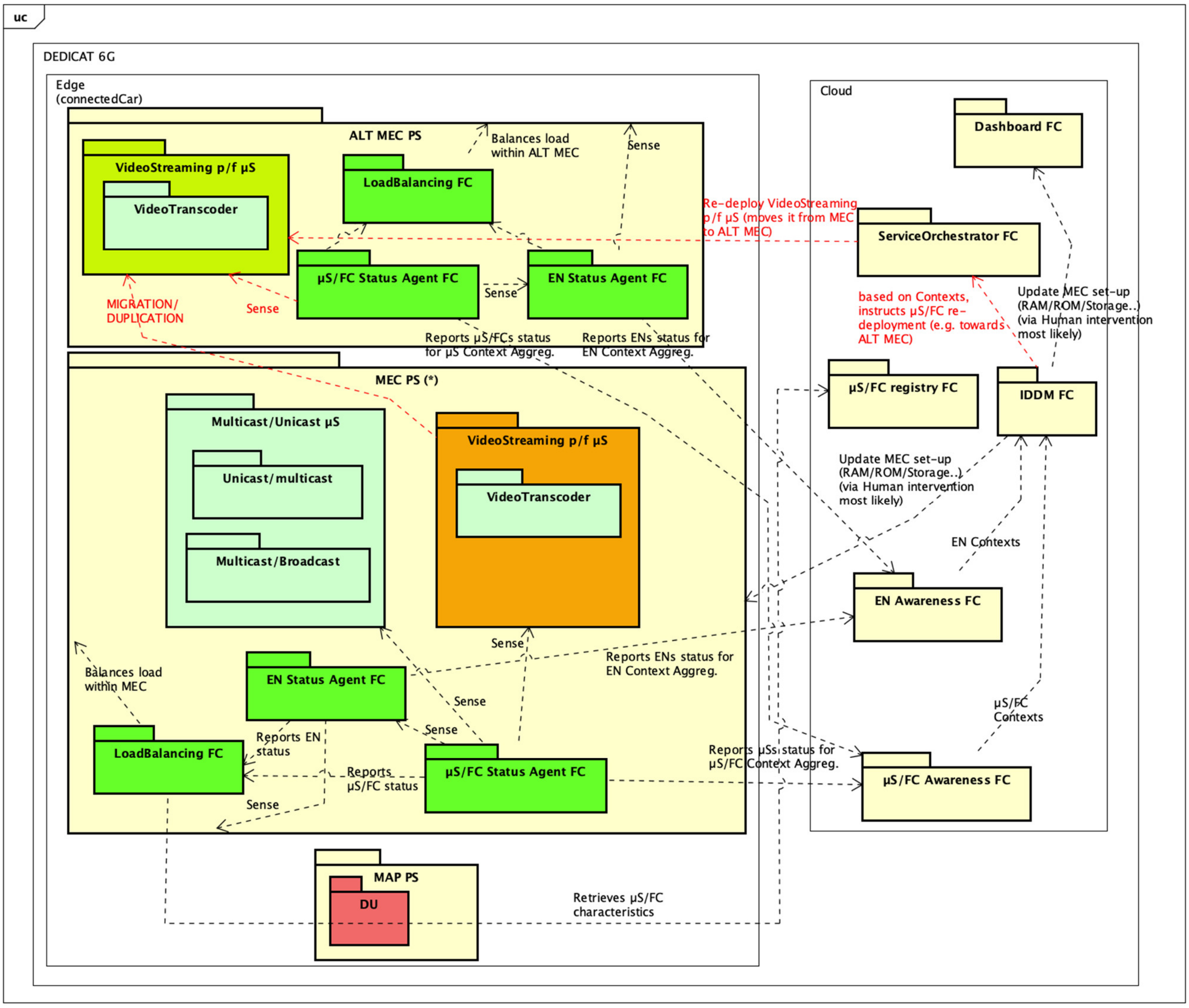

Figure 15: Enhanced Experience Load balancing UML

5.6 Requirements

The two following Table 5 and Table 6 respectively give the list of 1) functional and 2) non-functional and non-technical (e.g., business or societal) requirements pertaining to the Enhanced Experience UC only.

5.6.1 Functional requirements

Table 5: "Enhanced Experience" list of functional requirements

ID	Type	Category	Description	Priority	Rationale	Fit Criterion
1	FREQ	Load balancing	When UE devices support the multi-connectivity feature, UE association solution is required to fully utilized network resources.	H	Depending on a given condition (including the traffic congestion levels of networks, channel conditions, etc.), UE can be connected to networks via multiple links at the same time (e.g., a MAP and macro-BS).	Measured: The efficiency of load balancing will be derived from the measured network performance.
2	FREQ	Performance /Machine Learning	The dynamic changes of networks conditions and performance over time are collected and analysed in a central node.	H	Various network conditions (including the traffic load levels, traffic spatial distribution patterns, etc.) and the network performance achieved multiple Access Points (AP) can be analysed for coordination of multiple APs with machine learning.	Checked.
3	FREQ	Radio Coverage /Load balancing	Location of each MAP which is for capacity/coverage extension needs to be efficiently decided.	L	MAPs' positions will impact on various network performance (e.g., the num. of served UEs, sum data rate, spectral efficiency, energy efficiency, etc.)	Measured: When the locations of heavy data traffic generation vary over time, whether MAPs' position can be decided.
4	FREQ	Performance, networking, load balancing	Ability to dynamically switch from unicast to multicast	H	According to the number of simultaneous users' handover from unicast to multicast is done for bandwidth savings.	A decrease in mobile data traffic will be monitored and measured.
5	FREQ	Networking, platform	The live streaming from the event to multiple simultaneous users	H	The mobile multicast feature usage needs support from the operating network and requires guaranteed input throughput and latency.	BMSC server messages help to resolve possible interoperability issues.
6	DC	Platform, scalability	The system-wide functionality is prioritized to Android mobile devices and Linux/Macintosh laptops	M	Video applications and dynamic networking solution are primarily designed	n/a

					without the support for iOS and Windows-based systems.	
7	DC	Security, edge computing	Dynamic edge placement with computation offloading requires NAT/firewall free access from the operating network	H	Video transcoding or processing in the edge requires firewall-free access to the server for pushing content from several sources.	n/a
8	DC	Platform, UE characteristics	The Smart Glasses have device-specific restrictions for usage in live streaming	H	Camera resolution: 5M pixels (2592x1944) with embedded Autofocus feature. The output video frame rate depends on the resolution. Operating system: Android	n/a
9	DC	Networking	The Smart Glasses have device-specific restrictions for Wi-Fi connectivity	H	The Smart Glasses are using 2.4 GHz WIFI and could not use 5 GHz Wi-Fi	n/a
10	FREQ	Logging	System must be able to log performance of processes, resource utilization, their operating parameters and the network	H	For debugging and to perform evaluation of the performance of the system.	Several parameters are successfully logged
11	FREQ	Operability, networking, coverage	System must be able to decide when dynamic coverage extension or dynamic computation is needed	H	To allow efficient device usability and communication in all circumstances	Tested according to system needs
12	FREQ	Load balancing	The system should be able to manage the load distributed on the edge nodes	M	To avoid too much load and optimize operating parameters on specific devices, especially when computing power is limited.	Tasks are allocated within application-specific time constraints.
13	FREQ	Usability	End-users shall not be involved in the processes for dynamic coverage extension, intelligence distribution and security, privacy and trust assurance.	H	The system complexity should be hidden from the user.	Checked.
14	FREQ	Usability	The user perceived quality of service/quality of experience shall not be negatively affected by the dynamic coverage extension and intelligence distribution.	H	The system complexity should not decrease the quality experienced by the users.	Measured, observed.
15	FREQ	Security, privacy, trust	Communication between all nodes shall be realized in a secure and trusted manner.	H	The system operation and configuration should be restricted to DEDICAT staff only.	Checked.

16	FREQ	Platform, usability	Push-up notifications to user devices	M	The system should enable announcements of live streams to mobile multicast supporting devices	Tested, observed.
17	FREQ	Usability	The attendee shall possess Smartphone for using Smart Glasses with mobile network	H	The Smart Glasses require a mobile hotspot for connecting the service into live streaming session.	Checked
18	FREQ	Security, platform	The system must enable secure network usage and data upload and delivery	H	Several security aspects apply: mobile hotspot shall be secured (e.g., WPA2 protected access), video streaming server shall be accessed only by dedicated users, Facebook Live shall allow connections only to invited members	Checked
19	FREQ	Monitoring	The system must monitor the essential network parameters	H	(e.g., throughput, latency, number of service users) and devices-specific indicators (e.g., CPU/GPU allocation, execution time, resource utilization and operating parameters) for providing the necessary status info to Service Orchestrator	Tested
20	DC	Operability	The Multicast service requires specific video parameters for timing and scheduling the service	H	The video transcoder needs to produce MPEG-DASH compliant stream with fixed segment length according to 3GPP-DASH standard	Checked
21	DC	Networking, operability	The video bitrate shall not exceed network limitations regarding throughput	H	Mobile network (DU/RU) sets practical limitations to the throughput which might not match with the theory (standard)	Checked
22	FREQ	Load Balancing	The required micro-services can be distributed into various edge nodes for load balancing in the platform	M	Load distribution to edge nodes is monitored and the service Orchestrator can re-distribute micro-service for better load balancing.	Checked

5.6.2 Non-functional and non-technical requirements

Table 6: "Enhanced Experience" list of non-functional and non-technical requirements

ID	Type	Category	Description	Priority	Rationale	Fit Criterion
1	NFREQ	Privacy, ethics	The live-streaming video could expose the faces of participants who do not want to be.	H	Unless some background-blurring feature is not supportable for senders, event attendees' faces can be exposed in the video. Relevant terms and conditions should be prepared and agreed upon by participants.	Compliance with regulations
2	NFREQ	Business	The public events are totally cancelled	H	Total cancellation due to worldwide pandemic.	Restrictions imposed by government/ event organizers
3	NFREQ	Validation, verification	Measuring the success rate	H	How the DEDICAT 6G system or sub-system performs, what succeeded and what did not.	Pass/Fail criteria
4	NFREQ	Performance	Measuring the performance of the developed components	H	Measure, evaluate and analyse the developed components via performance indicators	Comparison to key performance indicators (KPIs)
5	NFREQ	Data	Sharing/uploading of multimedia content might not be allowed by event organizers		For paid events, the event organizers could impose limitations to share/upload their event videos. Such conditions should be clearly notified to participants.	Compliance with regulations and restrictions imposed by event organizers
6	NFREQ	Performance, Radio coverage, Networking	The wireless network in the event area should fulfill the basic requirements in terms of coverage, bandwidth and latency for live video streaming	H	Live video streaming from the event requires constant minimum throughput and latency, especially in the uplink.	Compliance with mobile network characteristics
7	NFREQ	Privacy, ethics	Video streams are not stored	H	The streams are not recorded and are purely used as live streams.	Compliance with regulation
8	NFREQ	Cost reduction, Efficiency	Reduce number of bits in the mobile network	H	Multicast instead of unicast reduces the core network load, delivers the live stream more efficiently to end users.	Comparison to KPIs

9	NFREQ	Energy efficiency	Reduce the service energy	H	Use of mobile multicast instead of unicast can save the total system power/energy in different nodes	Measured if possible
10	NFREQ	Interoperability	The use of Smart Glasses for event staff	M	The Smart Glasses can be used in public events not only for entertainment purposes but also for providing enhanced safety in the area	Comparison of the results achieved with the aspect of event area workers
11	NFREQ	Cost reduction	Dynamic edge offloading can bring cost reductions	M	Some of the run-time functionalities can be offloaded to edge/MEC dynamically depending on the service needs. A dedicated task offloading should allow flexible task performance.	Comparison of the current cloud costs for the developed mechanisms
12	NFREQ	Usability	The end users should not be affected negatively by the DEDICAT 6G platform functionalities	H	The coverage extensions and distributed intelligence must improve or maintain perceived QoE and QoS	Pass/Fail
13	NFREQ	Usability	End-users shall not be involved in the processes for dynamic coverage extension, intelligence distribution and security, privacy and trust assurance.	H	The system complexity should be hidden from the user.	Check that coverage extension and intelligence redistribution is performed automatically without user intervention and that these processes are transparent to the user.
14	NFREQ	Usability	Supporting microservices with user-defined functionalities.	H	For microservices allowing users to define part/all of the functionality, the DEDICAT 6G platforms should provide as operating system, compiler, library and hardware independent design and programming interface as possible. Besides ordinary parallel and distributed functionality development, only the intrinsic properties related to data, operations for processing it and dependencies between them would need to be addressed.	Comparison to current practices.

6 "Public Safety" (UC3)

Public Safety stakeholders are facing a transformation in the field of mission management started with the 4G technology and the expansion of IoT solutions. The use case, focusing on Public Safety, will support the description of the innovation brought by B5G/6G technology in leveraging First Responders mission when they are engaged in disaster management and support information sharing with the population in order to reduce the stress and risk incurred by the crisis with emphasis on distributed intelligence, dynamic coverage extension, security and human in the loop.

The scenarios related to the Public Safety use case are defined on the basis of two major contexts:

- The loss of network infrastructure after a natural disaster in a non-urban environment: this context describes the problem of critical communication connectivity for First Responders;
- Non-sufficient connectivity during a crisis in a large event with a large crowd: this context describes the issue encountered by First Responders and the population during a crisis when the network infrastructure is overloaded and/or degraded.

6.1 Use case objectives and relation to project objectives

The Public Safety use case aims to demonstrate innovation delivered by the DEDICAT 6G project for Augmented First Responders in order to pave the way to the future of Mission and Business Critical solutions.

The project will offer ubiquitous, resilient, real-time and high-capacity services. This objective is related to the following DEDICAT 6G global objectives:

- Objective #1: Provide imperceptible end-to-end latency and response time with minimal energy and resource consumption in B5G networks for the support of innovative applications;
- Objective #2: Dynamic, efficient expansion of the communication environment to enable access to all people, information and goods anywhere, anytime in an ultra-real time experience;
- Objective #3: Reinforce security, privacy and trust in B5G systems to support advanced IoT applications.

The demonstrations run-up based on the scenarios will be evaluated through the following global KPIs: Latency, availability, reliability and response time.

6.2 General context and set-up

Natural or man-made disasters are obviously different in nature; the former may occur in an organized (concert) or unorganized context in the same way random shooting/bombing events occur. Natural disasters like earthquakes or bushfires do not involve so-called security teams, but response teams. These response teams are mainly triggered by citizens, either directly using dedicated numbers, or indirectly using e.g., 112 in EU.

Two research and study papers have shown how drone based 5G network deployment [12] and CRAN based 5G resources allocation [13] can enable resiliency and enhance critical communication for Public Safety. The DEDICAT 6G project will aim to demonstrate through the two next contexts how it will leverage response and communications capacity for Mission Critical (First Responders) and Business Critical (Security Team) users.

A recent paper described how 5G leverage Context and Situational Awareness for Public Safety based on video processing and virtualized ecosystem [14]. Beyond 5G and 6G, the goal of the DEDICAT 6G project will be to demonstrate higher capacity in leveraging Situational Awareness with a rapid deployment of connectivity to support faster data processing and sharing.

6.2.1 Overview

Context #1: loss of network infrastructure after a natural disaster

Objectives of the context:

1. Support Disaster Response by making communications available for First Responders;
2. Provide tools and services for End-to-End mission management;
3. Alert and inform distress population.

These context goals relate to the use case KPIs:

- Availability: Deployment of network infrastructure with UAV-based (drones) mobile access point;
- Reliability: Use of Connected Car enabling a variety of communication technologies (5G, satellite…) in First Responder vehicles;
- Response time: Use of innovation devices and applications for response time improvement;
- Latency: 6G dynamic coverage mechanisms.

The demonstration will take place at Airbus outdoor area. Airbus has specific authorization for the flight of drones on its premises.

Actors from partners involved in UC3 will participate by playing different roles (First responders, civilians, casualties). In order to support dissemination, end users and stakeholders will be invited to assist or participate.

Context #2: non-sufficient working communication services during large event and large crowd

Objectives of the context:

1. Improve communication services for Mission and Business Critical situations;
2. Inform and share guidance with the public in order to keep them in a safer location;
3. Data collection from mobile device sensors.

The goals of this context relate to the use case KPIs:

- Availability: By supporting critical communication services based on mobile access points (drones, robots, smart devices);
- Reliability: By the use of AGVs in First Responders' vehicles and deployment of B5G systems;
- Response time: By utilizing mobile devices for sensor data collection based on crowd sensing techniques;
- Latency: B5G/6G dynamic coverage mechanisms.

The demonstration will take place on Airbus' indoor area (specific meeting rooms).

Actors from partners involved in UC3 will participate by playing different roles (First responders, crowd, attack perpetrator). In order to support dissemination, end users and stakeholders will be invited to assist or participate.

6.2.2 Actors involved

We will consider a super-set of actors for these scenarios:

- First Responders: Actors involved in organizing the emergency response (including rescuers specialized in first aid), complementing on-site medics (in case of an organized context). They are not present on site when the event occurs but are deployed rapidly. They are responsible for handling casualties and evacuation (starting with routing people to a safer place). They are also responsible for 1) deploying extra network capability (which is not necessarily needed in an organized context) and 2) communicating/coordinating with the security team already present on site, if any. They are equipped with smart glasses for the sake of efficiency and are the main provider of an evacuation plan;
- Security team: Actors who are part of the event staff in an organized context. In the case of a disaster occurring in that context (terror attack / fire / uncontrolled and sudden crowd movements), they are the first responders: Their duties are 1) to provide first aid via on-site medics, 2) to route people to a safer place, 3) to trigger intervention of a response team and finally 4) to coordinate with them. Likewise, they are equipped with smart glasses;
- Event organizers: In the context of the event, the event organizers are responsible to provide the *Quick Response (QR)* code for a nominative digital ticket and the availability of the event application to leverage the entertainment experience and safety rules to follow during the event;
- Event attendees or citizens: They are the actors at "the wrong place and time". They are the recipients of disaster handling (from first responders and rescuers) and receive guidance via their mobile phones (hence the need for an undisrupted and properly scaled mobile network). They also have the ability to request help or to report suspicious activity to the security team using the event application or emergency call, e.g., 112.

The different actors in the Public Safety use case will be played by partners and stakeholders during demonstrations:

- People from partners involved in the use case will take part as actors in the use cases;
- Stakeholders invited and agreed as volunteers to participate (formal GDPR agreement will be provided);
- Other resources: Drones, Connected Car, Access and Core Network (5G, B5G/6G), smartphones and other communication devices.

The DEDICAT 6G project will make sure that all participants in the demonstrations in both contexts will be volunteers and they will sign a letter of engagement as volunteers, describing the data to be used, the capacity to check, modify, or ask to delete the data.

6.2.3 Set-up plan

Set-up includes ready-to-deploy drones for the DEDICAT 6G platform, the deployment of smart devices (smartphones, smart glasses, smart watches, etc.) for First Responders and Security team. In case of the use of smart devices like smart glasses or smart watches, such devices will be connected to the DEDICAT 6G platform through a smartphone which will serve as a Wi-Fi hotspot.

First Responders are equipped with Mission-Critical (MCS communications, Mission Management) running on their smart devices and the Security team is equipped with Business-Critical applications. Both Mission-Critical and Business-Critical applications are subscribed to the

DEDICAT 6G platform. Applications (Android or iOS) will be preinstalled and configured on their devices or available on a private web portal.

Attendees to the event in the context #2 will receive a digital ticket with a QR-Code for identification and they will have access to an application dedicated to the event.

6.3 Pre-requisites and Assumptions

The following paragraphs describe the common pre-requisites and assumptions in both contexts of Public Safety UC3:

- First Responders will take part in both contexts in order to provide rescue and safety to the population and event attendees. They are equipped with smart devices (smartphone, smart glasses, smart watches, etc.) and they are enrolled in the DEDICAT 6G platform in order to allow multimedia sharing (picture, video, localization, mapping, voice, etc.);
- First Responders have specific applications to communicate and mission management: MC-PTT, MC-VIDEO, MC-DATA, Mobile Mission Management, Remote Expert;
- Mobile Access Points are available and can be rapidly deployed on-demand by the response team. They are self-organizing drones (networked in an ad-hoc manner) acting as B5G/6G cells and providing high availability/reliability and enough bandwidth for supporting the needed communication occurring during a natural disaster or terror attack. Quantifying the communication needs for a proper deployment is paramount here;
- Mobile Access Points offer private and secure communication for First Responders and Public communication capabilities with MEC services in order to support communication for citizens when the commercial infrastructure is overloaded or lost.
- Time T_0 is related to the initial phase of response to the crisis immediately after the disaster or emergency;
- Time $T_0+T_{RECOVERY}$ is the time related to the end of recovery phase after which the DEDICAT 6G communication infrastructure is available;
- Time T_0+T_{DEPLOY} is the time related to the end of First Responders human and asset deployment, after that time First Responders enter into Mission Management phase.

Following items are specific pre-requisites for context 2:

- Since different terror attacks occurred, event tickets are nominative, a QR-code embeds the attendee's name and given name in order to avoid fake IDs. To maximize the event experience, the ticket will be delivered digitally, and the attendee will be invited to download and install the official event organizer's application. The application will collect key information (gender, mobile phone number, email address, health disability for specific care). The use of the application can only be done by accepting the terms and conditions and including for that purpose a consent form. A GDPR disclaimer notice stating that all private information will only be used in case of a safety emergency and will be destroyed after the event ends;
- When attendees use the event application, they are asked to turn on the GPS location service on their smart phone;
- The Security Team is equipped with smart devices in order to share information (routing information, point of interest on a map, etc.);
- The Security Team has dedicated business critical applications running both on Android and iOS devices. The application allows business critical communication, real-time video sharing, mapping with positioning.

6.4 Stories

To conduct demonstrations and make evaluations regarding KPIs defined for the DEDICAT 6G project, this section describes 6 stories related to the two contexts.

Context #1:

- Reconnect First Responders immediately after a disaster in a non-urban environment;
- Inform the population of the situation;
- Innovative tools for efficient End-to-End Disaster Response.

Context #2:

- Evacuate the crowd to safer places during a crisis;
- End-to-End Crisis management;
- First Responders / Public interaction and cooperation.

6.4.1 Story in the context 1: Loss of network infrastructure after a natural disaster

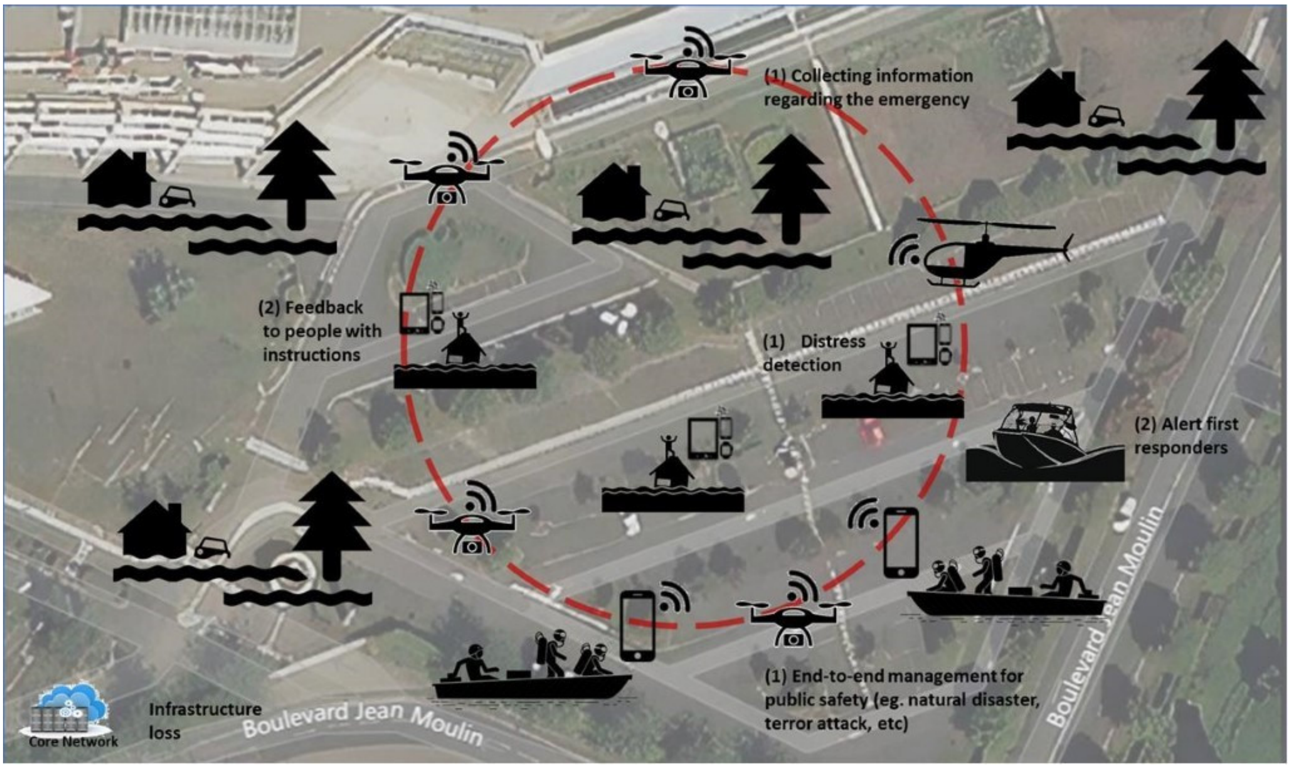

Figure 16: Critical Communication recovery after the loss of network infrastructure

Story 1: Reconnect First Responders immediately after a disaster in a non-urban environment

The goal of this story in the context #1 (see Figure 16) is to explore and evaluate deployment of a dedicated infrastructure after a natural disaster in a non-urban environment. During a natural disaster and the loss of the communication infrastructure, the DEDICAT 6G platform will be used to allow critical communication for First Responders available and allows the use of their own Mission Critical devices and applications.

This story does not take into account the disaster preparedness phase. The First Responders have received the coordinates of the area impacted by the natural disaster. The story starts immediately after the disaster.

The KPIs will be evaluated through the following measures:

- Measure time for deployment of communication resources in the field;
- Examine the types of vehicles as well as other resources, e.g., personnel/other equipment, involved in the response by the various actors;
- Test and demonstrate technology / operating standardized tools, guidelines, methods or mechanisms.

Story description:

1. Immediately after the disaster, at time T_0, the weather condition allows the flight of drones;
2. The Command-and-Control Center operator has integrated the disaster area coordinates into the system in order to calculate the optimal positioning of drones to get the optimum coverage;
3. Drones for Critical infrastructure deployment and video collection are sent to the disaster scene.
4. First Responders go to the disaster area with their vehicle;
5. At time T_0 + $T_{RECOVERY}$, critical infrastructure has been deployed and First Responders (Control and Command Center, and in vehicles) start to receive real-time pictures from the scene on their devices (smartphone, smart glasses, etc.);
6. From the pictures received in real-time and mapping, First Responders identify the position to arrive with vehicles, position of first identified victims and risks on assets to be protected;
7. At time T_0 +T_{DEPLOY}, vehicles arrive on the scene and First Responders engage resources to rescue identified victims and perform actions to secure the assets.
8. The First Responders are able to communicate between themselves in order to share:
    a. The On-going task situation;
    b. Care of victims;
    c. Support for securing the assets;
9. During the different missions performed, First Responders are able to use their smart devices to collect, share and visualize information;
10. The First Responders maintain the DEDICAT 6G platform until the rescue activity finishes and commercial network infrastructure recovers.

Story 2: Inform population on the situation

The goal of this story in the context #1 is to explore and evaluate deployment of an infrastructure after a natural disaster in a non-urban environment in order to make communications available for the population in distress and inform them on the situation.

This story starts at time T_0 + $T_{RECOVERY}$.

The KPIs will be evaluated through the following measures:

- Measure time for deployment of communication resources in the field;
- Measure quality of service.

Story description:

1. The DEDICAT 6G private critical communication infrastructure is available at the scene;
2. The Command and Control Center operator enables a public virtual wireless connectivity based on the DEDICAT 6G platform to allow communication for the population;
3. The DEDICAT 6G public virtual wireless connectivity is available;

4. The population's communication devices are subscribed to the newly deployed critical infrastructure and are able to call emergency services in order to ask for support and rescue;
5. The Operator at the Command and Control Center sends information through the infrastructure to the population:
    a. Updated information on the situation;
    b. Advice on how to keep safe;
    c. Status of on-going rescue.

Story 3: Innovative tools for efficient End-to-End Disaster Response

The goal of this story in the context #1 is to evaluate and demonstrate the benefits of DEDICAT 6G during Critical Mission management for First Responders. From the availability of a Critical Communication infrastructure and the innovative tools, this story will demonstrate efficiency and availability of communications during the entire rescue phase.

This story starts at time $T_0 + T_{DEPLOY}$: the DEDICAT 6G Critical infrastructure is deployed and available for use. First responders use their smart devices to communicate.

The KPIs will be evaluated through the following measures:

- Measure quality of service;
- Measure response time.

Story description:

1. The Operator in the Command and Control Center receives a call from people in distress. He gets a real-time video of the situation from drones to his smartphone;
2. Using the Mission Management tool on the smartphone, the situation is shared with the rescue team in real-time and the rescue team is tasked with helping the victim;
3. The rescue team gets the exact location of the victim on the map and continues to follow the situation based on drone images transmitted in real-time;
4. The rescue team prepares different actions to perform on arrival;
5. On arrival, the rescue team has the equipment to treat the victim;
6. The Operator from the Command and Control Center is able to follow the situation in real-time and is ready to trigger secondary support of rescue teams;
7. The victim has been treated by the rescue team.

6.4.2 Story in the context 2: Non-sufficient working communication services during a large event with a large crowd

The concert event park (see Figure 17) is split into a large number of zones. The Security team is organized to monitor and to respond immediately in case of an emergency in a particular zone.

Story 4: Evacuate crowd to safer places during crisis

The goal of this story in the context #2 is to explore and evaluate the deployment of an extension to the existing infrastructure during a crisis taking place at a large event with a large crowd. Due to the high frequency used in 5G and beyond, the network could be at risk to deliver the requested quality of service due to the large number of devices connected in the same place at the same time. DEDICAT 6G will support security teams in maintaining high connectivity services at the festival site.

The private security team has received a notification from the DEDICAT 6G platform that a suspicious crowd movement has been detected on the music festival site, in area X, and needs quick visual confirmation and possible subsequent actions to be undertaken.

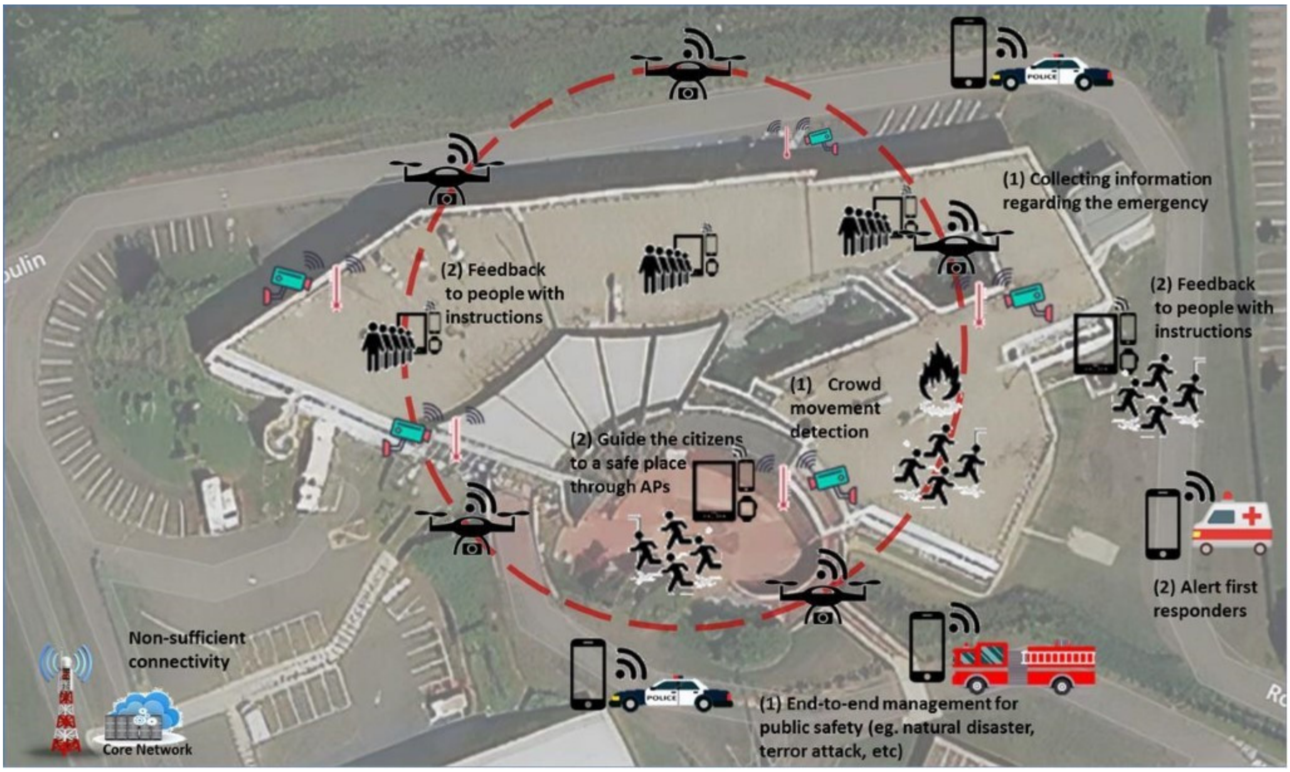

Figure 17: Public infrastructure overloaded during a crowd panic

When the public bought a ticket to attend the festival, they received a digital ticket with a QR code and an invitation to download the official festival smartphone application in order to:

- Allow connection to the event's private network;
- Receive and share information about the festival;
- Receive safety information in case of incident.

The KPIs will be evaluated through the following measures:

- Measure time for deployment of communication resources on the scene;
- No decrease in quality of services;
- Test and demonstrate technology / operating of standardized tools, guidelines, methods or mechanisms.

Story description:

1. A crowd movement has been identified by the DEDICAT 6G platform;
2. The security team operator received a system notification about connectivity problems;
3. An alert about the crowd movement has been sent to the security team present on the site:
    a. Notification received on the Security team's smart glasses or smart watches - relayed by their smartphone - informing about suspicious crowd movements in area X which is later confirmed visually;
    b. A map with the movement's direction is shared on smart devices;
4. The Control operator triggers the connectivity support provided by the DEDICAT 6G platform;
5. Drones (or other vehicles) are sent to the scene;

6. The Public launches and uses the festival application:
    a. An urgent pop-up is displayed on the festival application;
    b. By clicking on it, the festival application shares information on the situation and asks to allow the use of the device's sensors (accelerometer, localization, microphone, camera, etc.);
7. At time $T_0 + T_{RECOVERY}$, the DEDICAT 6G platform initiates the collection among the data to support the Security team's decision making:

    The Security team receives information on crowd movement, open escape routes and on the origin of the panic;

    a. The public receives information on the festival application with instructions to evacuate in a safe manner;
    b. Using the DEDICAT 6G connectivity capabilities, the Control operator activates or deactivates doors in order to help with the public's evacuation;
8. Outside the site, the public receives the position of the meeting point and first aid;
9. The Security team receives instructions.

Story 5: End-to-End Crisis management

The goal of this story is to explore and evaluate the evacuation of people after a crowd movement during a large event. The DEDICAT 6G platform is used to make communication available for the First Responders and Security team and inform attendees on the situation. This story aims to evaluate the efficiency of DEDICAT 6G for the use of innovative solutions during evacuation management.

This story starts when the crowd movement has been identified, at time T_0, and the Security team starts to apply safety guidelines for evacuation. The DEDICAT 6G platform is deployed and ready for use. The security team uses their smart devices for communication.

The KPIs will be evaluated through the following measures:

- Measure quality of service;
- Measure response time.

Story description:

1. The Emergency Response – 112 service receives multiple calls which are all linked to a crowd in panic and a blast;
2. The Emergency Response operator immediately receives the coordinates of the crisis and the Security manager's contact;
3. The Emergency Response operator confirms the alert with the Security manager on site;
4. The Security manager shares pictures and other relevant information with the Emergency Response operator;
5. First Responders (Police, Firefighters and Ambulances) are sent to the crisis;
6. On arrival, at time $T_0 + T_{DEPLOY}$, First Responders are able to connect to the DEDICAT 6G platform in order to support their mission:
    a. Police are managing the security of the site;
    b. Firefighters are looking for the origin of blast;
    c. Medical staff are going to the meeting point to start the first health condition assessments;
7. Firefighters, based on data analysis and an on-site assessment, have identified the origin of the blast:
    a. Defective Electrical equipment exploded;
    b. A fire has started immediately after the blast;

8. Firefighters put out the fire and secured area X;
9. Police, supported by the security team, finish evacuating the public and put people in safety areas;
10. The Medical staff treats the victims.

Story 6: First Responders / Public interaction and cooperation

The goal of this story is to explore and evaluate deployment of an extended infrastructure after a crisis during a large event with a large crowd in order to make communication available for the public in distress, inform them on the situation and support the emergency response.

This story aims to demonstrate how DEDICAT 6G will leverage communication capabilities and, based on the deployment of the DEDICAT 6G platform, how it will support public application, and First Responders and Security staff communications with the public in distress.

This story starts at time $T_0 + T_{RECOVERY}$.

The KPIs will be evaluated through the following measures:

- Measure time for deployment of communication resources on the scene;
- Measure quality of service.

Story description:

1. When buying a ticket to a festival, a QR-code is included so that the public can download an application dedicated to the festival;
2. The downloaded application informs about the purpose of the application and asks for some basic authorizations;
3. During the event, when the crisis takes place, a red notification appears on the festival application:
    a. By clicking on the red notification, information on the situation appears;
    b. The application asks for additional authorization (using a consent form) in order to allow data collection;
    c. By accepting the authorization, First Responders will be able to collect data and communicate with victims;
    d. First Responders (and Security staff) are able to receive personal information (name, position) about the victims;
4. Based on localization and accelerometer sensors, First Responders are able to receive information on victims blocked during the movement;
5. With the support of video, they are able to check the evacuation process;
6. First Responders are looking for victims identified inside area X;
7. Some identified people stay close to a victim and send a notification through the app;
8. First responders communicate with them asking to describe the situation and share first aid instructions to assist the victim;
9. First responders arrive at the scene and after assessing the medical situation, they start the evacuation process;
10. Victims are transferred to a hospital.

6.5 Relation to the functional decomposition

The Public Safety use cases, referred as UC3, identified different actors with their main activities in D2.2 [2], which are now further elaborated in this section with their relationship to the FCs. In this subsection we present the functional decomposition of UC3 grouped in the two assumed contexts, #1 loss of network infrastructure after a natural disaster, and #2 non-sufficient working communication services during large event and large crowd.

6.5.1 Context # 1: Management Setup

Figure 18 presents the initiation of the DEDICAT 6G platform in the mission critical context for the support of critical communications for PPDR users. It strictly follows the same procedure as described in Section 3 and other UCs CEaaS service provisioning phase.

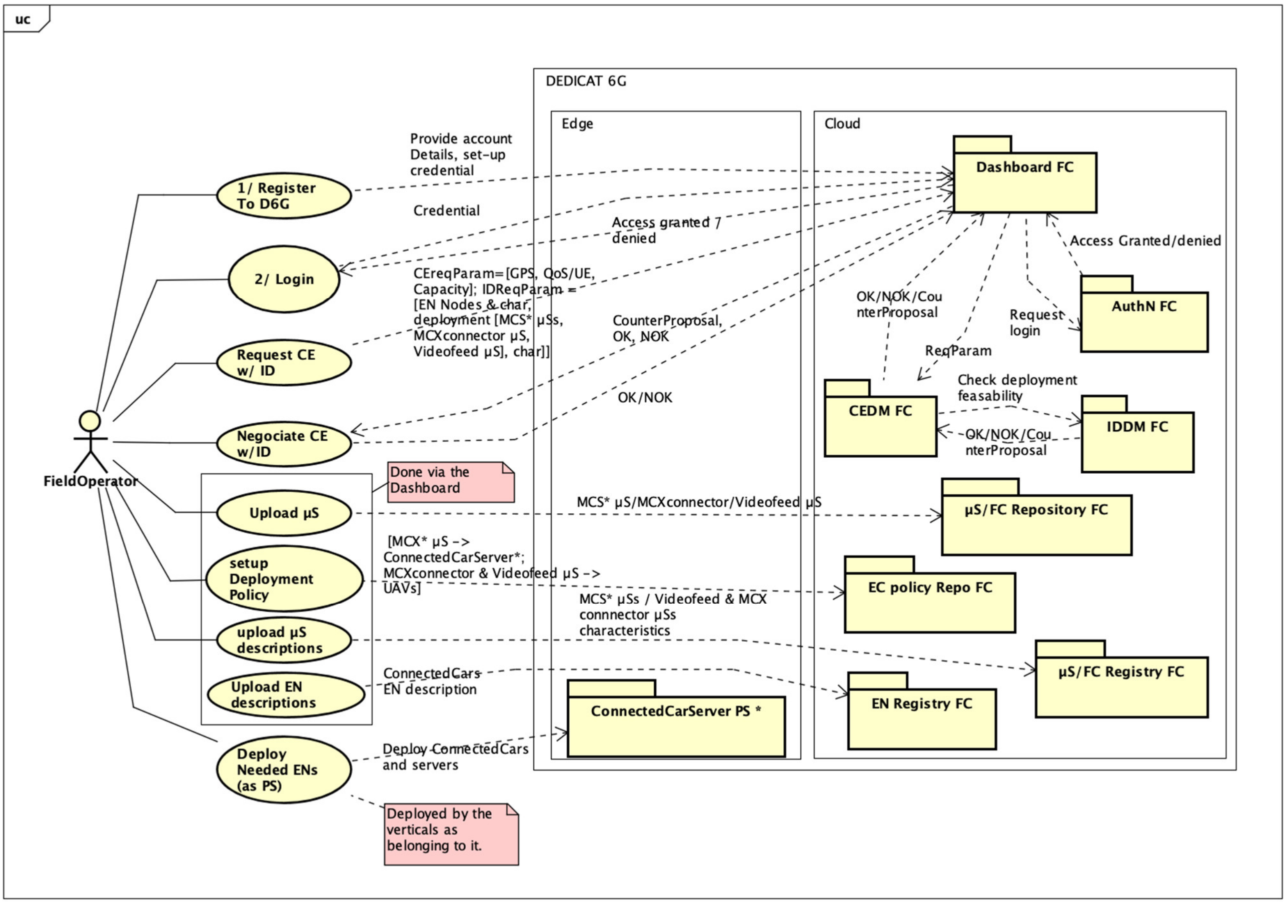

Figure 18: Public Safety context #1 platform setup UML

The DEDICAT 6G offers in the cloud an access to the Dashboard functions. The Dashboard functions allow the Field Operator to prepare the configuration needed for Mission Critical Services, as Quality of Services, localization service, 3GPP Mission Critical (MCX) services which will be deployed and the upload of the Mission Critical Services users (credential, role, authorization…). Access and authentication to the Dashboard functions are permitted with the authentication feature process in the background process in the platform.

The first context of use case UC3 takes the hypothesis that network connectivity will not be accessible due to the disaster. This is the first level of reliability for PPDR users in Mission Critical scenarios, therefore, they rely on *Coverage Extension (CE)* in the field of the disaster deployed by the DEDICAT 6G platform. The first objective is to support critical communication in the field between the engaged forces to the response. The second one will be to reconstruct the communication with the management through available connectivity interfaces as they will be reconstructed during the time of crisis management.

6.5.2 Context # 1: Platform Deployment

Figure 19 presents the services deployed by the DEDICAT 6G platform to support to support critical communications for PPDR users during crisis management.

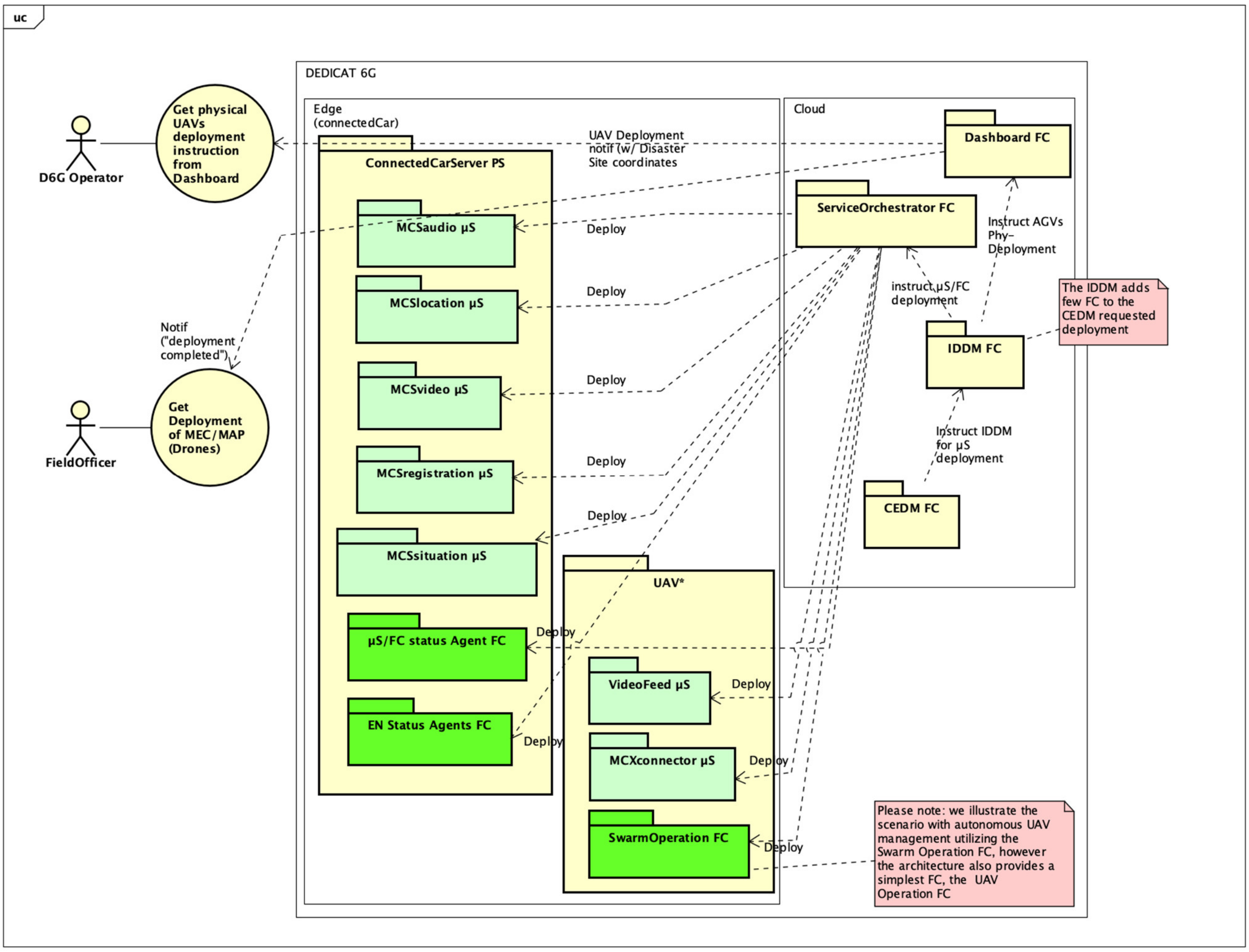

Figure 19: Public Safety context #1 platform deployment UML

The DEDICAT 6G platform has deployed the *Mission Critical Services (MCS)* into the Connected Car servers at the *Mobile Edge Computing (MEC)* level, the Field Officer receives the information of MCS availability (MEC) as the connectivity (MAP). By applying a distributed architecture, the DEDICAT 6G platform decreases the service latency for PPDR users by decentralizing the services at MEC level and impact positively the Quality of Services.

The Dashboard feature allows the DEDICAT 6G Operator to monitor the deployment of the Coverage Extension based on the Connected Car and UAVs.

Because of the large area impacted by the disaster, the PPDR users will use UAVs to get a global as a local view on the situation, thus the DEDICAT 6G deploy UAVs with capability to stream their video flows to the MCS Video service, making the video available to PPDR users.

Based on the various Status Agent features, the various Decision Making components will continue to monitor the QoS and limitation in coverage in to eventually deploy needed additional services. The Coverage Extension is described in section 3 and the load balancing management is described in the sub-section 6.5.4.

6.5.3 Context # 1: Disaster Operation

Figure 20, presents the interaction of First Responders with the DEDICAT 6G during the response to the crisis. The operations are operated because of the failure of the operated network (public or private network).

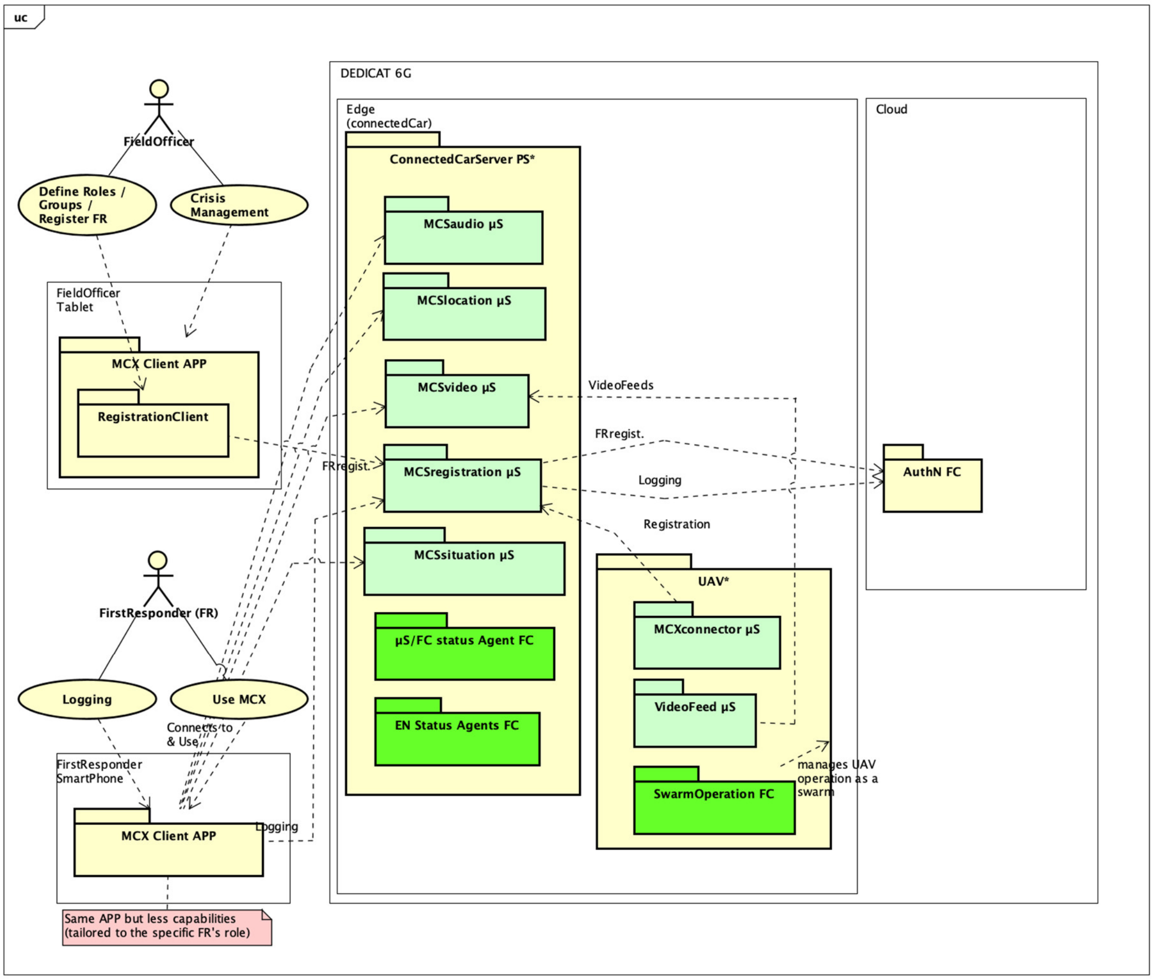

Figure 20: Public safety context #1 disaster operation workflow UML

The DEDICAT 6G deployed the services at the Edge and they are available to support PPDR and First Responders in the management of their missions.

The First Responders are using the MCX Client application which is installed on a Smartphone. The Smartphone is connected to the DEDICAT 6G. With the MCX Client application, First Responders are able to access to the Mission Critical Services deployed at the Edge and perform the following main functions: share localization and receive mapping, make audio group communication, make video group communication, stream video in real-time; this will leverage the situational awareness and support the decision-making process during the response to the crisis. The Field Officer is able to manage the overall situation and access administrative features of the MCS.

The DEDICAT 6G shall deliver services at the same level that described in 3GPP MCX. The distributed architecture shall not decrease the performance and quality of services expected by First Responders in such a critical situation.

6.5.4 Context # 1: Load Balancing

Figure 21 presents the management of load balancing into DEDICAT 6G for Public Safety.

The load balancing feature is performed at the Edge but instrumented from the cloud of DEDICAT 6G (decided by the IDDM FC based on Status Agent data, then implemented by the Service Orchestrator FC). This feature aims to distribute the load of Mission Critical Services for PPDR users in order to maintain a high-level of reliability during crisis management when no connectivity is available.

During the response and recovery phase, First Responders and PPDR organizations engage hundreds to thousands of forces. With the rise of 5G use, they rely on more and more data coming from the field (sensors, smart wearables, video streams) which significantly increase the number of devices or objects in use.

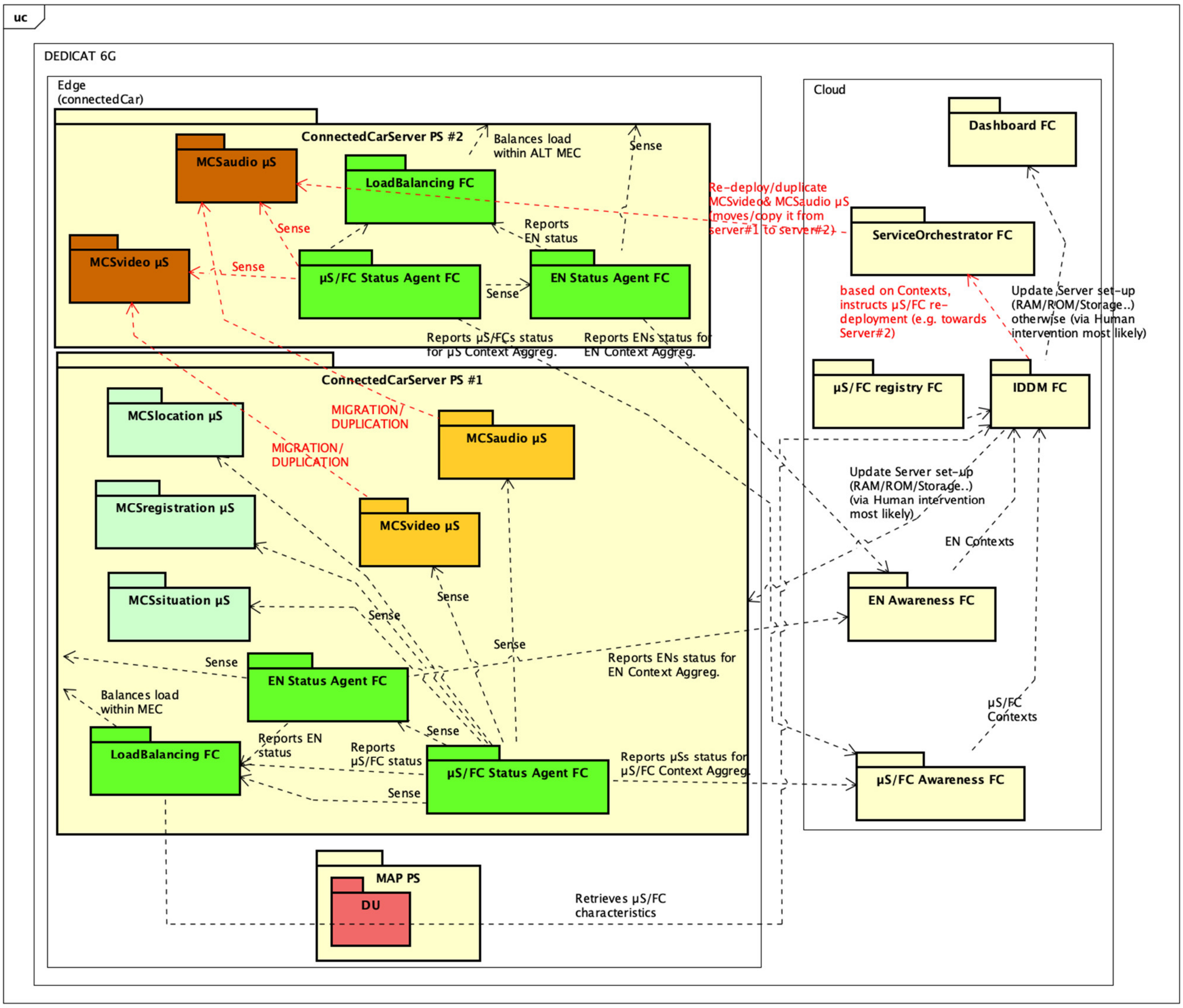

Figure 21: Public safety context #1 load balancing UML

After the actual deployment of Mission Critical Services, the load balancing feature, with sense from Status Agent feature, monitors the need to migrate or duplicate new Mission Critical Services which become at the limit of execution. When such a scenario is detected, load balancing requests the application of Orchestration rules from the DEDICAT 6G cloud to perform the migration or duplication of services.

As the Mission Critical Services rely on DEDICAT 6G connectivity, only services closed to overloading are duplicated: e.g., when video feature, from collection to sharing and multimedia communications, is coming on limitation, the load balancing feature detects such limit of services and request a duplication of MCS Video service which could be on a second connected car servers which is also closed to the users.

This architecture increases the reliability and efficiency of Mission Critical services and decreases the latency between devices in information sharing.

6.5.5 Context # 2: Setup

Figure 22 presents the initiation of the DEDICAT 6G platform in the business-critical context. This platform setup works in parallel of the initiation of the setup for the context #1 described in section 6.5.1. It addresses the critical communications for private security staff in the scenario of a public event.

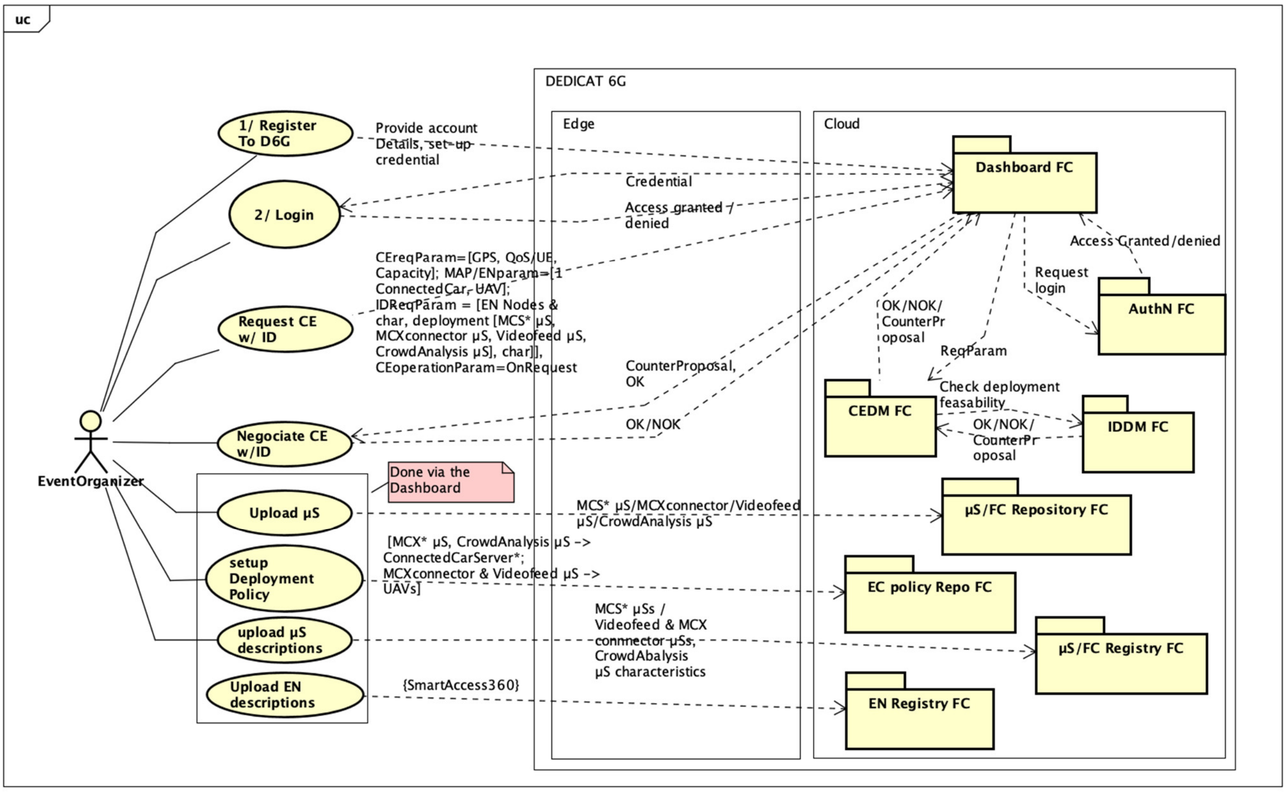

Figure 22: Public safety context #2 platform setup UML

Business Critical for private security users and private organizations, as Mission Critical for First Responders and PPDR users, rely on Mission Critical Services to management different task and operation (secure an area or a site, perform maintenance tasks…).

The Event Organizer (or similar to Network Services Administrator) requests the from DEDICAT 6G support for a specific event (e.g., a live concert with lots of attendees). The task is similar to the one requested by a Field Operator in Public Safety organizations.

This preparation is done to reduce the risk of loss of communication in case of connectivity failure or overloaded services of Commercial network which are the main connectivity which is in use.

6.5.6 Context # 2: Deployment

Figure 23 presents the deployment of the DEDICAT 6G MCS services for the business-critical context. This deployment is done to maintain network (connectivity and services) in case of failure or overload from public network in case a crisis happened.

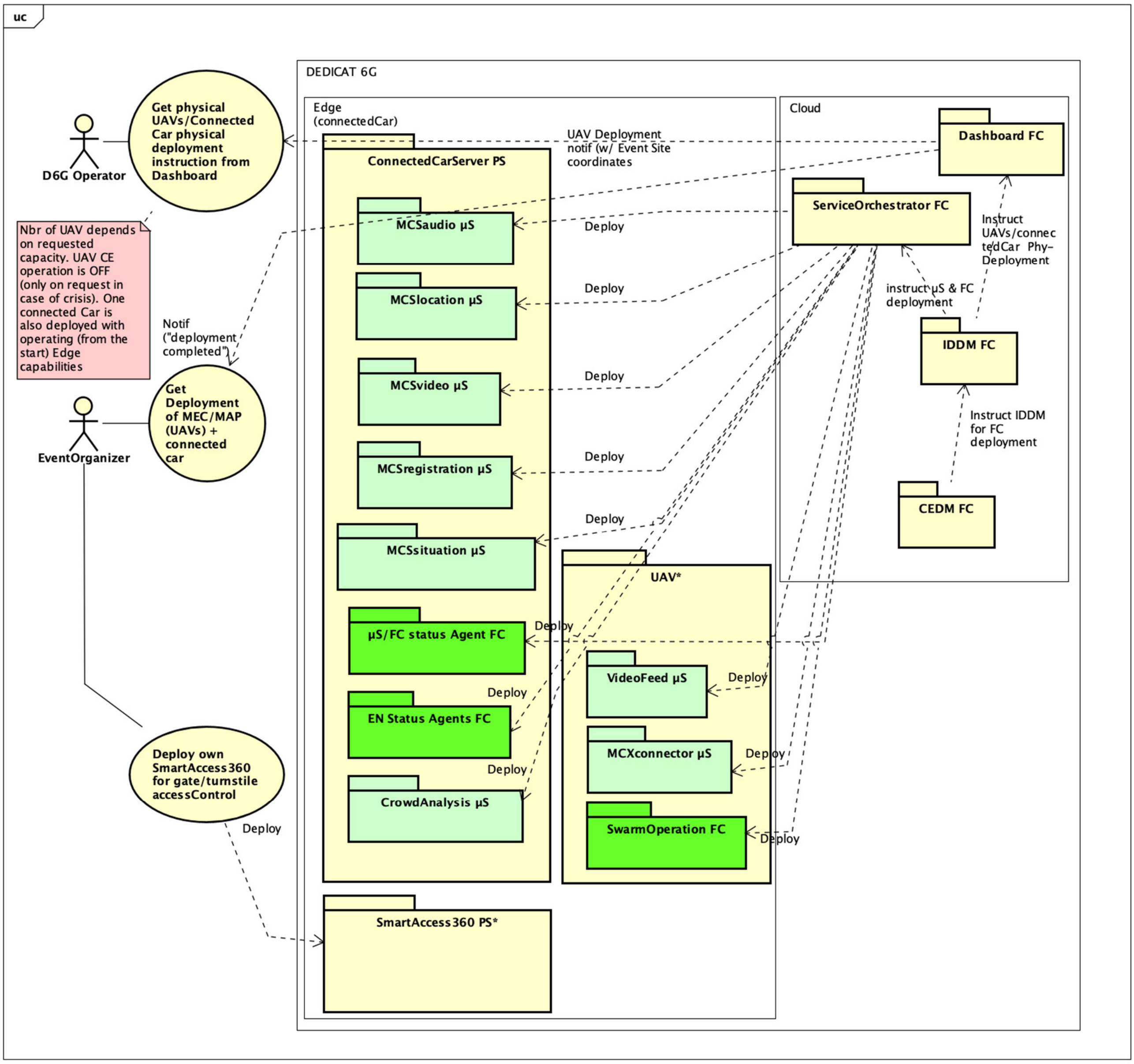

Figure 23: Public safety context #2 platform deployment UML

The deployment of MCS services is similar than the one in context #1, Section 6.5.2, but applying for private users who need Business Critical services offering a high level of reliability and efficiency.

6.5.7 Context # 2: Event safety operation before crisis

Figure 24 presents the interaction of Event Organizer and Security Staff users with the DEDICAT 6G as a normal operation.

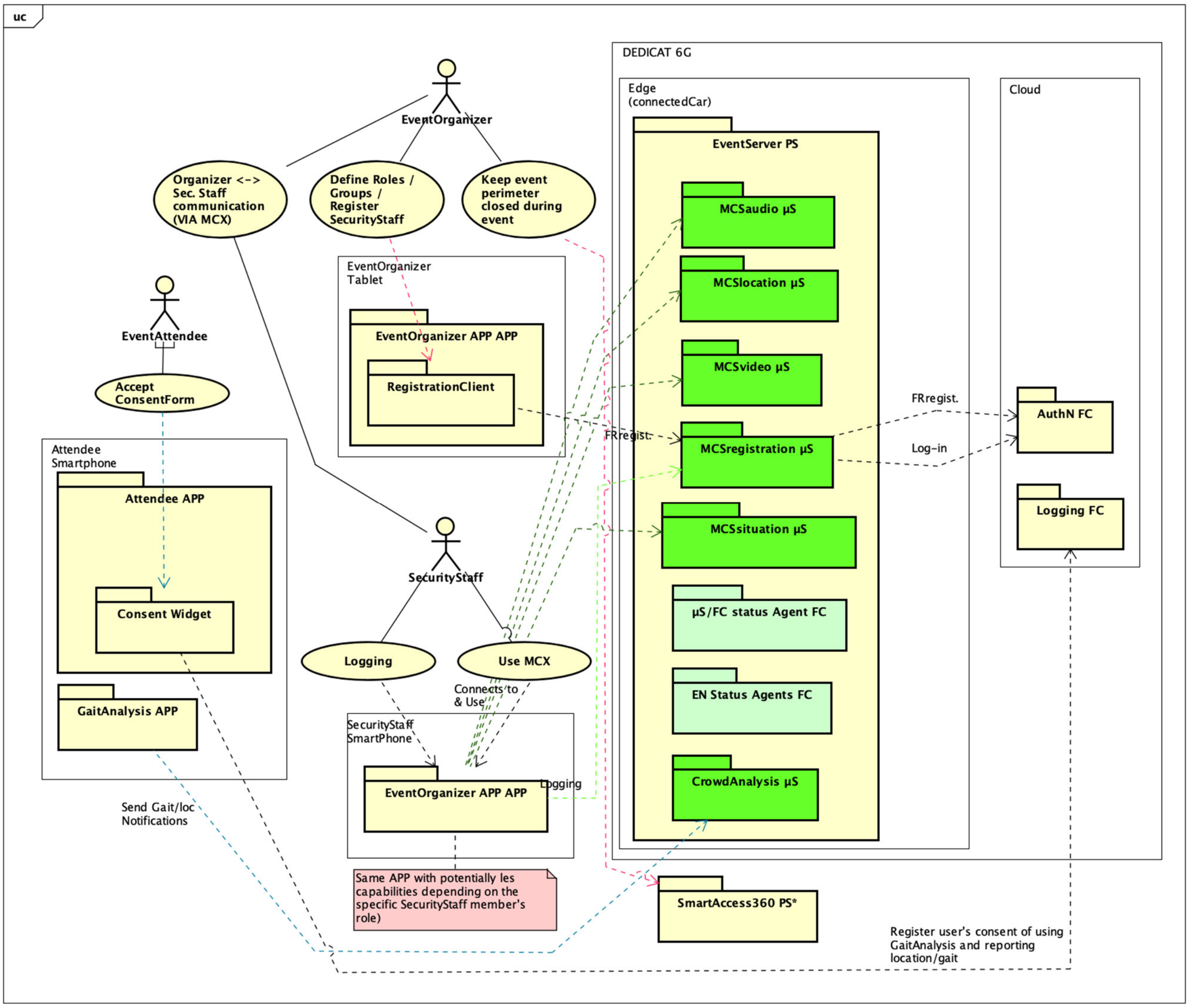

Figure 24: Public safety context #2 event safety operation before crisis UML

The DEDICAT 6G deployed the services at the Edge to support any failure or network overload because of a large number of attendees at the event.

The Event Attendee could use an application which is specific to the event and share inside the event with other Attendee through a digital social area after acceptance on the use of private data. All information related to Event Attendees will be simulated.

This part of the context #2 is similar to the use case UC2 which is about Enhanced Experience with strong focus on entertainment. In UC3 we might have a similar setting, however we shall ignore the entertainment relating aspects and focus only on the Business Critical for Security Staff users and Event Organizer who shall use DEDICAT 6G in a similar manner than the use by Frist Responders users. The difference is in the nature of their distinctive mission and roles.

The Security Staff using the MCX Client application, and the feature authorized based on their role definition, audio, mapping, data sharing, etc.

6.5.8 Context # 2: Event safety operation after crisis

Figure 25 presents the operation of the DEDICAT 6G MCS services to maintain network (connectivity and services) in case of failure or overload from public network in case a crisis happened.

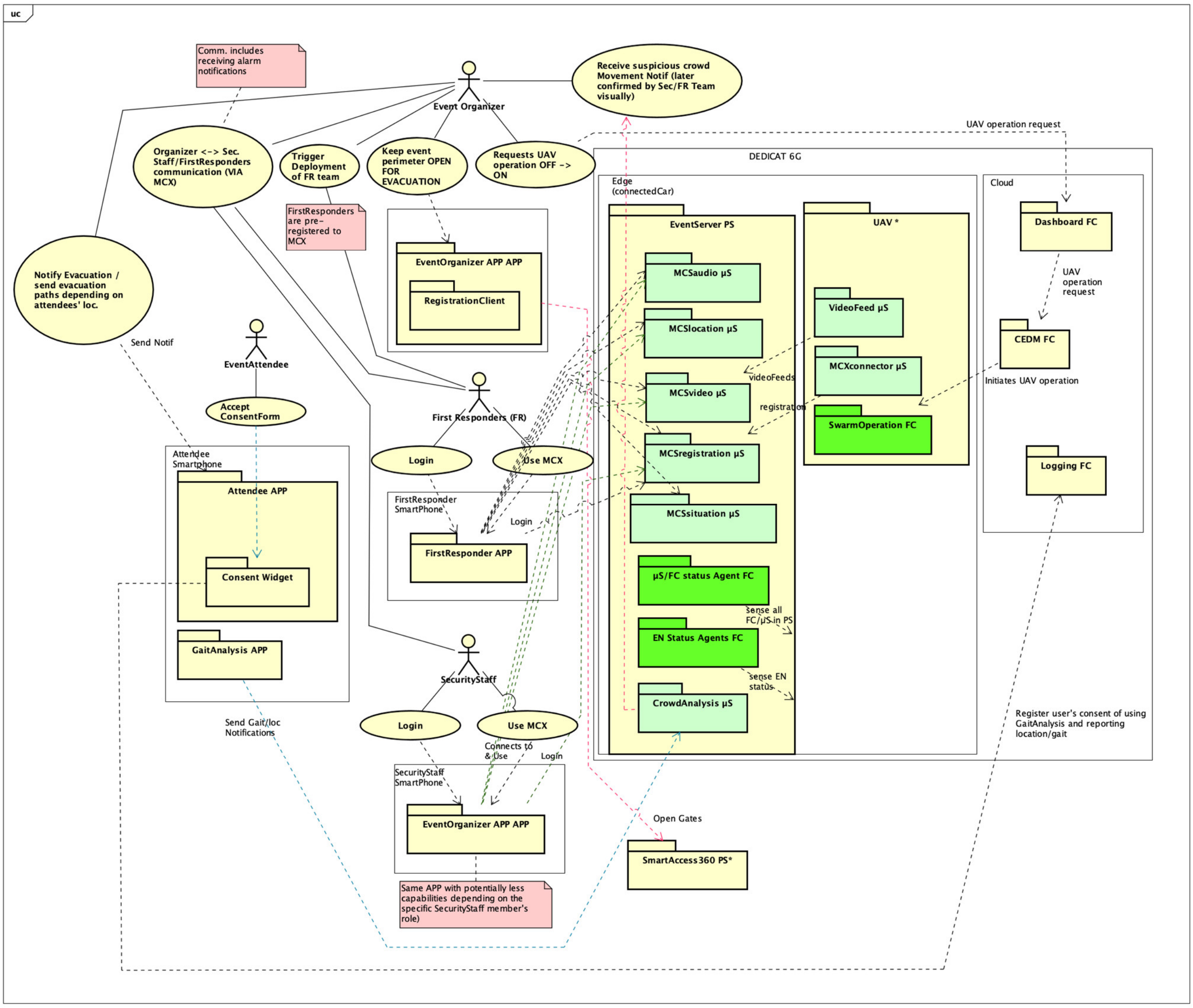

Figure 25: Public safety context #2 event safety operation after crisis UML

When a crisis occurs the crowdAnalysis µS can trigger the crisis management and consequently, First Responders arrive at the Event area. There is a panic and Security Staff has started to evacuate the Event Attendees to the Emergency Exits. Because of the panic, a lot of people are using the network to share live on social media or others about the situation, trying to join Emergency number and sharing photos; the network is in failure.

The First Responders who have arrived at the Event area, have joined the DEDICAT 6G platform to benefit from the coverage extension and can connect to the MCS which has been deployed at the Edge.

This solution offers a reliable and efficient service to support First Responders to perform their mission and the Security Staff in helping and protecting people.

Each organization, Security Staff, Event Organizer and First Responders using the MCX Client application to connect to MCS with their own role and permission.

6.6 Requirements

The two following tables, Table 7 and Table 8 respectively, give the list of 1) functional and 2) non-functional & and non-technical (e.g., business or societal) requirements pertaining to the Public Safety UC only.

6.6.1 Functional requirements

Table 7: "Public Safety" list of functional requirements

ID	Type	Category	Description	Priority	Rationale	Fit Criterion
1	FREQ	AI / Analytics / Edge Computing	Gait analysis for attendees	H	Abnormal Crowd movement detection is based on individual gait analysis	Crowd movement detection performs as expected
2	FREQ	AI / Analytics / Edge Computing	Crowd Movement analysis must be provided in order to trigger emergency response	H	Natural disaster or terror attack generally results in hectic crowd movements	Such simulated crowd movements are detected
4	FREQ	MMI	The Smart Glasses must display vital and essential information to the bearer amid crisis management.	H	During crisis management visualizing essential information must be possible without hand manipulation of the smart phone	Vital and essential information, as described in the final users' requirements document, are displayed on the Smart Glasses.
5	FREQ	MMI	The Smart Glasses must be fully integrated with the overall system and interfaced with the smart phone	H	Indeed, a rescuer or first responder is connected with the DEDICAT 6G platform with the smart phone	The Smart Glasses device is connected to the user's Smartphone device. Information displayed on Smart Glasses is duplicated on Smartphone device.
6	FREQ	Networking	For B5G/6G coverage extension, the drone must self-organize	H	During crisis management there is no time and qualified tech for network configuration	Ad-hoc network performs as expected and bears the load
7	FREQ	Cyber-physical security	Perform context aware actuation with deployed IoT system	M	Have an option to access and utilize cyber-physical security systems like control of locks and alarms without access to central command (accessed through internet connection)	System interacts with mobile devices (e.g., smartphones) and performs authorized actuation (onboard rely trigger)

8	FREQ	Distributed identity management	Ability to identify and authorize devices/equipment and actors without access to central identity provider	H	The Edge computing system must be able to perform identity and trust management autonomously in emergency situations	Systems identified and authorized with and without access to central authority in the same way
9	FREQ	Collecting performance logs	Local edge computing systems must be able to log performance of processes and resource utilization during emergency situations	H	Locally deployed computation and communication systems must be able to perform monitoring of established emergency processes and act on collected information in line with a pre-defined set of rules. Collected data is sent to the central platform for performance analysis and updates for local decision-making models.	Logs can be collected/accessed at any moment
10	FREQ	Coverage/Networking	AGVs/Robots, Drones and other devices should be able to communicate with each other and with the "central" network infrastructure.	H	This is required for setting up an ad hoc network where an AGV/robot or drone may be playing the role of a MAP.	Check data propagation between end points (ping messages between points).
11	FREQ	Coverage/Networking	Relaying shall be supported by central nodes or by edge nodes.	M	This will allow forwarding of data and control signalling in the scope of dynamic coverage extension through an ad hoc network.	Move AGV in area without fixed wireless network (the main network used within warehouse) coverage and observe other communication nodes establish communication link towards the AGV. AGV maintains access to core services.
12	FREQ	Coverage/networking	It shall be possible to identify the need for a dynamic coverage extension.	H		Check that trigger is properly recognized. We need project level fit-criterion for identifying the need for coverage extension.
13	FREQ	Coverage/Networking Load balancing	It shall be possible to identify the need for (re-)distribution of intelligence.	H		Check that trigger is properly recognized. We need project level fit-criterion for identifying the need for redistribution of intelligence.

14	FREQ	Coverage/Net-working	A device in an ad hoc coverage extension network shall be able to set up a connection with the central infrastructure. The infrastructure shall be able to trigger a device in an ad hoc coverage extension network to set up a connection.	H		Check that a device in an ad-hoc network can ping the central infrastructure. Check that the infrastructure can trigger the device to set up a connection with other devices.
15	FREQ	Coverage/net-working	The coexistence of ad hoc coverage extension networks shall be supported.	H		Setup two ad-hoc networks and monitor communication performance metrics (delay, packet drop rate, throughput).
16	FREQ	Load balancing	It shall be possible to dynamically distribute computation between central and edge nodes	H		Check that process for data analysis can run on central and at least two edge nodes in a federated manner.
17	FREQ	Coverage/Net-working Load balancing	The system shall be context aware.	H	The system shall be able to obtain information on application, service and network goals and objectives to be achieved, as well as potential policies. The system shall be able to obtain information on capabilities of network elements, MAPs and edge devices in terms of communication networking (e.g., radio access technologies (RATs) and spectrum, capacity, and coverage), physical movement, the type of the MAP, computation capabilities, storage capabilities and available power. The system should maintain information and knowledge on the context that has to be addressed in terms of computation tasks, power consumption requirements, a set of mobile nodes that need coverage, mobility and traffic profiles of the different nodes, radio quality experienced by client nodes, options for connecting to wide area networks, the locations of docking and charging stations for drone and robot	Check based on defined experiments. Check that the system is able to infer the current system context/situation.

					MAPs and the current locations of the terminals and MAPs' elements.	
18	FREQ	Coverage/networking	The system shall be able to make decisions on the creation, reconfiguration and termination of an ad hoc coverage extension network.	H		Check based on experimental setup. We need a project level fit criterion for this requirement.
19	FREQ	Load balancing	The system shall be able to make decisions on how intelligence should be distributed among nodes (when it is required, which nodes should be used, which functions should be distributed to which nodes, etc.)	H		Check based on experimental setup. We need a project level fit criterion for this requirement.
20	FREQ	Security, privacy, trust	Communication between all nodes shall be realized in a secure and trusted manner.	H		Check based on experimental setup. We need a project level fit criterion for this requirement.
21	FREQ	Security, privacy and trust	Local resources and private data stored in the devices and nodes used for coverage extension and intelligence distribution should be protected.	H		Check that data in local storage is encrypted with selected method.
22	FREQ	Security, privacy and trust	A device or node shall not be used for dynamic coverage extension or intelligence distribution without the approval of the user/owner/operator of the device/node.	H		Approve two out of three nodes and trigger coverage extension or intelligence redistribution and observe which nodes are involved in ad-hoc networks.
23	FREQ	Usability	End-users shall not be involved in the processes for dynamic coverage extension, intelligence distribution and security, privacy and trust assurance.	H	The system complexity should be hidden from the user.	Check that coverage extension and intelligence redistribution is performed automatically without user intervention and that these processes are transparent to the user.
24	FREQ	MCS response time	Critical communication shall not be decreased when DEDICAT 6G is deployed on the scene.	H	Based on legacy and 5G specifications, the average time to response has to be equal or less than existing specification in 3GPP Mission Critical (MCX) standards.	Measure the latency between UE during a MC-PTT call. The time shall not be decreased.

25	FREQ	Infrastructure deployment	On loss of network infrastructure after a natural disaster, the DEDICAT 6G infrastructure has to be deployed as fast as possible.	M	Depending on publication and reports on disaster response, the deployment of DEDICAT 6G shall be faster than legacy solution (divided by 2).	Evaluation of deployment time during recovery phase. Results should improve Response Times during the Recovery phase compared to legacy methods.
26	FREQ	QoS	On multiple connection, the system has to support the QoS and shall not decrease during crisis management	M	When the worst happened, the Quality of Services shall keep similar value compared to 3GPP MCS standards in any cases.	Measure of QoS. QoS measured shall not be decreased regarding the 3GPP MCS standards.
27	FREQ	UAV Video Stream	The system could support real-time video stream from a drone to a group of video communication and comply to 3GPP MCS standards.	L	With the raise of broadband technologies since 4G and now 5G, Public Safety users integrate in their mission the use of diversity of connected objects in order to leverage the situation awareness like the use of drones during operation with video uplink capability offered by MCS.	The video from camera on the drone is shared through the MC-Video feature which is described in the 3GPP MCS standards.

6.6.2 Non–functional and non-technical requirements

Table 8: "Public Safety" list of non-functional and non-technical requirements

ID	Type	Category	Description	Priority	Rationale	Fit Criterion
1	NFREQ	privacy, ethics	The way various information is collected amid the different deployed Android/iOS App must follow EU recommendations (including the use of Consent Form)	H	Sensitive and health related data (optional) may be collected when signing into the app. These are used to support efficient and personalized rescue.	Compliance with regulation
2	NFREQ	Ethics	The system shall follow appropriate health and safety procedures conforming to relevant local/national/EU guidelines/legislation in order to protect the environment and people.	H	Health and safety procedures need to be translated into system automation and decision-making processes provided by DEDICAT 6G system.	Translate selected regulations into a specific set of automation and decision-making rules. Confirm completeness.
3	NFREQ	Ethics	The system should keep a log of places, moments and trajectories where personal data is compiled,	H	This is important for privacy and data protection audits that can be requested by regulatory bodies.	Setup logging procedure, generate logs and check

			transferred, stored, deleted, anonymized (or pseudonymized) or processed in any other way.			their completeness in different experimental setups.
4	NFREQ	Ethics	The system shall include measures and tools to safeguard from misuse of data collected in alignment with the GDPR.	H		
5	NFREQ	AI / Analytics / Edge Computing	Latency for 1 and 2 must be reasonably low (e.g., a few seconds max)	H	The slowest the detection is the largest the casualty count will be	Measured
6	NFREQ	Collecting performance logs	Local edge computing systems must be able to log performance of processes and resource utilization during emergency situations	H	Locally deployed computation and communication systems must be able to perform monitoring of established emergency processes and act on collected information in line with a pre-defined set of rules. Collected data is sent to the central platform for performance analysis and updates for local decision-making models.	Logs can be collected/accessed at any moment
7	NFREQ	Fault	DEDICAT 6G introduces infrastructure deployment based on drones or robots or vehicles to support existing infrastructure in case of loss or lack of services.	L	DEDICAT 6G has to deliver high performances and take into account self-default to re-evaluate deployment process to maintain network infrastructure.	Evaluation
8	NFREQ	Usability	The user perceived quality of service/quality of experience shall not be negatively affected by the dynamic coverage extension and intelligence distribution.	H		We need project level fit criterion for user QoS and QoE assessment

7 "Smart Highway" (UC4)

Smart Highway is a use case that benefits from beyond 5G connectivity for connected and autonomous mobility [15], [16]. In this use case, the smallest possible delay and ultra-reliability in communications between road users are expected to allow safety on the roads. This use case will leverage the use of cars and roadside infrastructures as edges. In addition, cars that are by nature mobile will also be exploited as *Mobile Access Points* (MAPs).

7.1 Use case objectives and relation to project objectives

The main objective of this scenario is to provide safety at intersections by enhancing the awareness of road users. To realize this, faster detection of the presence of road users and faster dissemination of messages is required in the environment. This is in line with the project objectives, which are:

- Imperceptible end-to-end latency and response time, with minimal energy and resource consumption; the smart highway use case aims to explore the capabilities of edge devices to provide services closer to the end user so that not only the latency can be reduced but also the load for computation can be distributed by edge devices;
- Expansion of the communication environment in an ultra-real time experience MAPs will be deployed in this use case, making use of the cars that act as mobile relays for end users;
- Showcasing the novel interaction between humans and digital systems; The human-centric application will be further investigated in the case of smart mobility.

7.2 General context and set-up

7.2.1 Overview

The smart highway use case will be set up considering actors involved in the road. Two sites with different characteristics are chosen to demonstrate the use case, both take place at an intersection. The first site is in Germany, focusing on an urban scenario on a campus area. The second site will take place in Belgium, focusing on an exit of a highway. To support the deployment, assets from several partners will be offered to both sites.

7.2.2 Actors involved in the UC4 scenario:

- **Driver:** the driver will be driving the car having an *On-Board Unit (OBU)* equipped with Lidar and a camera, as well as being capable of transmitting long range and short-range communication;
- ***Vulnerable Road Users (VRU)***: pedestrians and cyclists are classified as VRUs. The pedestrian is present at the intersection possessing a device that can provide the awareness and the situation condition of the environment, whereas the cyclist has a device mounted on the bicycle capable of communicating and displaying the condition of the environment;
- **Operations Manager (new actor):** is responsible for Smart Highway service deployment and infrastructure management. This actor will interact with the DEDICAT 6G platform to deploy the necessary hardware and software in the UC sites to maintain the V2X applications and infrastructure functional.

7.2.3 Set-up plan

The two following sites will be used in order to showcase this use case:

- **German Site:** for the site in Germany the deployment will be located on the Reichenhainer Campus of the Technical University Chemnitz (see Figure 26). The square between various University buildings covers an area of almost half a square kilometer and hosts a large range of different transport modes from two single lane roads and a Tram line crossing through the square to bicycle and pedestrian traffic. A bus-tram interchange is as well available. For 2022, the deployment of an end point for an autonomously operated shuttle service is planned. The *Road Side Unit (RSU)* (providing situation awareness as well as connectivity) would be deployed on the square.

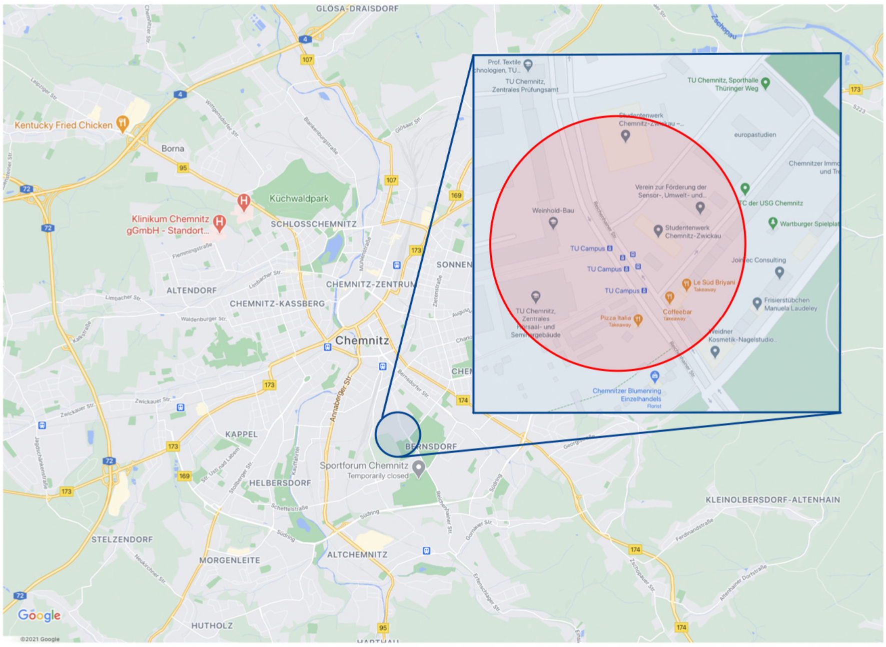

Figure 26: Location of the UC on a map (German site)

- **Belgian site:** the execution will take place in Wommelgem, near the city of Antwerp. The intersection is a junction between a national road and E313 highway in the form of a roundabout, as depicted in Figure 27 on a map. The highway on top of the intersection is equipped with a RSU, as seen in Figure 28, capable of transmitting signals through short range communication towards road users. The roundabout connects to the exits from the highway.

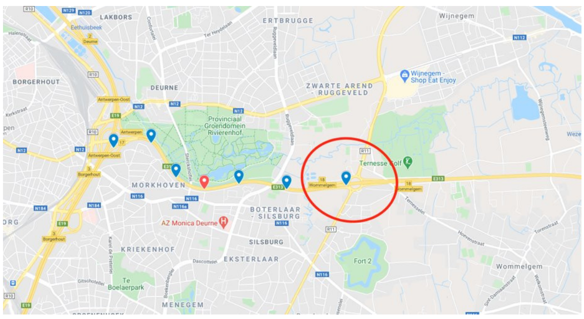

Figure 27: Location of the UC on a map (Belgium site)

Figure 28: Physical location of the UC (Belgium site)

7.3 Pre-requisites and Assumptions

- Pedestrian and Cyclists are classified as VRUs;
- A car is equipped with Lidar and camera on the OBU;
- VRUs are equipped with a small device having both short range and long-range communications capabilities. VRUs carry personal connected devices (e.g., smartphones, and smart watches);
- The RSU has edge computing capabilities and is able to transmit and receive short range signals from cars, pedestrians, and cyclists;
- *Human-Machine Interaction* (HMI) is installed in two cars;
- To monitor the behaviour of the connectivity, a dashboard is provided;
- A map-based application is set up, pinpointing the location and the predicted trajectory of the actors in the use case.

7.4 Stories

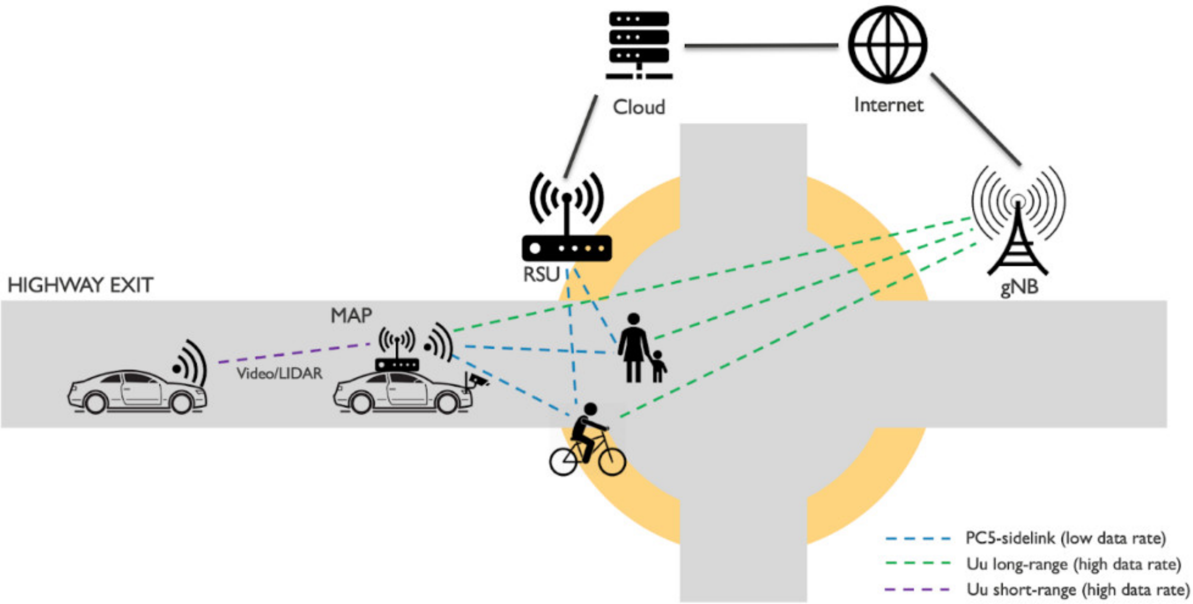

Figure 29: Smart Highway UC set-up

In this use case, the goal is to have a mechanism to detect the presence of the road users on a *Local Dynamic Map (LDM)*. The stories in this use case are represented in Figure 29 on how the actors are set up in the environment. Once a user is subscribed to the LDM service, its location is recorded in the system and shown on the HMI, displaying LDM application. The demonstrations on the smart highway use case are conducted under two sides of the story on detecting VRUs:

- At the exit of the highway: this will be implemented in the Belgian site;
- At the intersection within the urban environment: this will be implemented at the TUC site in Chemnitz.

7.4.1 Story 1: VRU Detection at the highway exit

This story takes place at an intersection, with an exit from the highway. The intersection is actually a roundabout where cyclists and pedestrians can cross.

Short description

An intersection is filled with road users, either cars, pedestrians or cyclists. In order to provide safety, the road users should be aware of the presence of other road users so that they can take navigational decisions carefully. The car can detect the presence of either pedestrians or cyclists through information streams obtained by Lidar or camera. This information will be processed either on the OBU of the car or offloaded to the RSU. This way, the information is circulated to all users, including the cars that exit the highway and are about to enter the intersection.

Story line

The storyline is described from the following three different *Points of View (PoV)*, namely, the VRU PoV, the car PoV and the RSU PoV.

VRU PoV:

- VRUs are present at the roundabout wanting to cross the street;
- VRUs have the device running an application (LDM) fetching information of the environment and sending its location information at the same time, which is offloaded to the RSU;
- The RSU is also aware of the presence of the VRUs, and cars will also distribute the information to the other RSUs;
- The RSUs will distribute the information to the VRUs that are in the vicinity;
- Information about the presence of cars approaching near the VRU's location is displayed in the VRU's HMI, either through a warning message or an icon on the LDM.

Car PoV:

- Car A is exiting the highway;
- Car A recognizes the VRUs via cameras and Lidar;
- Car A will process the information in its OBU to get the information of the presence of the VRUs. The processing can also be offloaded to the nearest RSU in order to lower the computational load;
- Car A will pass the processed information to Car B that is about to exit the highway;
- All cars, this can include other cars in the environment, having the communication modules will receive the information of the presence of the VRUs and cars that are connected to the network;
- The presence of VRUs is displayed on Car B HMI, through a warning message and an icon on the LDM.

RSU PoV:

- RSU is located on top of the intersection can sense the location of the VRUs having the information from both the cloud and direct communication with the VRUs;

- RSUs might get requests from cars or VRUs who want to offload a task;
- In the event of a malfunction during operation, an RSU can offload the task to the other RSUs connected via fiber and deactivate itself.

The information processed by the RSU can be distributed to the surrounding road users either via direct connection or through 5G long range connectivity (via base stations).

7.4.2 Story 2: Distributed situation knowledge in shared traffic spaces

Short description

Consider a public space in which various transport and mobility modalities share the space. Similar to the intersection in the previous scenario, there will be VRUs, autonomous and non-autonomous cars as well as public transport means sharing the space. Vehicles (cars/public transport) are equipped with sensors to detect the traffic related environment conditions and to glean situational knowledge.

But these vehicles are also equipped with sensors inside to 1) interact with the driver and to better understand driver intentions like when they aim to take back control from the autonomous vehicle steering (or detect situations that may require the autonomous control to take over), or 2) to understand the comfort levels of the driver and passengers to decide if the (autonomous) driving style needs to be adapted (always in conjunction with the external traffic situation).

In spaces that are shared between autonomous vehicles and VRUs it is difficult for either one to predict the intention of the other. Hence the RSU will survey its immediate environment with optical sensors (including cameras and lidars) as well as detecting via short range technologies (e.g., Wi-Fi and Bluetooth) the presence of VRUs (the assumption being that the vast majority of VRUs will be carrying a smart phone, connected smart watch or similar devices that can be detected via their electromagnetic footprint). The intention of the scenario is to give every player in the shared mobility space the right amount of information to move safely and effectively

In addition, a series of nodes will be deployed in the environment capable of detecting the short-range radio technologies of the general-purpose devices that are expected to carry most of the VRUs. This information will be accessible to all actors; therefore, it will be possible to generate heat maps of the occupancy of the environment and to feed the LDM map that will be used to prevent risk situations. Moreover, the nodes have the capacity to allow users to exploit their connectivity resources in case they need to download information through an additional connection (e.g., in case of failure of their main 5G connection or network outage).

Story line

There are three main actors or components in this story, these are 1) the VRUs, 2) passengers and drivers, and 3) connected vehicles that are active and mobile users within the shared traffic space. The RSU is for additional purposes and services only.

Car PoV:

- Car A is entering a shared traffic space and connects to the RSU (which maintains, updates and shares an LDM about the local shared space);
- Car A recognizes the mobility related environment via cameras and Lidar;
- Car A will process the local environment information together with information received from the RSU by its on-board unit to glean environmental or situation awareness. The processing may also be done by the local RSU, in that case the raw, or pre-processed sensor information will be transmitted from the car to the RSU;

- Once situation awareness is obtained (i.e., in form of an updated LDM), car A may adapt its driving actions accordingly. It also may inform cars that follow behind about its understanding of the situation (e.g., forward car A LDM to car B);
- The RSU may send LDM updates on a regular schedule or on an event basis.

Driver or Passenger's PoV:

- Autonomous to manual:
  - Car A autonomously driven, enters a shared traffic space;
  - The driver wants to take control and moves to grip the steering wheel. The sensors detect the movement, onboard processing determines the driver's intention and hands back control to the driver;
  - Car A informs the RSU about the change in driving control and transmits updated LDM.
- Manual to autonomous:
  - Car A, manually driven, enters a shared traffic space;
  - The sensors detect unusual movement of the driver, onboard processing determines that the driver may not be in full control and decides to switch over to autonomous driving;
  - Car A informs the RSU and surrounding vehicles about the change in driving control and transmits updated LDM.
- Passenger comfort:
  - The in-car processing (part of the HMI) determines from sensor data that passengers are nervous or uncomfortable about driving actions the autonomous control may have implemented;
  - Car A adapts its driving behaviour;
  - Car A forwards the information (updated LDM) to RSU and surrounding vehicles.

VRU PoV:

- VRUs are present in the shared space;
- Connected VRUs:
  - VRUs collecting information of the user movements and sending its location/movement information to the RSU for processing (the RSU then updates the LDM accordingly);
  - The VRU may receive warning signals (from the RSU) to their device informing about potentially dangerous situations.
- Non-connected VRUs:
  - Non- connected VRUs will be detected by the RSU through its resident sensors and sensing nodes distributed throughout the shared traffic space;
  - The RSU will add information about non-connected VRUs into the LDM (including location, expected trajectory, etc.).

7.5 Relation to the functional decomposition

The Smart Highway use case relates to the DEDICAT 6G functional components in the deployment stage of the infrastructure, in the configuration process, in the runtime of the V2X applications, and in the maintenance of the services. These four scenarios are described in four UML diagrams where we describe the interactions between components UC specific and common FCs of the DEDICAT-6G platform. The scenarios are described in the following.

7.5.1 Management Setup

The management setup (Figure 30) comprises all the actions done by the Operation Manager of the Smart Highway use case. Actions such as registering to the platform and login are necessary to validate the Operation Manager credentials and they need to be done as one of the first steps towards the configuration of DEDICAT 6G platform for this UC. Furthermore, the Operation Manager is responsible for uploading the V2X µS and setting up the necessary policies for its operations. Besides the V2X Application µS and the configuration of it, the Operations Manager is responsible for uploading the *Edge Nodes (EN)* description files to the EN Registry FC, and to deploy the physical hardware of the Edge Nodes placed on the Smart Highway. After the hardware deployed and the configuration uploaded, components in the Edge Nodes need to be configured accordingly.

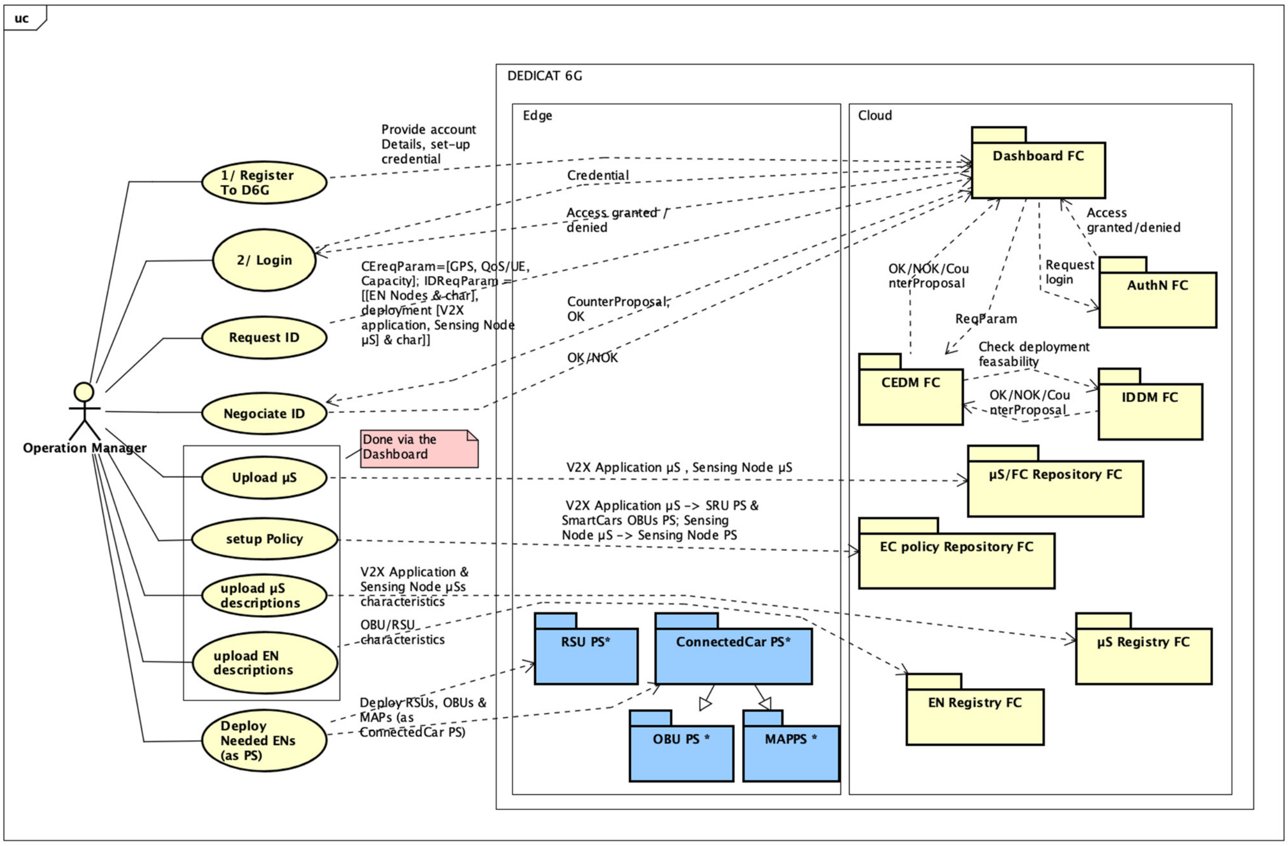

Figure 30: Smart Highway platform setup UML

7.5.2 RSU & OBU Deployment

The RSU, OBU and Sensing Nodes are the EN for the Smart Highway UC. The deployment of management services and UC specific µS in these ENs are actions done by the Operation Manager, as seen in Figure 31. These actions are done through the DEDICAT 6G dashboard and trigger the configuration of the ENs. These management services are FCs deployed in the EN that will gather information about the status of the EN, the status of the µSs running in it and collect information about the sensors available on the EN, such as LiDAR, GPS, Sensing Nodes or even extending the coverage of the network using the EN hardware available.

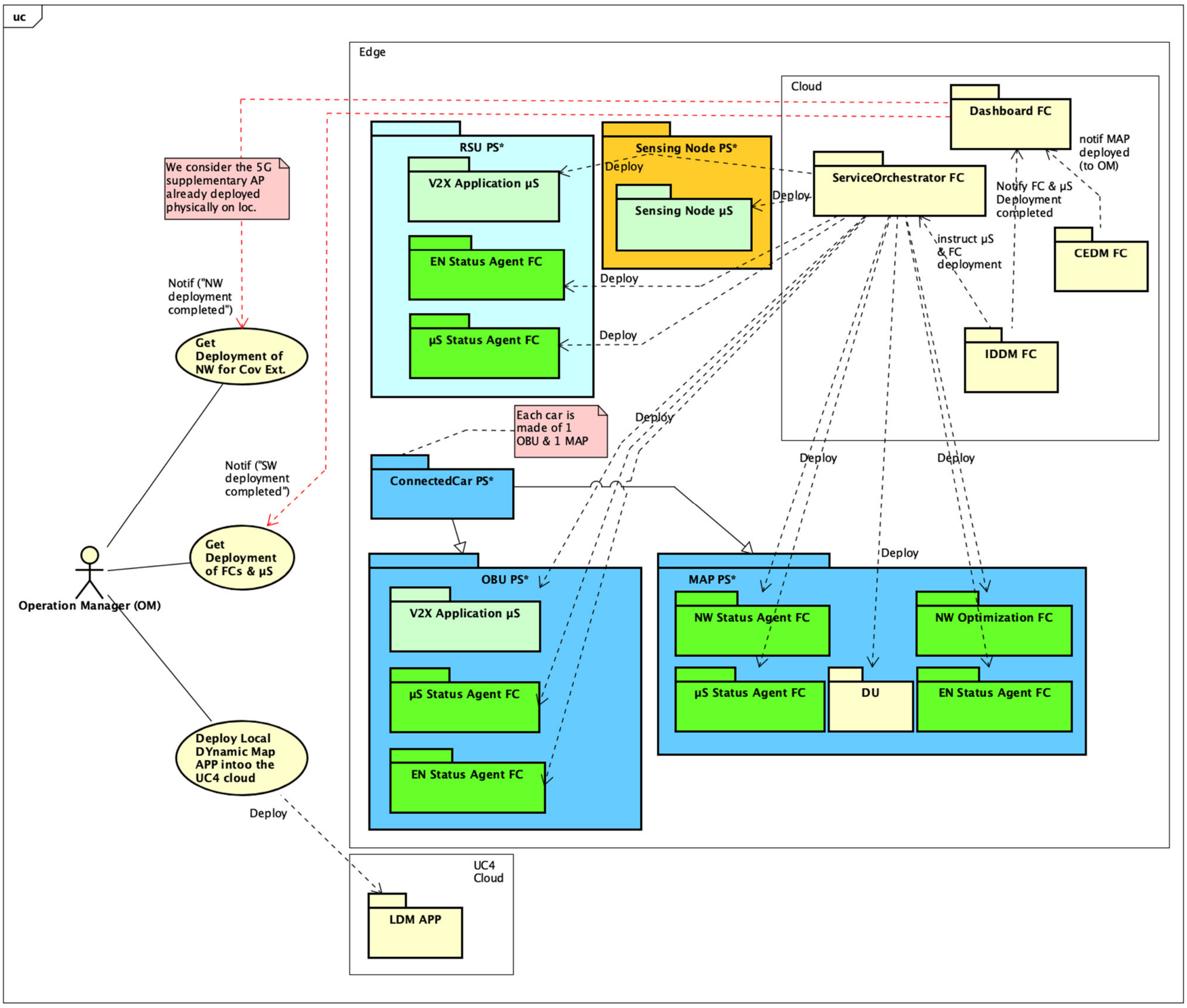

Figure 31: Smart Highway RSU & OBU deployment UML

7.5.3 Story 1 and 2

Figure 32 depicts the functional decomposition related to stories 1 (VRU Detection at the highway exit) and 2 (Distributed situation knowledge in shared traffic spaces) from a joint approach. The deployment of the V2X application is done after the ENs have been configured. At this stage, the Car drivers and the VRUs can communicate with the V2X Application µS placed in the EN for low-latency communication. The Car Drivers and the VRUs receive notifications about the Smart Highway status. Furthermore, the Basic car contributes with the LDM by providing its GPS information. The Smarter Car OBU provides, besides the GPS data, also the LiDAR data. This information together can provide a better understanding of the surroundings of the Smart Highway and contribute to the construction of the LDM. Moreover, the Smart Car OBU can host the V2X Application µS which serves as pre-processor for the LDM that is in the Cloud. The RSU also can host the V2X Application µS that provides server-side information for the VRUs and Car Drivers. The LDM is the Cloud component of the Smart Highway use case. It is responsible for processing the collected data from different OBUs, VRUs, and RSUs and co-relating the data into one single map which will give the status of the Smart highway.

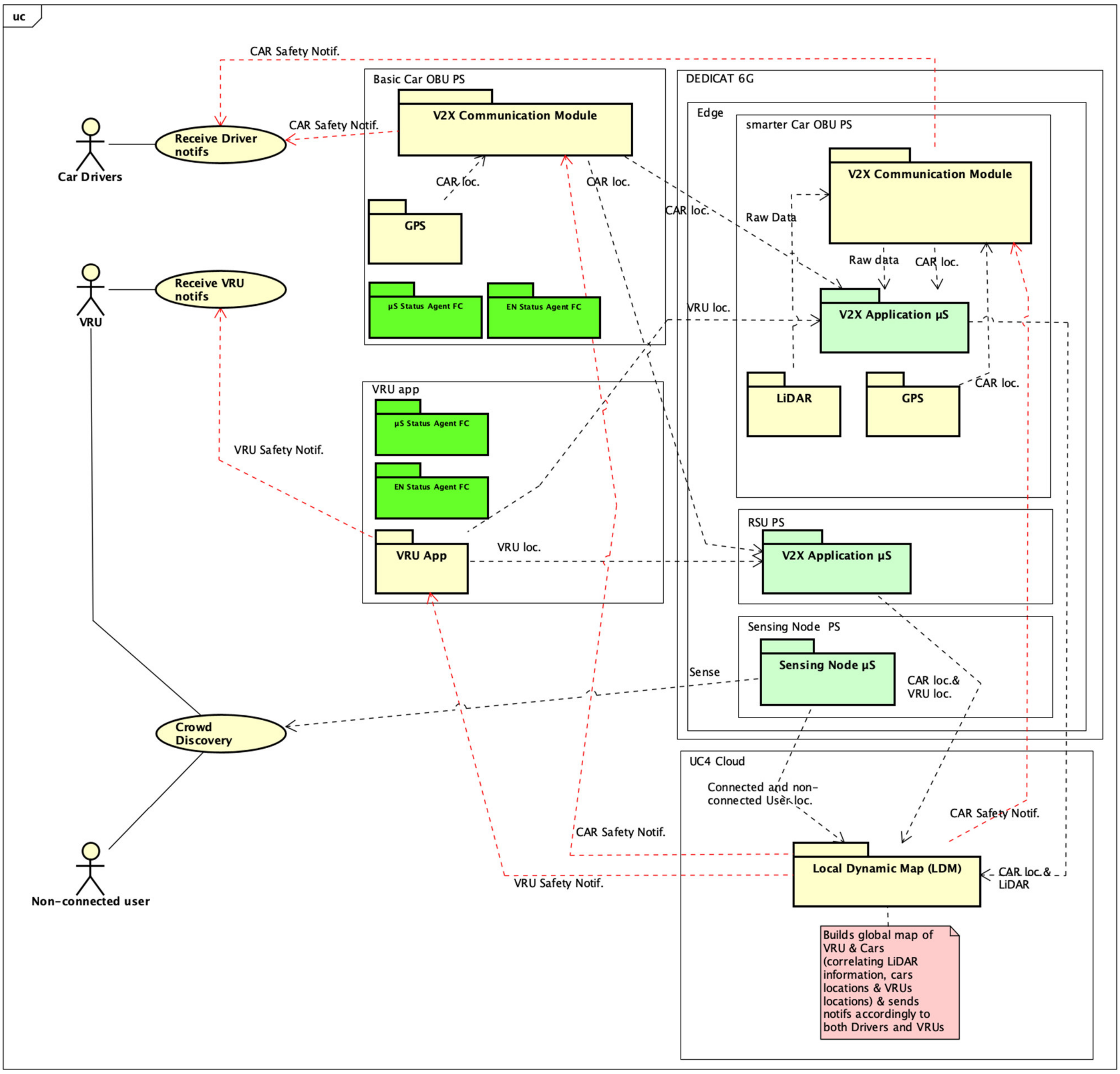

Figure 32: Smart Highway Story 1 & 2 UML

The sensing nodes monitor the connected and the non-connected VRUs. We assume that the vast majority of people present in the shared road scenario carry a smartphone. Therefore, each Sensing Node µS identifies the devices present in their coverage area by extracting the MACs of the radio interfaces and their signal strength. The information is processed in the UC4 cloud and sent to collaborate in the construction of a global map of VRUs and cars present in a given area (LDM). The sensing node network is in charge of discovering crowd issues in the shared traffic area in order to make DEDICAT 6G more secure through context awareness.

Additionally, VRUs (e.g., a bicycle that needs a backup connection to send location information to the DEDICAT 6G platform due to a one-time loss of 5G connectivity), belonging to the DEDICAT 6G network and depending on their location, can query connectivity information about accessible sensing nodes to use their connectivity resources and furthermore, through a Sensing Node µS dashboard serving the sensor network, it is possible for the

Operation Manager to manage and monitor the network of sensor nodes, as well as having MAC control of the devices detected by each sensor node for tasks such as generating context reports or displaying a heat map with the crowd in a given area or managing the sensor nodes to allow connected VRUs to use their connectivity resources.

7.5.4 Load Balancing

Figure 33 shows the Load Balancing in the UC4 occurs in parallel with the executing of the V2X application μS. Therefore, it occurs in runtime. The main component of this scenario is the Service Orchestrator which implements the decisions recommended by the IDDM FC on where the V2X Applications μS should be deployed. The IDDM FC collects information from the ENs and their μSs through the centralized monitoring components μS/FC Awareness FC and EN Awareness FC. These FCs collected data from the available ENs and their μS and made it available for decision making. The Service Orchestrator acts on the ENs (RSUs and OBUs) distributing the load of the V2X applications μSs among them to maintain the best quality of service to the Car Drivers and VRUs.

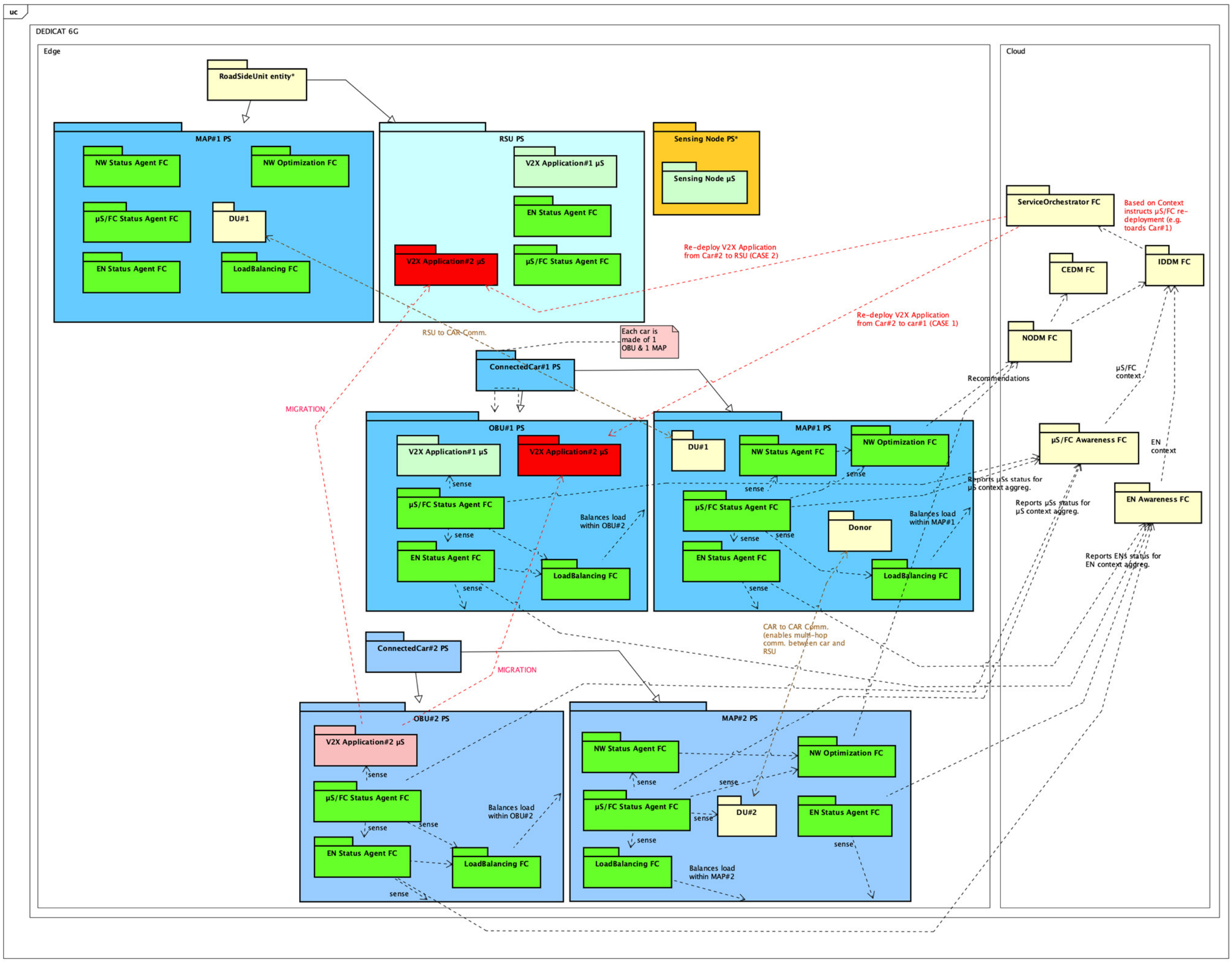

Figure 33: Smart Highway Load Balancing UML

7.6 Requirements

The two following Table 9 and Table 10 respectively give the list of 1) functional and 2) non-functional & non-technical (e.g., business or societal) requirements pertaining to the Smart Highway UC only.

7.6.1 Functional requirements

Table 9: "Smart Highway" list of functional requirements

ID	Type	Category	Description	Priority	Rationale	Fit Criterion
1	FREQ	Usability	The car should be able to recognize the presence of a VRU via the LIDAR/camera.	H	Detection of VRU is essential for increasing road safety.	VRU is detected within specified timing and range constraints.
2	FREQ	Coverage/networking	The car should be able to communicate with other cars, RSU and the 'central' network.	H	Data should be exchanged between the entities for distributed perception and computing	It is tested that data can be exchanged between the different entities.
3	FREQ	Coverage/networking	A vehicle in proximity of the MAP should be able to receive information transmitted by the MAP. Thus, these should be in the same network.	H	A vehicle in specific proximity of the roundabout should be able to receive information	It is tested that information can be received in a specific proximity from the MAP.
4	FREQ	Usability	The car must be able to warn the driver about the presence of a VRU on an HMI	H	The driver must get a visual warning when VRU is present	Checked that the driver can get a warning about VRU presence.
6	FREQ	Usability	The system must be able to present information on the presence of a car to the VRU	H	The VRU must be warned when a car is on a colliding path.	Checked that the VRU is warned when a car is on a colliding path.
7	FREQ	Resource control	The system must be able to be remotely controlled and configured	H	To allow testing and evaluation, the systems will be configured and controlled remotely	Checked that the system can be accessed remotely.
8	FREQ	Load balancing	The system should be able to manage the load distributed on the edge nodes	M	To avoid too much load on specific devices, especially when computing power is limited	Tasks are seamlessly well-allocated across RSUs and vehicles from a VRU initiator. No loss of information should occur between actors. Load distribution should happen within application-specific timing constraints.

9	FREQ	Interoperability	The system must be able to run applications in an interoperable manner	M	To support the load balancing requirement, applications should be able to be run by any nodes	VRU Application components can be executed on RSUs and vehicles, independent of software and hardware architectures.
10	FREQ	Geolocation	The system should provide geographic location information of the nodes	H	Road users' location should be discoverable in order to locate their position in the environment	Awareness location is incorporated in the system.
11	FREQ	Coverage/networking	It should be possible to identify the need for a dynamic coverage extension.	M	To allow communication between all the devices in all circumstances	Tested that the system identifies the need for dynamic coverage extension.
12	FREQ	Coverage/networking	The system must be able to automatically enable/disable a MAP in the vehicle to extend the coverage in a self-organized way	H	If coverage needs to be extended a MAP should be created	Tested that the system will automatically enable/disable a MAP when required.
13	FREQ	Coverage/networking	A device in proximity of MAPs must be able to identify and connect to it.	H	To allow other devices to setup a connection to a MAP	Tested that a device can identify and connect to the MAP.
14	FREQ	Logging	System must be able to log performance of processes, resource utilization and the network	H	For debugging and to perform evaluation of the performance of the system.	Several parameters are successfully logged.
15	FREQ	Context awareness	System must be able to generate a heat map of the crowd present in the coverage area of the sensing nodes	M	To have a control through of the number of devices present in an area to estimate events such as the presence of a crowd in the shared traffic area	Checked that the system can generate heat maps with the crowd.

7.6.2 Non-functional and non-technical Requirements

Table 10: "Smart Highway" list of non-functional and non-technical requirements

ID	Type	Category	Description	Priority	Rationale	Fit Criterion
1	NFREQ	Performance	A MAP should be able to provide the required downlink throughput	M	To satisfy the data stream requirements	Measured that the required downlink throughput is met.

2	NFREQ	Performance	A MAP should be able to provide the required uplink throughput	M	To satisfy the data stream requirements	Measured that the required uplink throughput is met.
3	NFREQ	Performance	The end-to-end one-way latency between a MAP and another receiving device in its proximity should be reasonably low	M	To satisfy the data stream requirements	Measured that the required latency is met.
4	NFREQ	Performance	Reliable communication	H	Communication between all the devices in all circumstances should be high reliable (99.999%).	No loss of information should be occurred between actors and no delays in the communication due to instable situations
5	NFREQ	Privacy, ethics	Position information of road users must be collected for locating the nodes in the map	H	App displayed on the HMI of the UEs must continuously gather location information of the users	Compliance with regulation
6	NFREQ	Privacy, Ethics	Video feed should be collected by cameras on the car	M	Camera on the car will continuously record the situation at the intersection	Compliance with regulation
7	NFREQ	Privacy, Ethics	Device's information (MACs, RSSI etc.) should be collected by sensing nodes on the coverage area	M	Sensing nodes will continuously record the devices information at the coverage area	Compliance with regulation
8	NFREQ	Usability	Sensing node network should have its own dashboard as part of the microservice that can potentially be used by the operation manager	M	To access to the complete information of the sensing node network	Checked that the sensing node dashboard can be accessed remotely

8 Conclusions

In this second iteration of the incremental document "Scenario Description and Requirements" we have summarized the main outcomes of the work done concerning the DEDICAT 6G use cases definition since the release of the D2.1 [1]. As a main remark, compared to D2.1 (and in the Context View in D2.2) the use cases are now presented from a functional point of view, putting the light on the roles to be played by the DEDICAT 6G platform in some key use case scenarios. This functional decomposition has been carried out at a high level of granularity, showing the interactions between the functional components of DEDICAT 6G and these dedicated to each use case. Also, it provides a set of functional interactions to be merged into D2.4 under a unified perspective, in the form of UML sequence diagrams.

Moreover, the effort invested in the functional decomposition has contributed also to updating of the former D2.1 [1] functional and non-functional requirements as needed in each use case. This work is contextualized within the tasks, T2.1 "Scenario Description", T2.2 "Requirement collection, analysis, unification, and cross-check" to feed T2.3 "Architecture design" and will also bootstrap the WP6 activities enabling a common understanding of challenges and objectives thanks to extensive and updated material, as well as driving part of the technical activities within the work packages WP3, 4 and 5 planned in the DEDICAT 6G project.

In consideration of the main relationship between the system architecture and the functional decomposition, this second iteration of the D2.1 [1] deliverable allows the evolution of the current version of the project architecture to be presented in D2.4 "Revised System Architecture" and will show a complete and updated architecture aligned with all use case requirements presented here.

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