5G ExPerimentation Infrastructure hosting Cloud-nativE Netapps for public proTection and disaster RElief

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D1.2: 5G-EPICENTRE experimentation scenarios final version

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	Altice Labs SA	Portugal	**ALB**
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	Foundation for Research and Technology Hellas	Greece	**FORTH**
	Universidad de Malaga	Spain	**UMA**
	Centre Tecnològic de Telecomunicacions de Catalunya	Spain	**CTTC**
	Istella SpA	Italy	**IST**
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	Athonet SRL	Italy	**ATH**
	RedZinc Services Limited	Ireland	**RZ**
	OptoPrecision GmbH	Germany	**OPTO**
	Youbiquo SRL	Italy	**YBQ**
	ORamaVR SA	Switzerland	**ORAMA**

List of abbreviations

Abbreviation	Definition
5GC	5G Core
5GTS	5G Traffic Simulator
5QI	5G Quality of Service Identifier
AF	Application Function
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
CCC	Command & Control Centre
CNF	Containerized Network Function
CPE	Customer Premises Equipment
CPU	Central Processing Unit
eMBB	Enhanced Mobile Broadband
FR	Frequency Range
gNB	Next Generation NodeB
GA	Grant Agreement
GPS	Global Positioning System
GPU	Graphic Processing Units
HMD	Head-Mounted Displays
IoT	Internet of Things
K8	Kubernetes
KPI	Key Performance Indicators

MCData	Mission Critical Data
MCPTT	Mission Critical Push-to-Talk
MCVideo	Mission Critical Video
MCX	Mission Critical Services
MIMO	Multiple input, multiple output
mMIMO	Massive Multiple input, multiple output
NF	Network Function
NFV	Network Functions Virtualization
NFVI	Network Functions Virtualization Infrastructure
NR	New Radio
NSA	Non-Stand Alone
PC	Personal Computer
PCF	Policy Control Function
PDU	Protocol Data Unit
PoP	Point of Presence
PPDR	Public Protection and Disaster Relief
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
REST API	Representational State Transfer Application Programming Interface
RRU	Radio Remote Unit
RTT	Round Trip Time
RV2	Project's Second Review
SA	Stand Alone

SC	Scenario
SG	Smart Glasses
TDD	Time Division Duplex
TI	Testbed Instances
UC	Use Case
UE	User Equipment
UPF	User Plane Function
VFIO	Virtual Function Input/Output
VM	Virtual Machine
VNF	Virtual Network Function
VPN	Virtual Private Network
VR	Virtual Reality

Executive summary

This deliverable details the experiments' conceptualisation from a 5G point of view. For this purpose, different 5G experimentation scenarios have been defined for each platform, which will provide the ideal environment for the first party experimenters. Thus, the allocation of each of the vertical Use Cases (UCs) to each of these scenarios has been made on the basis of the specific needs of the UCs and the suitability/capacity of the testbeds to implement them. For this purpose, the criteria defined in D1.6 "Experiment evaluation strategy and experimentation plan" have been followed.

The objective of this document is to identify the design choices made, in order to provide scenarios specifically tailored to the needs of the Public Protection and Disaster Relief (PPDR) sector. It provides a detailed overview of the 5G scenarios initially considered, which will be refined through vertical experimentation to reach their full potential. The initially considered scenarios are: i) ***5G for Video & Throughput optimisation*** (SC1); ii) ***5G in drone management environments*** **(SC2)**; iii) ***5G slicing and Quality of Service (QoS) control and management*** **(SC3)**; and iv) ***latency management and re-instantiation procedures in 5G*** **(SC4)**. The final version of these scenarios will be offered to third party experimenters.

Working groups have therefore been created, in which synergies between partners will be exploited. UC4 and UC5 video-related solutions will be deployed in ALB, to create a 5G scenario especially tailored for this kind of solution. UC3 and UC6 will lead the verticals deploying their applications at the HHI testbed to optimize their 5G scenario where airborne vehicles will be managed. In UMA, ATH's 5G Core (5GC) will be crucial to explore slicing in 5G networks and the advantages that QoS control can offer to PPDR verticals. CTTC, given its responsibilities at project level, will work on the Cloud-native nature of these networks, exploring the instantiation of services with NEM, or the improvement of a 5G scenario sensitive to packet loss with ORAMA. The document also provides a contextualisation in the framework of the project, clarifying its function and relationship with the other documents defined in 5G-EPICENTRE. It provides a quick and schematic overview of the experimental objectives of each scenario, from a 5G network environment point of view, oriented to PPDR solutions. To do so, an approach close to real network conditions will be emulated, considering the possible issues that may arise in real emergency situations, and the constraints of each of the testbeds.

With the optimisation of these 4 scenarios, the project will deliver attractive demonstrations and "Do It Yourself" (DIY) experimentation tools for the PPDR sector. It will significantly speed up their access to 5G technology, as it will offer pre-tested and optimised solutions for specific purposes, which can be reused by third party experimenters.

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1 Introduction

This document presents Deliverable D1.2 “5G-EPICENTRE experimentation scenarios final version”; and reports on the 5G scenario definitions, to complement the experimental definitions related to the different pilots considered. This second version of D1.1 “5G-EPICENTRE experimentation scenarios preliminary version” (delivered in M6) aims to expand the definition of pilots made so far, from the 5G context point of view. Whereas D1.1 provides a detailed explanation of the pilots that each UC has proposed; and D1.6 defines the processes and strategy for experimentation and testing, this deliverable provides the necessary context on the 5G scenarios, in which the experiments will be conducted.

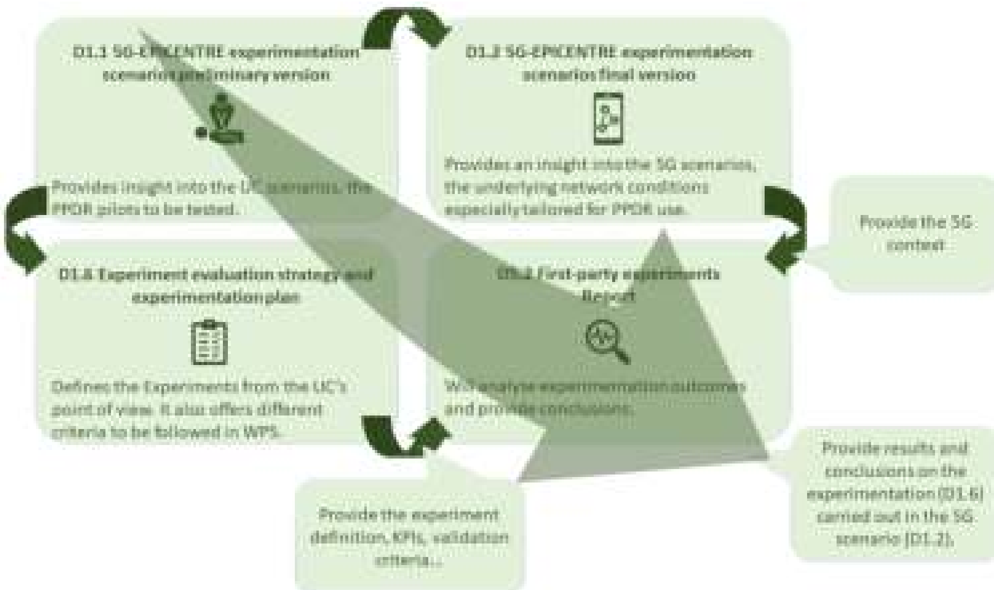

Figure 1: Deliverables’ contextualisation

Therefore, the pilots defined in D1.1 will perform the experiments defined in D1.6, applying the 5G configurations and scenarios defined in D1.2. Then, in D5.2 “First-party experiments report”, all the information will be aligned, providing the experimentation results for performed tests. This approach reinforces the objectives of the project by defining (at least) four 5G scenarios, specifically conceptualised for Public Protection and Disaster Relief (PPDR)-based solutions’ experimentation. The development of debugged 5G scenarios, optimised and specially tailored to PPDR needs, will provide third-party experimenters with refined 5G experimentation tools. These tools will be offered among 5G-EPICENTRE’s solutions.

This document shows how each scenario will focus its efforts in a distinct area, depending on the available 5G features and experimenters’ needs. The four different testbeds that compose the physical layers of the 5G-EPICENTRE solution, offer 5G heterogeneous configuration alternatives, which is an ideal environment for PPDR experimentation. Furthermore, thanks to the eight UC technology validators, along with the feedback and conclusions gained from the experimentation carried out by the first-party experimenters, specific scenarios can be drafted and offered to third-party experimenters, to test their own PPDR solutions in proven 5G environments. In summary, as the main contribution of this deliverable, four different 5G blueprints for experiments in PPDR will be offered, accelerating the access of PPDR solution providers to 5G technology.

The document begins with a summary of its contents (Section 2), showing in brief the 5G-EPICENTRE context; the specific 5G experimentation scenarios; the way the 5G network will be stressed; how the effort has been aligned towards optimising the outcome; and the way the scenarios will be evaluated. Then, Sections 3 to 6 will provide more detail on each 5G scenario, followed by the most significant experimentation objectives. This deliverable also seeks to provide a response to the notes and remarks made by the reviewers on D1.1. Although this deliverable has already been approved, these comments have been taken into account when outlining this document.

1.1 Mapping of project's outputs

The purpose of this section is to map 5G-EPICENTRE Grant Agreement (GA) commitments within the formal Task description, against the project's respective outputs and work performed.

Table 1: Adherence to 5G-EPICENTRE's GA Deliverable & Tasks Descriptions

5G-EPICENTRE Task	Respective Document Chapters	Justification
T1.1: Pilot experiments formulation *"The goal of this Task is for consortium partners acting as experimenters to define a commonly agreed set of experiment scenarios […]"*	Section 2 – Background and 5G Scenarios inception	Section 2 of this document shows the specific defined 5G scenarios. Four separate research areas have been agreed, all of them related to concepts of vital importance for PPDR vertical services (in this case, UCs). Efforts have been unified, associating UCs with similar needs to 5G scenarios that will be refined through experimentation.
T1.1: Pilot experiments formulation *[…] thorough experiment description, relying on a formal approach and standard […] along clear definition of what constitutes a successful outcome […]*	Section 3 – SC1 - ALB Aveiro (Portugal): Video & Throughput 5G scenario Section 4 – SC2 - HHI Berlin (Germany): Drone Management scenario Section 5 – SC3 - UMA Málaga (Spain): QoS & Slicing scenario Section 6 – SC4 - CTTC Barcelona (Spain): Instantiation & Latency scenario	In the subsections of each scenario and in each testbed, a detailed definition of a functional scheme or configuration has been described. The Key Performance Indicators (KPIs) information already presented in D1.6 have also been provided, as well as the essential experimentation objectives, also defined in D1.1 and D1.6.
T1.1: Pilot experiments formulation […] indication of network services that should be instantiated in order for the experiment to be deployed on top of the 5G-EPICENTRE infrastructure […]	Section 2 – Background and 5G Scenarios inception	It has been necessary to underline the importance of providing debugged 5G scenarios for specific PPDR needs. As explained in Section 2, after experimentation, the pre-engineered 5G scenarios will be offered among 5G-EPICENTRE's solutions for third-party experimentation. D4.2 "Network functions implementation" will provide

		the information related to the Network Services and Network Applications.
T1.1: Pilot experiments formulation *[…] foreseen resources required for the experiment, including the utilization of multiple testbeds […]*	Section 3 – SC1 - ALB Aveiro (Portugal): Video & Throughput 5G scenario	Depending on the experimentation needs of each UC, and the specific functionalities that each Testbed can offer, different scenarios have been defined. For each one, the necessary 5G network-linked requirements have been detailed. Further details with focus on vertical requirements are provided in D1.1 and D1.6.
	Section 4 – SC2 - HHI Berlin (Germany): Drone Management scenario	
	Section 5 – SC3 - UMA Málaga (Spain): QoS & Slicing scenario	
	Section 6 – SC4 - CTTC Barcelona (Spain): Instantiation & Latency scenario	
T1.1: Pilot experiments formulation *[…] will be useful, for one to derive requirements specific to the PPDR vertical targeted, and further, to translate these requirements into technical specifications for the architecture of the 5G-EPICENTRE platform […]*	Section 2 – Background and 5G Scenarios inception	The eight UCs offer a diverse range of PPDR solutions, that adequately model and fill the needs of the sector. By relevance technology validators, such as those envisaged in 5G-EPICENTRE, it will be possible to draft and target ideal 5G scenarios for the PPDR sector. Furthermore, these scenarios will be offered among 5G-EPICENTRE's solutions for third-party experimentation. The document shows the initial approach to these scenarios, which might be further customised during the testing phase.

1.2 Updates since the initial deliverable version

While D1.1 provided an overview of the pilots with a focus on PPDR verticals, defining different UCs, their services and experimentation objectives, this document will address the different 5G scenarios, on which the different UCs will experiment with.

1.2.1 Adherence to reviewers' comments and recommendations on D1.1

Following reviewers' recommendation, it has been decided to offer a broader vision of the 5G solution in the framework of 5G-EPICENTRE, joining efforts towards defining suitable and attractive 5G environments for PPDR sector's demanding requirements. Table 2 below, aims at explicitly clarifying how review report comments from the second project review have been addressed.

Table 2: Adherence to reviewer's comments on last review

Review comment(s) (as provided by the reviewers)	5G-EPICENTRE Adherence and Document Update (short reply and reference to the chapter that details the reply)
"It is not always explicitly clear how previous review comments have been addressed. Please provide a table to cross reference amendments to deliverable versions which are made to address each review comment."	The present Section aims to offer the adherence to reviewers' insights on which the deliverable is framed. Besides, Section 2.1 also offers the context to be considered, and how this deliverable interacts with other 5G-EPICENTRE outcomes.
"Synergies between UCs and contributions per partners have been clarified, although redundancies and synergies among UCs are still not well justified always."	Section 2.4 offers a quick view on how the verticals main experimentation objectives align with the 5G experimentation scenario developed, towards offering comprehensive tools useful to a PPDR audience. Different partner's work has been aligned towards optimising the effort in similar line of developments, with the final objective being that of obtaining a debugged 5G scenario, specifically tailored for PPDR users. This Section also explains other kind of synergies, such as QoS management (ADS, UMA, NEM, ATH); security (ONE, ATH); or MCX Smart Glasses (ADS, YBQ).
"In particular, for UC5, information on why deployment and testing take place in Malaga and Aveiro is provided but is not convincing to the value of the project. Also, the information explained in section 3.6.2.1 and 3.6.2.2 does not reflect the differences among the two scenarios previously presented. […] Again, there is no justification for the Barcelona and Andalucía trials as the deliverable indicates both are basically the same".	UC5 has given up experimenting in CTTC, limiting itself to two developments: in UMA (where it was already implemented) and in ALB (where it will work on the development of the proposed video solutions). Sections 3.2 and 5.4 offer a better view of the reasoning of these implementations. In Sections 3.2, complementary to D1.1 information is provided to further clarify the UC, it's experimentation needs, and objectives.
"The consortium should consider eliminating duplicated efforts that do not bring value to the development of the platform for optimizing the usage of public funds".	In Section 2.4, a summary table can be seen with the final deployment matrix. The number of deployments has been reduced, (UC1, UC2, UC4, UC5 & UC7) from previous deliverables. Partner's effort has been aligned to the development of each of four different 5G scenarios, to offer a final, debugged, and attractive to PPDR sector scenarios.
"For UC7, all synergies listed are indicated as 'can be'. We need to know the synergies that will be implemented and executed, not the possibilities. Also, synergies among UC8 and UC7 are not clear, nor between UC8 and other UCs. This must be clarified".	In addition to the synergy already shown in RV2 between UC1 and UC7, UC7 proposes an integration with the drone-based solutions experimenting in scenario 2 (Section 4). On the other hand, the demanding UC8 is an excellent technical validator for scenario 4 (Section 6). Both UCs envisage joint integration, thus creating new synergies besides their respective scope of 5G scenario building.

2 Background and 5G Scenarios inception

This Section aims to offer a quick understanding of the different 5G scenarios envisioned in the framework of 5G-EPICENTRE. It will provide short, visual and text-free (wherever possible) summaries, to provide a schematic approach to the deliverable's content. Using these principles, it will provide the context in which the deliverable is defined; its relevance within the project for the PPDR sector; and the specific scenarios' detail. The following Sections will provide the necessary details on the most interesting concepts; the verticals' needs; or the specific 5G constraints raised. Given the public nature of the deliverable, the target is to reach as many stakeholders as possible, including those not familiar with 5G technology.

2.1 5G-EPICENTRE context

This deliverable is framed within the needs identified during WP1 "5G-EPICENTRE platform requirements and experimentation planning". To properly plan the experimentation to be carried out, the specific 5G aspects should be considered. Until now, deliverables related to experimentation planning have been strongly linked to the vertical services of the 5G network; and focused on the UC's approach. This document instead explores the facets associated with the 5G network itself, presenting four specially defined scenarios to analyse the performance that these networks can offer to the PPDR sector, even in extreme situations (considering emergency environments or disasters, where the proper functioning of PPDR solutions is crucial).

Therefore, this paper is framed together with the rest of the WP1 documents, as shown in Figure 2.

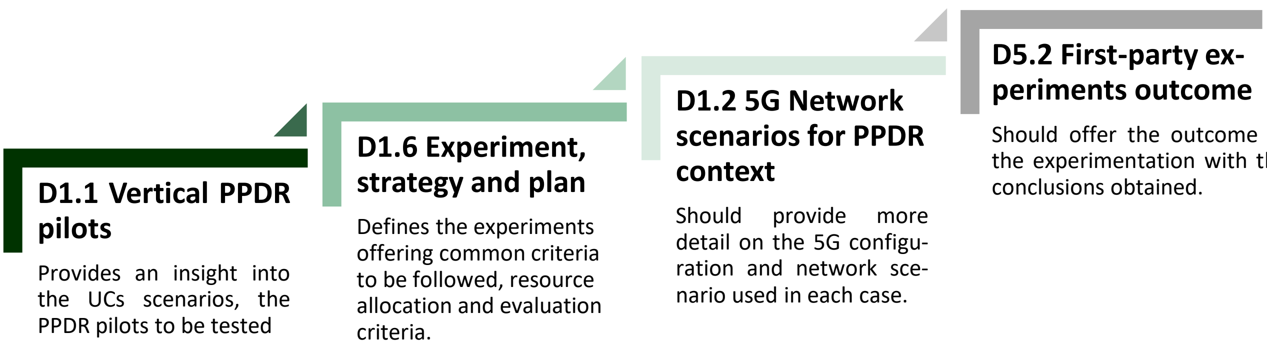

Figure 2: Deliverable's interrelation and context

More specifically: (i) D1.1 provides the pilot definition from the UC's point of view; (ii) D1.6 provides the common strategy and planning (for every partner) to be followed, as well as specific tests' detailed definition, target KPIs and validation criteria; (iii) D1.2 complements both deliverables, and provides the 5G context in detail, focusing efforts towards defining an optimal 5G parameterisation that can be offered to third-party experimentation; and (iv) D5.2 will consolidate the planning process carried out, and provide the experimental results of the tests defined in D1.6, for the vertical pilots defined in D1.1, and for the 5G scenarios defined in this document.

2.2 5G scenarios overview

The approach followed has enabled partners to join forces and create customised environments for 5G experimentation under PPDR-related network needs. This way, leveraging the four heterogeneous testbeds' particular strengths, four different 5G scenarios have been considered, giving response to PPDR needs. These can be decomposed in several subsets of scenarios, depending on the verticals' needs. In any case, the objective is to provide scenarios useful for a wide range of verticals, or UCs, so that the less UC-specific the approach, the more feasible it would be to offer those same scenarios to third-party experimenters. To this end, instead of the UC-specific approach, the scenarios have been defined to maximise the knowledge that can be gained during experimentation on areas of interest in the PPDR sector such as: (i) **SC1-5G for Video & Throughput optimisation**; (ii)

SC2-5G in drone management environments; (iii) **SC3-5G slicing and Quality of Service (QoS) control and management**; and (iv) **SC4-Latency management and re-instantiation procedures in 5G**.

Figure 3: 5G-EPICENTRE four 5G experimentation scenarios

These scenarios do not limit the experimental capabilities of testbeds. They seek to align partners with similar needs, to leverage common conclusions and to gather more ambitious objectives, whilst aligning the effort. The findings will be shared among the facilities, in order to offer similar features to third party experimenters. With this approach, 5G-EPICENTRE achieves the best possible results, aligning available resources towards common goals, while exploiting the strengths and capabilities of each facility.

In addition, it is important to be able to provide an environment that is as-close-as-possible to the real-life scenarios, in which PPDR agencies will find themselves. The aim is to offer experimental environments of interest to this sector, whose work is particularly important in emergency, chaos, disaster, or threat situations. In order to provide scenarios that address these situations, different methods for stressing the 5G network might be applied, taking advantage of the characteristics of each of the testbeds and the available functionalities. For each scenario, this document provides an overview of the resource adequacy and the target audience for such scenarios.

The Tables below (Table 3 to Table 6) provide the suitability of each of the testbeds for developing 5G scenarios. They also provide a brief overview the possible PPDR verticals interested in these scenarios.

Table 3: ALB's Video & Throughput 5G scenario

	SC1 - ALB Aveiro (Portugal): Video & Throughput 5G scenario
Indicative Testbed	ALB has an indoor facility with commercial 5G equipment. It is a controlled laboratory environment in which to work towards maximising throughput and video quality. The work done at 5G-VINNI[1] provides the 5G expertise needed to address this challenge.
Objective	This scenario is especially interesting for video streaming applications (UC4 & UC5), but also, for all kinds of video surveillance, or image recognition applications, among others.

Table 4: HHI's Drone Management scenario

	SC2 - HHI Berlin (Germany): Drone Management scenario

[1] https://www.5g-vinni.eu/

Indicative Testbed	HHI has an outdoor facility with commercial 5G equipment, and an own vertical application (UC3) based on drone management. The suitability of its facilities, as well as its needs as a UC, have been taken into account for the allocation of this scenario. The work done at 5G-BERLIN[2] provides the 5G expertise needed to address this challenge.
Objective	This scenario is especially interesting for PPDR verticals that require the use of drones (UC3 & UC6), or that want to experiment with drone solutions (UC7). Scenario's intrinsic aspects will be considered, such as flight licence management, or the optimal 5G parameterisation for this type of solution.

Table 5: UMA's QoS & Slicing scenario

	SC3 - UMA Málaga (Spain): QoS & Slicing scenario
Indicative Testbed	UMA has an outdoor/Indoor facility with commercial 5G equipment, which offers versatility in a single facility. It also has a 5G Core (5GC) powered by ATH, along with access to 5G technology functionalities (such as the QoS management demo described in [1]). The work done at 5GENESIS[3] provides the 5G expertise needed to tackle this challenge.
Objective	This scenario is especially interesting for wide range of PPDR verticals that require the control over the 5G network. Mission Critical Services (MCX) and solutions that want to ensure performance regardless of existing network traffic (such as UC1 & UC2), or other PPDR verticals that want to ensure their communications are adequately managed by the 5G network (UC4), are considered to be addressed by this scenario.

Table 6: CTTC's Instantiation & Latency scenario

	SC4 - CTTC Barcelona (Spain): Instantiation & Latency scenario
Indicative Testbed	CTTC has an indoor facility, a controlled laboratory environment in which many high-performance servers are available. Furthermore, the tasks led by CTTC in 5G-EPICENTRE are related to the need for service instantiation, so the development of this scenario is aligned with the needs of the project. As a technology centre, it has the proven expertise in 5G technology needed to tackle this challenge.
Objective	This scenario is especially interesting for PPDR verticals that require dynamism with respect to the physical location where they deploy their services (UC2), or verticals that are particularly sensitive to latency, or packet loss and want to test the robustness of their solution in this scenario (UC8). In any case, as these are key 5G issues, any PPDR service with interest in assessing self-recovery, or experimenting with special latency conditions, might be interested in this scenario.

2.3 Demanding 5G network conditions

This Section seeks to clarify the approach taken by the project in assessing PPDR related solutions in as-real-as-possible 5G network scenarios. To guarantee that the experimentation carried out in the framework of the 5G-

[2] https://5g-berlin.de/en/ueberuns/
[3] https://5genesis.eu/

EPICENTRE project will have insightful conclusions for PPDR audience, stressful network environments, which resemble real-life situations, should be considered.

For this purpose, the experimental environments will consider the underlying traffic, in addition to the traffic generated by the vertical under test itself. A Traffic Simulation Manager (5GTS) has been developed for this purpose. The 5GTS is based on the well-known iPerf tool. The 5GTS is composes by iPerf agents and by a control system that contacts with the agents to deliver the traffic configuration that has to be generated. The control system exposes a Representational State Transfer Application Programming Interface (REST API) that enable a flexible configuration. For traffic generation, two agents are needed at least, one is deployed behind the core network as an application function and the other can be installed in a User Equipment (UE) or in a Personal Computer (PC), the PC should be connected to the network via a 5G Customer Premises Equipment (CPE). This set up will enable to overload end-to-end the 5G network with the traffic generated between the agents. 5GTS will be further addressed in D2.5 “5G-EPICENTRE Experiment execution”.

The usage of emulated traffic will enable to reproduce different network conditions and realistic scenarios Emulators not only create realistic environments (at network conditions level), but they also provide a means by which the 5G network will be stressed at different levels, such as might occur in a real emergency. PPDR agencies must deal with situations where the network may become overloaded, either because of some node’s downtime, or because of the increase in panic-related calls. The 5GTS offered by the 5G-EPICENTRE experimentation platform will provide the means to demonstrate how the 5G network can be a reliable solution, even in high traffic load situations. The way the 5GTS will be used during the experimentation processes will be further elaborated on D2.5.

Although this is not the only research line proposed, it is, however, the most advanced and the one in which most effort has been put to date. However, other means of stressing 5G networks to demonstrate its suitability for PPDR solutions are also considered. Re-instantiation of services; rebooting of failed services; or on-demand 5G Network Functions (NFs) deployment, among others, are being considered to be included in the framework of 5G-EPICENTRE. Their feasibility, workload, interest for the project are currently under consideration.

- The ***SC1- Video & Throughput 5G scenario*** managed by ALB also explores the behaviour of PPDR verticals, by stressing the network in different planes. It thus extends the analysis to the control plane, which is important when large numbers of users concentrate under a single cell, as can happen in crowds or events. Exploring the feasibility of PPDR services over the 5G network, even in extreme situations, offers reassurance on the experimental results obtained.
- The ***SC2 - Drone Management scenario*** takes into account different UEs, in order to generate traffic on the physical plane, stressing the RAN’s air interface. As a scenario owned by HHI, especially oriented to unmanned aerial vehicle operation, its approach is particularly suitable for testing the 5G network for PPDR solutions.
- The ***SC3-QoS & Slicing scenario*** is geared towards ensuring 5G QoS in demanding environments. By having a 5GC provider (such as ATH), it is possible to exploit QoS management capabilities of 5G networks. The work carried out at UMA enables the allocation of resources to mission critical PPDR solutions, such as UC1 and UC2 MCX solutions. An experimental trial involving ADS, NEM, ATH and UMA [1]demonstrated that the request and allocation of resources can be successfully achieved. The next steps would be to demonstrate how this allocation has a relevant influence on the vertical PPDR service performance.
- The ***SC4-Instantiation & Latency scenario*** explores the instantiation of services; and the dynamicity to face situations in real emergencies. The responsible of this scenario (CTTC) is also working towards generating the federation layer between all the four testbeds, and as stated at Section 6, it is ready for such challenges. In relation to this kind of developments, UC2 aims to explore the re-instantiation of the vertical PPDR service to adapt and offer dynamic solutions to the different situations that may arise in emergencies. Emulating latency, or packet loss will also be explored to test its impact in solutions sensitive to such events, such as Augmented Reality (AR) solutions in UC8.

In any case, all scenarios will push the capabilities of their respective 5G networks approaching real possible scenarios, with the aim to test PPDR verticals under realistic emergency conditions, seeking to demonstrate the suitability of 5G solutions for the PPDR sector. In addition to scenario-specific roads, a 5GTS will be used for traffic emulation, bringing the experimentation conditions closer to PPDR reality.

2.4 Experimentation overview: effort alignment and synergies

In order to adequately model the scenarios to the needs of the PPDR sector, technologically demanding PPDR verticals have been assigned to the development of each of these scenarios. The UCs in charge of validating each of these scenarios are particularly interested in experimenting with 5G technology in these areas; and will provide insight into the needs of the sector.

The eight different UCs cover a heterogeneous portfolio of solutions, with different approaches to 5G technology, and different types of PPDR targets. This is the ideal context to offer experimental scenarios that truly represent the needs of the PPDR sector. However, it should also be considered that not all UCs will access 5G technology with the same initial knowledge, nor will they have the same need to deepen their understanding of 5G functionalities. This is true both for the UCs validating the technology in this project; and for the third party experimenters accessing the 5G-EPICENTRE platform to test their solutions on 5G networks.

This is the reason why all UCs will be considered as validators of the platform; and will experiment to provide output data to help draft the final 5G-EPICENTRE solution and conclusions. Looking for the best possible outcome, the 5G-EPICENTRE project has decided to approach experimentation by focusing on concrete scenarios, in which to align the work of the different partners. In the choice of the different deployments considered, the strengths of each of the testbeds have been considered, avoiding duplicated effort, or unnecessary deployments (when an existing solution was available).

Following this line of action, the number of deployments initially considered has been reduced, keeping those whose specific orientation is related to the concrete scenario. Although, those deployments that were in their final stages of implementation have been maintained, the final matrix has been considerably reduced (shown in Table 7: Vertical experimentation over different 5G scenarios). Furthermore, the specific verticals selected for each of the scenarios are aimed at analysing the specific 5G functionalities offered by the scenario. In this way, it is possible to share information; align work towards common objectives; and optimise experimentation towards valuable conclusions in selected areas.

By focusing efforts on unique scenarios in each testbed, rich working environments will be created, where verticals work in common areas, and the experimentation objectives or the 5G scenario under analysis seek similar results. Although concrete aspects of synergies between verticals have been demonstrated earlier in the project (*i.e.,* integration of UC1 MCX solution and UC7 Smart Glasses), others are currently under consideration for future reviews. Table 7 shows the main synergies to be achieved with the approach to experimentation scenarios.

When the UC knowledge and needs go deeper into 5G technology, new 5G functionalities will also be explored, deepening the benefits that this technology can offer to the PPDR sector. This is the case of the experimental tests carried out in relation to QoS management [1], guaranteeing MCX services' performance in 5G networks.

These tests were developed over UMA's testbed, powered by ATH's 5GC, and two different MCX verticals (ADS UC1 and NEM UC2) were able to interact with the 5G network for allocating specific resources. The collaboration and synergies identified between these 5G-EPICENTRE members, has succeeded in demonstrating that interacting with the 5G network and guaranteeing network conditions for the PPDR communications sector is possible. This breakthrough is at the centre of the 5G-EPICENTRE Network Application approach, as highlighted in D1.4. In this way, 5G-EPICENTRE makes 5G networks a more interesting environment for the PPDR verticals. In any case, this is a milestone reached by the project, in the definition of the future UMA QoS & Slicing scenario.

Table 7: shows the lines of research followed by each vertical, aligned with the experimental orientation that each testbed has acquired.

Table 7: Vertical experimentation over different 5G scenarios

	ALB SC1	HHI SC2	UMA SC3	CTTC SC4
UC1			Further explore 5G resource allocation for MCX (N5, Slicing, *etc*.).	
UC2			UC scenario 1 (D1.1). Further explore 5G resource allocation for MCX (N5, Slicing, *etc*.).	UC scenario 2 (D1.1). Explore instantiation, and 5G improvement in multi-PoP (Point of Presence) scenarios.
UC3		Outdoor drone navigation. 5G parametrisation for airborne vehicles control.		
UC4	Indoor 5G parametrisation for maximising throughput.		Outdoor drone navigation. 5G parametrisation for airborne vehicles control.	
UC5	Indoor 5G parametrisation for Video streaming optimisation.		Outdoor 5G parametrisation for maximising throughput.	
UC6		Outdoor drone image transfer and AI-Analysis. 5G parametrisation for air-borne vehicles control.		
UC7		Drone and smart-glasses synergy. 5G parametrisation for air-borne vehicles control.	5G parameterisation for the improvement of video streaming of Smart Glasses.	
UC8				Indoor 5G parametrisation for minimizing latency in AR deployments. Virtual Machine (VM) support and high processing capabilities.

Following this summary, Sections 3 to 6 provide more detail on the specific functionalities that make each testbed ideal for drafting the proposed scenarios. They also provide details of the specific sub-scenarios associated with each UC, the reasoning for the choice of these scenarios, and the most relevant experimentation objectives to explore in the framework of Task 5.1 “First-party experimentation”. A brief explanation is given for each of the UCs, that will be deployed as technology demonstrators of the scenario under analysis.

2.5 KPI and performance evaluation

As the aim of the project is to provide tools to speed up and enhance the PPDR sector's access to new broadband technologies, it is important to demonstrate the 5G technology’s feasibility for this sector. To do so, each of the UCs acts as a technology validator, defining their vertical’s specific network requirements. Deliverable D1.6 provides an overview of the experimentation strategy, addressing both the common definitions of 5G_EPICENTRE project and the experimental criteria to be used. It also offers an important catalogue of KPIs, associated to each of the verticals that represent the UCs, defining both the criteria under which the KPIs are going to be evaluated; and the target KPIs for each of the PPDR-related vertical.

Thus, the first-party experimentation’s performance shall be assessed according to the definitions given in D1.6. However, it is important to be able to frame these results in a scientific context, from which valid conclusions can be drawn for future developments. For this reason, it has been decided to align the experimentation to obtain four different scenarios, which characterise the 5G network in a different way. So, on the one hand the vertical experimentation on 5G networks has been considered (as defined in D1.6); and on the other hand, the specific scenarios, which provide different contexts to the data to be obtained from the experimentation. The execution of the tests defined in D1.6, on different scenarios posed in this document, will provide the project with more valuable conclusions, contextualising the results. It should also be noted that the performance of testbeds has already been evaluated in projects such as 5G-VINNI, 5GENESIS and/or 5G-BERLIN.

In any case, the most significant aspects to be analysed in each of the scenarios, on which D5.2 will offer conclusions obtained through experimentation, are summarised in Table 8:

Table 8: Vertical experimentation over different 5G scenarios

Scenario	Line of analysis
SC1 - Video & Throughput 5G scenario	• Study the behaviour of video-related PPDR solutions, seeking feedback from the vertical, for 5G parameterisation. • Identify the effect of traffic on the different layers considered in the scenario, weighing their relevance and proposing (if any) corrective measures. • Identify the conclusions obtained during the experimentation, that can help in future processes to improve performance of video solutions over 5G.
SC2 - Drone Management scenario	• Study the behaviour of drone-based PPDR solutions, seeking feedback from the vertical, for 5G parameterisation. • Analyse the radio interface, latency, and its influence on the handling of unmanned aerial vehicles. • Identify the conclusions obtained during the experimentation, that can help in future processes to improve performance of drone management over 5G.
SC3 - QoS & Slicing scenario	• Study the behaviour of PPDR solutions when a QoS management is available, seeking feedback from the vertical, for 5G parameterisation. • Identify the needs of these solutions, the drawbacks detected during the project, and the corrective measures.

	• Identify the conclusions obtained during the experimentation, that can help in future processes to enable critical services to benefit from exclusive network conditions.
SC4 - Instantiation & Latency scenario	• Study the way the PPDR service can be instantiated, towards auto-recovery solutions. • Identify the needs of these solutions, the time events, and the corrective measures that may have impact on the deployment time. • Identify the conclusions obtained during the experimentation, that can help in future processes to improve performance.

The following sections aim to offer an overview of available functionalities on each of the testbeds, and their alignment with the proposed scenario. The 5G scenarios are defined, offering a brief summary on how each UC is going to collaborate, towards developing PPDR-tailored 5G scenarios as project outcomes. It should be noted that each UC Owner has a different level of 5G technology knowledge, and their implication has been considered according to this statement. In any case, the collaboration of all UCs is essential, since they act as technological demonstrators, and will offer experimental data from their own vertical, contributing to the validation of the scenario.

3 SC1 - ALB Aveiro (Portugal): Video & Throughput 5G scenario

The ALB infrastructure (described in D1.6 Section 2.1 and D4.4 Section 4.2.3), is composed of a Stand Alone (SA) RAN (ASOCS[4]) and a 5GC (Fraunhofer Fokus O5GC[5]). This testbed is suitable for 5G PPDR indoor scenarios mainly (to a limited extent, to 5G outdoor scenarios, as well).

The main components of the ALB testbed are: (i) a Kubernetes (K8s) based infrastructure with a master and multi-node architecture for the UC components; (ii) a full 5GC instance (release 7 of Fraunhofer FOKUS Open5GCore), running in a VM; and (iii) ASOCS RAN, 5G New Radio (NR), splits in multiple components, following the 3GPP 5G RAN architecture, namely Centralised Unit (running in VMs), Distributed Unit (running in VMs) and Radio Unit (physical component). Table 9: NR characteristics provides the main characteristics of the ASOCS radio components.

Table 9: NR characteristics

Bands	Single Band (n78)
Bandwidth	Up to 100MHz per Cell
Operators	Single-Operator
Multiple input, multiple output (MIMO)	4*4
Output Power	24dBm per port
Interface	10G Eth + PoE over CatX
Protocol	ORAN-FH (split 7.2)
Antennas	Internal

Figure 4 represents the basic network setup used to implement and evaluate the stress conditions specified below (Table 10 - Table 12). The set of network stress conditions can be divided in user plane, control plane and management plane. The volume of background traffic to be generated, either through the user plane or the control plane, is supposed to be large enough to cause the expected stress conditions.

Table 10: User Plane

User plane
Stress 5G RAN user plane: Establish a single Next Generation NodeB (gNB) – core connection (gNB1-5G core in Figure 4). CPE1 is used to run the client component of the user case applications, whereas other CPEs are used to generate and receive background traffic to stress the radio link to gNB1 (additional clients and CPEs may be used to increase the traffic load, as needed).
Stress 5G core user plane: Establish a second gNB – core connection (*e.g.*, using virtual gNb simulator); establish multiple Protocol Data Unit (PDU) sessions; send/receive traffic; and check the performance of traffic to/from CPE1. Use additional virtual gNBs to increase the traffic load handled by the core, as needed.

[4] ASOCS - On-premise mobile clouds (asocscloud.com)
[5] Open5GCore | Open5GCore

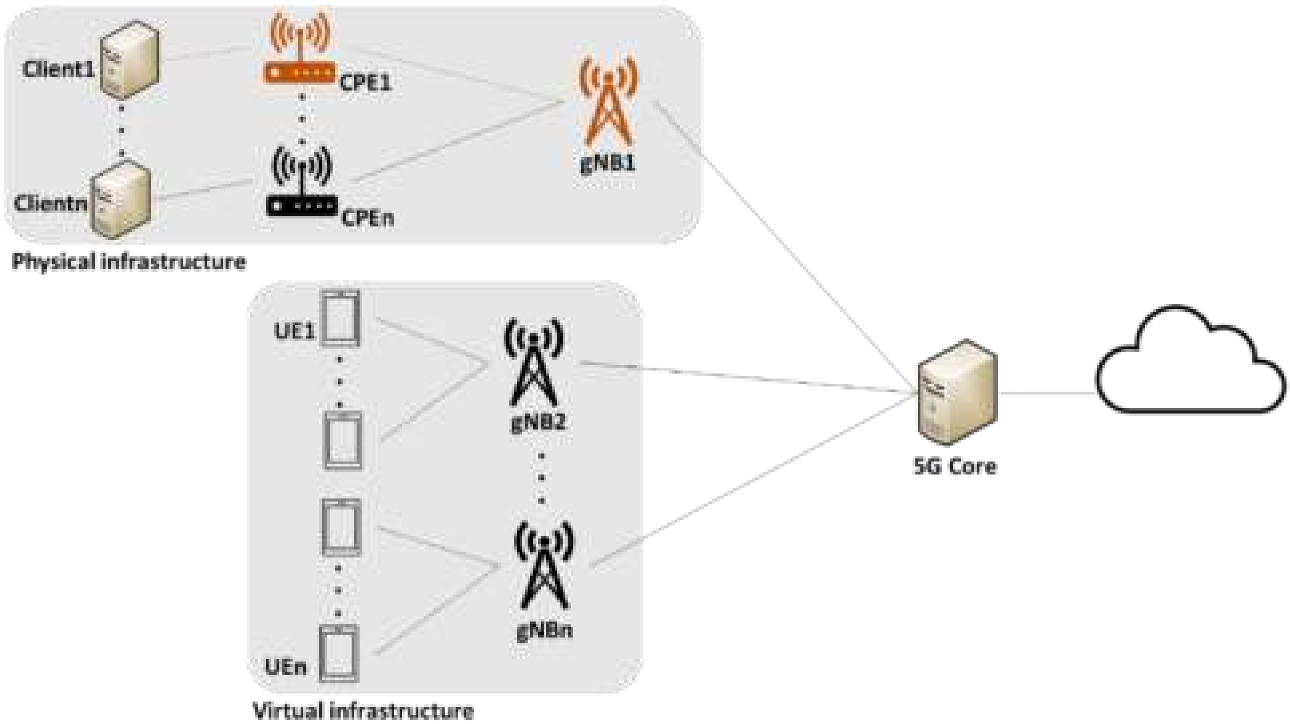

Figure 4: ALB's Test of network stress conditions - basic network setup

Table 11: Control Plane

Control plane
Stress 5G RAN control plane: Through gNB1/CPE2, setup/disconnect PDU sessions to generate a high volume of control plane traffic to be handled by the core through gNB1. Establish a new PDU session from CPE1; check that the network responsiveness is not affected (*e.g.*, PDU session establishment time below threshold).
Stress 5G core control plane: Through additional gNBs, setup/disconnect PDU sessions to generate a high volume of control plane traffic to be handled by the core. Establish a new PDU session from CPE1; check that the responsiveness of the network is not affected (*e.g.*, PDU session establishment time below threshold).

Table 12: Management Plane

Management plane
Apply management plane actions to minimize/overcome the effects of stress conditions. Verify that through the management plane, the following actions can be done "on-demand": • Create a new instance of the 5GC. • Create a new network slice with specific characteristics. • Modify the QoS profile of specific traffic flows to guarantee that performance is not degraded under stress conditions. • Modify the Priority level of specific traffic flows to guarantee that new PDU sessions are established under heavy load conditions.

3.1 UC4: IoT for improving first responders' situational awareness and safety

Expanding on the definition made in D1.1, UC4 aims to explore ALB testbed capabilities with a special emphasis on achieving the highest quality video transmissions.

PPDR scenarios may happen under the most different forms. Those that require the action of first responders indoors are equally important to the ones that happen outdoors, thus, this experimentation is crucial to ensure that situational awareness may still be assured in challenging conditions, like the ones present in major buildings, where communications are often a serious challenge.

Considering the unique characteristics of ALB testbed, it is as an excellent candidate for the collection of network related KPIs, namely the ones identified in D1.6. Testing and parameter hyper-turning activities (both on the Body-Kit modem; as well as on the 5G radio configurations) are foreseen, aiming to achieve the lowest latencies and higher throughput possible. These values are expected to serve as a baseline for further comparison with the ones achieved at UMA. In addition, this testbed has a close connection to potential end-users (Firefighters/EMS at Aveiro), which enables eventual demonstrations, thus, promoting the 5G-EPICENTRE project to one of its high-power target audiences (see D6.2, Section 2.3).

3.2 UC5: Auto scaling video routers in 5G Edge

The 5G-EPICENTRE project is building in Aveiro a video related experimentation scenario tailored to the needs of the public safety and emergency response market players. For UC5, it is particularly interesting to experiment in this scenario as the proposed solution is based entirely on 5G video conferencing. Besides, RZ's *BlueEye* solution will be an appropriate technology validator for the Video & Throughput 5G Scenario (SC1). The UC5's solution will be used in the development and validation of the new SC1 5G scenario. The *BlueEye Handsfree* wearable video solution, consisting of a wearable camera, mobile and cloud-based video platform, will be transmitting real-time point-of-view video (see Figure 5: UC 5 application for wearable video for paramedics.), to be analysed under SC2 premises.

Figure 5: UC 5 application for wearable video for paramedics.

The integrated solution allows critical communications on the move, to send 'You See What I See' video to remote experts for support and oversight. In Urban Search and Rescue, *BlueEye Handsfree* enables the in-field searcher to send real-time point-of-view video to a remote commander. The remote commander can see the situation from the searcher's perspective and provide them appropriate support and expertise. It is therefore a vertical clearly focused on the PPDR sector, whose experimental needs fit perfectly with the SC1 scenario, making it a suitable technology validator for this scenario.

Time-critical communication requires reliable and consistent low latency, to transmit video in real-time. A critical challenge here is to ensure optimum network performance with minimum delay, to ensure real-time communication (to the extent possible) in emergency scenarios. *BlueEye Cloud* uses different video regions for critical service providers. A 'video region' connects one or more video routers in order to broadcast video from one location to another; and contains a media relay to help mitigate the impact of network constraints, such as firewalls.

The architecture is shown in Figure 6: UC5's architecture. Typical video distribution deployment is centralised with added video application delay due to a longer path. In a 4G network, this can be 1000ms. Edge Cloud Video Distribution Deployments open up the following possibilities:

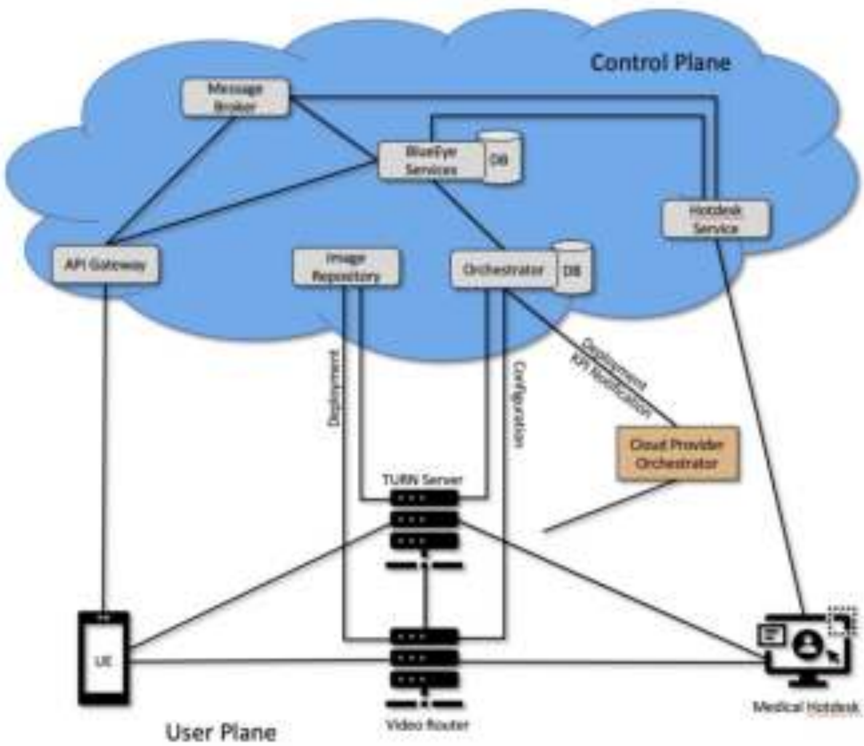

Figure 6: UC5's architecture

- Distributed between areas of operation.
- Deployment size can be tailored to customers.
- Lower Video delay, due to being closer to actual users.
- 5G + Edge Cloud provide near instantaneous video communication.

RZ has built video region auto-scaling architecture within the 5G-EPICENTRE project, to enable emergency video data requirements. To automatically scale the network for a resource-heavy video call, we generate a local 'video region' with one or more video routers, based on specific KPIs such as network usage, or CPU usage. This local video region allows for satisfactory quality of experience, because it prioritises and dedicates network bandwidth for the duration of the video call.

In the UC scenario, UC5 evaluated the auto scaling deployment of the video routers. There is an existing video region with 1 video router. A simulated scaling event has been initiated, which automatically scales the region and brings up a second video router. This small-scale self-test validates that the router is correctly configured.

The computer display result shows that the video is in fact deploying an extra and transient video router. It shows a video region with 2 video routers or pods to start; then 3 pods to show the video has been deployed; and back to 2 pods, to show the extra video router has been properly decommissioned.

4 SC2 - HHI Berlin (Germany): Drone Management scenario

The HHI testbed consists of a 5G SA RAN (Nokia) and a 5GC from ng4T[6], which was provided in cooperation with the 5G-BERLIN association. The testbed is operating in N78 band, and contains Massive MIMO (mMIMO) antenna, which again contains small array of 8x8 antennas, with state-of-the-art technology, such as beam forming up to 8 in Frequency Range (FR) 1 and network slicing. The following MIMO configurations are supported: 4x transmitters, 2x receivers and 4x transmitters, 4x receivers. This 5G technology is suitable to test PPDR applications, such as drone control management; and supports streaming of high-quality videos provided by the deployed drone. The important features of HHI testbed can be found in Table 13: HHI 5G SA FR1 configuration:

Table 13: HHI 5G SA FR1 configuration

Band	n78
Mode	TDD
Bandwidth	100 MHz
Carrier components	1 Carrier
MIMO layers	4 layers
DL MIMO mode	4x4
Max Modulation	256QAM
Beams	two beams (120° horizontal spacing)
Subcarrier spacing	30 kHz
Uplink/Downlink slot ratio	1/4
Output Power	23dBm per antenna

In addition, a wide area can be covered with the mMIMO antenna. If a valid license is available, the drone can be flown and different KPI's can be measured. The coverage can be seen in Figure 7: Coverage of the 5G HHI Testbed.

The 5GC from ng4T enables measurement of N2, N3 and N6 links, as described in 3GPP technical specifications, allowing the testbed owner to precisely test the performance, or troubleshoot the system.

In addition to the 5G base station, HHI has provided a Dell R440 server, on which the components for the various UCs will be integrated. A K8s-based infrastructure with a master and 2 worker nodes is provided for the UC deployments. HHI provides an external Virtual Private Network (VPN) access to K8 services. The following services are also included: Ingress Controller; Rabbit MQTT; Persistent Volume; and Prometheus. Especially for UC3, a Network Application is developed as a successor to the already existing *QGroundControl*[7] application. KPI's from different deployed UCs, but also their data, such as video streaming, can be exchanged; and fed to different

[6]https://ng4t.com/
[7]QGC - QGroundControl - Drone Control

UCs on the same server, motivating inter-operability of the UCs and promoting synergies among them. Furthermore, PPDR UCs pose a challenge for the testbed owners to create a real-world scenario in order to cross-check,

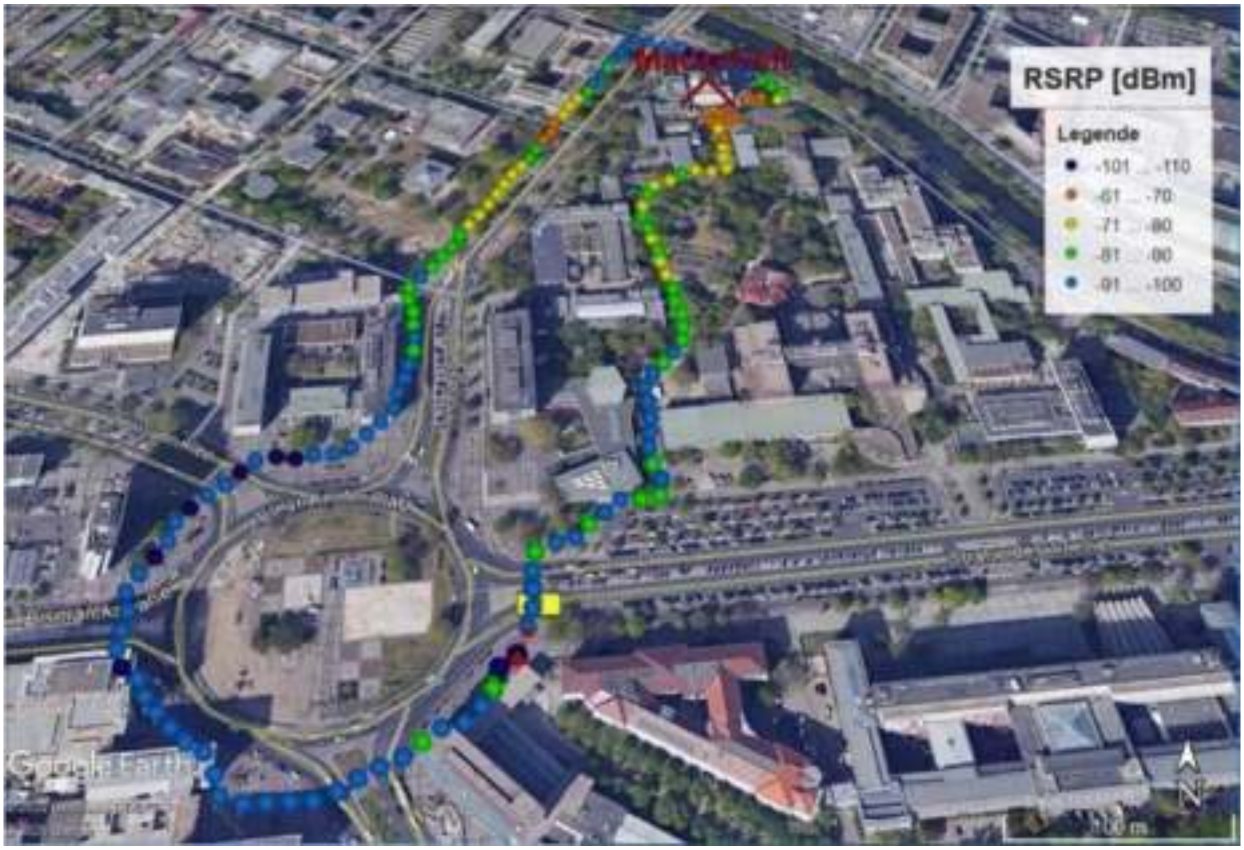

Figure 7: Coverage of the 5G HHI Testbed

if the KPIs are being satisfied or not. This is solved in the HHI testbed by stressing the network through different real UE's, such as Huawei, CPE's and Quectel modems. Apart from the UE's, HHI also have a UE emulator (VIAVI TM500[8]), which can artificially and flexibly load the 5G network. Measuring equipment, such as R&S spectrum analyser and noise generator, further allows the testbed owner to verify detailed different parameters of the network, enabling the UCe owners to precisely tune their UCs.

4.1 UC3: Ultra reliable drone navigation and remote control

Expanding on the definition made in D1.1, the drone can (optionally) utilize the network-slicing feature, which will additionally provide a reliable and dedicated connection to the 5G base-station. This drone can not only telecast the real-time scenario, but can also be controlled by the emergency forces, which will provide them an additional advantage to plan their strategies.

As HHI is both both UC and testbed ownerin this scenario, the continuous and rigorous integration of the UC is made easy. The 5G setup, provided by 5G-BERLIN, allows the testing of the UC in a real-world scenario, along with the validation of KPIs using state-of-the-art equipment available in our facility. Moreover, the testbed utilizes a dedicated application server for 5G-EPICENTRE UCs, which supports the following functionality: (i) controlling and monitoring the drone; and (ii) viewing the video stream sent by the drone. The video stream and

[8] TM500 Wireless Network Tester - Validate Performance | VIAVI (viavisolutions.com)

control information, such as position data, can also be forwarded to external clients, which will enable emergency forces to better analyse the onsite situation in the event of a disaster.

UC3 will be utilizing the HHI 5G SA testbed, which is operating in N78 band. The frequency of the base-station is 3.75 GHz and bandwidth utilization are 100 MHz. As the testbed is being granted under 5G-BERLIN initiative for experimentation, the Nokia base-station allows to change the parameters; and test the drone under such changed settings. In addition, the base station is equipped with a Nokia mMIMO antenna, which can be used to test new 5G functions, such as beamforming and network slicing. Therefore, the drone UC can be tested under future-oriented conditions. The 5GCsetup at HHI is provide by ng4T and is currently configured as Enhanced Mobile Broadband (eMBB).

In the event of a disaster, it is particularly important to ensure uninterrupted and high-resolution transmission of the drone's video stream. To verify this, the reliability and bandwidth of the transmission between the drone and the control centre will be measured. With 5G Network Slicing, the conditions required for the UC will be met. For the PPDR services, network resources are made available preferentially for this purpose.

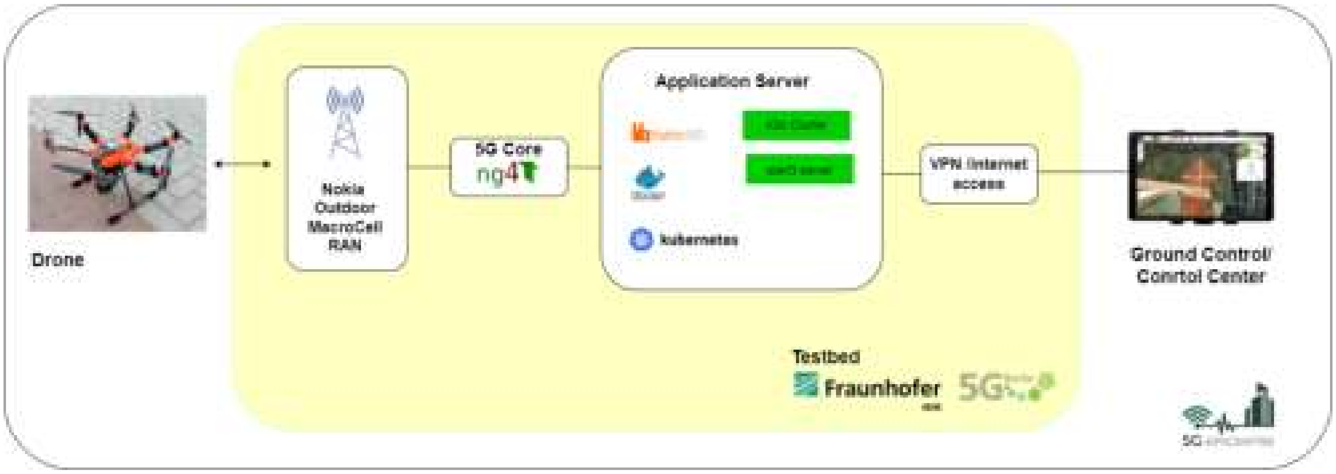

Figure 8: UC3's deployment architecture

4.2 UC6: Fast situational awareness and near real-time disaster mapping

OPTO, as stated in D1.1, is specialized in development, design and manufacture of sophisticated individual and complex large-scale solutions for measurement, monitoring, and control technologies. OPTO's UC6 uses drones for an in-depth analysis of the specific emergency situations that may arise. For this reason, it is particularly interesting for OPTO to experiment in a scenario focused on drone navigation, both because of the synergies in terms of logistics and the specialisation of the underlying 5G scenario. UC6's solution focuses on camera-based systems with image data transfer over networks rather than on an autonomous drone management. It will process the image using Artificial Intelligence (AI), customized for the PPDR-Sector, generating an image flow from a camera-based system connected to the 5G network, transferring the data via a Virtual Network Function (VNF) AI Analyzer to an 5G connected handheld display device. The AI-Analyzer, hosted in 5G-Core-Serverlandscape, is annotating detected objects in the image flow stream, which can be displayed at the 5G connected handheld display device. This means that rather than focusing on autonomous drone management, UC6's solution is a drone application more focused on image processing, which enriches the SC2 scenario, and brings new needs to 5G experimentation in drone contexts.

The camera-based system is connected to the HHI 5G SA testbed, which is operating in N78 band. A customized Quectel RM500 Modem is used. The Quectel RM500 is a 5G module optimized specially for Internet of Things (IoT)/eMBB applications; and allows connections to 5G-SA. The AI-VNF will be installed on a testbed server using Docker; and will receive the image flow from the camera-based system, for analysis and annotation purposes.

Then, the handheld display device connects via Wi-Fi to a 5G-Router connected to the 5G testbed, and receives the image flow from the AI-VNF, displaying the annotated images to the user.

For both SC2 and UC6, it is important to measure transfer times and latency, which can reflect the speed and reliability of the testbed under stress conditions (and it will have a special relevance for UC6's performance). To reach uninterrupted and high-resolution transmission of the camera-based system image flow, the network has to deliver bandwidth and reliability. The UC6 is therefore an ideal technology validator for SC2, a vertical based on a drone solution, focusing on image processing, which brings a new direction to 5G experimentation.

4.3 UC7: AR and AI wearable electronics for PPDR

YBQ's experience in the Smart Glasses (SGs) field can be used to develop the first 5G-native SGs, customized for the PPDR sector. For this UC, on-field operators, like civil defence workers, wear the SGs and are able to see in AR, a set of useful information about the scenario (coming from remote elaboration), but also, from the analysis of the context made thanks to the images acquired via frontal cameras. A remote team leader in a control room can communicate with each user on the field; see every video flow coming from SGs cameras; and also integrate with video flows coming from drones.

YBQ has chosen this testbed for the possibility to integrate the information flow via the use of drones flying on the scenario environment. The video flow of the drones is sent to the remote team leader, that can route it to the SGs users on the field. The scenario to be developed in HHI testbed offers an ideal environment for the elaboration of synergies related to the use of drones, that UC7 wishes to explore, by helping in their optimisation.

The use of the SGs in this 5G testbed will demonstrate the improvement of movement coordination of civil protection workers in disasters scenarios. In fact, resuming the KPIs' main features, the delay reduction will allow a real-time communication and the increase in bandwidth will allow the simultaneous audio-video bi-directional transmission of at least four SGs.

5 SC3 - UMA Málaga (Spain): QoS & Slicing scenario

The UMA testbed provides a 5G private network that supports different operation modes: 5G Non-Stand-Alone (5G NSA) FR1, 5G Standalone FR1 and 5G NSA FR2. Table 14 and Table 15 summarize the test setup, based on a 5G NSA FR1 deployment, with 4 5G NR Time Division Duplex (TDD) cells in FR1 band n78 at 3.5GHz, with an associated channel bandwidth of 50 MHz per cell. A 2x2 MIMO with 256QAM modulation enables the selected scheduling configuration to reach 342 Mbps per carrier. The gNBs have activated a feature called "proactive scheduling", which enables the scheduler to generate a configurable number of additional uplink grants and thus, avoid the latency associated with the scheduling request procedure. The average measured latency is in the order of 10-12 ms.

Table 14: UMA's 5G NSA FR1 configuration (4G Anchor)

Band	n78
Mode	FDD
Bandwidth	20 MHz
Carrier components	1 Carrier
MIMO layers	4 layers
DL MIMO mode	4x4 Closed Loop Spatial Multiplexing
Max Modulation	256 QAM

Table 15: UMA's 5G NSA FR1 configuration (5G)

Band	n78
Mode	TDD
Bandwidth	40 MHz
Carrier components	1 Carrier
MIMO layers	2 layers
DL MIMO mode	2x2 Closed Loop Spatial MultiplexingMax
Modulation	256QAM
Beams	Single beam
LTE to NR frame shift	3ms
Subcarrier spacing	30 kHZ
Uplink/Downlink slot ratio	2/8

The current configuration distribution also supports NSA mode, and 2 picocells 5G SA for indoor coverage in band n78 are provided, which configuration is described in Table 16.

Table 16: UMA's 5G SA FR1 configuration

Band	n78
Mode	TDD
Bandwidth	100 MHz
Carrier components	1 Carrier
MIMO layers	4 layers
DL MIMO mode	4x4
Max Modulation	256QAM
Beams	Single beam
Subcarrier spacing	30 kHz
Uplink/Downlink slot ratio	1/4

The 5G private network also includes two Radio Remote Units (RRUs) for millimeters waves, that operate in-band n258 (whose configuration is described in Table 17:

Table 17: UMA's 5G NSA FR 2 configuration

Band	N258, n61
Mode	TDD
Bandwidth	800 MHz
Carrier-components	8
MIMO-layer	2x2
DL MIMO mode	Close loop spatial multiplexing
Beams	32 (Analog beamforming)
Subcarrier-spacing	240 kHz
Uplink/Downlink slot ratio	¼

Figure 9: UMA's 5G private network

This state-of-the-art setup reproduces a 5G network in a box for controlled experimentation with 5G mobile devices, including RAN and NAS emulation both for signalling and radio protocols. The emulated networks can deploy multiple cells, not only in NSA configuration, but also in SA configuration (without the need for an LTE anchor).

The 5GC from ATH used in the 5G setup exposes in the N5 interface an Application Programing Interface (API) for the configuration of specific 5G QoS Identifiers (5QIs), a key parameter for the prioritization of PPDR application traffic. The usage of this API has been integrated into UC1 and UC2, and serves as the basis for the 5G-EPICENTRE Network Application approach (see D1.4).

5.1 UC1: Multimedia MC Communication and Collaboration Platform

This UC aims to demonstrate MCX in a 5G context: Mission Critical Push-to-Talk (MCPTT [2]); Mission Critical Data (MCData[3]); and Mission Critical Video (MCVideo [4]), such as group and individual voice calls; group and individual messaging; group and individual multimedia messaging; individual video calls; emergency calls; and location and map services, using the resources of the 5G-EPICENTRE platform.

The main goal with this set of experiments is to demonstrate MCX performances, with a strong focus on the user Quality of Experience (QoE) and reliability on top of a flexible 5G deployment, such as the 5G-EPICENTRE platform. This will be an important step on the path to developing a rich PPDR application ecosystem, which will leverage MCX through APIs, such as those exposed by the Airbus MCX application.

No specific 5G configuration is required in this UC, for it to stay as generic as possible, in order to be practicable in any kind of 5G configuration, either outdoor or indoor. This UC will make use of a cloud-native PPDR communication platform for experimentation on 5G testbeds: (i) fully leveraging 5G and cloud innovative features addressing the needs of PPDR users with previously unforeseen performance (Network Functions Virtualization [NFV], slicing, Multi-access Edge Computing, 5QI, *etc*.); and (ii) Fully interoperable and easily interfaceable with any kind of external applications or assets, for bringing added value on top of the communication application. In order to illustrate the added value of 5G for PPDR applications like:

- **Fast service creation:** one of the core performance-related KPIs defined by the 5G PPP calls for average service creation time cycles to be drastically reduced, ensuring to instantiate within some minutes a complete communication platform, especially in the context of PPDR crisis management.
- **Increased Resilience and scalability:** Cloud native core optimally schedules Containerized Network Function (CNF)/VNF to run on the available infrastructure; scale in and out in on demand; and utilize container-level isolation and health monitoring, so as to rapidly restart instances in case of failure. If a service fails, the infrastructure will immediately and automatically create a new instance of the service, so that the critical mission can be achieved, without any intervention from the user, or the operator. This is a core feature for PPDR end users and offered by 5G.

The 5G network will be stressed through traffic emulation, simulating the increase in network traffic that could occur in an emergency. To do so, it will work on the different possible planes, the user plane, the control plane, and the management plane. These stress conditions will allow illustrating how a PPDR application developed for exploiting 5G modern features can leverage 5QI mechanisms in order to guarantee efficient delivery of mission critical services.

The 5G KPIs and scenario objectives focus on the critical services that are enabled by 5G networks. These objectives include assuring high availability; low latency; and high throughput for mission critical services. All the KPIs and the expected values, compliant with MCX requirements, are detailed in D1.6. 5G Prioritization mechanisms can be demonstrated, to show that these requirements are fulfilled even in stressed conditions.

5.2 UC2: MCX coordination between first responders, slicing and QoS management in high traffic conditions

NEM defined two different UC-level experimentation scenarios in D1.1. In addition to the target KPIs, two different assumptions were made in order to explore new functionalities that MCX solutions can acquire in 5G environments. For the implementation of UC2 in UMA, the first of these two scenarios "*MCX coordination between first responders*" has been chosen to be analysed. This UC-level experimentation scenario targets a common coordination between first responders, each one from a different agency, or authority, with its own MCX, that will seamlessly facilitate merged and temporary talk groups for the various agencies involved during the time the emergency event takes place.

In addition, for the UMA experimentation scenario, the work started earlier in the project will be continued, addressing the interaction between the MCX vertical service and 5GC for QoS management. A multi-tenant MCX scenario is therefore envisaged, in which the possibilities offered by 5G slicing will be studied. It will also evaluate how QoS management can offer advantages to the PPDR sector (in this case, through MCX communications), assessing the difference in network behaviour that different 5QIs can offer. This will be possible thanks to the vertical service management policies deployed in ATH's 5GC, integrated at the UMA facility.

The proposed experimental environment is based on the Network Functions Virtualization Infrastructure (NFVI) deployed in 5G-EPICENTRE. The vertical MCX service is deployed in UMA's testbed in a multi-master, multi-node K8 environment, with a 5G Nokia picocell-based indoor coverage, powered by ATH's 5GC network. NEM provides its fully containerised, microservices-based MCX solution, which will be instantiated in the NFVI at UMA.

The MCX service's traffic flows through the User Plane Function (UPF) and requires a dedicated QoS. To dynamically manage it, this experiment focuses on the interaction between the MCX service and the Policy Control Function (PCF) via the N5 interface. The MCX service acts in this way as a trusted Application Function (AF). Upon solicitation by the AF, the PCF will be suitably configured to host the dedicated QoS flow policy profile (including the specific higher priority 5QI), so that it can be applied to the respective first responder's device. Further, the connection between ATH's 5GC and UMA's RAN has been evaluated.

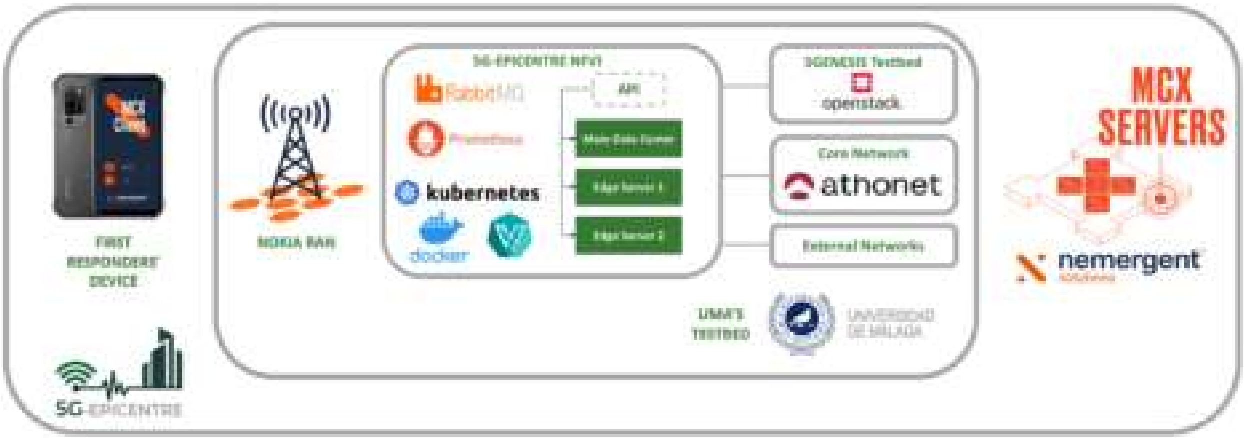

Figure 10: UC2's deployment architecture

For the 5G experimentation scenario at UMA, it has been decided to stress the network with emulated traffic. The objective is to provide an environment as similar as possible to the one that PPDR agencies and their MCX solutions may encounter when operating as vertical services over deployed 5G networks. . The objective is to evaluate the behaviour of NEM's MCX services and its interaction with the 5GC in high traffic load scenarios. For this purpose, 5QIs allocation – and their impact on service performance – will be studied and compared to the case where a QoS change for the MCX service was not applied. The creation of specific slices (if possible) for each of the agencies defined in D1.1 will also be explored, comparing the different parameterisation possibilities.

The proposed scenario seeks to explore interoperability of PPDR vertical services over 5G networks, through the N5 interface, managing the QoS, and assigning specific resources to MCX services. The 5GC PCF has to be able to handle MCX service requests for allocating different QoS policy profiles to the designed first responders' devices and manage QoS policy change. The aim is to explore the feasibility of working with different slices, parameterising them differently, and check how different tenants can have different outcomes depending on the parameterisation.

5.3 UC4: IoT for improving first responders' situational awareness and safety

Expanding on the definition made in D1.1, UC4 aims to explore UMA testbed capabilities with a special emphasis on demonstrating how 5GC functionalities may be used to prioritize traffic from first-responders, during a PPDR scenario with an overloaded network.

The 5G outdoor coverage available at Málaga testbed will allow the test and validation of the *Mobitrust* wearables in an open space, replicating a potential PPDR scenario where multiple first responders from different agencies would be acting in the same scenario.

Aiming to replicate the expected service congestion of the network during a PPDR event, the set of experimentation activities envisioned to be carried out in this testbed foresee the use of the traffic simulator with different payload profiles and different pressure points (*i.e.*, RAN and 5GC components).

The integration with the N5 interface made available by ATH's' 5G Core will allow to demonstrate the possibility of traffic prioritization, even in quite challenging situations, allowing to obtain time-sensitive information (*i.e.*, vital signs of a fallen first-responder).

The multiple technologies available at UMA (4G, 5G SA, 5G NSA), will allow the comparison of different KPIs under different network topologies, focusing on the demonstration of the advantages provided by 5G for PPDR.

The deployment of the Mobitrust platform in a distributed manner is also envisioned, with internal micro-services being executed in the Core and others being executed in the Edge. Such a division might have a several impacts on the quality of media content transmitted from the field, with a closer media management system allowing to achieve smaller latencies, thereby contributing to an improved field awareness. In addition, the Edge system may operate autonomously when external connectivity is not available, hereby improving the reliability and availability of the platform.

In addition, this testbed has a close connection to potential end-users (Police at Malaga), which enables eventual demonstrations, thus, contributing to the dissemination objectives of 5G-EPICENTRE (see D6.2).

5.4 UC5: Auto scaling video routers in 5G Edge

The UMA testbed was used as a starting place for UC5. The UMA testbed is flexible and proper for initial experiments. Early scenario experiments were conducted with UMA and RZ as a basis for learning. RZ learned how to properly containerize video routers, and went from VM base to simple docker containers to kubernetes compatible deployments. RZ was challenged by the advantages and constraints of a kubernetes type deployment, but in the end managed to generate something that is quickly scalable. As next steps, RZ will perform more tests in UMA as slicing and QoS management are key technologies for Medical Emergency Services and the logical next step in the progression of *BlueEye* deployments. RZ expect to learn the best ways to enable prioritized traffic for medical applications.

This was expanded to ALB, using this testbed and scenario as a validation site, ensuring that results are repeatable across different infrastructures and proving RZ's solution is indeed valid and not something that only works on a single specific testbed.

5.5 UC7: AR and AI wearable electronics for PPDR

The scenario to be performed in the UMA testbed will consider a task force on the disaster field, wearing the AR SGs, and a remote team leader in the Command & Control Centre (CCC). In this scenario, the drones are not available. Civil protection forces on the field will share their camera vision with the CCC; and also communicate via an audio channel in real-time.

YBQ decided to test the UC7 in the Malaga premises because it is possible to test the UC outdoor, to allow users wearing the SGs to test in an almost real environment. Other than this, YBQ is interested to test in a 5G vendor, like Nokia, and UMA can provide a Nokia RAN for the project.

The 5G KPIs to be assessed in this scenario have already been defined in D1.6. The use of the SGs in this 5G testbed will demonstrate the improvement of movement coordination of civil protection workers in disaster scenarios. In fact, resuming the KPIs' main features, the delay reduction will allow a real-time communication; and the increase in bandwidth will allow the simultaneous audio-video bi-directional transmission of at least four SGs.

6 SC4 - CTTC Barcelona (Spain): Instantiation & Latency scenario

The CTTC infrastructure is described in D1.6 Section 2.4; and D4.4 Section 4.2.4. It consists of a reconfigurable experimentation framework, including generic purpose computing to emulate cloud and edge datacentres – and a 5G network. This section describes the main configurations that can be applied over this framework; and the stress conditions that the framework provides. The CTTC 5G testbed allows creating multiple Testbed Instances (TIs). Each TI is a NFV ecosystem, which provides the capability of sharing the same testbed physical infrastructure; and building different sub-testbeds, according to the experimentation needs of each UC. A testbed instance may include: (i) computing capabilities (CPU, Graphic Processing Units (GPU), edge, cloud); (ii) 5G network capabilities (including UEs, RAN, and core); and (iii) Other devices. A global view of the CTTC testbed is presented in Figure 11: The 5G CTTC Testbed.

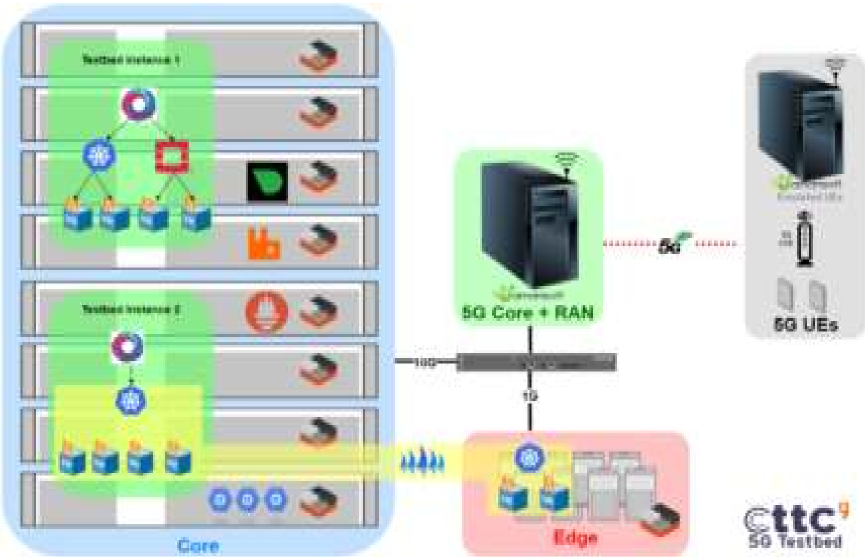

Figure 11: The 5G CTTC Testbed

The left part corresponds to generic purpose servers, over which the testbed instances deploy their VMs, or containers. Though the configuration of this part is flexible, this component can be seen as the cloud datacentre of the scenario under evaluation. The lower part corresponds to edge servers, which may be either generic purpose servers, or those equipped with GPUs, for offering services to demanding URLLC applications (*e.g.*, AR for UC8). The basic computing capabilities consist of 10 servers, with a total of 456 Central Processing Unit (CPU) cores; 2632 GB memory; 58 TB storage; and 6 GPUs distributed in two servers. For edge computing, there are 10 machines with a total of 40 cores; 147 GB memory; and 2.5 TB storage. It should be noted that the available GPUs can be virtualized for containers/VMs. Figure 12 shows the CTTC testbed, including the 5G network equipment.

Additionally, more servers, networking, and measurement equipment can be made available from another testbed of the Services as networkS (SaS) group, namely the EXTREME Testbed® (Figure 13: Part of the CTTC 5G Testbed. EXTREME Testbed ®).

The 5GC (and RAN) can be deployed either through commercial products, *i.e.*, the Amarisoft CallBox, or through open-source solutions integrated with Universal Software Radio Peripherals (USRPs). More specifically, the CTTC testbed consists of a variety of 5GC, namely: (i) Amarisoft 5GC[9], as part of the Callbox (Ultimate[10] and Mini[11]); (ii)

[9]https://www.amarisoft.com/app/uploads/2022/01/AMARI-Callbox-Ultimate.pdf
[10] https://www.amarisoft.com/app/uploads/2022/01/AMARI-Callbox-Ultimate.pdf
[11] https://www.amarisoft.com/app/uploads/2021/10/AMARI-Callbox-Mini.pdf

Figure 12: Part of the CTTC 5G Testbed showing some of the servers and the Amarisoft 5G equipment.

Figure 13: Part of the CTTC 5G Testbed. EXTREME Testbed ®

Containerized Open5GS[12]; and (iii) Containerized OpenAirInterface. The main characteristics may be found in the footnotes, although it is important to underline the possibility of working with a 4G network; the slicing (currently there is no options to allocate resources, under capabilities and operation analysis); or monitoring systems.

Given the relevance for the scenarios to be deployed, we focus on the 5G network configuration (including the RAN). The generic configurations that can be applied, on top of which UCs can be tested, are provided in Table 18: CTTC 5G SA FR1 configuration for the following setup: (i) gNB/core network: Amarisoft Ultimate Callbox; and (ii) UE: Amarisoft Simbox.

Table 18: CTTC 5G SA FR1 configuration

Band	n78
Mode	TDD
Bandwidth	100 MHz
Carrier components	1 Carrier

[12]https://open5gs.org/

MIMO layers	4 layers
DL MIMO mode	4x4
Max Modulation	256QAM
Beams	Single beam
Subcarrier spacing	30 kHz
Uplink/Downlink slot ratio	2/7

CTTC testbed can also offer 4G based networks, as shown in Table 19: CTTC 5G NSA FR1 configuration (4G Anchor), or 5G NSA networks as described in Table 20: CTTC 5G NSA FR1 configuration (5G).

Table 19: CTTC 5G NSA FR1 configuration (4G Anchor)

Band	N1
Mode	FDD
Bandwidth	20 MHz
Carrier components	1 Carrier
MIMO layers	2 layers
DL MIMO mode	2x2
Max Modulation	256QAM

Table 20: CTTC 5G NSA FR1 configuration (5G)

Band	N78
Mode	TDD
Bandwidth	100 MHz
Carrier components	1 Carrier
MIMO layers	4 layers
DL MIMO mode	4x4
Max Modulation	256QAM
Beams	Single beam

Subcarrier spacing	30 kHz
Uplink/Downlink slot ratio	2/7

There may be variations according to the capabilities described in previous sections and the UC needs.

The CTTC experimental framework allows generating a variety of cloud and network conditions and monitoring a variety of platform-level KPIs of interest for the UCs under evaluation over the testbed. We have classified such conditions into two main groups, each affecting one of the main parts of the evaluated scenario, namely RAN and Cloud/Edge.

The focus on network-level impairments is put on the RAN, since it is the most likely network segment to experience problems in PPDR scenarios. This may entail testing the network with different levels of RAN background traffic, to emulate congestion conditions in case of resource scarcity due to other parts of the network failing.

As for the cloud/edge, resource scarcity and congestion can also be emulated. Scarcity may come from an emergency happening in a certain spot requiring deployments of multiple teams in a certain area, or other parts of the network being unusable, hence having less resources available overall to serve the users of the network. In this direction, the testbed allows generating different levels of CPU background loads. This allows evaluating the performance of the whole framework, as well as that of the UCs when there are low computing resources.

In the same way, at the flow level, different levels of packet losses may be generated to test the reliability of communications and services under abnormal conditions. Additionally, more demanding PPDR scenarios could also be emulated, depending on the UC needs, by generating network disruptions in various components of the network, such as cluster down, or node in cluster down.

For monitoring the physical/virtual resources, Netdata and/or Prometheus can be used. This enables monitoring any metric from the RAN to the core and application; and visualizing it. An instance of RabbitMQ supports a message-passing service to transfer experimentation data and real-time monitored values for analysis and visualization. Some of the KPIs of interest for the deployed UCs are: (i) Service deployment time; (ii) UE-to-datacenter round trip time; (iii) Packet losses; (iv) Throughput; and (v) Scaling time.

6.1 UC2: MCX coordination between first responders based on geo-localization, dynamic re-instantiation to respond to PPDR mobility

NEM defined two different UC-level experimentation scenarios in D1.1. In addition to the target KPIs, two different assumptions were made in order to explore new functionalities that MCX solutions can acquire in 5G environments. For the implementation of UC2 in CTTC, the second of these two scenarios "*MCX coordination between first responders based on geo-localization*" has been chosen to be analysed. This UC-level experimentation scenario, as an enhanced first scenario, targets to make an Edge Mission Critical and 5GC services instantiation (close to the emergency event) via 5G gNB geo-localisation mechanisms and/or MCX Global Positioning System (GPS), based localisation reports, in order to adjust and improve the latency of the first responders attending the emergency event localisation.

In addition, for the CTTC experimentation scenario, NEM aims to explore instantiation and re-instantiation; and how the cloud-native design makes 5G networks an ideal ecosystem for PPDR services, which take advantage of the verticality with which the technology was conceived. It provides the means to achieve an agile and dynamic response to problems that may arise in network, in a particular element, or due to the relocation of the PPDR agency, leveraging the 5G-EPICENTRE platform's cloud native approach.

The proposed experimental environment is based on the NFVI deployed in 5G-EPICENTRE. The vertical MCX service is deployed in the CTTC testbed; and will have different instances deployed in three different physical servers. Two of the servers will contain MCX instances associated with independent PPDR agencies, while the third will be the MCX Root or control. The scenario will take advantage of the capabilities and number of servers that this testbed can provide.

For the 5G experimentation scenario at CTTC, it has been decided to stress servers 1 and 2 by emulating latency (emulating the movement of one of the agencies into the emergency), or micro-outages, or both. UC2 would then re-instantiate the services of Agencies 1 and 2 to Server 3, create a super-group, where Agencies 1 and 2 can synchronize and attend the emergency with better network conditions. The focus in this scenario is to demonstrate that despite the re-instantiation, the different predefined talk groups, or existing configurations, will be maintained. This emulates the need for a particular agency to move to the emergency, and how its MCX communications solution can adapt to the new situation, re-instantiating its services in a new location to achieve better performance, while maintaining the same initial configuration.

One of the most important outcomes of the experimentation to be carried out in this scenario, would be the conclusions obtained about re-instantiation time. However, the main objective is to explore how a cloud native 5G network, designed to work with containerised services, can provide interesting functionalities for the PPDR sector. Thanks to experimentation on this scenario, important conclusions would be obtained, on how PPDR agencies' movements towards emergencies (fires, volcanoes, floods, *etc*.) may have an improved functional communication response (coordination between MCX agencies with the creation of super-groups); and an optimal 5G network performance through edge deployment.

6.2 UC8: AR-assisted emergency surgical care

The UC8 aims to provide first aid PPDR responders with lightweight, portable AR Head-Mounted Displays (HMDs), providing them information and guidance through an AR interface on critical surgical operations. A detailed UC description along with its experiment phases or deployment scenarios can be found in D1.1, Section 3.9.

The UC8 will be deployed and tested in the CTTC testbed in Barcelona. It will explore the adaptation of this UC in the 5G setup as follows. For heavy processes, such as rendering (GPU required); computations; and physics (CPU required), computations will be performed on the edge component. The final rendered images will be streamed to the 5G connected AR HMD, which will receive, decode and project the streamed images. The VM-based application server component will be deployed on an edge node in the CTTC testbed, and another application will be installed in an AR-HMD, both connected to the 5G infrastructure of the testbed. Various tests will be performed on the proper connection of these two components through the 5G network, to identify issues/bottlenecks during identification; handshaking; and exchange of data; also logging network metrics throughout the procedure. The second objective of the experiment, besides identifying and solving connectivity issues, regards the proper configuration of the platform and the application server, towards minimizing latency and package-loss, hence providing high QoE to the first aid-responder.

The CTTC testbed was chosen to host this application as it supported VM-based applications via the use of the KubeVirt[13] K8 module, but also, because the edge nodes had sufficient GPU resources, capable to support a modern, demanding AR application, such as the one involved in UC8. The nature of the application also demands GPU pass-through, which was also available in the testbed. The functionalities mentioned are capable and sufficient for a similar application to be hosted in the CTTC testbed, even though the application's design may not allow containerization and/or demand use of a powerful GPU.

The UC8 edge server component will be deployed via libvirt[14] on a LXD container, as a VM running Windows 10. The edge node is equipped with an NVIDIA GeForce RTX 2080 Ti GPU card, suitable for the needs of a high-fidelity AR application. The CPU of the VM is an Intel(R) Xeon(R) Gold 5218 CPU @ 2.30GHz, with 16GB of RAM.

[13] KubeVirt.io

[14] libvirt: The virtualization API

The deployed VM needs exclusive use of the GPU, with GPU pass-through, since Virtual GPU (vGPU) licensing is not available in the testbed. The scenario will take advantage of the capabilities and number of servers that this testbed can provide. To provide GPU access, the KubeVirt K8 module is used, which can provide hardware devices to libvirt.

To support GPU pass-through, Virtual Function Input/Output (VFIO) is used to disable GPU utilization from within the host operating system; and hand it off to libvirt. It is important to note that this is done in the host system, meaning that no other application can make use of the GPU during the VM's runtime.

For the 5G experimentation scenario at CTTC, real network stress conditions will be emulated, similar to the ones dealt by first aid responders on disaster sites. Besides considering the underlying traffic (5GTS offered that will be defined in D2.5), latency will be emulated. This may be done at server-level, but could also be emulated in application-level, by the component running on the edge. Research is currently underway on how tosupport the ability to emulate package-loss and/or latency for our application, thus simulating real-life situations. As real-time AR applications are sensitive to both latency and packet loss, we shall investigate the proper threshold levels that allow a sustained and pleasant QoE for the end-user.

In D1.6 (Annex I, UC8), three basic KPIs are mentioned that are related to latency, as Round Trip Time (RTT); data throughput; and packet loss. During the experimentation, besides connectivity check, UC8 aim to address all three KPI-related topics. Current latency and its source will be measured – on-site application and testbed configuration tweaks will be made to minimize it. Similar approaches will be applied for data throughput and packet loss. First, UC8 will identify initial metrics, then determine what parameters may augment the results and finally, determine what are the maximum metrics that can be obtained without major application tweaking. If the metrics fall within the *upgradable* and *optimal* values (described in D1.6), UC8 shall continue to identify the optimal parameter configuration; otherwise, UC8 will identify the component causing the bottleneck and brainstorm on how to amend it. As a first version of the AR SGs developed in the context of UC7 is available, UC8 leaders will explore whether their application can be deployed in this specific hardware and the benefits of this hardware(UC7)-software(UC8) synergy.

Thanks to experimentation on this scenario, UC8 may identify the proper configuration that will provide first-aid responders with the best possible QoE during the use of AR-based applications, similar to the one of UC8. Such applications are sensitive to network performance, as the video streamed to the HMD must be in sync with the real scene, also viewed by the responder on site. Identifying the minimum thresholds of the network characteristics that should apply to provide a pleasant end-user experience will also allow to determine the mechanics to maintain such characteristics via proper 5G configuration; slicing; edge deployment; *etc*. A balance between what is required by the application; and what resources the network should bind, can then be identified and applied.

7 Conclusions

A major effort has been made to align experimentation planning processes in accordance with the PPDR sector's needs, in accordance with 5G-EPICENTRE's philosophy. The actions carried out have focused on the context that the underlying 5G network offers to verticals, and in creating a 5G environment, that is truly attractive to the PPDR sector. To this end, the strengths offered by each of the partners have been analysed, looking for commonalities and aligning efforts to obtain useful scenarios for the PPDR sector. These scenarios will seek to represent the demanding network conditions faced by the PPDR sector, offering an optimised 5G network, and aiming to demonstrate the suitability of these networks, even in the most difficult conditions.

For the elaboration of these scenarios, the experimental needs of the verticals covered by the project have been considered; and the aspects that could be of most interest to the PPDR sector have been identified. The number of deployments has been reduced, aligning efforts towards common objectives, working on synergies between partners to reach common objectives, such as the scenarios proposed in this document. These, exploit the strengths of each testbed, to offer a debugged and optimised 5G environment in interesting areas to the PPDR sector.

During experimentation, these scenarios will mature, providing an important asset for the 5G-EPICENTRE project and for future PPDR experimenters. Therefore, the project will not only offer a platform that simplifies experimental processes, with Network Applications that can be used by third parties to obtain results and conclusions in an intuitive way. It will also have four (if not more) 5G scenarios of particular relevance to the PPDR sector, such as: (i) 5G for Video & Throughput optimisation; (ii) 5G in drone management environments; (iii) 5G slicing and QoS control and management; and (iv) Latency management and re-instantiation procedures in 5G.

The next steps to be undertaken are framed into T5.1 "First-party experimentation". Each of the testbed owners will parameterise their respective solutions to maximise the performance of each scenario. To this end, UC's experimentation is vital, as they will provide the vertical viewpoint and the empirical data necessary for decision-making. The results of the experimentation, as well as the conclusions obtained in each line of research, will be presented in D5.2.

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