Co-funded by the European Union

IMAGINE-B5G

Advanced 5G Open Platform for Large Scale Trials and Pilots across Europe

IMAGINE-B5G Vertical Experiments

Version v3.0

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Introduction

IMAGINE-B5G has shortlisted the following seven verticals: Public Protection and Disaster Relief (PPDR), media, education, smart agriculture & forestry, eHealth, transportation & logistics, and Industry 4.0. In this document, we are providing a short description of the desired vertical experiments (alongside the facility that they can be performed) and linked used cases for each of these verticals. It is important to highlight that the following UC1: Improved localization mechanisms for transportation and logistics offered in the Portuguese Facility is identified as the missing use case in the gap analysis performed in IMAGINE-B5G, therefore it will be given the highest priority during the selection of the OC3 projects. However, IMAGINE-B5G projects welcomes any other vertical or different use cases under the specified verticals.

1. Public Protection and Disaster Relief (PPDR)

PPDR sector focuses on the creation of a stable and secure environment for the citizens and protecting their lives in case of natural and provoked disasters. The activities considered in the PPDR sector are routine day-to-day activities (such as police, firefighting, medical attendance), planned events (fairs, sports, conferences) and unforeseen incidents (natural disasters, terrorists attacks). Due to the nature of these activities, there is an increasing need for ensuring the real-time collection and exchange of information, including control data, pictures, and video streams, along with voice to ensure the success of operations and the collaboration between groups of first responders. PPDR imposes several challenges to the network such as deploying wireless broadband coverage with the orchestration of different radio access technologies, portability, mobility, and specialized requirements for different services.

1.1 UC1: Firefighting and forest surveillance (French Facility)

1.1.1. UC Description

In the future, sensors, cameras, and other automatic devices will be a significant source of information for public safety and other professional users. Information from IoT will also become important for developing a full picture and thus providing better support – before and during incidents. Public safety organizations will have significantly more information on which to base decisions. This could help critical operations be more active, for example, moving from extinguishing fires to preventing fires in advance. The UC's goal is to improve event identification and characterization, operation, and disaster relief. To achieve this, the IMAGINE-B5 platform will leverage B5G features for reliable and efficient information collection (from UAVs and other sensors) and data processing to provide smooth real-time reporting, critical updates, and actionable intelligence, as timing and reliability can be the difference between life-or-death disasters. Furthermore, the platform relies on the computing continuum to overcome the complex decision-making process throughout the cycle.

1.1.2. UC Scenario

The scenario should focus on the role that flexible networking and computing infrastructure coupled with IoT may have for the detection, characterization, and operation of fire scenarios (deployed team status, fire progression, weather, and other multiple data). This will be done by deploying the project capabilities, enabling the collection, and monitoring of big amount of information from the field and in control centres. Organizations improve the quality and timeliness of their operational decisions and communications (e.g., field deployment decisions or updates). The project components will be challenged, addressing both the dynamic and mission critical nature of the scenarios.

Forest surveillance and firefighting involve various PPDR organizations (e.g., fire fighters, civil rescue, police, local organizations, private organizations), with field operation being coordinated both in local field commander positions and control centers, and by the remote headquarters. The goal is to validate the applicability, performance, and benefits of the project for supporting Mission Critical multimedia communication in firefighting scenarios, and its interaction with data centric IoT technologies to improve event identification and characterization, operation, and disaster relief by PPDR organizations.

During firefighting scenarios, decisions and operations should be strongly aided by technologies such as communication networks, multi-source data and IoT analysis and assisted decision-making platforms, including UAVs / drones which are used both for realizing data collection (e.g., visible & thermal image, geo-references) and mission support (e.g., equipment delivery, signal repeating).

This UC is mainly based on:

- A 5G Core Network and a 5G RAN based on OAI and will run on a private edge based on Kubernetes.
- A vertical PPDR application, so called Mission Critical Multimedia Communication and Collaboration, a E2E solution, that implements the MCX services standardized in 3GPP services (MCPTT, MCData , and MCVideo).

1.1.3. OC Desired Contribution

The desired contributions include (but not limited to):

- Experiments that utilize UAVs/drones both for data collection (e.g., visible & thermal image, geo-references) and mission support (e.g., equipment delivery, signal repeating),

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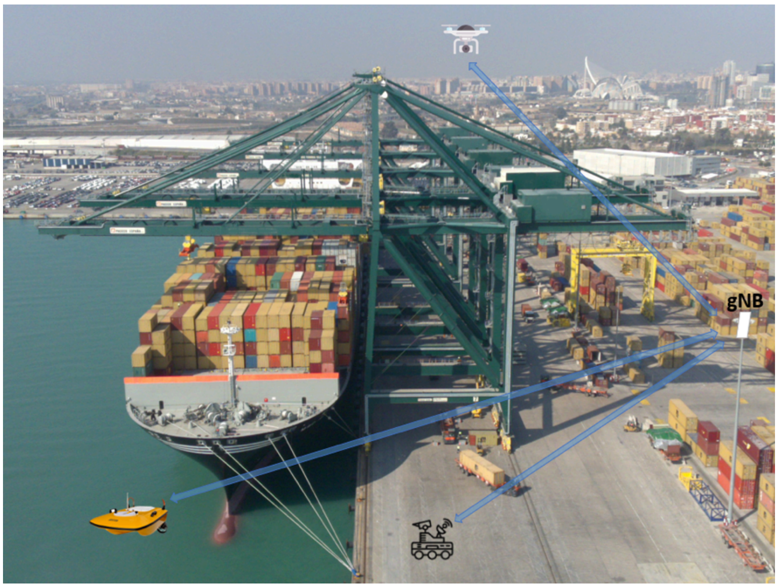
- Experiments involving IoT devices to improve fire forest surveillance (carbon monoxide, gas spreading, heat, ...),
- Applications of AI-based image recognition algorithms for different abnormal detection (fire, smoke), multimodal analysis (audio/video), data processing collection, UAV placement optimization,
- Experiments that leverage Augmented and Mixed reality (VR, AR, MR) to help situation awareness.

1.2 UC2: Coordinated UAV, USV, and UGV Operations for Enhanced Surveillance and Security in Maritime Ports (Spanish Facility)

1.2.1 UC Description

In this use case, coordinated operations between Unmanned Aerial Vehicles (UAVs), Unmanned Surface Vehicles (USVs), and Unmanned Ground Vehicles (UGVs) will be established to enhance maritime and terrestrial security at ports. The main goal is to demonstrate how integrating these technologies into a 5G network infrastructure can improve critical surveillance, inspection, and PPDR actions. Through 5G Rel.16 capabilities, such as Ultra-Reliable Low-Latency Communications (URLLC), network slicing, and beamforming, real-time operations will be achieved for ground, air and water-based platforms.



The UAV, USV, and UGV will coordinate to monitor port access areas, anchoring zones, and critical infrastructures to ensure port security. A specific scenario will simulate a coordinated threat response involving an unauthorized boat entering the port and discharging people and goods onto the shore. Both maritime and aerial assets will act in concert to respond to this threat by conducting simultaneous surveillance, identification, and interception tasks.

This use case also explores the potential of generative AI integrated with CCTV to detect and classify vessels at the port's entrance and to track movements of both people and goods in real-time. With the integration of AI and the cloud, advanced post-processing of images and data will be possible for enhanced decision-making.

1.2.2 UC Scenario

The scenario will take place in the Port of Valencia, where the existing 5G infrastructure will support simultaneous operations of UAVs, USVs, and an additional UGV. UAVs will perform aerial surveillance, USVs will handle surface inspections and tracking, and the UGV will focus on operations such as detecting threats or inspecting infrastructure.

This will involve seamless integration with the port's virtual control center, where the data streams from all three platforms (UAV, USV, UGV) will be managed and visualized in real-time. The experiment will also explore the capability to configure network slicing for various applications (surveillance, rescue operations, environmental monitoring) to optimize network performance for different tasks.

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1.2.3 OC Desired Contribution

- **UAV and USV Coordination:** Drive tests for both UAV and USV in air and water using 5G network connectivity to evaluate performance in various conditions.
- **UGV Integration (optional):** Incorporation of the UGV to extend the operational range and capabilities.
- **Platform Integration:** Development of a control platform that can handle real-time signals from UAVs, USVs, and UGVs. The platform should allow for the visualization of all data streams in a unified control centre, enabling fast decision-making.
- **Network Slicing Configuration:** Explore the possibilities of configuring network slicing to allocate network resources for specific use cases such as surveillance, real-time rescue operations, or environmental monitoring.
- **PPDR Use Case:** Simulate a coordinated response to a security threat, such as an unauthorized boat entering the port and unloading people or goods. The scenario will involve collaboration between air and water-based assets, and real-time video feeds from UAVs, USVs, and UGVs will be utilized to track and intercept the threat.
- **Generative AI for CCTV:** Develop AI models for the port's CCTV system to autonomously detect and classify vessels at the port's entrance. The AI should also monitor terrestrial and maritime movements, enhancing situational awareness and security.

Key Innovations and Technologies:

- **5G Rel.16 (URLLC):** Ensuring real-time control and operation of UAVs, USVs, and UGVs with ultra-low latency.
- **Network Slicing:** Optimize network resource allocation for different surveillance and rescue tasks.
- **AI-Enhanced CCTV:** Generative AI for vessel detection and tracking on both water and land environments.

*Note that the execution of such experiments will require the procurement of the UAVs, USVs as well as integration of cameras, surveillance hardware and/or other IoT devices

1.3 UC3: Unattended temperature inspection and remote fire's damage minimization in parked electric cars at the RoRo Terminal (Spanish Facility)

1.3.1 UC Description

With the purpose of preventing damage and minimizing the impact of potential accidents at the RoRo terminal, the use case involves utilizing an intelligent robot either autonomously or remotely controlled. This robot will conduct routine inspections to measure the temperature of electric cars, anticipating potential fire risks to secure the area and minimize potential damages. On certain occasions, remote control of the robot may be necessary to conduct a more detailed assessment of the scenario, especially when the fire already started and there is a need of apply counter actions to minimize the damage of surrounding parked cars. For remote control, a cloud continuum may be required to integrate various resource consuming elements comprising the application (e.g., remote control and image analysis). Moreover, the use case includes the deployment of a remote-control cockpit to manoeuvre the robot from the office. The robot will communicate with the cloud and the cockpit using the existing 5G connectivity in the port's testbed.

1.3.2 UC Scenario

The scenario should implement an AI-based system for early detection and preventative action using the thermal camera data, proactively detecting fire risks in electric car batteries. These systems must enhance safety through timely intervention and contribute to a robust safety infrastructure. The early detection capabilities reduce direct costs associated with damages, as well as indirect costs related to logistics disruptions and legal issues. Moreover, the use of AI-driven remote monitoring optimizes operational efficiency, minimizing the need for costly emergency responses and downtime. Overall, these use cases showcase a holistic approach to safety and security management, simultaneously improving operational resilience and reducing long-term costs.

1.3.3 OC Desired Contribution

The present use case will need the open call contribution for addressing the following functionalities:

- Provider of a robot with 5G connectivity and equipment with thermal cameras to monitor temperature of cars
- Development of a GUI to control and manage the alerts resulted from the AI system
- Deployment of a remote-control cockpit for the teleoperation of the robot

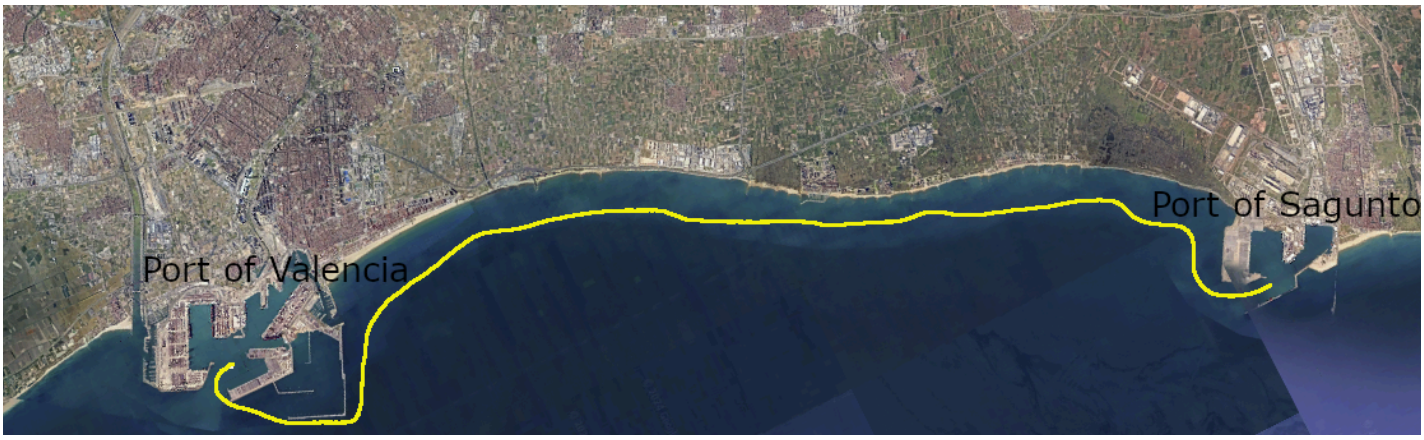
*Note that the execution of such experiments, the OC should cover the provision of a USV, thermal camera/s as well as integration of cameras, sensors and/or other IoT devices that can improve the results of the project.

1.4 UC4: Autonomous boat connecting Port of Valencia and Port of Sagunto for multioperation and safety border control (Spanish Facility)

1.4.1 UC Description

There are two main ports in the Valencian coast that are: Port of Valencia and Port of Sagunto. The optimal connection between these three ports is crucial for the development of their operations and for protection against security breaches and control of the maritime territory seeking access to the ports. Therefore, this use case is proposed in which an autonomous USV system equipped with cameras and 5G connectivity should be capable of carrying out trips between these two ports and ensuring the safety of the surrounding area.

1.4.2 UC Scenario



To cover the areas between its two largest ports (Valencia and Sagunto), a use case is proposed in which an autonomous boat or vessel, using public 5G connectivity, would be capable of conducting inspections along the 13 nautical mile maritime route between the ports and rescue and safety. The scope for this use case, due to network coverage limitations and resource deployment, will be restricted to the stretch of Patacona beach, north of the port of Valencia, covering 1 to 2 nautical miles.

The boat should be equipped with high-resolution cameras capable of detecting vessels up to 2 nautical miles and designed to operate in the harsh maritime environment. Additionally, it would be advisable for the boat to carry safety equipment such as life vests, lifebuoys, or inflatable rafts, which, in the event of spotting shipwreck survivors or swimmers who have strayed beyond the designated swimming area and are in distress, can aid in their survival.

1.4.3 OC Desired Contribution

1. **USV Coordination:** Sea water drive tests of 5G public network connectivity to evaluate performance in various conditions like out to sea to test the limit of coverage and tests following the coastline.
2. **Platform Integration:** Development of a USV control platform with a cockpit located in the UPV campus with 5G network.

3. **Network Slicing Configuration:** Explore the possibilities of configuring network slicing to allocate network resources for specific use cases such as surveillance, real-time rescue operations, or environmental monitoring.
4. **PPDR Use Case:** Simulate a coordinated response to a security threat, such as detecting a vessel unloading drugs or hazardous materials near the coast of the beach.
5. **5G Network Opengateway TLF:** Explore the use of commercial network APIs to enhance service quality in high-demand scenarios, such as crowded beach environments, leveraging QoD APIs both boat control and real-time video transmission can be optimized. This approach ensures reliable performance even when network usage is heavy

Key Innovations and Technologies:

6. **5G Rel.16 (URLLC):** Ensuring real-time control and operation of UAVs, USVs, and UGVs with ultra-low latency.
7. **Network Slicing:** Optimize network resource allocation for different surveillance and rescue tasks.
8. **Network APIs:** Optimize network resources in case of heavy network usage like a crowded beach.

1.5 UC5: VR/AR-enabled dispersed command post (Norwegian Facility)

1.5.1 UC Description

At present, the efficiency of command-and-control posts within Public Protection and Disaster Relief (PPDR) organizations and their operations is directly related to their scale, due to the intricate processes that necessitate interaction among numerous individuals from diverse expertise areas. Different units spread over a large disaster area needs to be able to be fast and efficient to establish a dispersed command and control post to facilitate the operations in disaster area. The objective of this Use Case (UC) is to facilitate the segmentation and distribution of the traditional single command post model, to enhance the efficiency of the operations during disaster scenarios. Simultaneously, it also aims to mitigate any reduction in efficiency by incorporating Virtual Reality (VR) and Augmented Reality (AR) technologies to ensure adequate interaction between humans.

1.5.2 UC Scenario

https://www.google.com/search?q=virtual+command+post&tbm=isch&ved=

The scenario should envision 20-30 people who are collaborating on PPDR operations planning and processes, dispersed over an area of 3-10 kilometres, in smaller command nodes of up to 4 people in each. The 5G technology should be the underlying carrier for a VR/AR-application, providing robust local communication with sufficient bandwidth. Very few off-the-shelf VR-goggles have 5G built-in, and it is not a requirement of the use case that the goggles themselves are 5G enabled, but the communication between the command nodes must be 5G-based. The use of VR/AR is to provide better human-to-human interaction for people who are not physically co-located, and to provide a larger working space for people who would have very restricted movement and restricted working area within their vehicle. All factors that would improve human-to-human interaction should be considered, for instance the use of proper spatial sound which is an area we know that current video-teleconferencing solutions (in the field) are a bit lacking.

Note: The accompanying picture is only for illustrative purposes and does not reflect the real scenario.

1.5.3 OC Desired Contribution

The desired contributions include (but are not limited to):

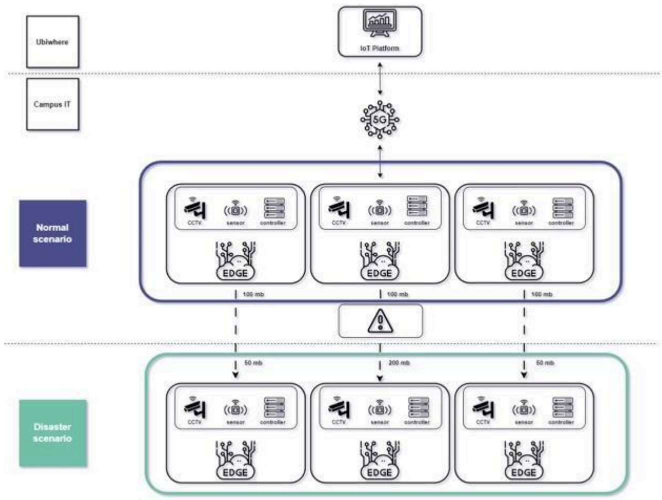
- Experiments that utilize either 5G local breakout or a self-sufficient private 5G-network, as the underlying technology for a VR/AR-solution for a dispersed command post.
- The beneficiary must provide at least 25 VR/AR-goggles as part of the experiment.
- Documented solution with a focus on reliability and local functionality within the command post (all the command nodes) - meaning that the degree of edge-compute has been carefully considered for both the application and the 5G-infrastructure.

- Documented which data needs to be transmitted, and which can be local, to support the VR/AR-application.
- An actual VR/AR-application that supports collaboration on PPDR organizations planning and processes

  In addition to scenario above, Norwegian facility is also open to other proposals targeting PPDR scenarios.

1.6 UC6: IoT Platform for crisis management (Portuguese Facility)

1.6.1 UC Description



IMAGINE-B5G will provide an IoT platform for the management of all emergency cycles. Focused on Emergency Management, this platform manages risks for communities, the environment and infrastructure. It is the core business of the Emergency Services, but every individual and organisation have a role to play. In addition, this platform uses IoT sensors and telecommunications infrastructure to increase the ability to collect data and make informed decisions. This solution helps companies to be better prepared, respond more quickly, and to send vital information to those who need it.

1.6.2 UC Scenario

The platform must be efficient in collecting and processing data to provide smooth real-time reporting, critical updates, and actionable intelligence, as seconds can be the difference between a life-or-death disaster. Furthermore, and since the emergency management cycle largely depends on latency and rapid decision making, edge/fog must be developed and implemented to adapt the network to the required real-time response. Thus, the platform focuses on the computing continuum to overcome the complex decision-making process throughout the cycle. Ubiwhere''s main contribution lies in concepts of interoperability, edge computing, and sensing. This platform must support:

- Information processing in the cloud, which will mainly serve to produce point-to-point data integration and large-scale data processing.
- Edge computing information processing, closer to users to reduce processing latencies and enhance faster decision-making scenarios.
- Automatic Device Discovery, part of the zero touch management capabilities
- Integration with 3rd party experimenter platforms/solutions through APIs
- CI/CD pipelines

1.6.3 OC Desired Contribution

The desired contributions include (but not limited to):

- Experiments from emergency responders such as civil protection, firefighters, police forces, with the goal of improving existing procedures and routines during disaster scenarios.

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- Solutions based on biometric devices with live data and other sensors relevant to emergency scenarios.
- Solutions based on novel computer vision algorithms to detect dangerous situations (natural disasters, guns, knives, etc.).

2. Media

The media industry is dedicated to creating multimedia content for a wide variety of applications, such as entertainment, gaming, sports, marketing, meetings, etc. Some media outlets are even appointed to be societal critical, in particular during crises. Traditionally, 2D video and stereo audio is used for these purposes, but with the introduction of new technologies such as stereoscopic video, 360 and volumetric capture, haptics, holograms, surrounding audio, immersive content is increasingly being demanded. However, this new kind of content asks for new functionalities and requirements from the networks that will carry the media, not only for the distribution of the content but also to produce it. Immersive technologies listed before are key for the future media ecosystem.

2.1 UC1: Robust and flexible remote production (Norwegian Facility)

2.1.1 UC Description

IMAGINE-B5G will develop and make trials for audio and video to be wirelessly transmitted from the capture setups to the production setup that will be finally broadcasted to the end nodes, where it is presented to the users, leveraging on B5G networks. This UC will cover the high-quality, studio or live content production, with capture and production sites remote or same.

In addition to utilizing 5G for improving production from content captured remotely, the media sector can also cut carbon emissions. Only a small crew need to travel to capture content, and the rest of the editorial staff can control the production from a central gallery.

The technical challenge is to achieve low latency and high quality on the camera-links as the controls *need to be responsive*. The lower the latency, the higher the bitrate needs to be (due to reduced coding efficiency with short GOP); thus, uplink favouring frame structures, MIMO in TX/RX, directional beamforming and stable low RTT is preferred. High uplink capacity is also of value when videographers in the field/studio will *upload recordings to utilize AI*, thereby achieving a more efficient workflow when production editors get immediate access and are empowered with image descriptors and transcribing of audio (editable/searchable text/images related to timestamps in the media stream speeds up editing).

The most important issue to solve for broadcasters, is creating *private nomadic networks* with robust and high-capacity wireless coverage *which extend, and ideally integrate, with the public network* (PNI-NPN). It is also preferred that the capacity available will be *prioritizing the camera on air* at the time (or in focus in PPDR-rescue) and *share available capacity* in a way that does not limit the amount of cameras as multiple angles are vital for situational awareness both when covering critical news/events and aiding PPDR-operations.

For the trials, the content will be captured wirelessly in one facility/field and the production will take place in the same facility/field or another facility/location remotely. The trials will be coordinated and conducted in coordination with NRK, a main UC stakeholder for immersive media production and distribution in Norway. NRK is the Norway's public owned broadcaster offering online, TV, radio, and audio content [NRK]. Live and studio broadcasting is an important part of NRK's activity, e.g., covering sports and entertainment events.

2.1.2 UC Scenario

The UC will be deployed in the Norwegian facility. Media-specific functions and applications for content production and distribution can be hosted on the central site at Fornebu, on Network on Wheels (a nomadic network) or on the edge site in Svalbard. Three RAN sites (Fornebu, Svalbard, Network on Wheels (NoW)) will be available to support the experiments.

2.1.3 OC Desired Contribution

The desired contributions include (but not limited to) innovative (immersive) media production/distribution solutions.

*The beneficiary is expected to have/procure any media hardware and software necessary for the scenario implementation and experiments, as well as relevant 5G UEs (e.g., 5G CPE or smartphones, to be coordinated with the Norway facility for the list of validated m odels).

In addition to scenario above, Norwegian facility is also open to other proposals targeting Media scenarios.

2.2 UC2: Holographic communication (Spanish facility)

2.2.1 UC Description

Immersive communication technologies, such as holography and XR, are becoming increasingly popular as they provide the users with more immersive visual and auditive information with respect to traditional media. Holographic and XR technologies are considered a key element in the future 5G-Advanced and 6G ecosystem, which aims to create a more interconnected, immersive, tactile, holographic Internet, providing a seamless connection between the real and digital worlds. This UC primary objective is to explore the potential of holographic and XR technologies in pre-recorded or real-time scenarios. It will consist in performing multiple tests and trials for different verticals to understand the value and requirements of these technologies transmitted through 5GA/6G networks. To achieve this, the IMAGINE-B5G platform will leverage beyond-5G features for high data rates and low latencies. In addition, through the IMAGINE-B5G platform numerous tests and trials will be performed to understand the specific requirements and value of these immersive technologies.

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2.2.2 UC Scenario

The UC will be mainly deployed in the UPV immersive laboratory premises but and it also can be deployed in other remote locations to test different scenarios, such as in the port of Valencia (e.g., for remote maintenance). Use case scenarios spanning through multiple locations are valuable, as they can demonstrate holographic and XR communications in a remote and distributed manner, achieving telepresence.

In this UC, the platform will examine the potential and requirements via relevant KPIs and KVIs of holographic and XR technologies. By leveraging beyond-5G features, such as high data rates and low latency, the platform will enable the transmission of this augmented content. This will allow for a more immersive and interactive experience for users, whether in remote teaching, training, marketing, showrooms, concerts, talks, events, webinars, etc. By enabling users to view and interact with virtual objects and environments, holographic and XR technologies can bring a new level of realism and excitement to these industries.

2.2.3 OC Desired Contribution

The desired contributions include (but not limited to) novel solutions for holographic and XR communications and experiments exploring KPIs and optimizing the performance of immersive communications. Additionally, this OC is related but not limited to the project’s PE4: Holographic and XR equipment and SW.

2.3 UC3: XR multi-user gaming competition (Spanish facility)

2.3.1 UC Description

This use case is motivated by the emergence of immersive technologies on the entertainment field, especially gaming or content such as 6 degrees of freedom video. To provide de user with an immersive experience, these technologies are supported by two main pillars: (i) the head-mounted displays, which provide the user stereoscopic video, giving the true impression of 3D view and (ii) application side, which is necessary to give the user passthrough video so he can perceive reality, augmented with virtual elements designed and inserted in this application. Current state-of-the-art devices are plenty advanced, with high image quality per eye, while most of the work in this field relies on the development of applications.

2.3.2 UC Scenario

The different scenarios can take place at the UPV immersive lab premises or other remote locations. The scenarios envisioned for this use case are related to immersive entertainment, more precisely, gaming. In this scenario, multiple users can play an XR game, in which the environment is either virtual or real by HMD passthrough, and virtual elements are added into it, that can be viewed through the HMD itself. Ideally, the virtual and real elements can interact with each other. For example, a real object that is controlled by the user can collide with a virtual object that has collision detection and reacts to the real object bumping into it, or giving the player rewards or penalties when the real object collides with virtual ones. Additionally, to playing on-site, remote users should also be able to participate in the game, even if they only perceive virtual environments and objects.

During the performance of the experiments in this use case, several KPIs and requirements of XR technologies should be collected, as well as evaluating KVIs and the quality of experience of the users

participating in the experiments. Different subjective and objective values should be measured and evaluated to determine if XR technologies propose added value for gaming.
The 5G-Advanced connectivity should be present in the parts of the scenario that require the transmission of XR media, i.e. from the capture devices to the processing application or to the application to the HMD.

2.3.3 OC Desired Contribution

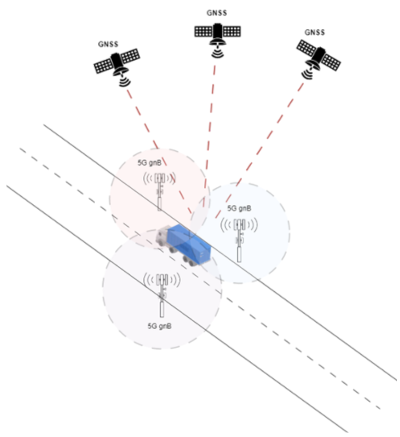
The desired contributions include (but not limited to) novel solutions for XR communications, specially dedicated to the entertainment and gaming vertical, giving the user new ways of interacting with the digital and real worlds and experiments exploring KPIs and optimizing the performance of immersive communications. Additionally, this OC is related but not limited to the project's PE4: Holographic and XR equipment and SW.

3. Transportation and Logistics

This vertical is dedicated to the organization and implementation of transportation workflows. The associated UCs must be enabled by high performance networks, but still very flexible communication architecture empowered by B5G functionalities. For example, advanced location functionalities have the potential to improve industrial environment by enabling utilization scenarios that range from flexible asset tracking and route optimization to Automatic Guided Vehicles (AGVs). Moreover, transportation scenarios are not limited to logistics, instead they are heterogenous by nature and may involve critical and non-critical communications, which imposes stringent requirements to the subjective networking system. Eventually, requirements will reach a level where the communication-related resources are not enough, requiring the combination of different technologies, empowered at large by advanced edge computing resources. As such, transportation and logistics scenarios will play a fundamental role in the validation of the IMAGINE-B5G functionalities.

3.1 UC1: Improved localization mechanisms for transportation and logistics (Portuguese Facility)

3.1.1 UC Description



This UC depicts a scenario of autonomous driving that relies on a hybrid positioning system utilizing both GNSS and 5G terrestrial base stations to provide an improved position accuracy and FTTF. This system utilizes RTK corrections and 5G signal information to achieve better accuracy. The road vehicle moves around a transportation route where the algorithms will determine its most accurate position. In principle, GNSS positioning can be accessed globally, anywhere on the Earth, without requiring any local or regional infrastructure and with great accuracy but have a not-so-great latency. On the other hand, 5G network-based positioning demonstrates good latency performance but requires indoors scenarios to achieve good accuracy in most of the cases. However, the latency of GNSS positioning can

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be improved with the assistance of 5G network-based positioning as a complementary trade-off between them, since on GNSS positioning we have a better accuracy while on 5G positioning we have a better latency, so joining them together we can have the better of both technologies.

3.1.2 UC Scenario

First, we will have a standalone solution using only the GNSS positioning solution and using the new 5G network to calculate the position of UE (User equipment) like a vehicle. The position calculation in 5G appears in Release 16, and there are enhancements in Release 17. To make this happen, it will be necessary to use dedicated algorithms that take the RAN information and can calculate the position of the receiver (UE). This is not enough, and the 5G core needs a new function to control the position side. That function will need to run the necessary algorithms to calculate the position. The Location Management Function (LMF) is responsible for tracking the position of the vehicle and other connected devices in the network. It is also responsible for selecting the methods that will be used to calculate the vehicle's position, such as AOA (Angle of Arrival) or others.

3.1.3 OC Desired Contribution

The desired contributions include (but not limited to) solutions that require localization information in the transport and logistics domain. Stakeholders such as logistics operator (e.g., cargo trucks), motorway/road/private operators that can deploy RSUs are encouraged to apply. Apart from the contributions described above, we are enthusiastic about investigating novel delivery techniques, mainly using employing smaller self-driving cars and UAVs to transport small packages effectively. Particularly in urban and challenging-to-reach areas, these technologies offer a frontier for improving last-mile delivery solutions by providing faster delivery times and greater accessibility. Proposals that use these vehicles are welcome if they include information on integrating, operating, and coordinating them with the current transportation and logistical networks and be kin to integrated hybrid position methods.
The use of Open-RAN technologies offered by the Portuguese facility (see IMAGINE-B5G Facility Description) is highly encouraged and will be considered a plus in the selection criteria.

3.2 UC2: Telepresence-aided Maintenance (Spanish Facility)

3.2.1 UC Description

The reparation or maintenance of machines in logistic environments is a highly expensive task, due to the necessity of sending experts to physically check the equipment. If the asset to repair is very specific, it may require experts from other countries to travel long distances, with the consequent carbon footprint. However, a minimally qualified engineer may also perform the task if he receives the proper assessment from a remote expert. By using immersive technologies such as telepresence and haptics, boosted by the capabilities of B5G networks, the remote expert would be able to provide the required instructions to the field engineer in real-time.
The field engineer will place a robot or an AGV equipped with a 360º/PTZ camera next to the damaged machine, allowing the remote expert to connect via 5G to visualize the video on a VR/AR HMD, controlling the viewing perspective via the HMD's IMUs. Moreover, the field engineer can be equipped with other VR/AR HMD to visualize instructions from the remote expert, who shows the action to perform using haptic gloves. The introduction of immersive communication into the workflow will be assessed and compared with

traditional methods. Different slices will be available so that multi-user deployments can be enabled based on GBR (Guaranteed Bit Rate) profiles for ensuring the required minimum quality in terms of assigned bandwidth for every single UE taking place in the UC.

3.2.2 UC Scenario

The remote collaboration for maintenance or reparation of logistic machinery with audio-visual feedback will be performed either in the Valencia Port or in the Rural Site. A field engineer located there will be supported by a remote expert located in the UPV Immersive Lab.
UPV's Immersive lab is an experimental facility that supports telepresence, AR/XR, volumetric/360º capture, haptics, and holographic technologies. If needed, the lab's equipment will be available for the VE, including chromas, LEDWall, and VR/AR headsets; volumetric and 360° video capture; haptic gloves and suits; and immersive cockpits for remote driving.

3.2.3 OC Desired Contribution

The desired contributions include (but not limited to) immersive telepresence solutions for maintenance of machines in logistic environments.

*The beneficiary should have experience in robotics, haptics and/or VR, to integrate the necessary components that guarantee a full view and feedback of the machine to the remote expert, as well as a full view and feedback of the instructions to the field engineer.

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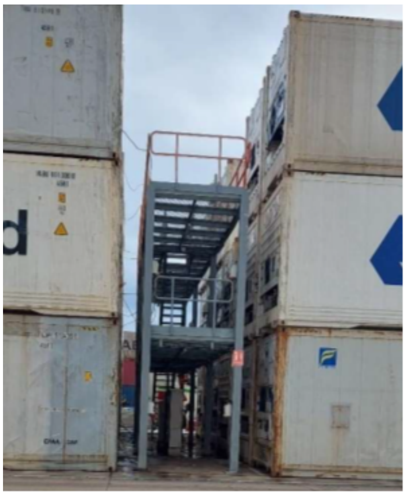
3.3 UC5: Remote Control of Robotic Arm for Reefer energy connector automatization (Spanish Facility)

3.3.1 UC Description

In this use case it is presented the need for an innovative automation system for the connection and disconnection of refrigerated containers at the APMT terminal in the Port of Valencia. The terminal aims to incorporate an artificial vision system and an automatic handling system for the connector and cable of the refrigerated containers. This system should either utilize the existing infrastructure in the connection area or modify it to make the automation of this process feasible. This process is the same for all refrigerated containers passing through the terminal at the Port of Valencia and will be carried out using a robotic arm connected to the 5G network, which need be operated from a control room via a joystick or similar robotic arm controller.

3.3.2 UC Scenario

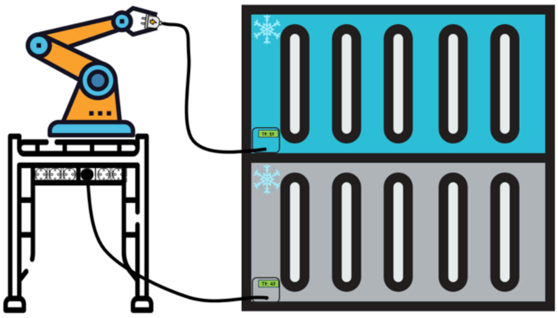


The use case will be implemented at the APMT facilities, with the presence of a refrigerated container (reefer) and a scaffold equipped with the required elements for the attachment of the robotic arm. An electrical panel will be provided with the specific requirements for both powering the robotic arm and installing the connection sockets for the refrigerated container cables.

The goal is to achieve the correct extraction of the connector with the minimum percentage of incidents due to breakage or deterioration of the connector or cable through an automated system used for gripping and handling. The connection plug can be modified in position and configuration, as well as the activation and deactivation system. The dimensions of the box where the connector and cable are located, as well as the access space, may vary by a few millimeters depending on the model and manufacturer of the container. The temperature display on the container must also be captured.

3.3.3 OC Desired Contribution

A vision system should be used to inspect the compartment, identifying both the connector and the cable's position. Due to volumetric constraints of the mechanical enclosure, the new inspection and handling system must be integrated into the current production system, with dimensions agreed upon by APMT's engineering department. The environment can be modified to control lighting and automation conditions. Multiple camera acquisitions will be merged into a single point cloud. 3D localization algorithms will be tested to independently detect the cable and connector in various positions and shapes. The accuracy of the 3D coordinate results of the detected elements will be validated against their actual positions. The necessary components for this use case include a 3D camera mounted on the robot, capable of capturing 3D images without external lighting, providing precise data even in low-light conditions, and specially designed computing for intensive point cloud processing and real-time analysis.



The aim is also to prove that the gripper's design, including its shape, gripping capacity, and sensitivity, will allow for efficient and safe operation inside the cable compartment. Additionally, the use of an onboard 3D camera will be tested to obtain various perspectives of the area by repositioning the robot, improving visibility and eliminating occlusion zones. These 3D cameras do not require external lighting and are resilient to changes in lighting conditions, enabling operation both day and night without being affected by sunlight. The study will also explore how 3D reconstruction and environmental mapping can help identify and plan strategies for accessing the connector and cable, ensuring precise detection and handling. Moreover, the gripper must be long and curved to access the interior of the cable compartment, minimizing the risk of collision with the container and allowing the robot to move the gripper within the compartment, reaching all interior points.

The system must run autonomously with the processing core in the edge of the network and, in the case of the autonomous process fails, the system must change the operating mode automatically to a remote control via cockpit/joystick for a remote manual operation. Therefore, the OC will include the provisioning of such cockpit for the remote control of the arm. All the information sent between the cockpit and the robot such as the telemetric data and cameras' images will be done using the 5G network provided by the Spanish Facility of the IMAGINE-B5G project.

Some of the network capabilities that IMAGINE-B5G will be test are:

- Analyse the possibilities of configuring network slicing to allocate network resources for specific use cases such as real-time logistic operations.
- Optimize network resources in case of heavy network usage like several robot arms working at the same time and sending all the data to the edge.
- Analyse all critical network parameters (e.g. E2E Latency) necessary for the smooth remote operation of the robot, especially in a challenging environment due to the presence of container stacks acting as metallic walls.

The network configuration and all necessary 5G connectivity elements will be provided by the IMAGINE-B5G project partners.

* Note that the execution of such experiments, the OC should cover the provision of the robotic arm, video camera/s as well as integration of cameras, sensors and/or other IoT devices that can improve the results of the project.

4. Industry 4.0

The industry vertical is dedicated to the production of goods, with the help of equipment, machines, tools, etc. Industries of the future aim to be benefited by emerging technologies that can enhance the production processes. These processes will be increasingly smart, connected, and automated and will allow for a more efficient, cost effective, faster, and greener production industry. The transformation envisioned for this vertical is focused on the smart automation and optimization of the production processes. This will be thanks to the advanced mobile network technologies, IoT, big data analytics, ML, AI, and robotics.

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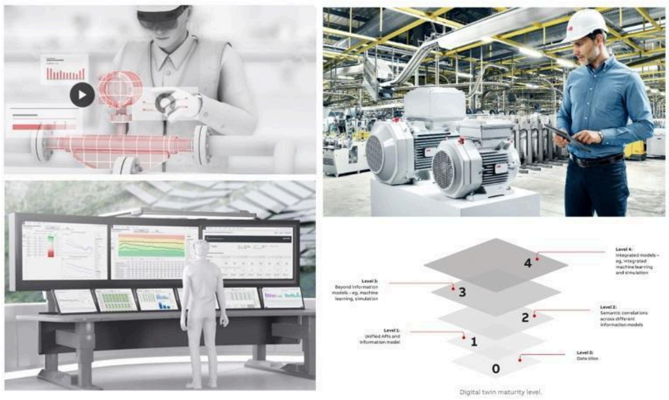
4.1 UC 1: Industrial Infrastructure Automation (Norwegian Facility)

4.1.1 UC Description



The aim of this UC is to empower industries with B5G technologies to facilitate the prediction of problems, increase production, flexibility, safety, mobility, scalability, reduce downtime, maintenance intervention and costs, thus improving manufacturing competitiveness. In this context, IMAGINE-B5G advanced features will be leveraged to explore novel UCs on the process plants such as industrial control systems to support realtime communication between sensors, actuators and controllers, equipment tracking via precise positioning, close loop control for process automation, network-based AGV control, analytics for predictive maintenance, augmented reality for repairs, digital twins with Realtime feedback, among others. Moreover, leveraging edge computing capabilities and the integration of such technologies with factories' Manufacturing Execution System (MES) and production line will enable a low latency closed control loop targeting diverse production aspects including orders, machinery status and asset location. This UC will then leverage B5G technologies to provide very low latency and advanced edge based IoT solutions, while satisfying industry isolation requirements.

4.1.2 UC Scenario

The UC will be deployed in the Norwegian facility. Industrial-specific functions and applications can be hosted either on the central site at Fornebu, or on the edge site in Svalbard. Two RAN sites (Fornebu, Svalbard) will be available to support the experiments. An additional private 5G network at ABB premises can be foreseen for purposes of use case execution (ABB is a main stakeholder of the Norwegian facility).

4.1.3 OC Desired Contribution

The desired contributions include (but not limited to):

- Advanced edge based IoT solutions for running process applications in the field.
- Extracting stranded performance and health data from field equipment utilizing private 5G network.
- Networks convergence for running E2E OT & IT applications over the common private 5G network.
- Merging virtual control system with private 5G network.
- Framework or toolkit for real time private 5G network performance assessment.
- AR/VR industrial applications for repairs, digital twins, predictive maintenance, and improved safety.

In addition to scenario above, Norwegian facility is also open to other proposals targeting Industry 4.0 scenarios.

*The beneficiary is expected to have/procure any industrial hardware and software necessary for the scenario implementation and experiments, as well as relevant 5G UEs (e.g., 5G CPE or smartphones, to be coordinated with the Norway facility for the list of validated models).

4.2 UC2: Industrial Optimization through Advanced Connectivity and Energy Monitoring (Portuguese Facility)

4.2.1 UC Description

This use case aims to enable industries to harness cutting-edge technologies to optimize their operations. This includes both 3GPP and non-3GPP technologies, creating more advanced and integrated network solutions that aim at boosting production efficiency, improving flexibility, or enhancing safety. By leveraging these technologies, with B5G at their core, industries can achieve greater scalability, reduce downtime, and lower maintenance costs. These advancements significantly enhance the competitiveness of the manufacturing sector, allowing industries to adapt more effectively to evolving market demands and operational challenges.

4.2.2 OC Scenario

The UC will be hosted by the Portuguese facility and will focus on two main objectives:

- Evaluating new concepts for leveraging 3GPP and/or non-3GPP technologies to support efficient industrial control systems that require real-time communication between sensors, actuators, and controllers. This evaluation will preferably include comparative studies, relying on identified, monitored, and validated KPIs, which may lay the groundwork for further exploration of inter-operation scenarios between these technologies.
- Exploiting an existing platform for collecting insights and exposing metrics related to resource and energy consumption, particularly through advanced and disaggregated monitoring. This involves leveraging the platform to specifically track the contribution of selected factory resources, including specific virtual functions (VMs or containers), to overall energy consumption at the node level. This data will be complemented by metrics on the consumption of computing resources, such as CPU and GPU usage.

4.2.3 OC Desired Contribution

The desired contributions include (but not limited to) advanced edge based IoT solutions, digital twins, energy consumption monitoring, process automation solutions, as well as performance studies.

*The beneficiary is expected to have/procure any industrial hardware and software necessary for the scenario implementation and experiments.

5. Education

The education vertical is dedicated to the transmission of knowledge. Education practices are evolving nowadays since information technologies are being introduced in this field. Rethinking education in the digital age should become a central matter for today's society: first, remote teaching should be allowed to facilitate the attendance of students who cannot be physically present in the classrooms and second, they should enhance improve the current means of knowledge transmission to enhance understanding and retention. During the COVID-19 pandemic, online classes and digital media resources became very common but were unable to replace physical presence for hands-on education, group work and social interactions.

Seeing the benefits of online education, further steps forward must explore ways to exploit them. New technologies like immersive telepresence, holograms, XR and haptics are key to the evolution of education.

5.1 UC1: Immersive remote education (Spanish, Norwegian Facilities)

5.1.1 UC Description

As information technologies are being introduced in this field, education practices and opportunities are rapidly evolving worldwide. The primary challenge that this UC will aim to address is remote/distance teaching to facilitate the participation of both teachers and students who cannot be physically present in the classroom. On the other hand, certain skills such as lab work and hands-on experiences, require extra tactile stimulation to produce the same level of learning online as in real life and real-time. Learning such skills or visualizing abstract concepts in an interactive way can benefit from the integration of AR and VR into immersive classrooms. Further, haptic responses that are possible through tactile internet, and can reproduce the feeling, touch, or motion of interacting directly with a physical object, could introduce tactile forms of learning to a classroom through traditional video conferencing platforms, thus enriching the interactions. 5G/B5G can help in this direction as it will improve personalization by creating intelligent systems, using Artificial Intelligence, to understand the unique needs of each student and create targeted learning pathways. To achieve a highly immersive and interactive experience between the two ends (e.g., by using VR Robotics, Figure 16), it will exploit B5G features and KPIS, mainly focusing on low latency and network reliability aspects, as well as advanced data analytics and AI algorithms to perform predictive analyses (e.g., latency) and enhance the end-to-end performance. In addition, it will explore solutions towards improving the current means of knowledge transmission from a learning retention perspective.

5.1.2 UC Scenario

This UC will be deployed in two different facilities: UiO's SIN-Lab is a playground for immersive networking research. SIN-Lab consists of state-of-the art cameras and LIDARs, such as tracking camera, Velodyne LIDAR, Intel RealSense LIDAR(L515), Azure Kinect, and several headsets for VR and AR. In addition, the lab is equipped with a Shadow Hand and a UR10e arm. For the haptics equipment, it has Gloves and Suit Full Body.

UPV's Immersive lab is an experimental facility that supports telepresence, AR/XR, volumetric/360º capture, haptics, and holographic technologies. To bring these capabilities, the lab provides multiple equipment for each type of communication: chromas suited with specific processing hardware and software from Brainstorm multimedia, Alfalite LEDWall, and several VR/AR headsets (e.g. Meta Quest Pro) for telepresence; Evercoast volumetric video capture, YBVR 360º video capture; several haptic gloves (e.g. bHaptics TactGlove) and suits (e.g. bHaptics TactSuit X40, OWO Vest) for haptic feedback and control of UR5e arm; and immersive cockpits for remote driving of AGVs/AMRs (e.g. Robotnik Summit XL) equipped with RoboSense LiDAR and 360º cameras.

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5.1.3 OC Desired Contribution

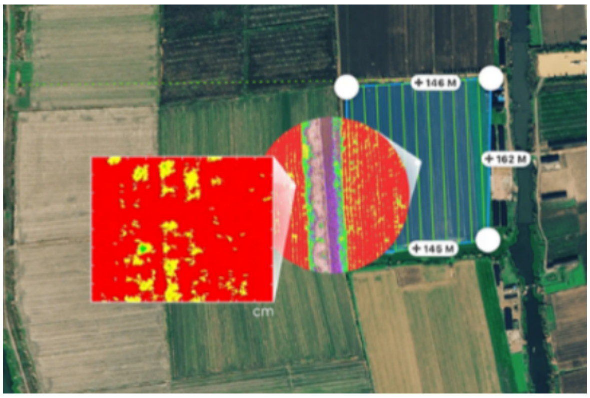
The desired contributions include (but not limited to) novel solutions for VR/AR/XR educational environments, intelligent personal assistants, and experiments exploring and optimizing the performance limits of immersive remote education.

6. Smart Agriculture & Forestry

The agriculture vertical is focused on the cultivation of plants and livestock. The world of agriculture is changing towards an unprecedented digitalization and automation. The use of autonomous vehicles for preparation of the soil, sowing, harvesting, etc. is common, but much more enhancements can come into play with the introduction of new technologies such as advanced mobile networks, vehicles, imaging techniques, AI, ML, immersive communications, etc. These new technologies can be used for infestation detection, fertilization, fields performance analysis via imaging, teleoperation of machinery and vehicles, surveillance, weather prediction, etc.

6.1 UC1: Smart agriculture in rural areas (Spanish Facility)

6.1.1 UC Description



IMAGINE-B5G aims to improve the agricultural efficiency helping to increase the performance of the cultivation providing accurate and real time information that can be used for agro-management decisions, thus reducing the environmental impact of pesticides or saving water. To achieve this, the use of Agricultural AGVs and the use of new sensors with multispectral cameras deployed in sensor networks will be supported. The use of these new devices in 5G networks will support the remote visual monitoring of remote or difficult-to-access crops, also the phenological monitoring of large areas of agricultural crops must be automated. It is very relevant to facilitate the monitoring of phenological changes in crops with advances or delays in the start of activity.

6.1.2 UC Scenario

The Matanza 5G experimental site is ideal for the experimentation of agricultural isolated areas using private 5G infrastructure for the automation of industrial or agricultural tasks. Currently the experimental site is logging data from sensors deployed in the coverage area of the 5G radio. The information of the sensors is updated in real time, including electrical energy devices consumption, electrical energy generated by wind, electrical energy generated by sun, electrical energy consumed by servers and radio baseband. The site will support also the NaC and CAPIF APIs for third parties to integrate easily the 5G connectivity and features, like the provision of Slices and QoS 5Qis profiles that can be updated on-the-go as the connected devices changes dynamically the operations requirements.

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6.1.3 UC Desired Contribution

The desired contributions include (but not limited to):

- Solutions based on advanced video processing automated tasks that help the phenological monitoring of large areas of agricultural crops.
- Solutions based on high temporal resolution imaging for estimating quantitative and qualitative parameters in phenological monitoring of large areas in agricultural crops.
- Solutions based on a proximal multispectral sensor network for ripeness monitoring, incorporating artificial intelligence.
- Solutions for AGV missions, the implementation of some AI algorithms for improving the treatment of plants, the implementation of programmed multispectral drone missions, the generation of detailed report on scalability of the proposed solutions and the cost of energy for each mission.
- Autonomous AGV-based monitoring solutions, integrating cameras for live, high-definition crop surveillance accessible from anywhere via 5G, with no latency, specifically for technicians, agronomists, and experts.
- Integration of the AGVs and sensors network with the NaC & CAPIF APIs for the automation of the use of the 5G network facilities including: provision of SIMs, configurations of profiles and storate of Applications KPIs storage.
- Experimentation in large areas of agricultural crops in Spain where there is 5G public network coverage.

*Note that the execution of such experiments will require the procurement of the agricultural AGVs as well as integration of cameras, sensors network, and/or other IoT devices

7. eHealth

7.1 UC1: Remote care with immersive media facilities (Norwegian Facility)

7.1.1 UC Description

The aim of this UC is to develop and make real-world trials regarding remote care by providing immersive equipment (e.g., MR/AR/VR headsets, controllers, 3D cameras) for seamless interactions between a remote medical expert and the local doctor/technician or the patient that needs specialized consultation, diagnosis, monitoring, or treatment. Such interactions are considered mission critical, however, do not imply dedicated applications for the purpose. For this UC to work, future B5G technologies will be leveraged to provide high-quality immersive media with very low latency between the remote and local sites.

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7.1.2 UC Scenario

The UC will be deployed in the Norwegian facility. eHealth-specific functions and applications can be hosted either on the central site at Fornebu, or on the edge site in Svalbard. Two RAN sites (Fornebu, Svalbard) will be available to support the experiments.

7.1.3 OC Desired Contribution

The desired contributions include (but not limited to) the implementation of innovative (immersive) remote care solutions and performance studies.

In addition to scenario above, Norwegian facility is also open to other proposals targeting e-Health.

*The beneficiary is expected to have/procure any medical hardware and software necessary for the scenario implementation and experiments, as well as relevant 5G UEs (e.g., 5G CPE or smartphones, to be coordinated with the Norway facility for the list of validated models).

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