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

Deliverable D2.1
Initial 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
BC	Business Case
BLE	Bluetooth Low Energy
BMSC	Broadcast Multicast Service Centre
BS	Base Station
BT	Bluetooth
CCTV	Closed Circuit Television
COVID-19	Coronavirus Disease 2019
DC	Design Constraint
DoA	Description of Action
ERP	Enterprise Resource Planning
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	Identifier
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
MC-PTT	Mission Critical Push to Talk
MCS	Mission Critical Services
MEC	Mobile Edge Computing
ML	Machine Learning
MPLS	Multi-Protocol Label Switching
n/a	Not Available
NAT	Network Address Translation
NFREQ	Non-Functional Requirements
NS-3	Network Simulator 3
OBU	On-Board Unit
PC	Personal Computer
POP	Point Of Presence
PoV	Point of View
QoE	Quality of Experience
QoS	Quality of Service
QR	Quick Response
RAN	Radio Access Network
RAT	Radio Access Technology
RF	Radio Frequency
RSU	Road Side Unit
SDR	Software Defined Radio
SLAM	Simultaneous Localization and Mapping
SOTA	State Of The Art
UC	Use case
UE	User Equipment
UNI	Unified Requirement
UPS	Uninterruptible Power Supply
V2X	Vehicle to Everything
VR	Virtual Reality
VRU	Vulnerable Road User
vs.	versus
WMS	Warehouse Management System

w.r.t.	With Respect To
WYSIWIS	What You See Is What I See

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Executive Summary

This document introduces the outcomes of the initial use cases description and requirements elicitation work carried in the H2020 DEDICAT 6G project. The overall objective of this project is to design a smart connectivity platform that is green, highly adaptive, ultra-fast, and dependable/resilient for securely supporting innovative, human-centric applications that will be validated in representative use cases. For this, DEDICAT 6G will address techniques for efficient dynamic connectivity extension and intelligent resources placement in the mobile network, through the exploitation of novel mobile client nodes, with the required secure and trusted exchange of information.

This document provides a detailed definition of the DEDICAT 6G use cases. Each use case perfectly matches the project's technical objectives while being relevant both from a social as well as a financial point of view. Therefore, they have been selected to test, demonstrate, and validate the solutions that will be developed during the project. Multiple stories are depicted for each use case to illustrate the expected workflow using the DEDICAT 6G platform and identify various ways for stakeholders to interact with each other.

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 through utilization of automated guided vehicle (AGV) for improving operations such as picking sequence and quality assessment of products. It has a strong emphasis on real-time human machine interaction, computation offloading and security.
2. **Enhanced experiences:** It provides live streaming applications that use enhanced data overlay in 360° and augmented reality (AR) applications as well as more complex datasets in virtual reality (VR) with the needed hard requirements in terms of bandwidth and computing capabilities for heavy video processing and distribution. This use case is focused on distributed intelligence, computation and caching offloading, and dynamic coverage extension.
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 such as natural disasters or terror attacks by the use of diverse assets (drones, AGVs, etc.). This use case is concentrated on intelligence distribution, dynamic coverage extension, security guarantee, and human in the loop.
4. **Smart highway:** It describes how connected and autonomous mobility can benefit from beyond 5G (B5G) and 6G connectivity, especially in the area of efficiently offering the smallest possible delay and ultra-reliability. It is related to intelligence distribution, computation and caching offloading, dynamic coverage extension, safety, and human in the loop.

DEDICAT 6G use cases are presented from the standpoint of several relevant actors, contextualized in every use case business field. Gaps are identified, and a set of requirements considering existing technologies and trends are extracted. Finally, proposals on how to fill these gaps are discussed, envisioning the expected functionalities of the DEDICAT 6G platform.

This deliverable provides the basis for the design and implementation of technical innovation work that will be performed in multiple work packages: WP2 where the architecture will be detailed and WP3, WP4, WP5 where the key DEDICAT 6G technical enablers will be designed and developed and WP6 where performance evaluation and validation through demonstrations of DEDICAT 6G architecture and solutions will be accomplished.

1 Introduction

DEDICAT 6G focuses on four use cases:

1. **Smart warehousing:** It covers the trustworthy automated real-time monitoring, surveillance, and optimized operation of a warehouse through utilization of automated guided vehicle (AGV) for improving operations such as picking sequence and quality assessment of products. It has a strong emphasis on real-time human machine interaction, computation offloading and security.
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This deliverable investigates for the selected use cases some specific performance, security and scenario operation aspects that can be improved leveraging the DEDICAT 6G architecture and its secure smart connectivity services. Starting by sharing the interests of the consortium members along the project with participation in the aforementioned use cases, and accompanied by the use cases description, including pre-requisites, assumptions and specific infrastructure and needs, the DEDICAT 6G use cases are described to identify relevant stories and derive requirements for the platform architecture design.

Therefore, the objectives of this deliverable include:

- Positioning of the different use cases regarding the project technical objectives and enumeration of demonstrated functionalities (sub-sections 3.1, 4.1, 5.1, 6.1);
- COVID-19 contingency plan for each pilot in the case of an extension of the current pandemic situation (sub-sections 3.2, 4.2, 5.2, 6.2)
- Textual description of all scenario-specific infrastructure demands in each use case including the context in which it takes place (sub-sections 3.3, 4.3, 5.3, 6.3);
- To detail use cases for the new DEDICAT 6G architecture which can be relevant to demonstrate how the platform is expected to be used (sub-sections 3.5, 4.5, 5.5, 6.5);
- Gathering and prioritization of requirements for architecture design and implementation from the selected use cases (sub-sections 3.6, 4.6, 5.6, 6.6).

Use case scenarios and requirements identified in this deliverable represent a preliminary though comprehensive description of what the DEDICAT 6G architecture is expected to address. Use cases will be 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. These will be then reported in deliverable D2.3 "Revised scenario description and requirements", planned for M14 (February 2022).

This document is structured as follows. Section 2 provides an overview of the requirement engineering process that will be followed throughout the project. Sections 3-6 provide the detailed descriptions of the use cases and corresponding derived requirements for Smart Warehousing, Enhanced Experiences, Public Safety and Smart Highway. Finally, section 7 concludes the document with a summary of the key points.

2 Introduction to requirement engineering

The requirement engineering process consists of several steps, which ultimately lead to a set of Unified Requirements (a.k.a. UNIs) captured within a VOLERE document (Excel template).

This process will be explained in depth in the architecture document (Deliverable 2.2). However, Figure 1 below gives a taste of the different steps involved and what they consist of:

- **Requirement collection:** to collect requirements from the use cases as is the objective of this document in addition to the use case descriptions;
- **Requirements' consistency checking:** to check and deal with potential requirement inconsistencies, especially when multiple sources are involved;
- **Requirement rewriting, factorization, alignment:** to discard duplicates and factorize as much as possible, to align with common vocabulary;
- **Requirement mapping:**
  1. To map Functional Requirements (**FREQs**) to a Functional View, perform functional decomposition;
  2. To map Technology and Design Constraints to Design Choices following chosen tactics;
  3. To map Non-Functional Requirements (**NFREQs**) to other views and all perspectives.

Figure 1: Requirement engineering steps

The first phase of the requirement engineering process[1] comes with collecting requirements from the different project stakeholders: both scenario/use case driven, and technology driven ones. The different sources of requirements in DEDICAT 6G are therefore:

- **Scenario/use case requirements:** they focus on the four use case stories and objectives and identify various needs and expectations the use case scenarios have, as far as the supporting DEDICAT 6G platform is concerned, in term of properties, functionalities, interfaces, etc. These use case scenarios do not focus much on the technology side but rather on the functional aspects (which functionalities are needed in order to implement the story) and also non-functional aspects such as performance, privacy, deployment, scalability, etc.; those requirements should reflect end-users concerns as well;
- **Platform requirements:** they capture the technical objectives that have been described along the Description of Action (DoA) document [2] and which materialize the steps beyond the state of the art (SOTA) that the project will undertake to implement;
- **Business requirements:** they reflect business or exploitation-related needs;

Requirements are generally classified into three categories as follows:

- **Functional requirements:** they directly refer to capabilities of the system in terms of WHAT it has to do. Functional requirements are mainly used to build up the Functional View;

- **Non-functional requirements:** they refer to what the system should be or which properties the system should feature. The non-functional requirements are used to build up the Information and Deployment & Operational Views and all system perspectives;
- **Technology and Design constraints:** They impose restrictions on how the system should be designed and which technology should be used and therefore influence both views and perspectives.

In a nutshell, while FREQs dictate WHAT the system must, should, or could do, (depending on priority levels high/medium/low (H/M/L), NFREQ focus on HOW the system must, should, or could do it.

In order to facilitate the next steps of the requirement process, it is a good practice to capture additional information about each requirement beyond its description and the category it falls into. Table 1 below describes the comprehensive list of fields, which are used within the VOLERE template [3] for the Unified Requirement (output of the Requirement Analysis), which was also extensively used in the IoT-A project [4][5]. However only a subset of the VOLERE template fields has been used in the requirement tables assigned to each use case. The fields in green will be used only for Requirement analysis and are therefore out of the scope of this document, however, they have been left in this document in order to give a glimpse of what will be done next as far as Requirement Analysis is concerned (in Task 2.2 "Requirement collection, analysis, unification, and cross-check"). The VOLERE template for DEDICAT 6G will be issued after requirements collected at the beginning of Task 2.2 (in this document) have been analyzed and unified during Task 2.2 activities. This template will be included as an Annex of the Architecture documents and will be updated continuously (referred to as "cross-check" in Task 2.2) in order to keep track of how every requirement has been dealt with during the system architecting activities (Task 2.3 "Architecture design").

Table 1: VOLERE template Field description

FIELD	DESCRIPTION
ID	Each requirement is uniquely identified
Requirement Type	1. Functional Requirements (FREQ) 2. Non-Functional Requirements (NFREQ) 3. Design Constraints (DC) It is easier to write an appropriate fit criterion when the type of requirement is established. When one groups all of the known requirements of one type, it becomes readily apparent if some of them are missing or duplicated.
Description	The description is the intent of the requirement. It is a statement about what the system has to fulfill according to the rationale (see further below).
Categories	Technical or non-technical topics covered by the requirement. Could be more than one. List to be decided between partners. Here is a starting list: • Security • Privacy • Trust • Performance • Scalability

	• Platform • Networking • Edge computing • Cloud computing • Machine learning • Latency • Interoperability • Management • Data • Discovery • Look-up • Business • Societal • Ethics • Load balancing • Bandwidth • Radio coverage • 6G • ….
Rationale	The rationale is the reason behind the requirement's existence. It explains why the requirement is important and how it contributes to the system's purpose.
Owner/ Source/Req. Name	The owner or originator is the person or organization which raised the requirement in the first instance or the person to whom it can be attributed. The originator's name should be attached to the requirements so that there is a referral point if questions about the requirement arise or if the requirement is rejected. The person who raises the requirement must have the knowledge and authority appropriate for the type of requirement.
Originating Scenario/BC	Identifier (ID) of the originating use case scenario or business case (BC) if relevant
Fit Criterion	A quantification or measurement to assess to which extent the original requirement has been eventually implemented or taken into account within the system. Can be used as the "Definition-of-Done" in agile development practices.
Priority	The priority of a requirement is the decision on the importance of the requirement's implementation. The priority depends highly on the specific domain of the application. Priority takes values from {high, medium, low} with a decreasing priority level where high, medium, and low mean, respectively, compulsory, recommended, and optional.
Dependencies [optional]	Indicates if the requirement depends on another one. Relations between two or more requirements should be noted and separated by comma(s).
Conflict [optional]	Conflicts between requirements imply that there are contradictions upon system implementation, or one requirement makes the implementation of another requirement less feasible. Values: default "(none)" or requirement number(s), separated by comma(s).
View	One or several views to which the requirement is related.

Functionality Group	One or several functionality groups in the functional decomposition to which the requirement is related.
Functional Component	One or several components in the functional decomposition to which the requirement is related. These functional components are part of the groups listed in the functionality-group field.
Domain Model	One or several domain-model entities to which the requirement is related.
Perspective	One or several perspectives to which a requirement is related.
System Use-Case	ID of the System Use Case that needs the requirement under consideration.
Comment [optional]	Any comment providing useful information

Note: In the final version of this deliverable (the one delivered to the EC), only the following 7 fields (table columns) are included for the sake of better readability: ID, requirement type, description, categories, rationale, fit criterion, and priority.

3 "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) can be improved (efficiency in resource utilization, safety and security and overall automation performance) with AI, edge processing, and blockchain for improved trust [6][7]. Human-robot interaction in smart warehousing is one of the main research topics from technological and societal point of view [8].

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 throughout value chains.

This will be achieved through an integrated state-of-the-art operational system based on *Automated Guided Vehicles* (AGVs), drones, and Internet of Things (IoT) systems with edge computation capabilities supporting deployment of DEDICAT 6G enablers.

3.1 Use case objectives and relation to project objectives

The main objective of the use case scenario 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 HD video and AR/VR functionality to enable human interaction.
    - Target innovation: *Mobile Edge Computing* (MEC) could help reduce response time to perform certain action as well as enable near real-time human intervention. This can also include advanced AGV operations enabled by 5G 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 fixed 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 and drones 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 Smart 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

3.2 COVID-19 contingency plan

The main risk of a lasting pandemic is that not all of the contributing partners (including use case leader) are from the same country where the scenario will be deployed and validated (Greece). This risk might introduce delays in setting up the scenario and require additional organizational overhead since most of the technology deployment and configuration efforts would be done remotely. In order to mitigate the risk, the scenario partners have prepared a contingency plan:

- Regular calls/virtual meetings among involved partners to ensure that all issues are identified and handled as early as possible;
- Technology providers will make sure that they can supply equipment to the site;
- Technology providers will organize remote support for deployment, configuration and experiments with their technology;
- On site partners DIA and WINGS will provide the necessary support for remote system configuration and management.

3.3 General context and set-up

The smart warehousing scenario 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.

3.3.1 Overview

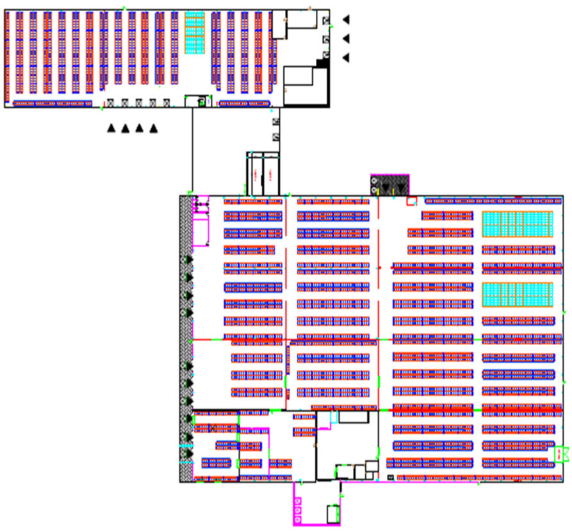
The DIAKINISIS (DIA) Warehouse "Imeros Topos" is located in NW Attica, 27 km from Athens city center (see Figure 2 below). The Warehouse is easily reachable via highway. Corresponding Google map coordinates:

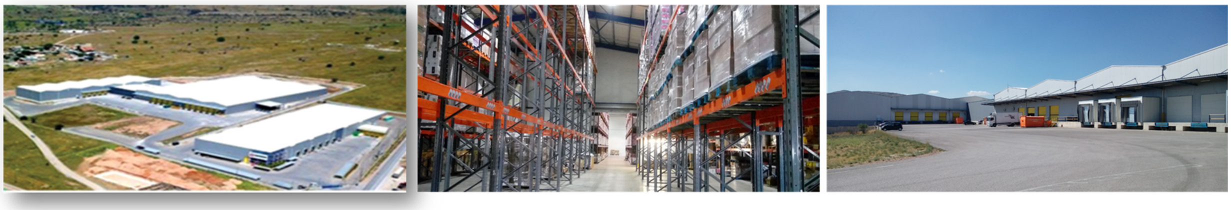
- Longitude: 23°37'35.51"
- Latitude: 38° 3'51.74"

Figure 2: Warehouse "Imeros Topos" location

The following Table 2 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 2: Warehouse "Imeros Topos" Information

Plan	Resources
	• 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



3.3.2 Actors involved

Table 3 presents the "Warehouse ecosystem" in terms of the actors/roles and interrelationships reflecting the current conditions and operational procedures.

Table 3: The Warehouse "ecosystem".

Actor	Role	Relationship(s)
Warehouse Manager	Overall management	Coordinates Technical Manager, Safety Manager and Supervisors.
Technical Manager	Equipment monitoring and maintenance	Coordinates 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 Supervisors for everyday safety tasks.
Robot/AVG(s)	New actor to be included in the context of warehouse enhancement.	This can act a Mobile Access Point 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
Workers	Implementing warehouse processes e.g., picking, packing, checking, loading/unloading.	Implement certain procedures and follow Supervisor's guidelines
Forklift/Machine Operators	Operation of forklift/machines in the context of warehouse processes.	Implement certain procedures and follow Supervisor's guidelines

The above-described roles and interrelations are depicted in the following Figure 3. 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;

- Robot/AVG(s) needs to be linked to the existing roles.

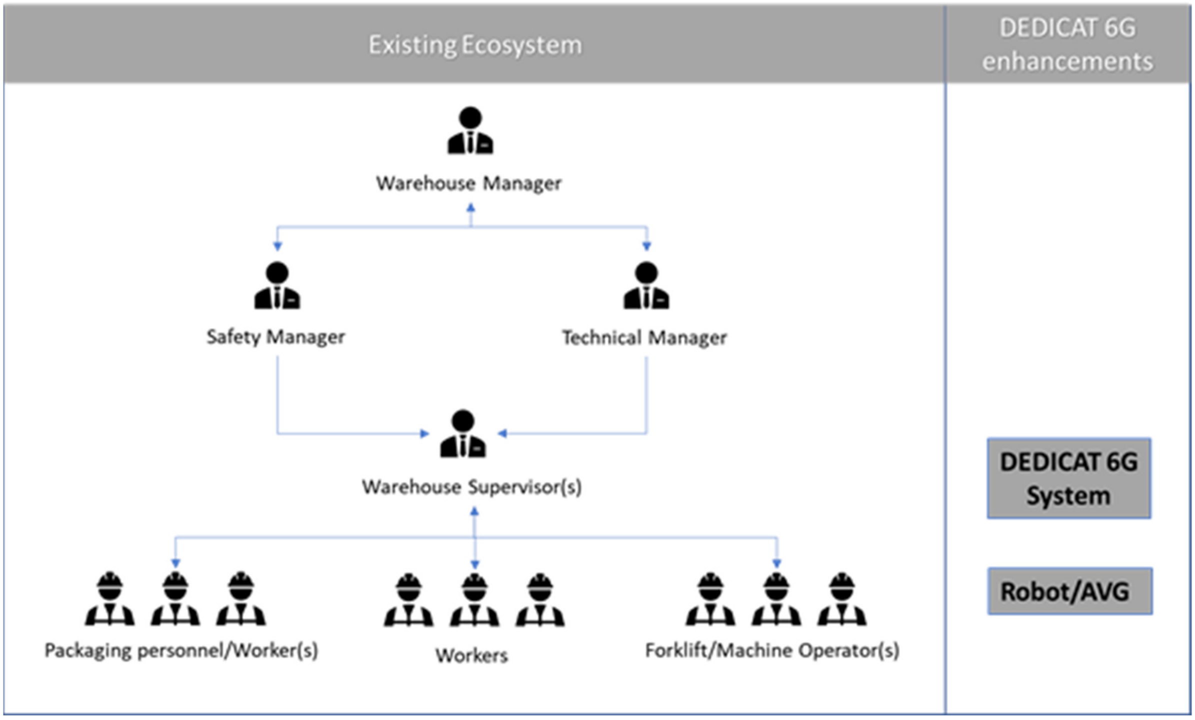


Figure 3: Smart Warehousing "ecosystem".

3.3.3 Technology provided by partners

- WINGS:
  - AGV - TurtleBot3 Waffle-Pi: 360° LiDAR for SLAM, Camera, 3-Axis gyroscope, accelerometer and magnetometer, OpenCR controller board 4 degree-of-freedom robotic, laptop for computing;
  - Platform for integration and mechanisms including image processing (e.g., for quality assurance) and decision making on positioning of Mobile Access Points for dynamic coverage extension.
- VLF:
  - BLEMAT - Bluetooth Low Energy Microlocation Asset Tracking based on VLF IoT controllers will be used for tracking AGVs, goods and personnel. Also, the system provides configurable geo-fencing capabilities so that safety managers can setup security zones and configure notifications for on-site personnel. Bluetooth Low Energy (LE) high precision battery powered location beacons will be provided and deployed on strategic resources (like AGVs) and key personnel;
  - Smart Access 360 - IoT system for cyber-physical security, smart sensing and smart actuation. This system will provide IoT controllers capable of smart sensing and actuation (through built in circuit relays). The controllers will perform edge based computing and necessary identity management in order to ensure context aware authorization of the smart actuation processes (controlling electric locks, gates, lights, alarm systems, and HVAC - Heating, ventilation, and air conditioning);
  - The two systems rely on the same IoT resources (controllers). These controllers can be configured to perform other necessary edge computing and coverage extension tasks required by the smart warehousing setup.
- DIA: provides the warehouse as described above technology currently being utilized for warehouse operation includes:
  - Network

- Wireless MPLS 10 Mpbs (Rolaware)
- Backup Wireless MPLS (Wind)
- Local gateway to Internet 12 Mbps (Rolaware)
- WiFi corporate
- WiFi guest – public Internet (legacy system planned to be upgraded)

- RF scanners for picking/packing and forklift operations;
- Warehouse management system (WMS, provided by Mantis) for supporting warehouse functionality and management;
- Enterprise Resource Planning system (ERP, provided by SAP) for data collection and message distribution, connected to WMS;
- Backoffice connected to both ERP and WMS systems;
- Provides test site – warehouse for realization of the smart warehousing use case. See section 3.3.1 for details about the warehouse.

- NOKIA:
  - Datapace which is a data marketplace built on blockchain. Datapace be used to stream data from any source, IoT devices, physical assets, autonomous cars, drones, and many more. As one of the Datapace features, NOKIA Sensing as a Service allows operators to manage their networks through remote monitoring of network assets. Both Datapace and Sensing as a Service product will leverage on DEDICAT 6G results to achieve an industrial-grade IoT platform with orchestration and management capabilities and open the possibility of novel approaches to IoT data monetization;
- ORANGE:
  - Decision-making algorithms, at different timescales, for the coverage extension and resources orchestration depending on the service requirements and with isolation guarantees for security purposes. These algorithms will be implemented on top of the cloud management platform.

3.3.4 Set-up plan

The setup shown in Figure 4 below is considered at this time for realization of the Smart Warehousing use case. This setup considers the following:

- AGVs are deployed and configured to perform smart warehousing tasks;
- IoT system deployed and configured to perform smart warehousing tasks;
- BLE (Bluetooth Low Energy) 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.

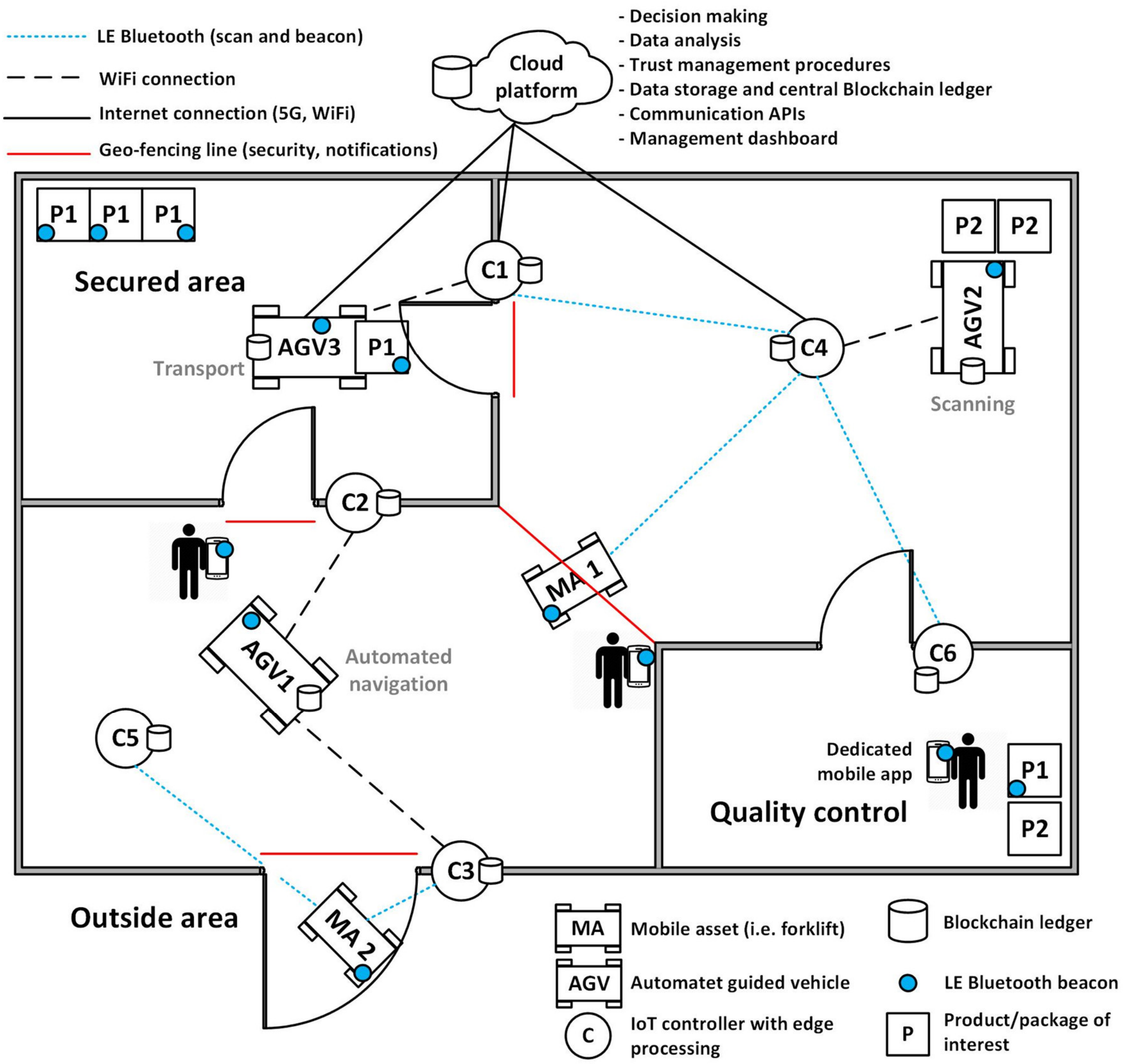


Figure 4: Smart warehousing use case setup plan

3.4 Pre-requisites and Assumptions

The main assumption for the scenario is that a warehouse operator/owner 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 can 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. 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 and drones deployed and configured for coverage extension, 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: LE Bluetooth location 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.

3.5 Stories

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 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.

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.

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

Short description

This story puts focus on a warehouse administrator or 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 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 might or might not be at the same location as the warehouse itself.

Story line

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, the IoT system performs indoor positioning of the mobile assets and personnel through BLE beacons, monitors environmental conditions in the warehouse and manages access to warehouse areas with specific authorization rules:
   a. The IoT system provides alerts to workers and the warehouse manager when social distancing rules are breached (many workers in 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 analyzes 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 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.

3.5.2 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 those 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 AGV1 and AGV2 and directs AGV1 towards a product that needs to be moved to the loading bay while AGV2 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 AGV1 to the loading bay;
4. X receives a notification to check AGV3 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 AGV3 in the upright position. X requests temporary authorization for Y to access the area. The manager grants the 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 AGV3 and are back to the non-restricted area;

5. Y goes back to monitor AGV1's 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 AGV1, 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 AGV1 intervenes and alerts Y to go back;
6. AGV2 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 AGV2 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 AGV2 to remove the product from the line. The conveyor belt is restarted. AGV2 brings the damaged product to the inspection area while AGV4 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.

3.6 Requirements

The following two tables, Table 4 and Table 5 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.

3.6.1 Functional requirements

Table 4: "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	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 pre-defined set of rules. Collected data is sent to central platform for performance analysis and updates for local decision-making models. Exact performance metrics will be defined within 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	Configurable authorization levels implemented and tested.

					admin, warehouse manager, warehouse personnel, test user	
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 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 analyzing 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	Check in experimental setup. Mobile app installed on a mobile device 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 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	DEDICAT 6G system must be able to provide incident report 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 (systems, layout, mobility paths, personnel etc.).	Process for creating warehouse virtual entity 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	H	Node/resource owners must be able to make decision about their resources and	Approve two out of three nodes and trigger coverage

			distribution without the approval of the user/owner/operator of the device/node.		devices being utilized in local ad-hoc networks with devices belonging to other users.	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 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 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 placement of products – dynamic obstacles.	Set mobility route (point A to point B) for AGV, put obstacle on the rout and monitor AGV ability to reach destination without manual reconfiguration.

24	FREQ	Machine learning	Decision making based on monitored environmental parameters (temp, 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 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 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/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 mobile access point (MAP).	Check data propagation between end points (ping messages between points).

31	FREQ	Coverage/Networking	Relaying shall be supported by central nodes or by edge nodes.	M	This will allow forwarding of data and control signaling 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.
32	FREQ	Coverage/networking	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-criterion for identifying the need for coverage extension.
33	FREQ	Coverage/Networking/ 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-criterion for identifying the need for redistribution of intelligence.
34	FREQ	Coverage/Networking	Device and infrastructure capable to set-up connection	H	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.	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.
35	FREQ	Coverage/networking	More than one coverage extension networks 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 communication 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 creation of ad-hoc opportunistic systems.	We need project level fit criterion for user QoS and QoE assessment

3.6.2 Non-functional and non-technical requirements

Table 5: "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	Emulate addition of a new IoT system and test interoperability.

					can be integrated and made interoperable.	
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 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 overall safety of the personnel.
3	NFREQ	Efficiency	Warehouse automation improves energy efficiency	M	Certain automation processes might result in improved energy efficiency. Lights can be turned off in area of warehouse without personnel. AGVs can operate in conditions which are less energy demanding (in dark, sub-optimal temperature etc.).	Asses 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.
4	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.
5	NFREQ	Cost reduction	Reduce internet bandwidth consumption	L	Edge computing reduces internet bandwidth usage since most data are analyzed locally.	Check internet bandwidth usage of outbound channel

						with and without edge processing.
6	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 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.
7	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.
8	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.
9	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 regulation into specific set of automation and decision-making rules. Confirm completeness.
10	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 warehouse manager or regulatory bodies.	Setup logging procedure, generate logs and check their completeness in different experimental setups.
11	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 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

12	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 product and perform quality inspection with camera and other sensors.	Check that AGV is able to perform package handling operation with experimental setup.
13	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.
14	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
15	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 the personally identifiable information when transferred and stored.	Check data collected at source (personal data) and check data when stored in database – confirm that data is anonymized.
16	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 local database.
17	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.
18	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

4 "Enhanced Experience" (UC2)

The Enhanced Experience use case scenario 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[10], [10]. As a consequence, a large audience is vying for the same network resources within a small area [11]. In addition, large crowds would move from one venue to another depending on the time and places (e.g., multiple stages attract varying size of audience). In this case, dynamic network coverage is needed to provide seamless connectivity[12], [13]. The DEDICAT 6G solution for Enhanced Experience focuses on these issues and strives for providing richer quality of experience to local spectators as well as delivering enhanced live experience to remote users using B5G/6G networking.

4.1 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.

4.2 COVID-19 contingency plan

As the scenario is intended to focus on live public events, prolonged COVID-19 restrictions can prevent the implementation of large audience in the events. However, our solution considers and supports remote participation to such events, which can be live streamed to large remote audience via mobile B5G networking. In either event, all the sub-solutions will be simulated or demonstrated in a laboratory environment. The considerations for contingency plan:

- Pre-trial simulations and demonstrations in a laboratory environment enabling multiple users and congested traffic;
- Demonstrating use case in smaller live public context in scaled-down environment regarding people density;
- Producing the live content from the field with limited number of participants (possibly limited according to the government rules) to remote audience at home. The field users can consist of DEDICAT 6G staff.

4.3 General context and set-up

4.3.1 Overview

Public mass events tend to have a large audience with different roles. We consider the selected on-site users, which 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.

4.3.2 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 uses 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 home, parks, or other remote places accessible to mobile network. They have the opportunity to 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 the access for the DEDICAT 6G group for the area, permission to perform experiments, and to provide the multimedia content.

4.3.3 Technology provided by partners

- VTT:
  - Unicast/multicast video streaming platform and applications;
  - Network offloading and adaptation solutions for dynamic edge processing;
  - Laboratory and piloting facilities.
- ORANGE:
  - Decision-making algorithms, at different timescales, for the coverage extension and resources orchestration depending on the service requirements and with isolation guarantees for security purposes;
- OPTINVENT:
  - ORA-2 Smart glasses with BT accessory capabilities and a custom application with a specific user interface for the glasses;
- UOS:
  - Intelligent resource allocation mechanism considering a large number of moving audiences and dynamic MAPs.

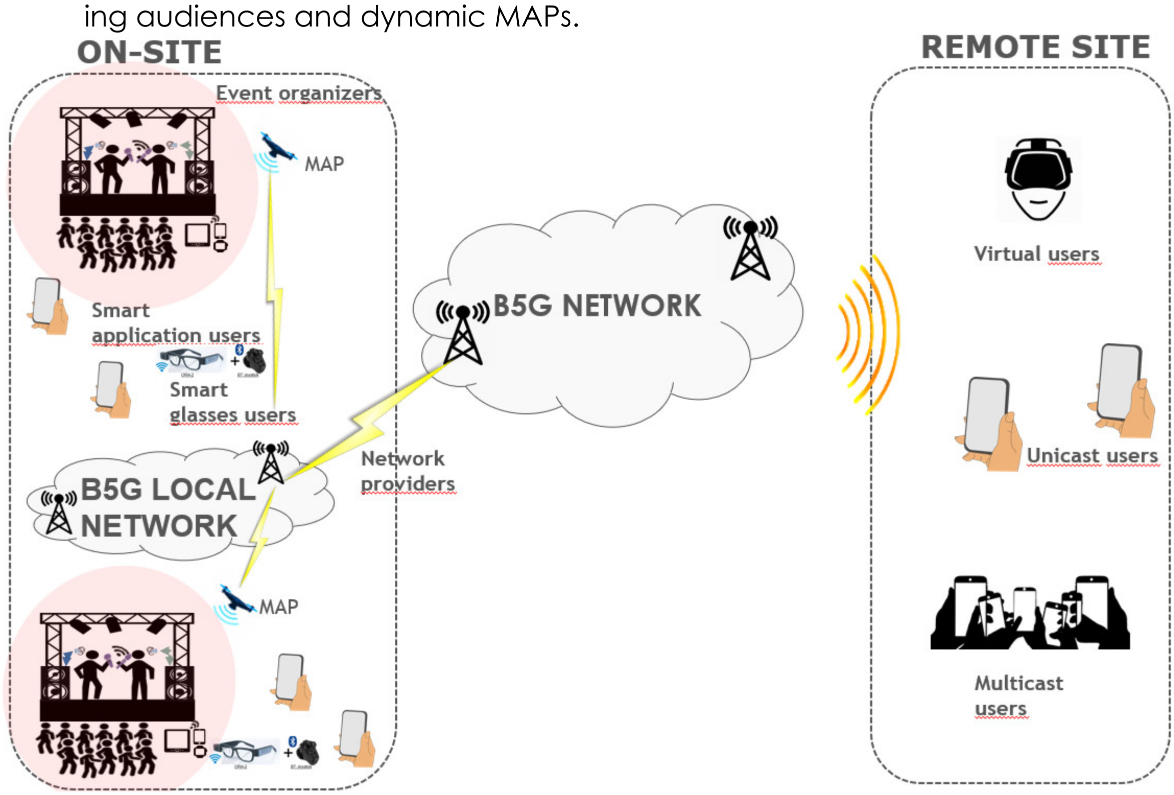


Figure 5: The set-up in the Enhance Experience use case.

4.3.4 Set-up plan

The site setup 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.

4.4 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.

4.5 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.

4.5.1 Story 1: On-site participant at public event

This story takes places 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 favorite 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 are 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.

4.5.2 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.

4.5.3 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 are featuring 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. Drones have been deployed at the beginning of the concert to increase radio capacity as the event is expected to be the first massive Facebook Live event over 6G. Those drones are recalled and re-deployed roughly every 20 minutes for battery replacement.

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™[1] smartphone, he easily set-up a private WiFi hotspot;

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;

4- In order to increase the radio capacity, some additional mobile access points – in the form of drones- are regularly (due to limitation of the battery life) deployed over the concert park;

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.

[1] Android is a trademark of Google LLC.

4.6 Requirements

The two following Table 6 and

Table 7 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.

4.6.1 Functional requirements

Table 6: "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 analyzed in a central node.	H	Various network conditions (including the traffic load levels, traffic spatial distribution patterns, etc.) and the network performance achieved multiple APs can be analyzed 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 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 dependable of the resolution. Operating system: Android	n/a
9	DC	Networking	The Smart Glasses have device-specific restrictions for WiFi connectivity	H	The Smart Glasses is using 2.4 GHz WIFI and could not use 5 GHz WiFi	n/a
10	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
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 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.

4.6.2 Non-functional and non-technical requirements

Table 7: "Enhanced Experience" list of non-functional and non-technical requirements

ID	Type	Category	Description	Priority	Rationale	Fit Criterion
1	NFREQ	Privacy, ethnics	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 to 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 to 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 to 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 to regulation

5 "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.

5.1 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, response time.

5.2 COVID-19 contingency plan

Location of demonstrations will take place on the Airbus site located at Elancourt (Paris area). Airbus site management applies all sanitary and safety rules defined by the French government in order to protect Airbus workers and visitors against Coronavirus propagation. Depending on the EU travel policy and conditions, the Airbus site will be able to welcome DEDICAT 6G stakeholders for test and demonstrations.

In case of a drastic evolution of conditions, project partners will organize together running remote demonstrations and manage the needs of asset shipments for specific integration.

The use case will take into account non-functional and non-technical requirements in order to identify the need for shipment and possible remote demonstrations.

5.3 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 [14] and CRAN based 5G resources allocation [15] can enable resiliency and enhance critical communication for Public Safety. The DEDICAT 6G project will aims 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 [16]. 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.

5.3.1 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 drone-based mobile access point;
- Reliability: Use of AGVs 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 on 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 as sist 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 to 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.

5.3.2 Actors involved

. We will consider a super-set of actors for those 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 (i) to provide first aid via on-site medics, (ii) to route people to a safer place, (iii) to trigger intervention of a response team and finally (iv) 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, 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.

5.3.3 Technology provided by partners

AIRBUS (ADS) plans to provide its 3GPP Mission Critical Services (MCS) platform and applications for both contexts in UC3. The 3GPP MCS platform and associated applications will permit voice and video communications in real-time and data sharing using broadband technologies between First Responders and Security Team actors. ADS will provide mission management tool to support story 2 and story 3 in the UC3, the tool will be used by First Responders. ADS will provide 3 smartphones in order to run its MCS applications and mission management tool, 1 PC or tablet will simulate the Command and Control operator. During the DEDICAT 6G project, ADS will study the possibility to extend its Mission Critical Push to Talk (MC-PTT) and MC-VIDEO applications with smart glasses and MC-VIDEO with drones. Based on smartphones or smart glasses, ADS will study and implement Remote Expert features to allow First Responders to give consigns and orders to Security team about Safety strategy to follow for evacuation.

WINGS plans to exploit and extend its IoT platforms, combined with mechanisms and functionality developed in the scope of serving underserved areas through 5G, coupled with IoT, Big Data and the utilization of drones. WINGS has worked with the Parrot AR Drone 2.0 Power Edition. The aim is to use 1-2 drones as mobile access points in this scenario potentially combined with AGVs on the ground. WINGS has worked with a TurtleBot3 Waffle-Pi equipped with: 360° LiDAR for SLAM, Camera, 3-Axis gyroscope, accelerometer and magnetometer, OpenCR controller board 4 degree-of-freedom robotic, and laptop for computing. WINGS also plans to extend an AR evacuation application based on indicating evacuation paths to civilians for showcasing innovative interfaces.

VLF plans to provide its SmartAccess360 solution for this use case. VLF will supply two smart access controllers, which are IoT controllers with the logic for access control or smart actuation with embedded circuit relays. The system also includes mobile app, but certain functionalities can be integrated with the App which is planned for this use case. Basically, application provided with trusted digital key can turn any mobile phone into a keycard. This would allow first responders to engage with the controlled infrastructure (e.g., open doors with electric locks, turn on emergency sings/light/alarm). The controllers can be used to perform computation or networking functionality when needed.

5.3.4 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 WiFi 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.

5.4 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 installed 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 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 application offers a “Help Me” feature in case assistance during the event is needed;
- 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.

5.5 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 on 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.

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

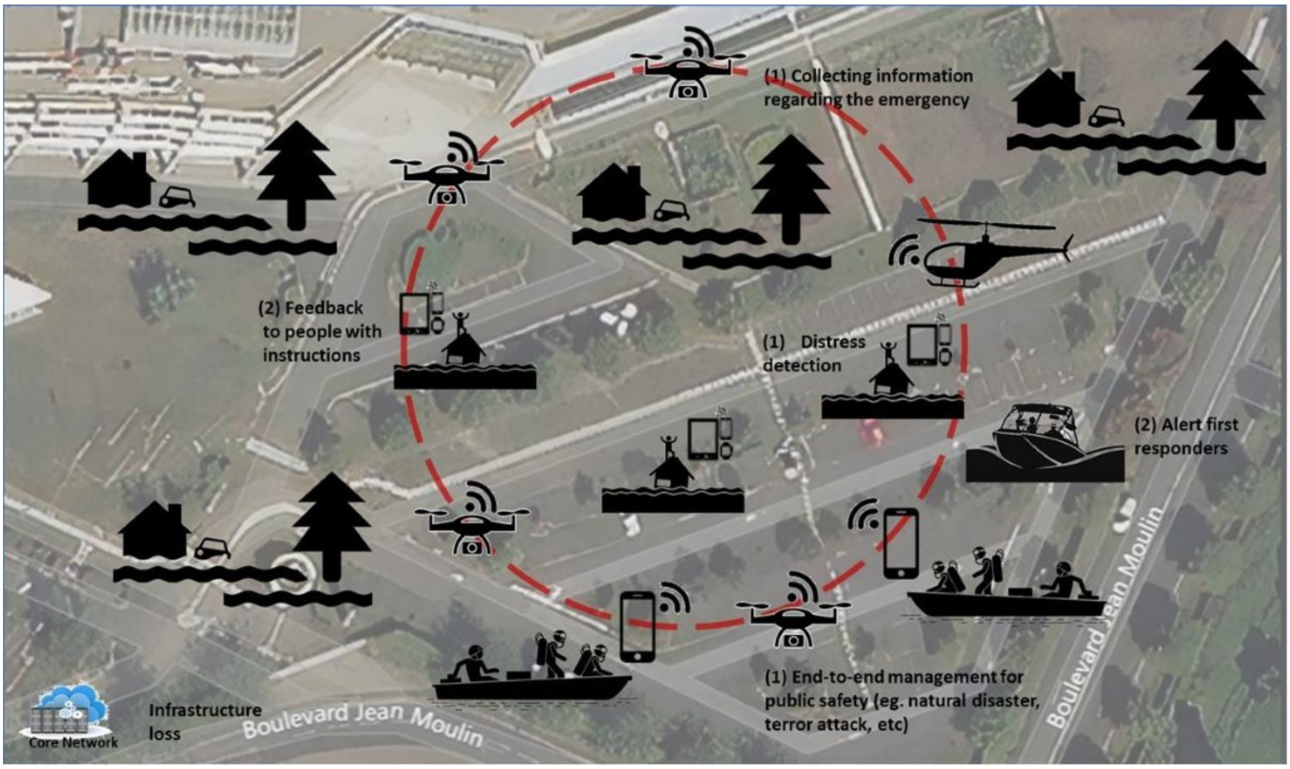


Figure 6: Critical Communication recovery after the loss of network infrastructure

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 6 above) 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 on 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.

Evaluation methods:

1. Demonstrations
2. KPIs will be related to:
    - Time of infrastructure deployment;
    - Availability of communications;
    - Quality of communications;
    - Report on demonstration and measures.

Expected outcomes:

- Final use case and scenarios
- Results and report in WP6 deliverables

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 on 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 the on-going rescue

Evaluation methods:

1. Demonstrations
2. KPIs will be related to:
    - Time of infrastructure deployment;
    - Availability of communications;
    - Quality of communications;
    - Report on demonstration and measures.

Expected outcomes:

- Final use case and scenarios
- Results and report in WP6 deliverables

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 the 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.

Evaluation methods:

1. Demonstrations

2. KPIs will be related to:
    - Availability of communications;
    - Quality of communications;
    - Efficiency;
    - Report on demonstration and measures.

Expected outcomes:

- Final use case and scenarios
- Results and report in WP6 deliverables

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

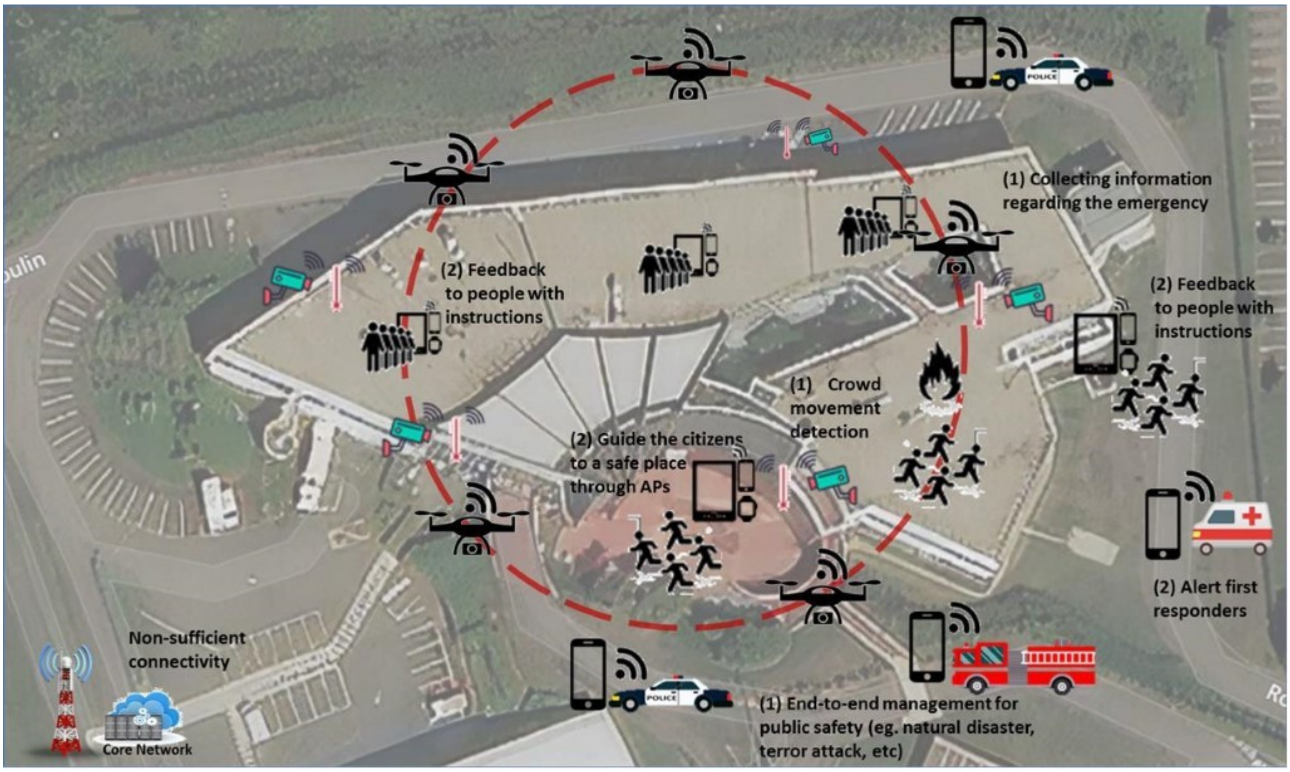


Figure 7: Public infrastructure overloaded during a crowd panic

The concert event park (see Figure 7 above) 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 at the music festival site, area 51, and needs quick visual confirmation and possible subsequent actions to be undertaken.

When the public bought a ticket to attend the festival, they have 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 51;
    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.

Evaluation methods:

1. Demonstrations
2. KPIs will be related to:
    - Time of infrastructure deployment;
    - Availability of communications;
    - Quality of communications;
    - Report on demonstration and measures.

Expected outcomes:

- Final use case and scenarios
- Results and report in WP6 deliverables

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 the 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 52;
9. Police, supported by the security team, finish evacuating the public and put people in safety areas;
10. The Medical staff treats the victims.

Evaluation methods:

1. Demonstrations
2. KPIs will be related to:
    - Availability of communications;
    - Quality of communications;
    - Report on demonstration and measures.

Expected outcomes:

- Final use case and scenarios+

- Results and report in WP6 deliverables.

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 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 51;
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.

Evaluation methods:

1. Demonstrations
2. KPIs will be related to:
    - Availability of communication;
    - Quality of communication;
    - Report on demonstration and measures.

Expected outcomes:

- Final use case and scenarios
- Results and report in WP6 deliverables.

5.6 Requirements

The two following tables, 8 and 9 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.

5.6.1 Functional requirements

Table 8: "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 bear 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	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 situation	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 pre-defined set of rules. Collected data is sent to 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 signaling 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 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 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 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.

5.6.2 Non–functional and non-technical requirements

Table 9: "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. Those are used to support efficient and personalized rescue.	Compliance to 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 regulation into 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, transferred, stored, deleted, anonymized (or pseudonymized) or processed in any other way.	H	This is important for privacy and data protection audits that can be requested by regulatory bodies.	Setup logging procedure, generate logs and check 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 situation	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 pre-defined set of rules. Collected data is sent to 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

6 "Smart Highway" (UC4)

Smart Highway is a use case that benefits from beyond 5G connectivity for connected and autonomous mobility [17],[18]. 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).

6.1 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; human centric application will be further investigated in the case of smart mobility. In this use case, we will analyze how to interface user's facial expressions and movements that can affect traffic behavior, by translating the driver intention, either going to the manual or autonomous driving operation.

6.2 COVID-19 contingency plan

In the case of a lasting pandemic that requires physical distancing, a limited number of personnel are present on the UC sites, which in this case, are in Belgium and Germany. Remote support is provided by participating partners for the deployment. In the meantime, developments that do not involve physical presence can keep going on remotely. For instance, in the case of software integration and interface, this can be conducted without having to go on site. In addition, if access to the equipment is limited, the testing can also be supported by simulation studies as a preliminary testing method before going on the field afterwards.

6.3 General context and set-up

6.3.1 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 on 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 partner will be offered to both sites.

6.3.2 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* (VRUs)
  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.

6.3.3 Set-up plan

Two sites will be the show case for 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 8). The square between various University buildings covers an area of almost half a square kilometre 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 RSU (providing situation awareness as well as connectivity) would be deployed on the square.

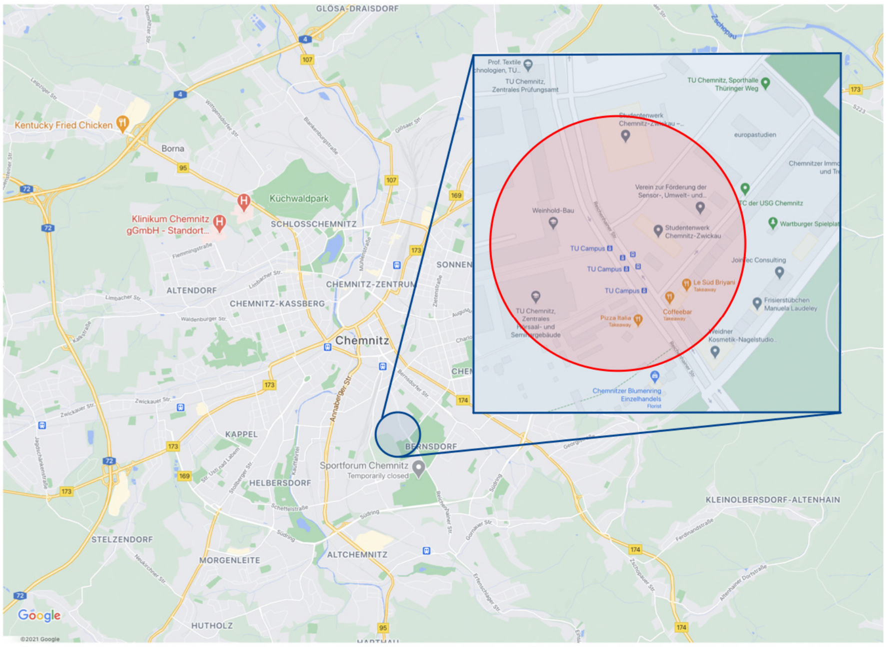


Figure 8: Location of the UC on a map (German site)

- 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 9 on a map. The highway on top of the intersection is equipped with a Road Side Unit (RSU), as seen in Figure 10, capable of transmitting signals through short range communication towards road users. The roundabout connects to the exits from the highway.

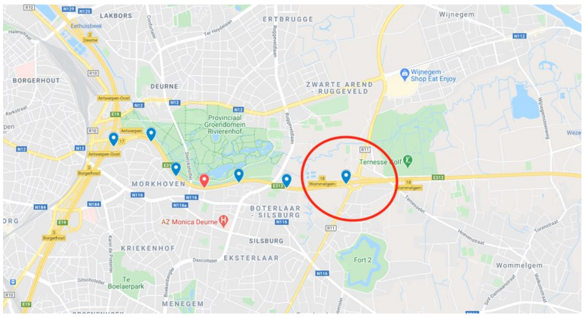


Figure 9: Location of the UC on a map (Belgium site)

Figure 10: Physical location of the UC (Belgium site)

6.3.4 Technology provided by partners

- IMEC: IMEC will bring the smart highway testbed in the use case. This testbed is composed of a car equipped with an OBU, and a *Road Side Unit* (RSU) located on E313. The testbed can be considered as a platform for both vehicle to everything (V2X) connectivity and edge computing. For the connectivity part, the units on the testbed have communication modules capable of transmitting signals via short range, either cellular V2X (C-V2X, via PC5 side link interface) or ITS-G5 (Wi-Fi based technology), and long-range, via 5G. This is also supported by SDR equipment thus making the testbed flexible and open to the whole community since it is based on open source. The architecture presented in Figure 6 below, depicts how the components of the testbed connect to each other, detailing the communication modules as well. The backend includes an MQTT server that handles the data stream from the RSU and OBU. Also, GNSS receiver are installed in order to capture the location. In addition, both OBUs and RSUs can offer distributed computing features thanks to a powerful General Purpose Processor (GPP). On the OBU side, the information captured by the sensor is forwarded to a sensor fusion platform through CAN (Controller Area Network) Bus, which is an internal in-vehicle bus that connect car's components. DUST framework, a framework aimed at simplifying the creation and maintenance of distributed software, is offered to allow flexible, dynamic allocation of computational, distributed resources. IMEC will also provide a local dynamic map application that can show the location of the road users as well as displaying a warning message. In addition, both OBUs and RSUs can offer distributed computing features.

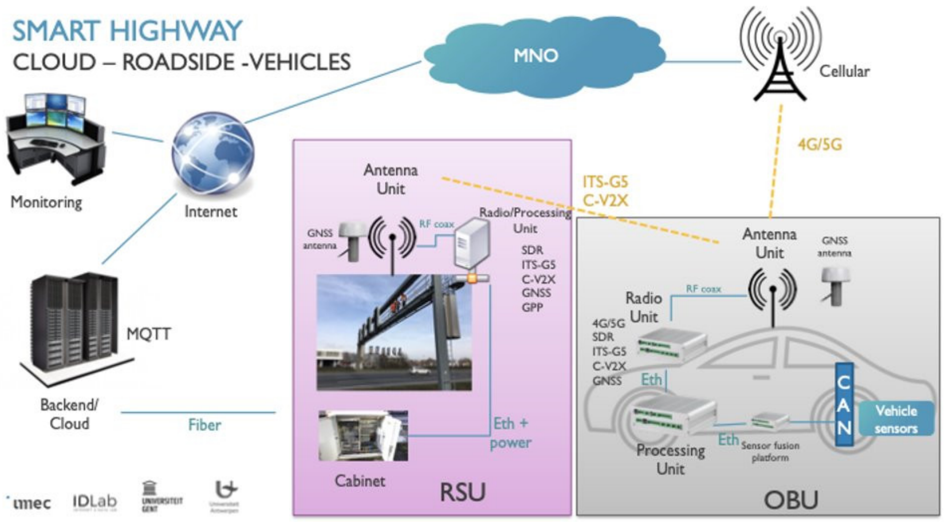


Figure 11. Testbed architecture for smart highway UC

- TUC: TUC will provide their vehicular research platforms for data collection and testing in this use case. The facilities consist of three vehicles (CARAI 1-3) supporting SAE (Society of Automotive Engineers) levels 1-4, and an RSU that connects via IEEE802.11p and via 5G to vehicles in the vicinity. Sensors to derive context and situation knowledge around and inside the vehicles are deployed and extensive data sets capturing user behaviour and deriving user intention. The deployment will take place either in the city of Chemnitz, or around the train station in Schlettau (Ore mountains).
- CEA: CEA main role is to enable dynamic coverage extension by elastically exploiting mobile access points. CEA will design the management and orchestration of the network capable of reconfiguring itself in an elastic, robust and efficient manner using NS-3 based network simulator with heterogeneous deployment capabilities, handling different air interface variants (below and above 6 GHz) and multiple traffic sources. This simulator will be used to evaluate the end-to-end ultra-reliable low latency communications (URLLC) performance at RAN level. CEA may eventually provide a proprietary baseband platform based on software programmable hardware, which can be seen as a 5G software defined air interface platform. This platform could be upgraded to demonstrate dual RAT communications (26 GHz and sub-6 GHz).
- ATOS will provide their Network Function Virtualization (NFV) testbed equipped with three *Points of Presence* (POP), composed by two Openstack nodes and a Kubernetes cluster. These machines are placed in Madrid and their main purpose is developing and testing of functionalities. Regarding this use-case, the testbed will be used for testing migration and tasks offloading techniques.
- TTI: TTI will contribute with customized IoT nodes equipped with high computational and memory resources as well as multiple interface support, coping with dynamic coverage and contributing to computation offloading. These nodes will count with specific interfaces to interact with the rest of equipment deployed in the scenario, eventually taking part in the V2X communications originated in the vehicle. Therefore, the sensors on the IoT nodes not only will provide a computational resource but also be capable of delivering useful sensing data to generate meaningful context information.

6.4 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 capability and able to transmit and receive short range signals from cars, pedestrian, and cyclist.
- *Human-Machine Interaction* (HMI) is installed in two cars.
- To monitor the behavior 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.

6.5 Stories

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 7 below 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 showed 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.

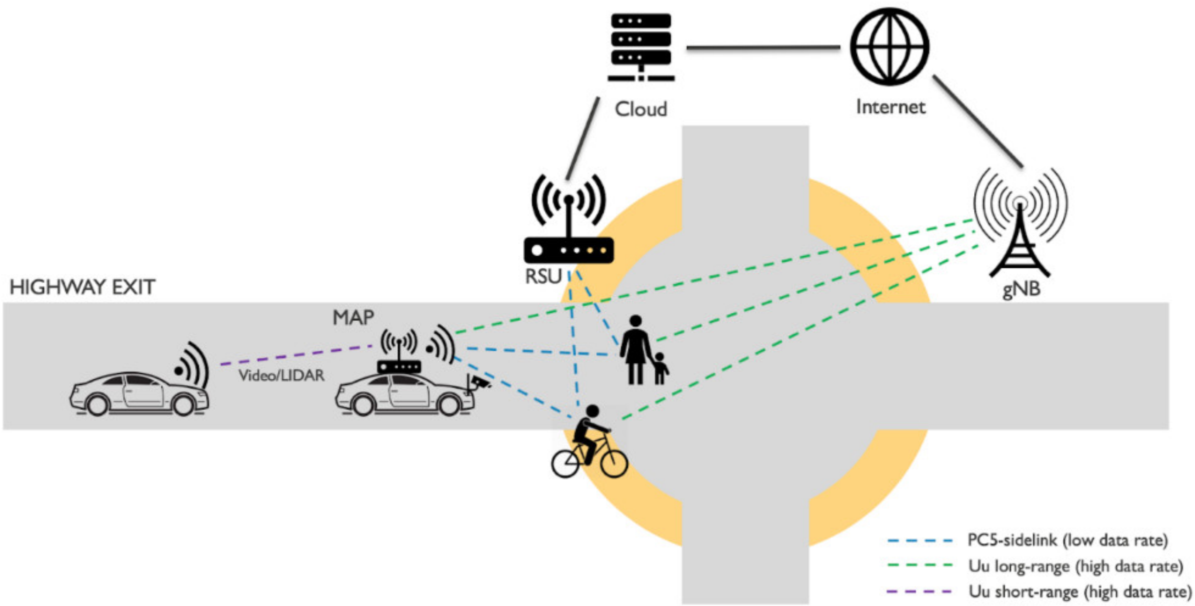


Figure 12: Smart Highway UC set-up

6.5.1 Story 1: VRU Detection at the highway exit

This story takes place in 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 decision 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.
- RSU that 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.
- Presence of VRUs is displayed on Car B's 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).

6.5.2 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 **A)** 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 **B)** 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., WiFi 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.

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 preprocessed 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 behavior.
  - 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.
    - The RSU will add information about non-connected VRUs into the LDM (including location, expected trajectory, etc.).

6.6 Requirements

The two following Table 10 and Table 11 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.

6.6.1 Functional requirements

Table 10: "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 the 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 the 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 its 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 the 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.

6.6.2 Non-functional and non-technical Requirements

Table 11: "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 to 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 to regulation

7 Conclusions

This first release of the document "Scenario Description and Requirement" provides necessary information on one hand to bootstrap the WP6 activities with precise and extensive material enabling common understanding of challenges and objectives while on the other hand to provide the essential list of technical and non-technical requirements, defined as functional and non-functional requirements that will bootstrap tasks T2.2 "Requirement collection, analysis, unification, and cross-check" and T2.3 "Architecture design".

The requirements are use case requirements meaning they are requirements that to a great extent aim to express potential views of end users of the DEDICAT 6G system, i.e., the various actors of the four use cases. As a matter of fact, expressing requirements is much easier when addressing something "visible", e.g., a functionality of the system, the actor is directly interacting with, rather than when addressing something "invisible", e.g., the underlying network which are by design as transparent to the user as possible.

However, a user is conscious about throughput, latency, and other properties of the underlying system. Defining requirements about the system properties, allows to indirectly address those "invisible" parts of the whole DEDICAT 6G system. Defining strict constraints including KPIs on scalability, latencies, availability, throughput, etc., allows justifying the use of edge computing, coverage extension, migration of functionalities through the network, to name just a few. This is one of the objectives of Task 2.2 to understand how the architecture of the overall DEDICAT 6G system is impacted by those non-functional requirements.

The second iteration of this document will be edited after the first release of the DEDICAT 6G architecture has been elucidated, considering feedback from the WP3-5 partners. An updated list of requirements (D2.3) will then be used to trigger the second architecting phase.

It is also worth mentioning that the list of unified requirements as a result of the requirement analysis phase will be handled as a living document and used in particular for cross-checking the architecture outcome vs. the requirements.

References

[1] "IoT-A Deliverable D1.5 – Final Architectural Reference Model for the IoT v3.0," F. Carrez, Ed.

[2] DEDICAT 6G consortium, "DEDICAT 6G Description of Action"

[3] VOLERE Requirements Resources, http://www.volere.co.uk/

[4] E. Ho et al., "IoT-A Deliverable D6.1 – Requirements list"

[5] A. Pastor, "IoT-A Deliverable D6.2 - Updated Requirements List"

[6] K. Zhang, Y. Zhu, S. Maharjan and Y. Zhang, "Edge Intelligence and Blockchain Empowered 5G Beyond for the Industrial Internet of Things," in IEEE Network, vol. 33, no. 5, pp. 12-19, Sept.-Oct. 2019, doi: 10.1109/MNET.001.1800526.

[7] Kamran Mahroof, A human-centric perspective exploring the readiness towards smart warehousing: The case of a large retail distribution warehouse, International Journal of Information Management, Volume 45, 2019, Pages 176-190, ISSN 0268-4012, https://doi.org/10.1016/j.ijinfomgt.2018.11.008

[8] D'Andrea R. (2021) Human–Robot Collaboration: The Future of Smart Warehousing. In: Wurst C., Graf L. (eds) Disrupting Logistics. Future of Business and Finance. Springer, Cham. https://doi.org/10.1007/978-3-030-61093-7_12

[9] A. Kostopoulos, I. P. Chochliouros, E. Sfakianakis, D. Munaretto and C. Keuker, "Deploying a 5G Architecture for Crowd Events," 2019 IEEE International Conference on Communications Workshops (ICC Workshops), Shanghai, China, 2019, pp. 1-6, doi: 10.1109/ICCW.2019.8757152.

[10] M. Keltsch, S. Prokesch, O. P. Gordo, J. Serrano, T. K. Phan and I. Fritzsch, "Remote Production and Mobile Contribution Over 5G Networks: Scenarios, Requirements and Approaches for Broadcast Quality Media Streaming," 2018 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB), Valencia, Spain, 2018, pp. 1-7, doi: 10.1109/BMSB.2018.8436772.

[11] H. Dujuan, "Mobile communication technology of sports events in 5G era," Microprocessors and Microsystems, Vol. 80, Feb. 2021, https://doi.org/10.1016/j.micpro.2020.103331

[12] Y. Mao et al., "A Survey on Mobile Edge Computing: The Communication Perspective," IEEE Commun. Surveys & Tutorials, Vol. 19, Issue 4, 2017.

[13] R. Borralho et al., "A survey on coverage enhancement in cellular networks: Challenges and solutions for future deployments," IEEE Commun. Surveys & Tutorials, 2021, DOI: 10.1109/COMST.2021.3053464

[14] Syed Ahsan Raza Naqvi, Syed Ali Hassan, Haris Pervaiz, Qiang Ni, "Drone-Aided Communication as a Key Enabler for 5G and Resilient Public Safety Networks", 2018 IEEE Communications Magazine Volume: 56, Issue: 1, pp 36-42, DOI: 10.1109 / MCOM.2017.1700451.

[15] Lei Feng, Wenjing Li, Peng Yu, Xuesong Qiu, "An Enhanced OFDM Resource Allocation Algorithm in C-RAN Based 5G Public Safety Network", 2016 Mobile Information Systems Volume: 2016, pp 1-14 DOI: 10.1155/2016/9586287.

[16] Pedro E. Lopez-de-Teruel, Manuel Gil Perez, Felix J. Garcia Clemente, Alberto Ruiz Garcia, Gregorio Martinez Perez, "5G-CAGE: A Context and Situational Awareness System for City Public Safety with Video Processing at a Virtualized Ecosystem", 2019

[17] Naderpour, M., Lu, J. and Zhang, G., 2014. An intelligent situation awareness support system for safety-critical environments. Decision Support Systems, 59, pp.325-340.

[18] Lee, J. and Park, B., 2012. Development and evaluation of a cooperative vehicle intersection control algorithm under the connected vehicles environment. IEEE Transactions on Intelligent Transportation Systems, 13(1), pp.81-90.