H2020 5Growth Project
Grant No. 856709

D1.1: Business Model Design

Abstract

This deliverable represents the first outcome of WP1 of 5Growth, as a result of the activities performed in Task 1.1. This document gathers the initial analysis of the vertical services for 5Growth pilots to identify their business, functional and technical requirements, and offers an introduction to the business models that will have to be validated in 5Growth.

Document properties

Document number	D1.1
Document title	Business Model Design
Document responsible	Jesús Alonso (INNO)
Document editor	Jesús Alonso (INNO)
Authors	Jesús Alonso (INNO), Simone Panicucci (COMAU), Paulo Paixao (EFACEC_S), Paulo Delfim (EFACEC_E), Carlos Parada (ALTICE), Daniel Nunes (ITAV), Alberto Solano (TID), Pablo Murillo (TELCA), Sergio Barberis (TIM), Andrea Di Giglio (TIM), Giulio Bottari (TEI), Giovanni Rigazzi (IDG), Engin Zeydan (CTTC)
Target dissemination level	PU
Status of the document	Final
Version	1.3
Delivery date	September 30, 2029
Actual delivery date	September 30, 2029 (Feb. 18, 2022 for v1.3, fixing a typo)

Production properties

Reviewers	Daniel Corujo (IT) Giada Landi, Juan Brenes (NXW), Carlos J. Bernardos (UC3M)

Disclaimer

This document has been produced in the context of the 5Growth Project. The research leading to these results has received funding from the European Community's H2020 Programme under grant agreement Nº H2020-856709.

All information in this document is provided "as is" and no guarantee or warranty is given that the information is fit for any particular purpose. The user thereof uses the information at its sole risk and liability.

For the avoidance of all doubts, the European Commission has no liability in respect of this document, which is merely representing the authors' view.

Contents

Contents ... 3
List of Figures ... 5
List of Tables ... 7
List of Acronyms ... 8
Executive Summary and Key Contributions ... 9
1. Introduction ... 11
2. Vertical Pilot's Overview ... 12
2.1. Industry 4.0 Pilot - INNOVALIA ... 12
2.1.1. General Description ... 12
2.1.2. Main Stakeholders ... 14
2.1.3. Trial Use Cases - Present Scenario ... 15
2.1.4. Trial Use Cases - Future Scenario ... 16
2.1.5. Expected Results ... 17
2.2. Industry 4.0 Pilot - COMAU ... 18
2.2.1. General Description ... 18
2.2.2. Main Stakeholders ... 19
2.2.3. Trial Use Cases - Present Scenario ... 19
2.2.4. Trial Use Cases - Future Scenario ... 21
2.2.5. Expected Results ... 23
2.3. Transportation Pilot - EFACEC Engenharia e Sistemas ... 24
2.3.1. General Description ... 24
2.3.2. Main Stakeholders ... 25
2.3.3. Trial Use Cases - Present Scenario ... 26
2.3.4. Trial Use Cases - Future Scenario ... 27
2.3.5. Expected Results ... 28
2.4. Energy Pilot - EFACEC Energia ... 28
2.4.1. General Description ... 28
2.4.2. Main Stakeholders ... 30
2.4.3. Trial Use Cases - Present Scenario ... 30
2.4.4. Trial Use Cases - Future Scenario ... 31

2.4.5. Expected Results 32

3. Pilot's Requirements 34

3.1. Industry 4.0 Pilot - INNOVALIA 34

3.1.1. P1UC1: Connected Worker Remote Operation of Quality Equipment....34

3.1.2. P1UC2: Connected Worker: Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS)....39

3.2. Industry 4.0 Pilot - COMAU 43

3.2.1. P2UC1: Digital Twin Apps....43

3.2.2. P2UC2: Telemetry/Monitoring Apps 45

3.2.3. P2UC3: Digital Tutorials and Remote Support 48

3.3. Transportation Pilot - EFACEC Engenharia e Sistemas....50

3.3.1. P3UC1: Safety Critical Communications....50

3.3.2. P3UC2: Non-Safety Critical Communications 56

3.4. Energy Pilot - EFACEC Energia....60

3.4.1. P4UC1: Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV Distribution Substation 60

3.4.2. P4UC2: Advanced Critical Signal and Data Exchange Across Wide Smart Metering and Measurement Infrastructures....66

4. Business Model Design....72

4.1. Stakeholders & roles 72

4.2. Business Flow per Pilot 73

4.2.1. Industry 4.0 Pilot - INNOVALIA 74

4.2.2. Industry 4.0 Pilot - COMAU 75

4.2.3. Transportation Pilot - EFACEC Engenharia e Sistemas and Energy Pilot – EFACEC Energia 75

5. Conclusions....77

List of Figures

Figure 1: The Automotive Intelligence Center (AIC) in Amorebieta, Spain 13
Figure 2: Automotive Smart Factory (ASF) - Gestamp I4.0 Pilot Line 13
Figure 3: Automotive competence center in advanced quality services – INNOVALIA’s lab 14
Figure 4: Photographs of the uc1 current operation 15
Figure 5: Example of the CMM Measures 16
Figure 6: Example of the result of the Quality analysis 17
Figure 7: COMAU Headquarters and Production Plan in Grugliasco (Turín, Italy) 18
Figure 8: Digital Twin Scenario 20
Figure 9: Exemplary work cell and monitoring Dashboard Concept layout....22
Figure 10: Digital Tutorial and Remote SUpport Exemplary Tools 23
Figure 11: Geographical location of the envisioned 5G facility to support the Vertical Transportation pilot....25
Figure 12: Traditional Level Crossing environment 27
Figure 13: Aveiro Pilot Site 28
Figure 14: Geographical location of the envisioned 5G facility to support the pilot....29
Figure 15: Aveiro site....32
Figure 16: Last-gasp use case exemplification triggered by an outage 33
Figure 17: P1UC1 overview 34
Figure 18: P1UC2 Overview 39
Figure 19: Inspection execution flow 41
Figure 20: P3UC1 the Vertical Transportation pilot....51
Figure 21: P3UC2 – Scenario #2 Vertical Transportation pilot 56
Figure 22: P3UC2 – Scenario #3 Vertical Transportation pilot 56
Figure 23: Advanced monitoring and maintenance support of secondary substations 61
Figure 24: Fault detection in the low voltage network....66
Figure 25: Use Case Flow for Use Case 2....68
Figure 26: Stakeholder roles in the 5g ecosystem (source 5gppp) 72
Figure 27: INNOVALIA's Pilot Business Flow....74
Figure 28: COMAU's Pilot Business Flow....75

Figure 29: EFACEC Engenharia e Sistemas & EFACEC energia PILOTS Business Flow 76

List of Tables

Table 1: Business Requirements (P1UC1) 37
Table 2: Functional Requirements (P1UC1) 37
Table 3: Technical Requirements (P1UC1) 38
Table 4: Business Requirements (P1UC2) 41
Table 5: Functional Requirements (P1UC2) 42
Table 6: Technical Requirements (P1UC2) 42
Table 7: Business Requirements (P2UC1) 44
Table 8: Functional Requirements (P2UC1) 45
Table 9: Technical Requirements (P2UC1) 45
Table 10: Business Requirements (P2UC2) 47
Table 11: Functional Requirements (P2UC2) 47
Table 12: Technical Requirements (P2UC2) 48
Table 13: Business Requirements (P2UC3) 49
Table 14: Functional Requirements (P2UC3) 50
Table 15: Technical Requirements (P2UC3) 50
Table 16: Business Requirements (P3UC1) 53
Table 17: Functional Requirements (P3UC1) 54
Table 18: Technical Requirements (P3UC1) 54
Table 19: Business Requirements (P3UC2) 58
Table 20: Functional Requirements (P3UC2) 59
Table 21: Technical Requirements (P3UC2) 59
Table 22: Business Requirements (P4UC1) 63
Table 23: Functional Requirements (P4UC1) 64
Table 24: Technical Requirements (P4UC1) 65
Table 25: Business Requirements (P4UC2) 69
Table 26: Functional Requirements (P4UC2) 69
Table 27: Technical Requirements (P4UC2) 70
Table 28: Roles & Stakeholders in 5Growth 73

List of Acronyms

AIC – Automotive Intelligence Center

AGV – Automated Guided Vehicle

AQCS – Advanced Quality Control Systems

ASF – Automotive Smart Factory

CMM – Coordinate Measuring Machine

CPE – Customer Premises Equipment

CPPS – Cyber Physical Production System

DSS – Decision Support System

DTC - Distribution Transformer Controllers

LX – Level Crossing

LV – Low Voltage

M2M – Machine-to-machine

MANO – Management and Orchestration

MTTR – Mean Time to Repair

MV – Medium Voltage

NR – New Radio

PLC – Power Line Carrier

RASTA – Rail Safe Transport Application

SAIDI - System Average Interruption Duration Index

SCADA – Supervisory Control and Data Acquisition

SIL – System Integrity Level

ZDM – Zero Defect Manufacturing

Executive Summary and Key Contributions

This document reports the work done in Task 1.1 (T1.1) regarding the revision of the functional and technical requirements of the pilots and the definition of the business model designs that will be validated in 5Growth.

INNOVALIA's industry vertical pilot will deploy two use cases. In the first use case, *Connected Worker Remote Operation of Quality Equipment*, it will be explored how 5G technologies can be used to enable remote access to M3BOX, an edge device used to control the Coordinate Measuring Machine (CMM), in order to perform setup and configuration operations that nowadays require an expert to travel to the customer's premises. The second use case, *Connected Worker Augmented Zero Defect Manufacturing Decision Support System* will involve the development of a Machine to Machine (M2M) collaboration system using 5G technologies that will improve the flexibility and productivity of the CMM.

In the case of COMAU's industry vertical pilot there will be three use cases. First, the deployment of *Digital Twin Apps*, that will allow the plant manager to receive live information about the production line through a digital representation of the factory. Second, the development of *Telemetry/Monitoring Apps*, that will provide deeper information, monitoring the status of the equipment installed in the stations (robots, conveyors, motors, and so on), by installing a high number of sensors that use 5G communication technologies. Finally, the last use case will develop *Digital Tutorials and Remote Support*, to enable a high-resolution interface to remotely train and assist the worker on certain tasks.

The transportation vertical pilot, led by EFACEC Engenharia e Sistemas, proposes to replace the wired communication used nowadays on a railway level crossing by 5G based wireless devices. This is the basis to deploy two use cases: *Safety Critical Communications* which are focused on railways signalling operations and *Non-Safety Critical Communications*¸ which provide additional information, to reinforce the security and to avoid accidents at Level Crossing area, both to the train driver and to the level-crossing maintenance team.

Finally, EFACEC Energia's energy vertical pilot will involve the deployment of two more use cases: *Advanced Monitoring and Maintenance Support for Secondary Substations MV/LV Distribution Substation*, consists of a system to assist the maintenance team when repairing the substation by providing information with augmented reality. The *Advanced Critical Signal and Data Exchange Across Wide Smart Metering and Measurement Infrastructures* use case will deploy a system to use the last gasp of energy before an outage to save and transmit important information to identify and prevent greater problems.

The main roles identified in the four pilots are, in first place, the customer, which are the verticals, that consume services (network services, indoor coverage, frequency spectrum, and monitoring services and, in some cases, cloud edge/data center services), which are provided mainly by the operator. On the INNOVALIA use case, there is also another service provider who provides video streaming services to the customer, and to whom also the network operator provides the communication and monitoring services. Another role that is not always present is the hardware and software provider. In 5Growth ecosystem this role provides the hardware and software to the network operator needed to deploy the solution, and the maintenance services during operation.

Finally, there is one more role to be highlighted, which is the system integrator, that provides consultancy and integration services to the final customer, matching the requirements of the verticals with the services that the other stakeholders can provide, and, in some cases, also trains the customer to use the new deployments.

The key contributions of the work reported in this deliverable are:

- Final detailed description of the pilots and the use cases.
- Business, functional and technical requirements of the use cases.
- Identification of the stakeholders in each pilot.
- Definition of the business model and the services flow per pilot.

1. Introduction

This document summarizes the work done under task T1.1 gathering the high-level requirements for the different vertical pilots and designing the business model that will be validated throughout the project duration.

Section 2 of the document offers a general overview of each of the vertical pilots, the stakeholders involved in each of them and their roles, and what are the expected outcomes for each of the pilots.

In section 3 each of the pilots specifies the requirements for each of the use cases that are going to be developed throughout the project, starting with their detailed description, and then specifying their requirements on three levels: business requirements, functional requirements and technical requirements. Additionally, functional requirements are mapped towards business requirements, and technical requirements towards functional ones.

Finally, section 4, presents first a global view of the different stakeholders involved in the chain of 5G network and vertical services. Then, the business models for the different roles or stakeholders are described per pilot. First, these roles are identified and described for each pilot, and then the business relationship between them is developed, and the services provided outlined.

2. Vertical Pilot's Overview

This section provides an overview of the four vertical pilots of 5Growth, and the main stakeholders involved in each of them and their roles, based on the stakeholder analysis described in section 4.1. We also highlight the main differences between the as-is scenario (as deployed today using the legacy and existing technologies) and the to-be scenario (to be deployed in 5Growth using the developed 5G technologies), as well as the expectation from the verticals regarding the benefits that 5G technologies will bring to these scenarios.

2.1. Industry 4.0 Pilot - INNOVALIA

2.1.1. General Description

The Industry 4.0 vertical pilot from INNOVALIA will improve the effectiveness of the workforce by enabling a remote connection to the equipment, and to develop new M2M collaboration methods to make quality control processes faster and more flexible. 5G technologies will enable INNOVALIA to share large amounts of data with a very low latency to bring new functionalities for its Zero-Defect Manufacturing (ZDM) system. The first use case will allow the remote configuration of the CMM. The second use case will introduce the remote access to the measured information and the automation of the measuring process with the assistance of a remotely controlled Automated Guided Vehicle (AGV).

The activities of this pilot will span over two nearby trial sites located in the Basque Country (Spain), within the **Automotive Intelligence Center (AIC) in Amorebieta** (see Figure 1). AIC is a European center generating value for the automotive industry, based on the concept of open manufacturing production innovation in which companies improve their competitiveness through cooperation. Using a market-oriented approach, AIC integrates knowledge, technology and industrial development under one umbrella. The AIC-Automotive Intelligence Center is managed by ACICAE, the Basque Country Automotive Cluster (over 300 companies). The AIC hosts 26 companies including OEMs (Daimler), Tier 1 and Tier 2 component providers such as GESTAMP (6.500 M€ & 100 locations), ZF Lemförder TVA (18.400 M€ & 230 locations), Pierburg, CIE Automotive (2.631M€ 33 locations), Maier, Amaya Telleria.

FIGURE 1: THE AUTOMOTIVE INTELLIGENCE CENTER (AIC) IN AMOREBIETA, SPAIN

Regarding the pilots, the following production facilities are described:

Production Facility 1: Automotive Smart Factory (ASF) – GESTAMP I4.0 Pilot Line (see Figure 2). The ASF is a Competence Center specialized in advanced manufacturing, providing integral services for the implementation of Industry 4.0. The ASF has a combination of physical and virtual capabilities which makes it ideal for analysing the benefits of digital technologies and Industry 4.0 solutions. The physical workspace includes cutting-edge equipment, such as a stamping servo-press, an arc-welding cell and different control and in-line verification systems. It is also equipped with an AGV (Automated Guided Vehicle) to provide advanced flexibility in the handling process. The virtual workspace consists of a Smart System that manages the manufacturing process with an integral approach and triggers real-time modifications of process parameters.

FIGURE 2: AUTOMOTIVE SMART FACTORY (ASF) - GESTAMP I4.0 PILOT LINE

Production Facility 2: Automotive Competence Centre in Advanced Quality Control Services (AQCS) – INNOVALIA Metrology´s Lab (see Figure 3). The AQCS Competence Center is part of the INNOVALIA Zero Defect Manufacturing (ZDM) Digital Innovation Hub (DIH) with the vision that any local manufacturing industry should master manufacturing excellence through zero defect manufacturing products, processes and services. The DIH mission consists in ensuring that local industry can fully benefit from digital opportunities (technical support, access to experimental infrastructures, financing, skill development, market intelligence etc.) on the following competences: (1) Digital automation, Industrial IoT and CPPS (2), ZDM digital platforms (3) Factory 4.0 Big Data & 3D mobile data visualization, (4) Cybersecurity and digital trust.

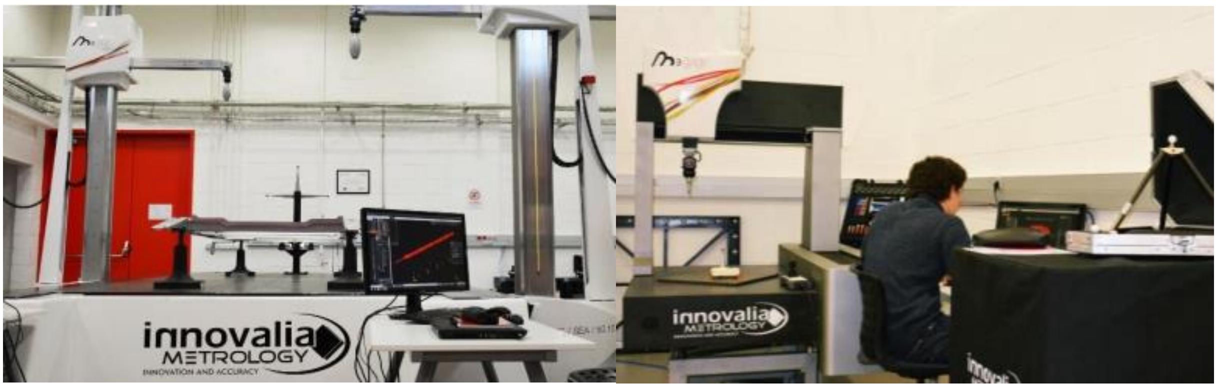

FIGURE 3: AUTOMOTIVE COMPETENCE CENTER IN ADVANCED QUALITY SERVICES – INNOVALIA'S LAB

2.1.2. Main Stakeholders

2.1.2.1. Customer: INNOVALIA

INNOVALIA is the Industrial Partner of the Pilot, and, as such, will define, develop, deploy and validate the pilot in Industry 4.0 in the field trials assessing the obtained results. INNOVALIA will provide the environment and the necessary equipment to operate the CMMs (it is still not defined the final model(s) of CMM to be used), such as the controllers, the edge node (M3BOX) and the software components that will be adapted to enable the deployment of the use cases.

2.1.2.2. Customer: ASTI

ASTI will participate in the *Augmented Reality Zero Defect Manufacturing Decision Support System* use case described in sections 2.1.3.2 and 2.1.4.2 by providing the AGV and adapting their software and systems to enable the deployment of the use case.

2.1.2.3. Service Provider: IDG

Interdigital (IDG) will provide the video streaming services required in the *Remote Operation of Quality Equipment* use case. This includes the supply and installation of the cameras, the deployment of the video server over the cloud-edge infrastructure provided by TID and the general setup process of the service.

2.1.2.4. Operator: TID

Telefonica (TID) will bring the network operator perspective to the analysis phases and contribute from this same perspective to business model description and verification, including its experience in OSS/BSS evolution when considering the definition of the 5G business layer. TID will also provide the cloud-edge infrastructure and the networking and monitoring services for the pilot.

2.1.2.5. Operation Support Provider: TELCA

Telcaria (TELCA) is one of the Technical Support Partners of the pilot. Telcaria will help on the design, deployment, operation and validation phases of the INNOVALIA use cases, especially in the network monitoring, control and orchestration innovations in which Telcaria will contribute to the 5Growth project. Moreover, Telcaria will use the know-how and skills acquired in the other 5GPPP projects in which it is also actively involved, namely 5G-CORAL[1] and 5G EVE[2].

2.1.2.6. Hardware/software supplier: ERC

Ericsson Spain (ERC) will be involved in the INNOVALIA pilot by providing the equipment required by TID in order to deploy the services that it will provide both to INNOVALIA and IDG. For the use case, Ericsson will also take care of the maintenance of this equipment.

2.1.3. Trial Use Cases - Present Scenario

This subsection will describe the scenarios before the start of the project, which are the currently deployed technologies and the motivation to innovate through 5Growth.

2.1.3.1. P1UC1: Connected Worker Remote Operation of Quality Equipment

A Coordinate Measuring Machine (CMM) is a device that measures point positions to calculate geometries of physical objects by sensing discrete points on the surface of the object with a probe. A common use of CMMs is in manufacturing and assembly processes to test a part or assembly against the design intent (to make sure, for example, that the holes in the measured part are exactly in the right place to assemble it with the rest of the pieces).

INNOVALIA's CMMs use an optical probe and are highly automated. There are different sizes, models and types to cover all the needs of its clients. Together with M3[3], the Metrology software solution, a digital copy of any piece (what it is called a *digital twin*) can be created in less than 30 seconds. The machine will capture millions of points, and the software will process all this data to generate a 3D visualization of the data and compare it with the reference model to highlight the differences and potential fails.

FIGURE 4: PHOTOGRAPHS OF THE UC1 CURRENT OPERATION

However, the process of configuration and calibration of a CMM is a fundamental process for the correct operation of the machine. It is a highly complex process, which must be carried out by

[1] http://5g-coral.eu/
[2] https://www.5g-eve-eu/
[3] https://www.INNOVALIA-metrology.com/metrology-products/metrology-software/metrology-software-m3/

specialized personnel, that either travel to the installation point or the machine must be sent to the facilities of INNOVALIA Metrology to execute the process. This is a great inconvenience to offer a quality service, since it generates significant costs to the client.

In addition, each time a new piece or component needs to be measured the machine must be reconfigured, and new trajectories must be defined for scanning the piece, so every time the client redesigns a piece or wants to measure a new component, it must either submit the piece to INNOVALIA's Lab or hire INNOVALIA to send its personnel to their site to do the job.

2.1.3.2. P1UC2: Connected Worker Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS)

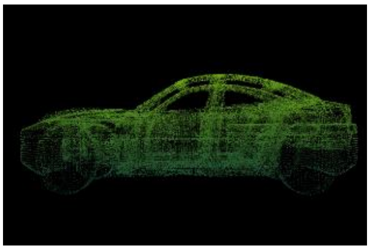

FIGURE 5: EXAMPLE OF THE CMM MEASURES

In the manufacturing sector, quality control processes are important but expensive stages of the product life cycle, that require specialised professionals to control and configure the quality control equipment, like the CMM.

Nowadays, a quality control process requires reconfiguring and recalibrating the CMM every time that the model of the piece being measured is changed. Most often, the quality control worker does not have an updated information of the pieces coming out of the production lines, so he does not know the reference of the piece/product to measure until the piece itself arrives to the measuring station. Then, a different scanning program must be loaded, and the CMM has to be configured and calibrated. This process takes some valuable time that could be reduced if the quality control worker could know the flow of pieces to be measured and their reference number, as the program could be loaded while the piece is being carried from the production line to the measuring station.

2.1.4. Trial Use Cases - Future Scenario

This subsection describes the scenario of the use cases with the innovations that 5Growth will bring, and the improvements that these will produce on the processes.

2.1.4.1. P1UC1: Connected Worker Remote Operation of Quality Equipment

This use case will investigate 5G network slicing capabilities and latency reduction to enable the implementation of a global virtual joystick for remote human programming of the CMM, Cartesian robot trajectories and hybrid (tactile/3D scanning) data acquisition; i.e. quality control routines.

The remote operator will be able to control the movement of the CMM by means of a virtual joystick and two video cameras: one providing with a real video stream with a general vision of the CMM and another one with a detailed vision of the surface being scanned (with another camera mounted on the optical sensor). The pilot will consist on the remote programming from the Production Facility 2 of M3 quality control routines for CMM machines placed in Production Facility 1.

This way, one of the most expensive maintenance tasks for the CMM will be significantly reduced thanks to the use of the 5G technologies, which will effectively enable remote control operations, thus avoiding the cost of the in-site human interventions.

2.1.4.2. P1UC2: Connected Worker Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS)

This use case will investigate how 5G technologies can be used to support large (automotive chassis) 3D point cloud for computational geometry processing and visualization while keeping the time required to perform this analysis low. The pilot will consist on the processing and visualization of large 3D point clouds (see Figure 6).

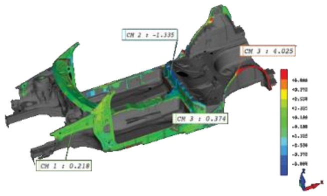

FIGURE 6: EXAMPLE OF THE RESULT OF THE QUALITY ANALYSIS

A second aspect that will be addressed in this use case is the development of a new M2M collaboration process, to automatize the process of loading the inspection program for the CMM while an AGV is taking the piece to be measured from the production line to the measuring station. This M2M collaboration process will not only bring more flexibility to the quality control system but also optimize the process, by using the time that it takes to move the piece to start loading the inspection program.

2.1.5. Expected Results

With this pilot INNOVALIA expects to improve its ZDM service portfolio by the introduction of a remote CMM configuration service, and by the exploitation of M2M communication to provide automatic quality control machine configurations to include the remote configuration of the machine and increasing the flexibility of the solution.

The new remote operation capabilities of the CMM will reduce by half the total preparation of deployment time of a new measuring program, gaining agility on the process of changing the parts being measured. This will also bring a significant reduction of the assistance and support costs, cutting them by a 30% by reducing the travelling costs. Also, this will bring a higher service availability, as specialised personnel will not be unavailable because of travelling.

By being able to share a CMM among different production lines and being able to change the reference being measured in a quick and automated way, the measuring execution cycle (that is, the time that it takes to measure the piece and analyse the results) will be optimized, reducing it by, at least, a 15%. This means a higher productivity for the CMM, and a higher flexibility in the production line, which will be increased by a 30%.

To our clients, this will mean they will be able to measure more parts, increasing the control coverage (number of produced pieces that are inspected) by 15%, which means more quality, a reduction of scrap (not re-usable material used in defective pieces) by in-line flexible inspection by 10% and a capacity to predict a lack of quality that will be improved by a 30%.

2.2. Industry 4.0 Pilot - COMAU

2.2.1. General Description

COMAU is a worldwide leader in the industrial automation field. It offers complete engineering solutions, from product development to the realization of industrial process and automation systems. Through dynamic research and development COMAU constantly expands and improve its product portfolio. The competencies in Body Assembly, Powertrain Machining & Assembly, and Robotics enable COMAU to deliver innovative products, systems, and solutions that suit manufacturing requirements in industries such as Automotive, Aerospace, Railway, Commercial Vehicles, Renewable Energy, Heavy Industry, and General Industry.

This pilot will be developed in Automation Systems and Robotics floors of COMAU Grugliasco (Turin, Italy), a site in charge of production for the whole European area of Robots and Automated production lines, providing "body-in-white" solutions (i.e., car bodies production) for main Original Equipment Manufacturers (OEM)s such as FCA, Daimler, Jaguar/Land Rover, Volvo, Porsche etc. The COMAU facility in Italy is composed of two buildings, organized as shown in Figure 7.

FIGURE 7: COMAU HEADQUARTERS AND PRODUCTION PLAN IN GRUGLIASCO (TURÍN, ITALY)

From the industrial point of view, the advent of the 5G technology could bring wireless connectivity, while guaranteeing strict constraints both in terms of latency as well as throughput.

In addition, 5G has more powerful security features and the possibility to use network slicing in order to create private and isolated connections over the public one, tailoring the network to accommodate the particular requirements of each use case. Thus, it is possible to obtain the same isolation level of wired connection in every place where there is network coverage.

Some of the most important benefits using 5G technologies in industrial environments are:

- Unified network across the plants, reducing network deployment and management costs.
- Sharing of the resources using secure and scalable cloud computing to reduce hardware.
- Reliable and secure machine-to-infrastructure communication.
- Removing network cables in plants reducing execution time as well as initial cost.
- Reduced costs of acquisition and reduced infrastructure deployment time.

2.2.2. Main Stakeholders

2.2.2.1. Customer: COMAU

COMAU is the pilot owner and will provide the environment for the integration of the 5Growth platform components.

2.2.2.2. Operator: TIM

Telecom Italia (TIM) activity will be mainly concentrated on the collaboration with the 5G-EVE project and on the infrastructure design and configuration, to enable the interaction between the Industry 4.0 testbed placed in the COMAU factory and the 5G-EVE Italian facility.

2.2.2.3. Operation Support Provider: TEI

Ericsson Italy (TEI) will lead the deployment of the COMAU pilot. Specifically, TEI will support all operations needed to replace cables with Industry-grade cellular connectivity that allows to delocalize the robot control and the related applications on a centralized edge computing platform. Specifically, the set-up of the infrastructure (mobile and transport) will be defined and suitable configured in order to meet the requirements for the vertical support.

2.2.3. Trial Use Cases - Present Scenario

This subsection will describe the scenarios before the start of the project, which are the currently deployed technologies and the motivation to innovate through 5Growth.

2.2.3.1. P2UC1: Digital Twin Apps

The concept of the digital twin has been around since 2002. Although, the increased adoption of IoT and cloud technologies has now made it cost-effective enough to gain real momentum in telecoms and enterprise.

A digital twin is essentially a digital representation of something which exists in the real world as physical assets, processes, people, places, systems and devices. In order to have an actual and exact representation, the digital twin needs a continuous stream of data coming from the field (e.g. reading cycle time from PLCs) with a very low latency (to avoid delay in the digital representation) and usually a high data rate.

One of the most useful use cases regarding digital twin is about modelling and gathering data from an entire production line or even an entire plant. Having that knowledge allows the development of predictive analytics tools in order to predict and prevent line faults.

COMAU is currently developing a tool which uses the same information to prevent cycle time deviation, just informing people in charge of production or (in next developments) suggesting how to early solve future problems. If something unexpected happens in the production flow, for instance a component delivered out of sequence, several alternative scenarios are possible. Such alternatives can be simulated in parallel in the virtual environment of the digital twins and the most appropriate action can later be applied to the "real" twin.

Nevertheless, digital twin is applicable to robots as well, even if the case of the entire production line is more useful and valuable as industrial use case.

Currently the telecommunication systems in industrial environments are managed by traditional ICT departments and rely on a lot of components both hardware and software to correctly and securely work. This current approach, used in all the industrial realities, leads to complex and sophisticated solutions and high operational expenditures (OpEx).

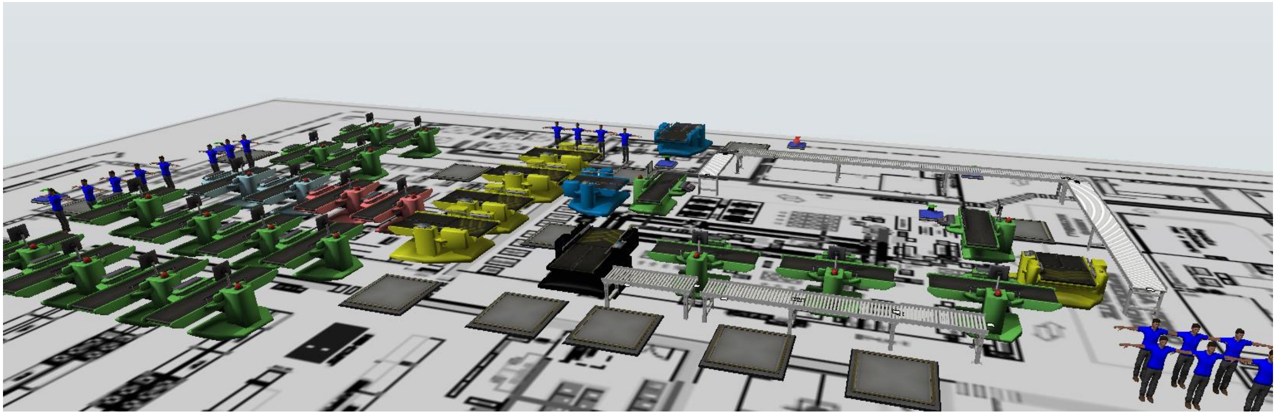

FIGURE 8: DIGITAL TWIN SCENARIO

2.2.3.2. P2UC2: Telemetry/Monitoring Apps

The use case defined in the previous section gives, as an output, a digital twin of production lines or plants represented as a set of stations. Therefore, it works at a high level of granularity since it does not go into the status of the single stations (all the components and devices are aggregated up into the cycle time).

This second use case regarding monitoring and telemetry goes deeper, aiming to monitor all the machineries and equipment inside the stations (robots, conveyors, motors, and so on), installing on them specific sensors which could be really numerous and bandwidth consuming.

For such use cases 5G technology will allow to provide the suitable amount of bandwidth, tight latency and connect high density of connections.

2.2.3.3. P2UC3: Digital Tutorials and Remote Support

This third use case aims at providing in-field technicians and maintenance staff with digital tutorials and remote support for troubleshooting by means of high definition videos (for example delivered on a tablet) and the possibility to establish a real-time connection with a remote technical office for further support. COMAU has not yet implemented this application.

2.2.4. Trial Use Cases - Future Scenario

This subsection describes the scenario of the use cases with the innovations that 5Growth will bring and the improvements that these will produce on the processes.

2.2.4.1. P2UC1: Digital Twin Apps

The future scenario is to replace the existing infrastructure by moving the communication through 5G and, instead of being the owner of it, just pay for the service provided by telco companies.

In this future scenario the real devices and machines will be equipped with a massive number of sensors that will send status data to its virtual reproduction on a constant basis. In addition, controllers (e.g., PLCs) feed the virtual replica with status data. A requirement management system works as a digital requirements library, gathering the incoming data and comparing it against the specifications. If a discrepancy is detected, then engineers can work on potential solutions directly on the digital twin - after which the real machine can then be updated to resolve the problem as quickly as possible.

5G wireless networks can will offer low and predictable latency, under different traffic patterns and network loads. Wi-Fi on the other side provides low average latency but is more sensitive to varying network loads. Besides, in a factory hall with hundreds of devices the available unlicensed spectrum may not be enough. Furthermore, cellular networks provide better mobility support than Wi-Fi due to its connection handover capabilities, which is important, for example, for AGVs (Autonomous Guided Vehicles) which move around the plant.

2.2.4.2. P2UC2: Telemetry/Monitoring Apps

Failure detection is a challenge that exists throughout the manufacturing industry. Issues, such as vibration patterns affecting the robots, could be revealed by monitoring the process in real time.

5G will facilitate using a plethora of new wireless sensors, easy to attach on robots even in legacy plants: sensors with long lasting batteries and communicating few data in real time. Example of sensors are: pressure, temperature, vibration (IMU). Correlating data from these sensors would enhance monitoring and prevention.

Using the same infrastructure of use case P2UC1, the main purpose of the application of this use case is to gather real-time data from machines and sensors to continuously monitor production and machines' behaviour. An analysis and mapping of the data collected will lead to a "health status" definition and, as said, allow preventive maintenance.

Figure 9 illustrates an exemplary scenario. On the left of the picture is reported a robotic work cell which includes robots (i.e. manipulators, welding guns), automated guided vehicles (AGV), tools, a PLC controller, sensors. On the right side is displayed an example of dashboard/app reporting telemetry/monitoring data in an aggregate way. This data could also be used to feed expert systems (located in the plant or in a centralized company location) to determine what is happening, to predict future issues, and to prevent failures. In summary, the main purpose of this application is to gather real-time data from machines and sensors to continuously monitor production and machines' behaviour. An analysis and mapping of the data collected will lead to a "health status" definition and, as said, allow preventive maintenance.

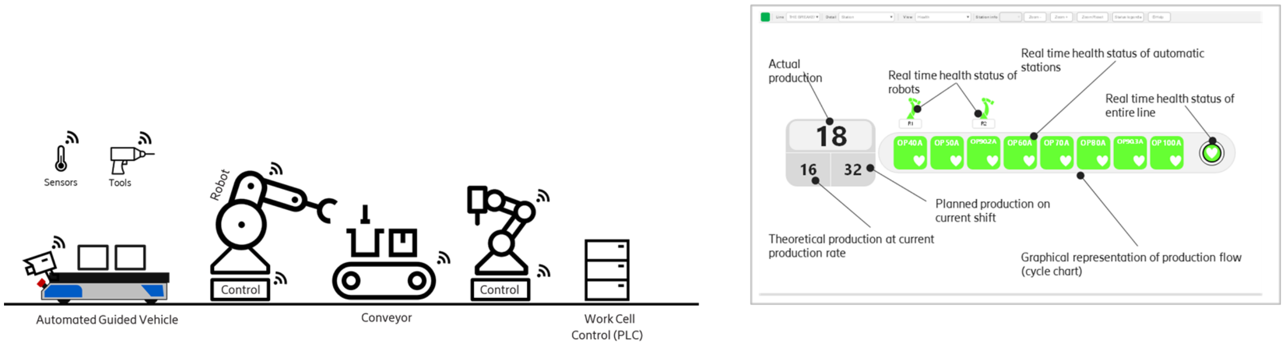

FIGURE 9: EXEMPLARY WORK CELL AND MONITORING DASHBOARD CONCEPT LAYOUT

The use case will explore the capabilities of 5G to support massive communication with sensors pinging data, in all machines on the shop floor, maintaining at the same time the same availability/reliability over wireless, compared to the one offered by conventional wired connections. Moreover, battery-powered sensors will also benefit from low power consumption for 5G connectivity.

2.2.4.3. P2UC3: Digital Tutorials and Remote Support

This use case has the objective to reduce the Mean Time to Repair (MTTR), as well as the cost of maintenance and fixing activities.

In this use case we aim to achieve this providing a of a digital tutorial library combined with remote support thank to high definition streaming and live connection. Hence, it is not strictly necessary to get skilled people directly where the problem actually happens; a local technician could be assisted there by a more specialised staff physically far from him. Doing that it is possible to reduce costs and increase the availability of technical staff that can operate remotely.

Figure 10 reports an exemplary scenario for the use case. Tables or a monitor can be used to deliver the required information to the technician where and when needed. Information can include: a description of actions to be performed, an action cycle chart, a procedure completion status, virtual reality or 3D model, augmented reality superimposed descriptions and so on.

The value of 5G here is mainly related to its provided high data rates to stream video flows at any definition with no interruptions and with the possibility to scale up the number of active users, using the application.

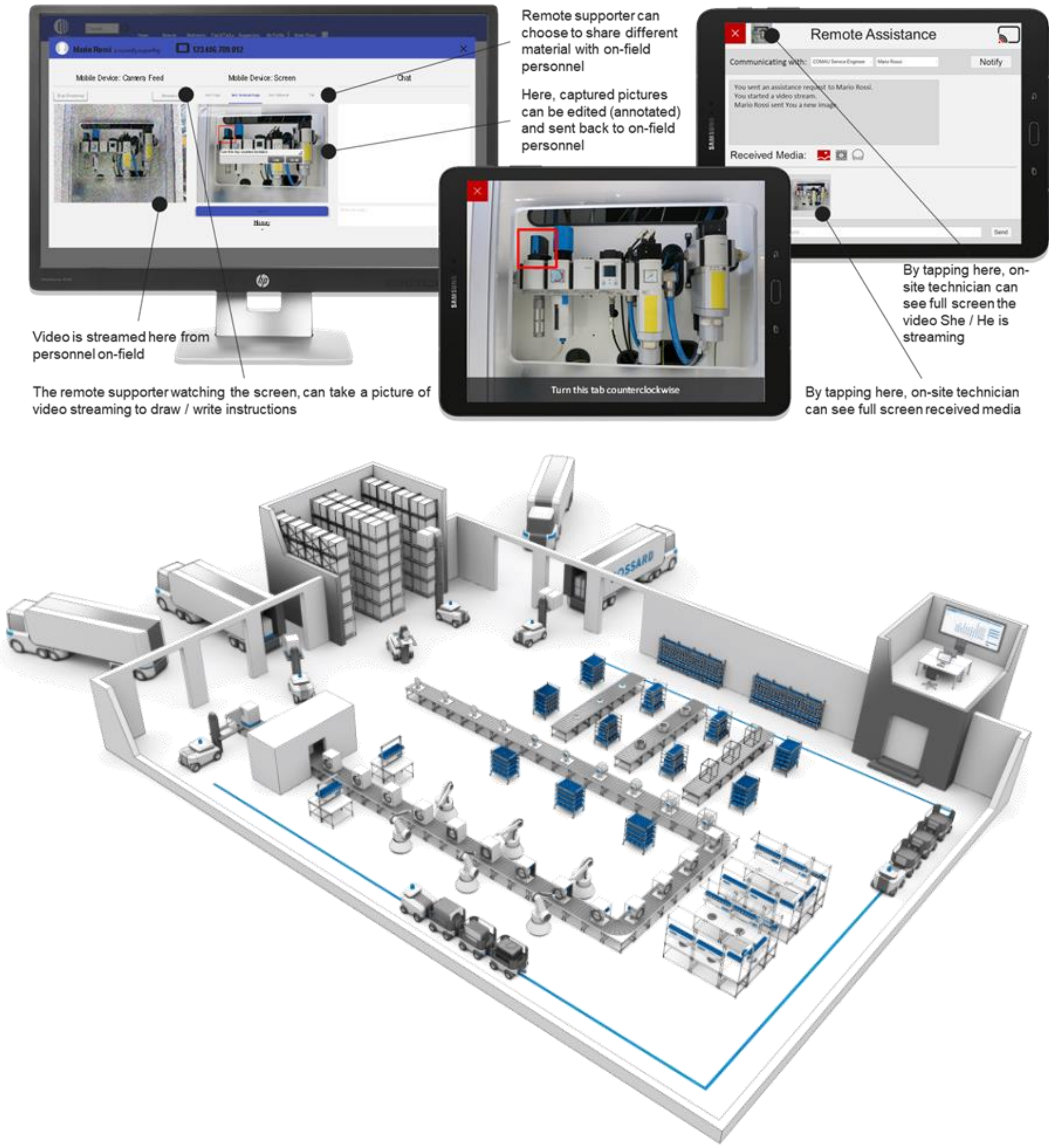

FIGURE 10: DIGITAL TUTORIAL AND REMOTE SUPPORT EXEMPLARY TOOLS

The value of 5G here is mainly related to its provided high data rates to stream video flows at any definition with no interruptions and with the possibility to scale up the number of active users, using the application.

2.2.5. Expected Results

COMAU is particularly interested in evaluating 5G business, functional and technical impact on its industrial applications, because from the technical point of view, the 5G network slicing capabilities offer three main advantages such as low latency and huge bandwidth.

These characteristics enable many improvements: thanks to stronger security, due to network slices, machinery all around the world can be connected to the same network and remotely programmed or updated with smaller latency than before; low latency could be really useful to remove cables, switches and many other hardware components in order to both reduce costs, installation and reconfiguration time; a huge bandwidth allows to collect data from many different components to develop useful algorithms, as example, for predictive maintenance.

The main expected result is the one regarding the network hardware replacing, doing that COMAU can simplify network architecture and introduce some innovations as well about production plants architecture.

The results across all use cases are to reduce the infrastructure cost by 20%, reduce the technician time travel by 30% using both monitoring and remote maintenance tools, connect to the same wireless connection many devices in a wide area and a zero perceived downtime regarding services and a really available and reliable network for control applications.

2.3. Transportation Pilot - EFACEC Engenharia e Sistemas

2.3.1. General Description

The Vertical Pilot 3 – Transportation, involves two use cases. Located in the Aveiro harbour (Porto de Aveiro), the pilot intends to demonstrate Railways Signalling Operation over 5G networks. In the field trial, 5G communications will be used to support railway signalling operations to meet railway level crossing communication requirements, outlined in section 3. The 5G network infrastructure, including radio access, fronthaul/backhaul and edge point of presence will be part of the 5G-VINNI[4] experimental site, located in Aveiro and operated by Altice Labs. This infrastructure will be partly shared with other 5G-related activities, both national and international, in which Altice Labs is playing the leading role, including those under the auspices of Aveiro 5G City, a joint effort with the Aveiro Municipality and local academic institutions, namely the University of Aveiro and the Institute of Telecommunications. Altice / Portugal Telecom will be providing access to the experimental 5G infrastructure. In the transportation pilot, a 5G wireless solution is foreseen to support the backhaul segment.

Figure 11 depicts the geographical location of the use cases.

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

FIGURE 11: GEOGRAPHICAL LOCATION OF THE ENVISIONED 5G FACILITY TO SUPPORT THE VERTICAL TRANSPORTATION PILOT

2.3.2. Main Stakeholders

This Pilot includes three partners, which will be responsible for the design and development, i.e., EFACEC Engenharia e Sistemas (EFACEC_S), Altice Labs, and IT Aveiro. Other partners will also contribute by providing technical support, either providing software tools or technical skills in several areas.

2.3.2.1. Customer: EFACEC_S

EFACEC ENGENHARIA E SISTEMAS (EFACEC_S) will be involved in the Pilot definition during the development, the deployment and the integration of the new solution**.** EFACEC_S will also realize the verification and technical validation of the 5G technologies applicability to the different use cases implemented in the Transportation pilot. Additionally, an assessment is projected over the general alignment of the service KPIs defined for the railway signalling use cases, as well as the monitoring of these KPIs, to show evidence that the targeted metrics are achieved.

2.3.2.2. Operator: ALB

Altice Labs (ALB) will play a key role in this UC by providing the entire 5G infrastructure, including the 5G Core, as well as 5G-NR coverage of the UC location: the train cross level area on the Aveiro harbour.

Altice Labs will provide the cloud infrastructure required to support the deployment of the 5G network elements, as well as the UC related services. The cloud infrastructure will be provided in several locations, not just in the core, but also at the edge, to cope with the UC needs, especially when complying with strict latency requirements.

Altice Labs will provide the management and orchestration (MANO) tools required to deploy the network and the UC services. Those tools will enable the full management of the lifecycle of network functions and services, as well as its integration.

Altice Labs will also provide all the interfaces towards the verticals to interact with the operator to request 5G connectivity with certain requirements. The requirements stated by the UC owner will be those defined as service KPIs in vertical language. Those tools should be responsible to map these high-level requirements to network slices, services, VNFs and resources from the operator perspective.

Altice Labs will operate and manage this entire ecosystem for the full period of the project lifetime.

2.3.2.3. Cloud Service Provider & HW/SW Supplier: IT

IT Aveiro (IT) will be instrumental in mapping associated communication requirements between the Transportation and Energy verticals use cases and the Campus Infrastructure capabilities. In this respect, IT will provide both interfacing and support actions towards that infrastructure, developing the necessary integration aspects. These interfacing aspects between the infrastructure and the vertical's operations will also be addressed for the verification and validation of the use cases.

Additionally, IT will assess the deployment viability of the inter-domain orchestration and secured virtualization research items that are being pursued under the scope of WP2, considering the use cases needs of the Transportation and Energy verticals.

2.3.3. Trial Use Cases - Present Scenario

Figure 12 illustrates a traditional railway level crossing and the main devices involved in the signalling operation (axle counter/train detector system, road signals, level crossing signal protection, half-barriers and the Controller's cabinet)

In the presence of an approaching train, the train detector system sends data messages to the level crossing (LX) controller, to inform that a train is approaching the level crossing and to transmit the status of the equipment on the track. The LX controller then must start the set of actions to assure safe conditions to the train, cars and people. After detecting that the train has left the LX, the peripherical devices must return to normal state. Therefore, the LX controller retrieves the sensors information to automatically define the position of the half-barriers, the traffic lights and the protection signal.

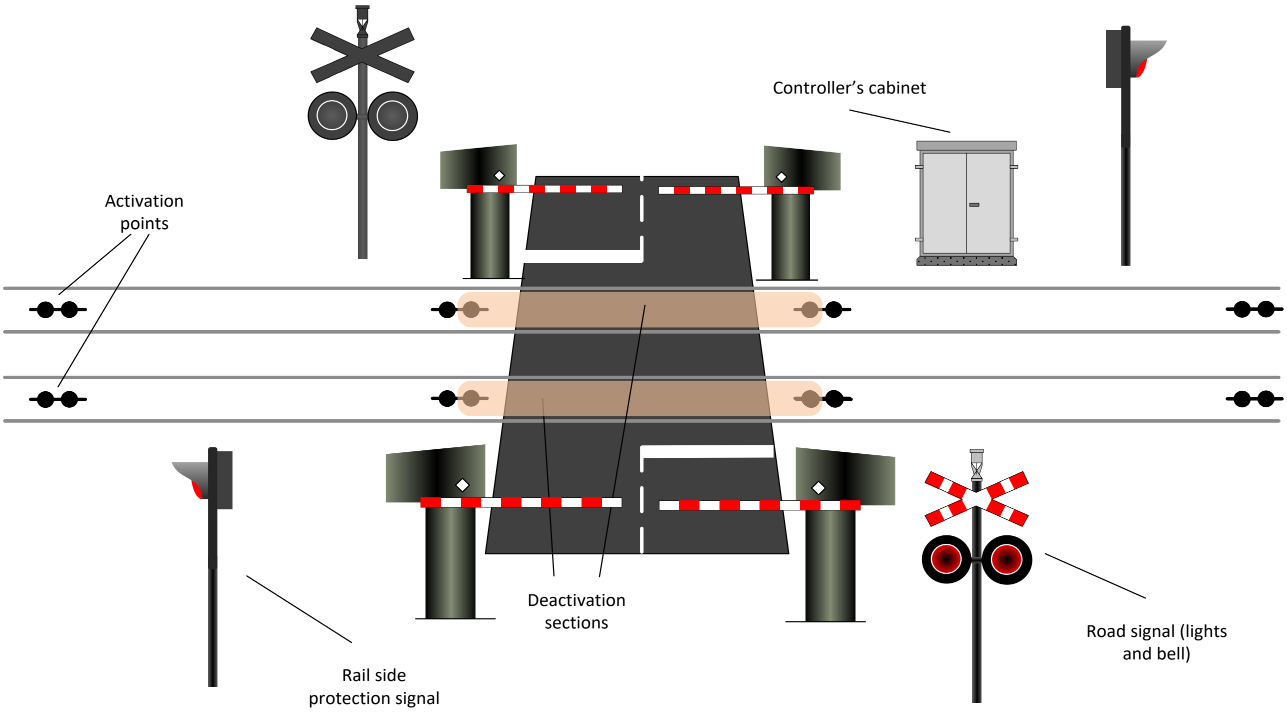

FIGURE 12: TRADITIONAL LEVEL CROSSING ENVIRONMENT

In a level crossing signalling system, the communication between the controller system and the peripheral devices (train detectors, signals and barriers) is typically assured by means of copper cable wires, involving considerable costs regarding the communications infrastructure.

2.3.4. Trial Use Cases - Future Scenario

In the pilot, it is desirable to replace cabled based networks by 5G technologies, assuring two types of critical communications: safety critical and non-safety critical.

In the field trial, 5G communications will be used to support railway signalling operations, in particular to meet railway level crossing communication requirements (M2M), namely (*i*) for safety critical communications from approaching train detectors (Strike In detectors) to the level crossing controllers – P3UC1, and (*ii*) for transmission of level crossing real-time video images to mobile devices on approaching trains and to maintenance agent's tablet devices – P3UC2

These Use Cases will be supported by the 5G-VINNI 5G infrastructure, extending the coverage to the Aveiro UC locations (in particular for the transportation UC). Figure 11 depicts the 5G-VINNI PoPs, Core and Edge, which will support the 5G-Core and 5G-RAN components, respectively. The Figure also shows the locations where the 5G radio will be deployed, in the perimeter of the Aveiro harbour.

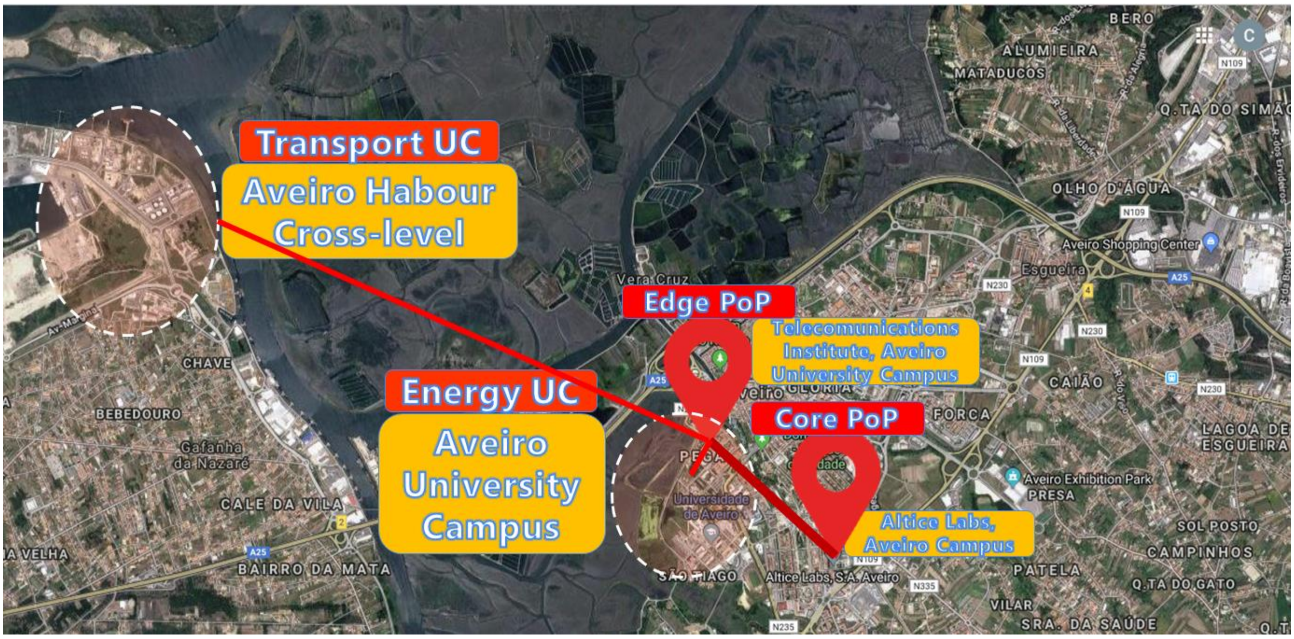

FIGURE 13: AVEIRO PILOT SITE

2.3.5. Expected Results

Related to the first use-case, the solution shall reduce the level crossing capex by 20%. The XSafe (EFACEC_S Level Crossing solution) level crossing system product will become more competitive with respect to the traditional wired level crossing signalling solutions. The level crossing time installation shall be reduced by 50%.

The second use case will allow the development of a new market, the mobile video level crossings safety reinforcement with public standard communications. The remote asset monitoring using 5G will allow much more competitive, flexible and agile solutions compared to the actual wired solutions, allowing the reduction of costs and service response time, creating new market opportunities

2.4. Energy Pilot - EFACEC Energia

2.4.1. General Description

The envisioned use cases aim to demonstrate a high performance, but still very flexible communication architecture provided by 5G to deal with heterogeneous environments. The pilot, hosted by the Technological Campus of the University of Aveiro, will address the advanced monitoring and maintenance support of Low Voltage (LV) smart grid infrastructures within the secondary substations, including surveillance HD video streaming from local and mobile cameras. It will also address the experience of on-demand local augmented reality, accessible from the control centre and on maintenance crew mobile devices, together with the empowering of the infrastructure automation

The main purpose is to validate advanced smart grid control solutions through use cases promoting the concurrent usage of network resources, which must be shared among multiple applications demanding different service requirements within an LV-Smart Grid area, framed in a wider smart city/campus. Considering a LV smart grid infrastructure, equipped with advanced monitoring and control solutions for the secondary substation(s) and distribution cabinet(s) automation, i.e. Distribution Transformer Controllers (DTC), sensors and meters, and empowered by 5G technologies, different use cases will be further explored across field trials.

Thus, the use case scenario “Advanced monitoring and maintenance support of secondary substations – Medium Voltage/Low Voltage (MV/LV) distribution substation” (use case 1) and “Advanced critical signal and data exchange across wide smart metering and measurement infrastructures” (use case 2). Figure 14 depicts the geographical location of the use case (University of Aveiro campus) where the UC will be deployed, as well as the existing control centre software used to monitor and control the smart grid.

FIGURE 14: GEOGRAPHICAL LOCATION OF THE ENVISIONED 5G FACILITY TO SUPPORT THE PILOT.

2.4.2. Main Stakeholders

This Use Case (UC) includes three partners directly involved in the design and the development; Efacec Energia, Altice Labs, and IT Aveiro. Other partners will also contribute by providing technical support, either providing software tools or technical skills in several areas.

2.4.2.1. Customer: EFACEC_E

In 5Growth, EFACEC Energia (EFACEC_E) contribution will be focused on the preparation, integration, execution, validation and demonstration of the Energy Pilot. EFACEC Energia will contribute to the establishment of the specification of functional/non-functional requirements and to the characterisation of the relevant KPIs related with the envisioned Smart Grid use cases, proposed under the Energy pilot; it will accomplish all the required integrations to implement and execute the proposed use cases within the Energy pilot, using the defined services APIs of the 5Growth platform.

Apart from the fully integrated pilot framework, ready for validation, EFACEC Energia will also contribute to the report of the energy pilot use case results and will realise the verification and technical validation of the 5G technologies applicability to the different use cases implemented in the energy pilot. Additionally, an assessment is projected over the general alignment of the service KPIs defined for the smart grid use cases, as well as the monitoring of these KPIs, to show evidences that the targeted metrics are achieved.

Finally, EFACEC Energia will communicate and disseminate results (demos) of the Energy pilot in Aveiro, and utility-oriented publications.

2.4.2.2. Operator: ALB

Altice Labs will play the same role in this pilot as in pilot 3, explained in section 2.3.2.2.

2.4.2.3. Cloud Service Provider & HW/SW Supplier: IT

IT Aveiro will play the same role in this pilot as in pilot 3, explained in section 2.3.2.3.

2.4.3. Trial Use Cases - Present Scenario

The communication between intelligent electronic devices present in the pilot is made mainly through radio frequency technologies (LoRa and 4G) and Power Line Carrier (PLC). LoRa technology enables wireless communications over long distances with minimal energy consumption. The communication through PLC supports a wired communication channel with low operation costs and low bandwidth. 4G mobile communication technology enables mobile web access, IP telephony, high definition mobile TV and video conferencing.

However, all these technologies are not effective for priority services, such as the energy services. Taking into account the case studies with focus on mobile communications, it is verified that the theoretical maximum speed of data transmission of 300 Mbps for 4G networks (the typical real world network speed is only around 30Mbps), and a latency of approximately 40ms do not allow the transmission of data with sufficient precision to address the features desired in this pilot. It is therefore vital to ensure substantially lower latencies and higher data rates to achieve HD video transmissions and real-time communications.

2.4.4. Trial Use Cases - Future Scenario

An enhanced performance from the critical signals' communication, across wide smart sensors infrastructures, is crucial for the deployment of advanced control applications. Also, an enhanced performance from the advanced monitoring and maintenance support of secondary substation is crucial to improve the outage management and match the high reliability indexes required within a smart grid environment.

Supported by smart devices, e.g., sensors, distributed controllers and concentrators, cloud based edge, electric data meters and more centralised advanced management systems with very low latency communication, the pilot will permit targeting an agile signal exchange, between the capable devices deployed across the network, placed within an area up to 10 km2, and both the distributed intelligence and the centralised controllers.

By means of data processing, it will add value to the data of low-voltage distribution networks. From the standpoint of maintenance and operation, it will take advantage of 5G's communication capabilities to streamline the process, delivering robust results.

Once covered by the communications framework proposed for the pilot, the most relevant 5G features and requirements, subsequently identified, will allow the implementation of the above-mentioned functionalities.

Edge solutions will be implemented for cloud computing optimisation of the dedicated edge centre. Edge computing will add enhanced distributed control and the capacity to run critical applications for the supervision and control of multiple LV-Smart Grids, and the advanced management of LV Micro Grids.

Concerning 5G communication connectivity, the energy pilot will be supported by the 5G-VINNI experimental site, located in Aveiro and operated by Altice Labs. The Figure below depicts the 5G-VINNI PoPs, Core and Edge, which will support the 5G-Core and 5G-RAN components, respectively. The Figure also shows the extended 5Growth locations covered by the 5G new radio, in the perimeter of the Aveiro University Campus.

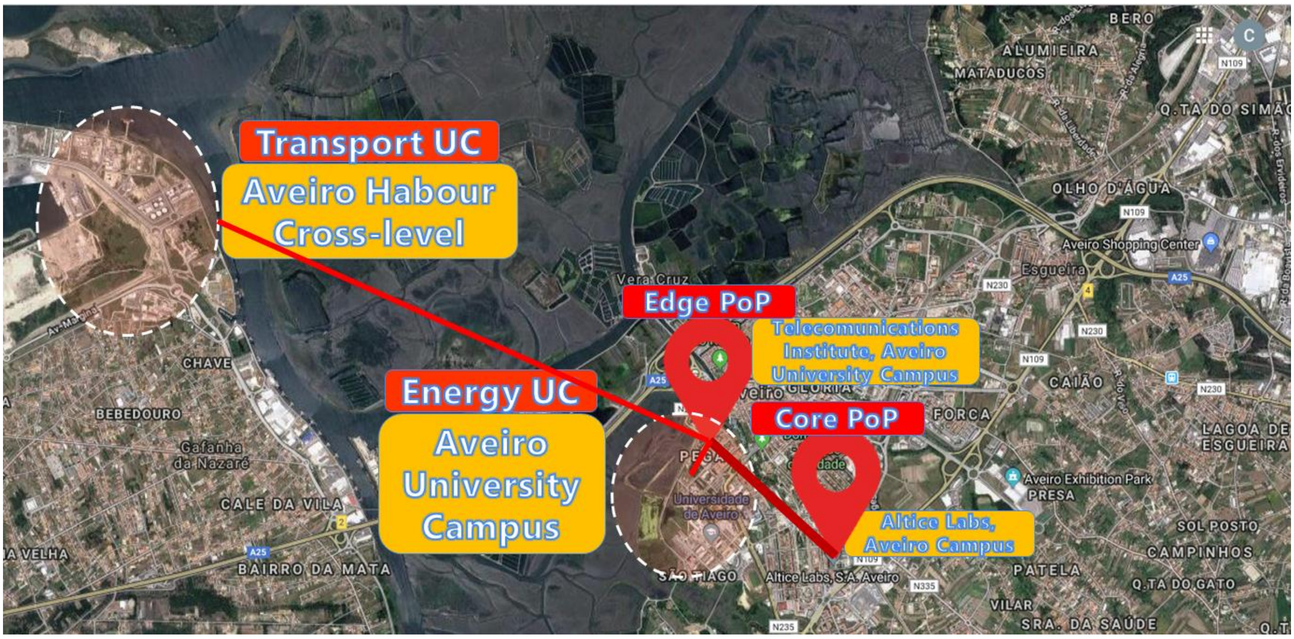

FIGURE 15: AVEIRO SITE

2.4.5. Expected Results

P4UC1 Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV distribution substation will assist the remote operator and then the crews dispatched to the field to better assess the severity and the impact of the outage they are facing. From the local surveillance systems available in the secondary substation, an HD video signal must be streamed in nearly real-time to the control centre and to the mobile devices of the maintenance crew. Aware of the infrastructure state, the crew and the operator managing the intervention, can be more efficient when implementing contingency and service restorations measures. Locally, the crews should also be capable of assessing and broadcasting an augmented reality experience on the affected critical assets. The crews will thus gain an insight over the damage magnitude and the immediate consequences of the outage they are dealing with, leading to shorter response times.

As critical data from remote real-time monitoring and control must be exchanged between several smart devices deployed across an entire infrastructure, the synchronisation is particularly relevant, ideally with delays of a few milliseconds. P4UC2 Advanced Critical Signal and Data Exchange Across Wide Smart Metering and Measurement Infrastructures concerns the last-gasp features of smart devices, once fed from the bus they are monitoring, and they can process the value of the data exchanged during that critical last-gasp process. In other words, the control and management systems can extract relevant information from the last-gasp data received in order to perform faster and more precise fault detection and location.

Low latency communications are therefore required immediately after the power outage is detected by the device, to minimise the demand on the device power supply, enabling the device to perform the required housekeeping and to hold the communication channel active to send the last-gasp message before the device power supply storage capability is totally exhausted. An even lower latency and higher connection density are required when trying to synchronise the referred smart devices – meters and sensors –, for data exchange, which will improve the general quality of the gathered data, benefiting advanced control applications dependent on correlation analysis and big data processing.

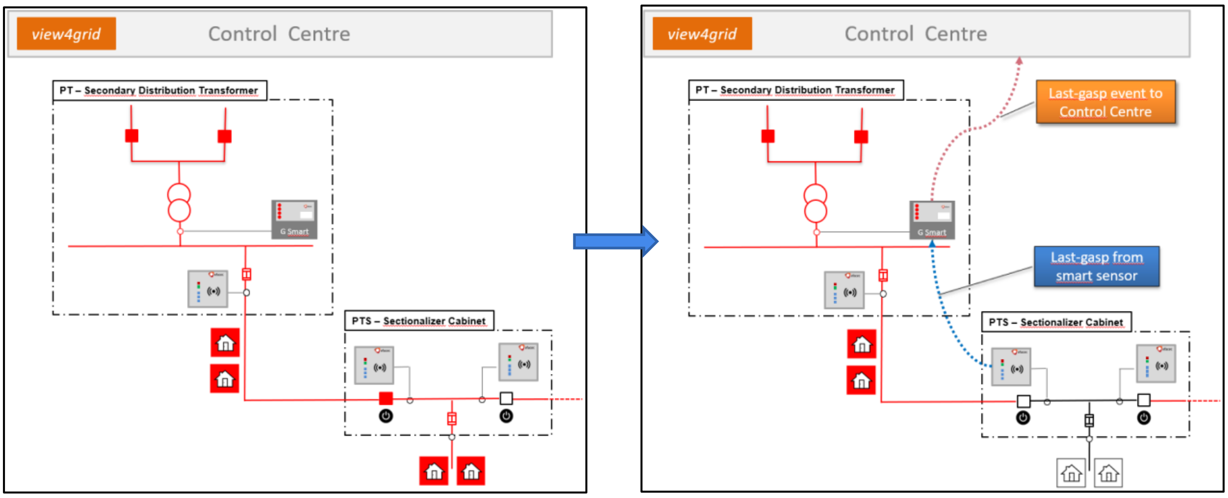

FIGURE 16: LAST-GASP USE CASE EXEMPLIFICATION TRIGGERED BY AN OUTAGE

3. Pilot's Requirements

This section gives a more detailed vision of each of the use cases that are going to be developed in 5Growth. First, a description of the use case and the new developments is provided, and the main objectives are highlighted. Then, what are the main conditions on each use case, the main actors involved in each process, the flow of the enhanced use case and the key performance indicators create a framework to define the requirements for each use case in three levels: business requirements, which are high-level, and focus on the business point of view; functional requirements, that refer to the process itself and the functionality and, finally, the technical requirements, that are more related to the technologies applied.

3.1. Industry 4.0 Pilot - INNOVALIA

3.1.1. P1UC1: Connected Worker Remote Operation of Quality Equipment

3.1.1.1. Use Case Description

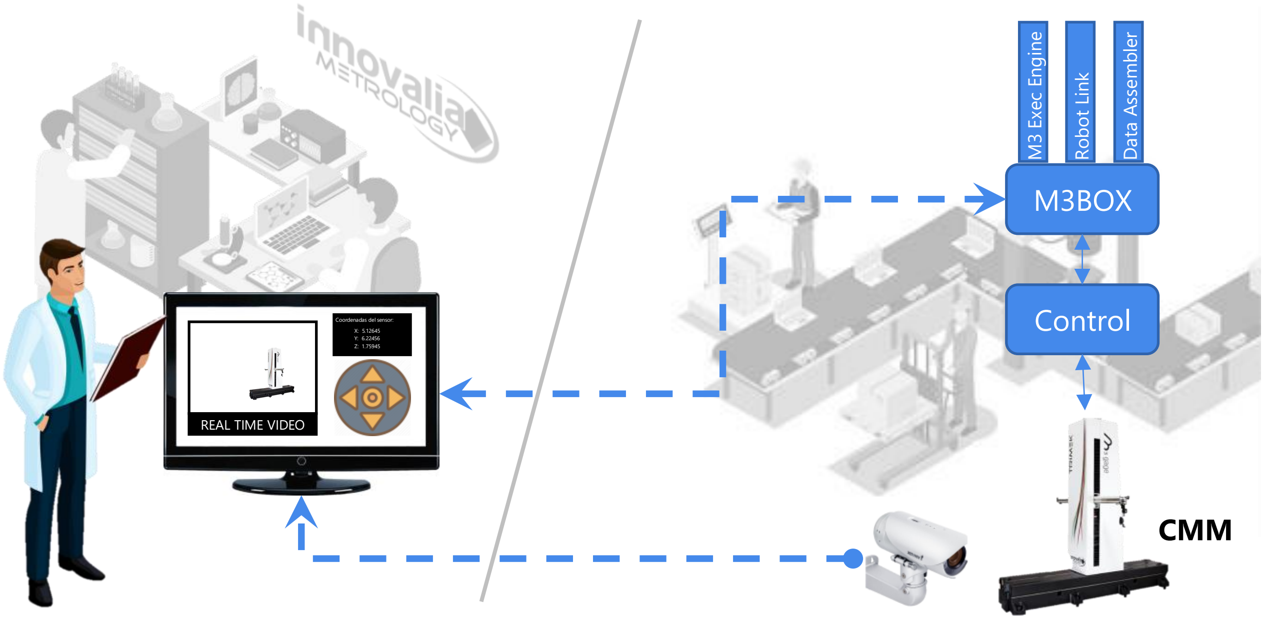

FIGURE 17: P1UC1 OVERVIEW

The first scenario of this pilot is the *Connected Worker Remote Operation of Quality Equipment*, that consists of enabling the remote operation in real time of the CMM. This means that the metrology expert will be able to configure the CMM that is in the manufacturing site from the INNOVALIA headquarters, saving time and money by reducing travels or submissions of parts.

In Figure 17 we have a representation of the use case. To the right, we have the production line, where there's a CMM and its controller, connected to M3BOX, an edge device provided by INNOVALIA that runs the three main software services needed to operate the CMM:

M3ExecutionEngine¸which stores the inspection program, *RobotLink*, used to manage the machine itself (basically, the movement of the arm that holds the sensor in 3 axes), and *DataAssembler*, which manages the functioning of the optical sensor (setting the resolution and turning it on and off). The camera represents the video streaming from both cameras (a general view and a light camera attached to the sensor to see the detailed zone being scanned) from the site to the INNOVALIA's premises (to the left), where metrology experts will have an interface to see the video streaming while controlling the machine with a virtual joystick.

For this development, most of the components of the CMM and its behaviour will have to be virtualized, and a remote connection will have to be configured. On a first step, this will allow to configure the machine via command line (by introducing the coordinates), and on a second step a virtual Joystick will be developed to make the use of the system more usable.

To see how the CMM is moving, and to ensure the correct configuration of the trajectory of the sensor, the operator must see in real time how the CMM is moving as he programs it, that's why there's also a need to transmit high definition video from the client venue, where the machine is, to the operators workplace, in INNOVALIA headquarters. This video should have a very low latency, as the user (the INNOVALIA expert) has to control the CMM based on the video feedback.

This way, the metrology expert will be able first, to upload the measuring program that he will have prepared and simulated offline, and then prepare the machine (with the processes of qualification and referencing) and then check and optimize the measuring program, leaving it ready to measure a specific reference.

3.1.1.2. Use Case Objectives

The main objective of this use case for INNOVALIA is to demonstrate the benefits of using 5G services in an industrial environment to enable a secure & independent channel to connect to INNOVALIA's quality control equipment without interfering with the regular operation of the factory where it is installed.

This will allow INNOVALIA to develop a new range of services, beginning with the remote configuration of the CMM's, which will improve the service provided to its clients, by drastically reducing the response time and the costs of this operation.

3.1.1.3. Use Case Conditions

The use case requires, first of all, the virtualization of the CMM, to enable the remote control of the machine and the virtual representation of the status of the machine (position of the sensor, etc).

Second, a real time visualization of the environment (a video stream of the machine) to show the movement of the sensor and avoid collisions, and a more detailed video visualization of the surface the sensor is scanning (with a light camera attached to the sensor) is also necessary to assess the trajectory of the sensor and verify that the scan covers all the needed parts of the piece.

To provide information to the metrology expert who is connecting remotely, a 3D virtual display of the machine in real time will also be required.

From the network point of view, 5G services must be available both in INNOVALIA premises and in the factory where the CMM is installed.

3.1.1.4. Actors Involved

There are two main actors on this scenario:

- Factory Manager: Initiates the process, by giving access to the metrology expert.
- Metrology Expert: connects remotely to configurate the CMM.

3.1.1.5. Use Case Flow

1. The client requests INNOVALIA Metrology to reconfigure the CMM for any reason. They factory manager requests the operator to give access to the network to the metrology expert assigned.
2. The metrology expert connects remotely to the machine from INNOVALIA's HQ.
3. The metrology expert charges the measuring program prepared and simulated offline.
4. The expert configures the machine using the command line and a virtual joystick.
5. The instructions are received by Robotlink or DataAssembler, as part of the M3Box, which is an edge device.
6. Robotlink or DataAssembler process the instructions, and submit them to the controller of the CMM, that activates the movement of the CMM.
7. The two cameras show the movement to the operator as it happens.
8. The metrology expert saves the configuration and quits the connection.
9. The client now can use the CMM with the new configuration.

3.1.1.6. Use Case Indicators

- Reduce the total program preparation and deployment time (necessary time from the submission of the CAD file until the CMM can start measuring) by 50%, compared to conventional programming.
- Optimize the inspection execution cycle (that is, the cycle from the piece arriving to the measuring station until the manager gets the results), by reducing the time it consumes by 15%, which means a significant increase of the productivity.
- Reduce assistance and expert support costs by 30%: The remote operation of the CMM by the metrology experts in order to configure the machine can reduce in a significant way the number of visits that metrology experts have to make to the clients, although there are still many maintenance tasks that will require these visits. This will reduce the travel expenses and also increase the availability of the experts, that will be able to give service to more clients in the same time.

- Reduce the service response time by 40%: By connecting remotely the service response time will be drastically reduced in the cases that this can be applied, as it won't be necessary to organize a trip and the experts will have more availability to attend the service support requests.

3.1.1.7. Business Requirements

TABLE 1: BUSINESS REQUIREMENTS (P1UC1)

BR-ID	Description	Notes
BR-P1UC1-01	Deploy a system to remotely configure the machines, to reduce the travel of CMM's experts	
BR-P1UC1-02	Have an independent and secure channel to connect to the M3Box device to control the calibration procedure	
BR-P1UC1-03	Deploy a fully operable infrastructure to ease the process of factory remote operation	
BR-P1UC1-04	Provision of monitoring parameters (through a portal or in the form of a dashboard) to ensure the correct operation of the factory	
BR-P1UC1-05	Assurance of SLAs agreed with the customer (QoS, reliability, etc)	

3.1.1.8. Functional Requirements

TABLE 2: FUNCTIONAL REQUIREMENTS (P1UC1)

FR-ID	Description	BR-ID
FR-P1UC1-01	The factory manager is the one that initiates the process	BR-P1UC1-01 BR-P1UC1-02
FR-P1UC1-02	Security measures to avoid unauthorised access to the CMM	BR-P1UC1-01 BR-P1UC1-02
FR-P1UC1-03	Usable interface for the Metrology Expert (virtual joystick)	BR-P1UC1-01
FR-P1UC1-04	Real time video streaming to see the movement of the CMM	BR-P1UC1-01
FR-P1UC1-05	Enable 5G connectivity to the M3Box edge device	BR-P1UC1-01 BR-P1UC1-02
FR-P1UC1-06	Security of the data interchange (encryption)	BR-P1UC1-01 BR-P1UC1-02
FR-P1UC1-07	Radio of action – From Bilbao to Europe	BR-P1UC1-03 BR-P1UC1-04 BR-P1UC1-05
FR-P1UC1-08	The industrial environment must be equipped with 5G-enabled devices	BR-P1UC1-03 BR-P1UC1-04 BR-P1UC1-05
FR-P1UC1-09	High availability of the remote connection including redundant connection in order to guarantee the communication in case of failure	BR-P1UC1-05

FR-P1UC1-010	Solution shall include additional capabilities (e.g., specific features, probes) that will take care of the monitoring process	BR-P1UC1-04
FR-P1UC1-011	Solution must support programmability and virtualization to enable flexible and dynamic reconfiguration	BR-P1UC1-03 BR-P1UC1-04 BR-P1UC1-05
FR-P1UC1-012	The solution must guarantee proper levels of isolation (in the form of network slice)	BR-P1UC1-02 BR-P1UC1-05
FR-P1UC1-013	Simultaneous support of integrated communications (voice, data, etc)	BR-P1UC1-02

3.1.1.9. Technical Requirements

TABLE 3: TECHNICAL REQUIREMENTS (P1UC1)

Code	Description	
TR-P1UC1-01	Apply cybersecurity policies to protect the connection from unauthorised access.	FR-P1UC1-02 FR-P1UC1-06
TR-P1UC1-02	Transmission of coordinates and some other parameters (start-stop, etc) between the Metrology expert terminal and the CMM	FR-P1UC1-03
TR-P1UC1-03	Video minimum HD definition. Better 4K.	FR-P1UC1-04
TR-P1UC1-04	End-to-End encryption usage	FR-P1UC1-06
TR-P1UC1-05	Availability 99,99%	FR-P1UC1-09
TR-P1UC1-06	Max. Speed 3km/h (operator walking)	ALL
TR-P1UC1-07	Usage of TCP protocol for the control. (Joystick to M3Box)	FR-P1UC1-03
TR-P1UC1-08	Usage of RTSP for the video streaming (TCP and UDP)	FR-P1UC1-04
TR-P1UC1-09	E2E Latency <5ms	FR-P1UC1-03 FR-P1UC1-04
TR-P1UC1-10	Bandwidth: 100Mbps (4K video needs 15Mbps) eMBB slice	ALL
TR-P1UC1-11	Bandwidth: 128 - 400 Kbps (Control slice) URLLC slice	ALL
TR-P1UC1-12	Camera, M3Box, Joystick and Display must allow 5G connections	ALL
TR-P1UC1-13	The 5G network must allow 5G slicing. For eMBB and URLLC. It could be non-permanent slices	ALL
TR-P1UC1-14	The network shall offer QoS marking according to the flows required to be differentiated	ALL
TR-P1UC1-15	The network shall offer traffic prioritization policy	ALL
TR-P1UC1-16	Maximum 2 simultaneous users in the INNO site (2 metrology experts can operate machines in different factories from the INNOVALIA premises) and 1 per factory	ALL

3.1.2. P1UC2: Connected Worker: Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS)

3.1.2.1. Use Case Description

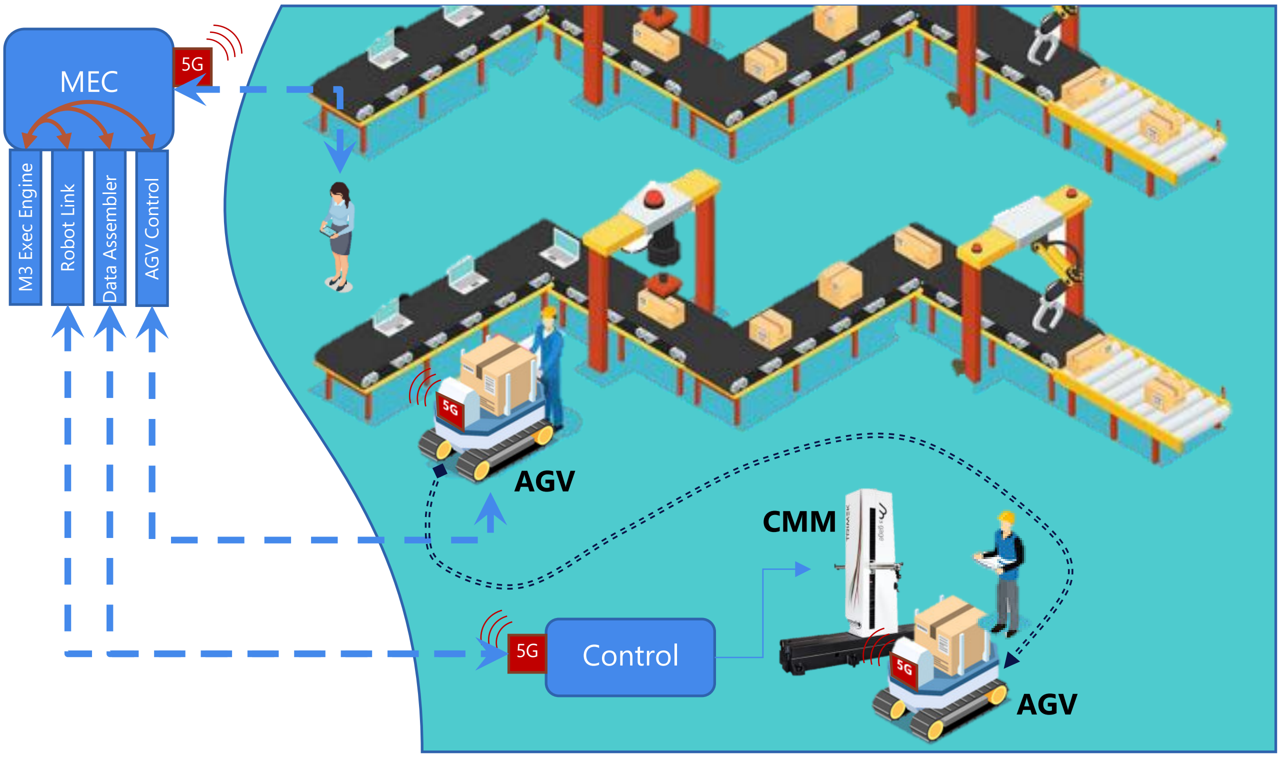

FIGURE 18: P1UC2 OVERVIEW

On the second scenario, the edge components used on the metrology process (M3ExecutionEngine, RobotLink and Data Assembler) will be deployed on a cloud-edge service provided by the operator, as well as the component that controls the AGV. This will allow to semi-automatize the measuring process, by enabling the communication between the AGV controller and the CMM.

The AGV will be equipped with the fixtures where the piece to be measured is attached. These fixtures force the operator to place the piece in a certain position so the inspection program can measure it. It will go to the production line, where the operator will take a specific part and will attach it. Then, the AGV will take it to the CMM, where the AGV will communicate with the CMM so that the measuring process starts. When the process finishes, the AGV will take the piece to the proper place.

With the usage of flexible fixtures, it will not only be possible to measure one kind of piece from different production lines, but also to measure similar pieces or different series of the same piece.

3.1.2.2. Use Case Objectives

The objective of this Use Case is to explore the potential benefits of using a 5G edge infrastructure to deploy INNOVALIA software components together with other machines to enable M2M communication, creating new collaboration capabilities between systems.

A first example of these new collaboration capabilities would be the collaboration between the CMM and AGV's to improve the performance of the quality control station by allowing to share one CMM among several production lines making the same product or, if using flexible fixtures, even different products.

3.1.2.3. Use Case Conditions

First, both the AGV controller and the CMM controllers must be deployed in the cloud-edge provided by the service provider.

Second, it will be necessary to establish a communication language between both machines, defining the type of messages that will be interchanged and the protocol for the communications. This protocol must be simple in terms of computing operations but robust in terms of failover mechanisms, include the part/program identifier (to indicate M3EE which program has to load), being able to communicate the system status, events and errors.

A dashboard with the process status shall be developed to show the current service status information.

Finally, both machines have to enable 5G as a communication technology.

3.1.2.4. Actors Involved

The main actors involved in this use case are:

- Production line operator: will attach the piece to be measured in the fixtures that are on the AGV, and indicate the AGV to take it to the measuring station.
- Quality control operator: will overlook the measuring process.
- Quality control manager / plant manager: will analyze the data obtained.

3.1.2.5. Use Case Flow

1. The operator in the production line gets a piece to be measured and attaches it to the fixtures in the AGV. Introduces the reference that has been attached in the AGV program (or the manager does it previously). The AGV informs the CMM of the reference code of the next product to be measured.
2. The AGV takes the piece to the CMM, while the inspection program of the reference is charged in the M3 Execution Engine.
3. When the AGV arrives, sends a message to the CMM, that does the part alignment and then starts the execution of the measuring process. The AGV is blocked, waiting for the CMM to finish.
4. The CMM sends a message to the AGV indicating the scan is over and starts the calculation process.
5. The AGV returns the piece to the operator (or somewhere else).
6. The Manager gets the data and visualizes it.

Figure 19 pictures the communication flows between the AGV and the CMM.

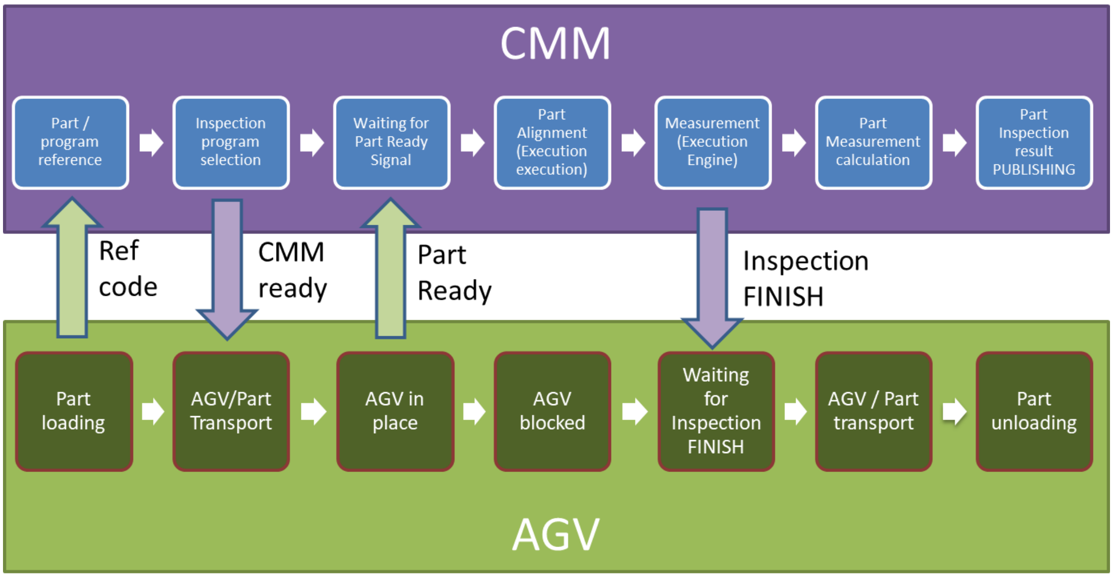

FIGURE 19: INSPECTION EXECUTION FLOW

3.1.2.6. Use Case Indicators

There are four specific Business KPI's related to this use case:

- Inspection execution cycle optimization, increasing inspection capacity by 15%: sharing a CMM among several production lines and being able to measure different pieces without changing the fixtures will increase the occupancy of the measuring machine.
- Increase in production line flexibility by 30%: being able to change the measuring execution program allows to change the reference being produced with a low impact on the measuring station.
- Increase the quality control coverage, which is the number of inspected parts, by a 15%.
- Reduction of scrap by the in-line flexible inspection on a 10%.

3.1.2.7. Business Requirements

TABLE 4: BUSINESS REQUIREMENTS (P1UC2)

BR-ID	Description	Notes
BR-P1UC2-01	Share a CMM among different production lines	
BR-P1UC2-02	Allow the deployment of the software to control the CMM (Robotlink and DataAssembler) into any Edge Device	
BR-P1UC2-03	Fully operable infrastructure to ease the process of factory remote operation	
BR-P1UC2-04	Provision of monitoring parameters (through a portal or in the form of a dashboard) to ensure the correct operation of the factory	
BR-P1UC2-05	Assurance of SLAs agreed with the customer (QoS, reliability, etc)	

3.1.2.8. Functional Requirements

TABLE 5: FUNCTIONAL REQUIREMENTS (P1UC2)

FR-ID	Description	BR-ID
FR-P1UC2-01	Externalization of the Edge Computing system	BR-P1UC2-02
FR-P1UC2-02	M3 software deployed in the manager device (laptop, tablet)	BR-P1UC2-01
FR-P1UC2-03	Deployment of Robotlink, DataAssembler and AGV control services on a Cloud Edge System	BR-P1UC2-01 BR-P1UC2-02
FR-P1UC2-04	Enable 5G connectivity on the CMM controller	BR-P1UC2-01
FR-P1UC2-05	CMM-AGV communication protocol working over 5G connection	BR-P1UC2-01
FR-P1UC2-06	Enable 5G connectivity on the AGV	BR-P1UC2-01
FR-P1UC2-07	Enable 5G connectivity on the manager device	BR-P1UC2-01
FR-P1UC2-08	Security: end-to-end encryption	ALL
FR-P1UC2-09	The industrial environment must be equipped with 5G-enabled solutions	ALL
FR-P1UC2-10	High availability of the remote connection including redundant connection in order to guarantee the communication in case of failure	BR-P1UC2-03 BR-P1UC2-04 BR-P1UC2-05
FR-P1UC2-11	Solution must include additional capabilities (e.g., specific features, probes) that will take care of the monitoring process	BR-P1UC2-04
FR-P1UC2-12	Solution must support programmability and virtualization to enable flexible and dynamic reconfiguration	ALL
FR-P1UC2-13	The solution must guarantee proper levels of isolation (in the form of network slice)	ALL

3.1.2.9. Technical Requirements

TABLE 6: TECHNICAL REQUIREMENTS (P1UC2)

TR-ID	Description	FR-ID
TR-P1UC2-01	Availability/Reliability of 99.99%	ALL
TR-P1UC2-02	E2E Latency < 5ms	ALL
TR-P1UC2-03	Bandwidth: 1 Gbps	ALL
TR-P1UC2-04	Low connection density (less than 20 connections)	ALL
TR-P1UC2-05	Mobility (AGV) 3-50km/h	ALL
TR-P1UC2-06	The network shall support QoS marking according to the flows required to be differentiated	ALL
TR-P1UC2-07	The network shall support Traffic prioritization policy	ALL
TR-P1UC2-08	Concurrency: for this use case, one AGV, one CMM and one quality control manager will be connected simultaneously	ALL

3.2. Industry 4.0 Pilot - COMAU

3.2.1. P2UC1: Digital Twin Apps

3.2.1.1. Use Case Description

Gartner[5] named the digital twin function as one of the Top 10 Strategic Technology Trends for 2017, and IDC[6] predicts 60 percent of manufacturers will use digital twins as a means of monitoring product/asset performance within the next two years.

Production plants could be really vast and involve a huge number of devices as well as different processes. Having a digital twin of the entire production plant allows to sum up all the information (in terms of cycle time) coming from the field and collect it in order to create historic data and calculate some statistics. Historical data are also used as dataset to retrieve information about future problem.

3.2.1.2. Use Case Objectives

The main idea behind this scenario is to internally develop a tool, which uses the 5G capabilities, to provide plant managers with actual information about the status of the production lines, predicting future failures or bottlenecks, giving the opportunity to move up actions and prevent problems.

3.2.1.3. Use Case Conditions

5G radio must be available at the plant facilities and must be able to collect data from many PLCs guaranteeing no delay in the virtual representation.

3.2.1.4. Actors Involved

The main actors involved in this use case are:

- Plant Manager: is the person who mainly uses this application to be updated about the current, past and future status of plant production lines and carry out actions to keep production rate optimised.
- Logistics: could be involved due to re-arrangement made by the plant manager.
- Operator: the operator could check if his/her production is in line with the programmed one and participate in warding off bottlenecks or failure due to plant manager decisions.

[5] https://www.gartner.com/en/newsroom/press-releases/2016-10-18-gartner-identifies-the-top-10-strategic-technology-trends-for-2017

[6] https://www.idc.com/getdoc.jsp?containerId=US43171317

3.2.1.5. Use Case Flow

1. The plant manager uses the dashboard to monitor actual production and statistical data about historical data.
2. The tool collects data from the field as cycle time values and in case of deviations performs calculations to predict if there will be bottlenecks or line stops.
3. In case of bottlenecks or stops, the plant manager understands which parts of the production plants would be affected and plan actions to mitigate future problems (e.g., increasing shifts).
4. Plant manager has access to a suggestion tool which can show some actions to avoid the problems detected.
5. The plant manager can monitor the effects of his/her decisions monitoring data coming from the field after the re-arrangement.

3.2.1.6. Use Case Indicators

The main indicator is the number of production faults or bottlenecks the system has anticipated and could be measured as the value of the products that would not be produced without it. Other indicators are:

- Reduce infrastructure cost by 20% removing cable and hardware.
- Reduce of technicians' travels by 30% since some problems could be anticipated before a complete damage, requiring less experienced maintenance crew.
- Reduce of failure rate at least of 20% with objective 90% predicting bottlenecks and stops.
- 1000 times higher wireless area capacity and more diverse service capabilities compared to 2010.
- Secure, reliable and dependable Internet with a "zero perceived" downtime for services provision thanks to 5G capabilities.

3.2.1.7. Business Requirements

TABLE 7: BUSINESS REQUIREMENTS (P2UC1)

BR-Id	Description	Notes
BR-P2UC1-01	Connect all the devices in the plant through 5G	
BR-P2UC1-02	Gather quasi real-time data from PLCs	
BR-P2UC1-03	Reduce product line bottlenecks and stops	
BR-P2UC1-04	Have historical data regarding the past and useful statistics	
BR-P2UC1-05	Suggest options to rapidly solve future and imminent problems	

3.2.1.8. Functional Requirements

TABLE 8: FUNCTIONAL REQUIREMENTS (P2UC1)

FR-Id	Description	BR-Id
FR-P2UC1-01	Wi-Fi coverage up to 400m² for office and double for open factory	BR-P2UC1-01
FR-P2UC1-02	Cellular indoor coverage of up to 800 m² for office and double in open factory	BR-P2UC1-01
FR-P2UC1-03	Implement industrial protocols based on cable via wireless connection	BR-P2UC1-02
FR-P2UC1-04	Guarantee updated information with no delays	BR-P2UC1-02
FR-P2UC1-05	Use the COMAU internal tool to collect and analyse data in order to predict future problems in production lines	BR-P2UC1-03 BR-P2UC1-04 BR-P2UC1-05

3.2.1.9. Technical Requirements

TABLE 9: TECHNICAL REQUIREMENTS (P2UC1)

TR-Id	Description	FR-Id
TR-P2UC1-01	Availability/Reliability of 99.9999%	FR-P2UC1-04 FR-P2UC1-05
TR-P2UC1-02	Latency (E2E) < 15ms	FR-P2UC1-03 FR-P2UC1-04 FR-P2UC1-05
TR-P2UC1-03	Bandwidth up to 250Mbps	FR-P2UC1-04 FR-P2UC1-05
TR-P2UC1-04	Connection Density up to 5000devices/km²	FR-P2UC1-01 FR-P2UC1-02
TR-P2UC1-05	Mobility 3-50km/h	FR-P2UC1-01 FR-P2UC1-02
TR-P2UC1-06	Wide-Area Coverage of 5km²	FR-P2UC1-01 FR-P2UC1-02

3.2.2. P2UC2: Telemetry/Monitoring Apps

3.2.2.1. Use Case Description

This second scenario aims to monitor and prevent failures of machinery and equipment through collecting data using sensors (some gathered dimensions could be, as example, vibration, pressure, temperature and so on). 5G facilitates installing a wide range of different wireless sensors easy to attach on machinery with very low latency and huge bandwidth.

COMAU has already developed its own IIoT (Industrial Internet of Things) solution which gathers data directly from machinery as well as sensor data. This tool is constantly updated and now the next objective is to reinforce the fault predictive capabilities.

Using 5G enables to remove cables and many other network hardware, COMAU is thus interested in exploring new production plant architectures with less costs, high resilience and flexibility maintaining of course wired performance.

3.2.2.2. Use Case Objectives

Telemetry is used to monitor the actual health of the machinery and to collect data useful to develop predictive maintenance algorithms. Having software components instead of hardware really increases resilience and flexibility with a significant reduction of costs as well (instead of having our own network infrastructure, we would like to test it as external service).

3.2.2.3. Use Case Conditions

It is really important to check with authorities the feasibility (in term of impact on people health) of installing a 5G architecture in the plants.

3.2.2.4. Actors Involved

The main actors involved in this use case are:

- Plant Manager: he/she uses monitoring/telemetry app to be updated about the status of each machinery in the production line, in case of problems, he/she could arrange maintenance activities in order to prevent stops.
- Maintenance crew: they receive the updates about the maintenance activity from the plant manager.
- Production line programmer: he/she has to deal with a different network architecture (due to cable and hardware removal) and with a set of services moved on virtual machines.
- IT department: it loses the responsibility to manage the network infrastructure but in the new scenario it has to manage with high availability/reliability virtual machines where the production services and controls are hosted.

3.2.2.5. Use Case Flow

1. All the connections on the production plant are not wired anymore and so the operator has to set up the 5G connection as well.
2. The monitoring/telemetry app constantly monitors machinery deployed on the production field and provides their status to the plant manager through a dashboard.
3. In case of arising unexpected problems, the plant manager can change maintenance schedule in order to prevent machinery faults.
4. The IT department has to keep updated and maintained all the virtual machine in order to guarantee high availability and reliability.

3.2.2.6. Use Case Indicators

The use of Telemetry/Monitoring Apps over 5G, will eventually reduce network infrastructure TCO (Total Cost of Ownership) and limit factory outages thanks to a deep preventive maintenance.

- Reduce infrastructure cost by 20% removing cable and hardware.
- Reduce of failure rate at least of 20% with objective 90% predicting machinery faults.
- Reduce MTTR by 20% retrieving early all what is necessary in terms of materials.
- Reduce of technicians' travels by 30% since some problems could be anticipated before a complete damage, requiring less experienced maintenance crew.
- 1000 times higher wireless area capacity and more diverse service capabilities compared to 2010.
- Secure, reliable and dependable Internet with a "zero perceived" downtime for services provision thanks to 5G capabilities.

3.2.2.7. Business Requirements

TABLE 10: BUSINESS REQUIREMENTS (P2UC2)

BR-ID	Description	Notes
BR-P2UC2-01	Connect all the devices in the plant through 5G	
BR-P2UC2-02	Gather quasi real-time data from PLCs	
BR-P2UC2-03	Replace as much network hardware as possible to reduce Total Cost of Ownership	
BR-P2UC2-04	Have historical data regarding the past and useful statistics regarding single machineries such as robots, conveyor, and so on	

3.2.2.8. Functional Requirements

TABLE 11: FUNCTIONAL REQUIREMENTS (P2UC2)

FR-ID	Description	BR-ID
FR-P2UC2-01	Wi-Fi coverage up to 400m² for office and double for open factory	BR-P2UC2-01 BR-P2UC2-03
FR-P2UC2-02	Cellular indoor coverage of up to 800 m² for office and double in open factory	BR-P2UC2-01 BR-P2UC2-03
FR-P2UC2-03	Guarantee updated information with no delays	BR-P2UC2-02
FR-P2UC2-04	Enable 5G connectivity on as much machineries as possible	BR-P2UC2-03 BR-P2UC2-06
FR-P2UC2-05	Implement industrial protocols over wireless channel	BR-P2UC2-06
FR-P2UC2-06	Use the COMAU internal tool to collect and analyse data in order to predict future problems in machineries	BR-P2UC2-04 BR-P2UC2-05
FR-P2UC2-07	High availability and low latency of connection in order to avoid machine stops	BR-P2UC2-06

3.2.2.9. Technical Requirements

TABLE 12: TECHNICAL REQUIREMENTS (P2UC2)

TR-ID	Description	FR-ID
TR-P2UC2-01	Availability/Reliability of 99.999%	FR-P2UC2-04 FR-P2UC2-05 FR-P2UC2-07
TR-P2UC2-02	Latency (E2E) $\subset$ [15 ms-100 ms]	FR-P2UC2-03 FR-P2UC2-04 FR-P2UC2-05
TR-P2UC2-03	Bandwidth up to 250Mbps	FR-P2UC2-03 FR-P2UC2-06
TR-P2UC2-04	Connection Density up to 5000devices/km^2	FR-P2UC2-01 FR-P2UC2-02
TR-P2UC2-05	Mobility 3-50km/h	FR-P2UC2-01 FR-P2UC2-02
TR-P2UC2-06	Wide-Area Coverage of 5km^2	FR-P2UC2-01 FR-P2UC2-02

3.2.3. P2UC3: Digital Tutorials and Remote Support

3.2.3.1. Use Case Description

The purpose of this use case is to provide technicians and maintenance staff with digital tutorials and remote support by means of high definition videos and live connections to remote technical offices.

3.2.3.2. Use Case Objectives

The main objective is to reduce the MTTR using real-time streaming with a skilled technician in remote locations to support maintenance and repair operations. Other advantage is the possibility to access to tutorials and instructions for training purposes.

3.2.3.3. Use Case Conditions

It is really important to check with authorities the feasibility (in term of impact on people health) of installing a 5G architecture in the plants.

3.2.3.4. Actors Involved

The main actors involved in this use case are:

- Maintenance operator: he/she could use the application both for training or to call a more experienced maintainer in order to be able to perform a task that he/she would not able to do alone.

- Experienced maintenance operator: could help remotely and rapidly colleagues less experienced reducing MTTR and getting rid of the need to trip to the plant where the problem is.
- New maintenance operator: he/she uses this app to receive his/her first practical course and to increase his/her experience as well.

3.2.3.5. Use Case Flow

1. Load all 3D models and maintenance procedures on the system in order to populate the database.
2. In case of problems in a production plant where there is not an enough experienced maintenance operator, thanks to the tool developed in P2UC3, it is possible to call the right technician (wherever he/she is) who can drive step by step the maintenance task.
3. Talking about training, it is possible to learn new maintenance procedures studying step by step example as much natural as possible thanks to augmented/virtual reality.

3.2.3.6. Use Case Indicators

Main benefits will be an increase in productivity due to the possibility to access live tutorials/instructions and video tutorials, as well as a reduction of MTTR thanks to the real-time connection with technicians in remote locations supporting maintenance and repair operations.

- Reduce infrastructure cost by 20%.
- Reduce MTTR by 20%.
- Reduce of technicians' travels by 30%.
- Reduce of failure rate at least of 20% with objective 90%.
- Service response time reduced by 30%.
- 1000 times higher wireless area capacity and more diverse service capabilities compared to 2010.
- Secure, reliable and dependable Internet with a "zero perceived" downtime for services provision.

3.2.3.7. Business Requirements

TABLE 13: BUSINESS REQUIREMENTS (P2UC3)

BR-ID	Description	Notes
BR-P2UC3-01	Connect maintenance crew devices all over the plant	
BR-P2UC3-02	Reduce the Mean Time to Repair (MTTR)	
BR-P2UC3-03	Reduce the need of moving technicians where the problem is	
BR-P2UC3-04	Train more effectively and faster new employees	

3.2.3.8. Functional Requirements

TABLE 14: FUNCTIONAL REQUIREMENTS (P2UC3)

FR-ID	Description	BR-ID
FR-P2UC3-01	Wi-Fi coverage up to 400m² for office and double for open factory	BR-P2UC3-01
FR-P2UC3-02	Cellular indoor coverage of up to 800 m² for office and double in open factory	BR-P2UC3-01
FR-P2UC3-03	High quality stream video with low delay	BR-P2UC3-02 BR-P2UC3-03
FR-P2UC3-04	Provide the possibility to interact using the same tool	BR-P2UC3-02 BR-P2UC3-03
FR-P2UC3-05	Have a storage where save procedures and 3D models of machineries	BR-P2UC3-04

3.2.3.9. Technical Requirements

TABLE 15: TECHNICAL REQUIREMENTS (P2UC3)

TR-ID	Description	FR-ID
TR-P2UC3-01	Availability/Reliability of 99.9999%	FR-P2UC3-03 FR-P2UC3-04 FR-P2UC3-05
TR-P2UC3-02	Latency (E2E) < 15ms	FR-P2UC3-03 FR-P2UC3-04
TR-P2UC3-03	Bandwidth up to 500Mbps	FR-P2UC3-03 FR-P2UC3-04 FR-P2UC3-05
TR-P2UC3-04	Connection Density up to 1000devices/km²	FR-P2UC3-01 FR-P2UC3-02
TR-P2UC3-05	Mobility 3km/h	FR-P2UC3-01 FR-P2UC3-02
TR-P2UC3-06	Wide-Area Coverage of 5km²	FR-P2UC3-01 FR-P2UC3-02

3.3. Transportation Pilot - EFACEC Engenharia e Sistemas

3.3.1. P3UC1: Safety Critical Communications

3.3.1.1. Use Case Description

The use case will demonstrate the use of 5G communications in railway safety critical communications, between the level crossing train detector activation points and the LX (Level Crossing) controller (Figure 20). The traditional copper wire cables will be replaced by wireless 5G communications technology and safety communications protocols will be developed to comply with railway signalling safety communications standards EN50159-2 class 77.

The use case will install a complete half barrier level crossing control system in a railroad crossing in the Aveiro harbour premises. The system will include a LX controller cabinet equipped with SIL4 safety PLC, an axle counter train detection system, EMC protection devices, an uninterruptible power supply and a 5G CPE. Each approaching train detector will use a 5G CPE to communicate with the level crossing controller. Two half barrier drives, controlled by the LX controller, will protect the entry of cars in the rail crossing during the train approaching and passing. All the communications will be supported by safety-critical protocols (Safe Ethernet and RASTA), developed and certified under the scope of the project.

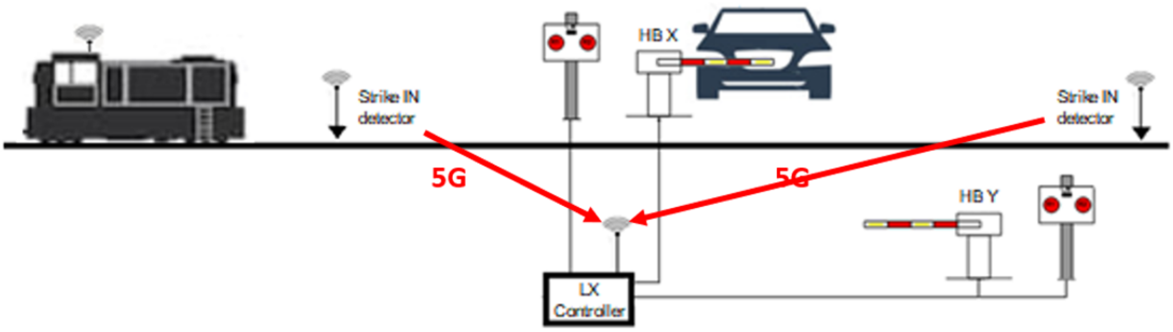

FIGURE 20: P3UC1 THE VERTICAL TRANSPORTATION PILOT

3.3.1.2. Use Case Objectives

The purpose of this pilot use case is to use 5G communications to support railway signalling operations, in particular to meet railway level crossing (Figure 20) communication requirements (M2M), namely for safety critical communications from approaching train detectors (Strike In detectors) to the level crossing controllers.

3.3.1.3. Use Case Conditions

Preconditions

Typically, if the communications are established properly (between the train detectors and the Level Crossing controller) the half barriers must be open (allowing the cars passing through it), the traffic lights must be green. If the communications are not established, the level must be set to safe mode position (half barriers must be down, not allowing the car to pass over the track line) the traffic lights must be red, and the LX signal protection must be also red. Therefore, the communication between all Level Crossing equipment must be guaranteed.

Postconditions

In the presence of an approaching train (strike in/train detector), specific messages (axle detection and axle count information) must be sent to the LX controller, to inform that a train is approaching the level crossing as well to transmit the status of the equipment on the track. The LX controller then must start the set of actions to assure safe conditions to the train, cars and people. After detecting that the train has left the Level Crossing (passing), the peripherical devices must return to normal state. Therefore, the LX controller gets the sensors information to automatically define the position of the half-barriers, the traffic lights and the protection signal.

3.3.1.4. Actors Involved

The main actors in this use case are:

1. Train: The machine responsible to transport people or freight.
2. Driver: Person who is responsible to drive the train.
3. Strike in detectors/axle counter train detector system: Device (system) that is able to detect if a train is approaching the level crossing area.
4. Train detectors/axle counter train detector system: Device (system) that detects if the train is occupying the Level Crossing section or to the detect the absence of the train in that section.
5. Traffic lights: Device that is installed in the Level Crossing area and is responsible to process traffic information.
6. Lx protection signals: device used to inform the train driver that he can proceed (level crossing is free), or if he must stop the train (level crossing is occupied, or its operation status is unknown).
7. LX controller: it is a shelter of devices that receive sensors and equipment information, process this information and assures the LX actions (railways signalling operation).
8. Half Barriers: The device that physically protects the Level Crossing against non-authorized entrances.
9. 5G CPEs: device responsible for 5G Machine-to-Machine data exchange.

3.3.1.5. Use Case Flow

Regarding the flow, the scenario can be characterized as follows:

1. Train detection system detects the presence of an approaching train.
2. Train detection system sends information to the LX controller (LX controller is permanently requesting and receiving equipment status and detection information.
3. LX controller starts safety actions managing all the peripheral devices (road and protection signals, bells, half-barriers) according to the track section occupancy status.
4. Train detection system detects that the level crossing train section is released (not occupied) and sends this information to the LX controller.
5. LX controller starts new safety actions managing the peripheral devices properly (Lx area is free for people and cars).

3.3.1.6. Use Case Indicators

Following an initial analysis performed during the proposal phase, several business KPIs are provided, used to validate the use cases from a business perspective. The indicators are:

- Reduce system capex by 20%.
- Reduce system installation cost by 50%.
- Reduce installation time by 50%.
- Reduce cable cost by 80%.
- Reduce maintenance visits by 20%.
- Reduce service response time by 20%.

3.3.1.7. Business Requirement

TABLE 16: BUSINESS REQUIREMENTS (P3UC1)

BR-ID	Description	Notes
BR-P3UC1-01	A train detector system will be needed to detect trains approaching the Level Crossing	
BR-P3UC1-02	A train detector system will be needed to detect if the train is occupying the Level Crossing section or to the detect the absence of the train in the section	
BR-P3UC1-03	An information system will be needed to inform car driver's if the Level Crossing is free	
BR-P3UC1-04	An information system will be needed to inform train drivers that the Level Crossing is free	
BR-P3UC1-05	A dedicated and critical system will be needed to receive sensors and equipment information and to assure the LX actions (railways signalling operation)	
BR-P3UC1-06	Communication technology need to be present to exchange information between the system components	
BR-P3UC1-07	Wireless Communication, with the same level of safety and security need to be present to exchange information between the system components in order to reduce installation and maintenance costs	

3.3.1.8. Function Requirements

TABLE 17: FUNCTIONAL REQUIREMENTS (P3UC1)

FR-ID	Description	BR-ID
FR-P3UC1-01	The communications between the components (track lines equipment's and LX controller) must use standard protocols both for safety and security	BR-P3UC1-06 BR-P3UC1-07
FR-P3UC1-02	A Strike-In detector/axel counter train detector system will be needed to detect trains approaching the Level Crossing	BR-P3UC1-01
FR-P3UC1-03	A Train detector/ axel counter train detector system will be needed to detect if the train is occupying the Level Crossing section or to the detect the absence of the train in the section	BR-P3UC1-02
FR-P3UC1-04	A LX controller will be needed to receive sensors and equipment information and to assure the LX actions (railways signalling operation)	BR-P3UC1-05 BR-P3UC1-06
FR-P3UC1-05	The communication between the Strike-in detectors and the LX controller must be supported over IP	BR-P3UC1-06
FR-P3UC1-06	In a presence of communication failures, the LX must be set to its safe mode (protection mode)	BR-P3UC1-06
FR-P3UC1-07	The communication between the axel counters and the LX controller must be 5G	BR-P3UC1-07
FR-P3UC1-08	Traffic lights will be needed to inform car driver's	BR-P3UC1-03
FR-P3UC1-09	Protection Lx Signals will be needed to inform train drivers that the Level Crossing is free	BR-P3UC1-04
FR-P3UC1-10	5G CPE devices will be needed to assure the 5G connectivity of Lx devices to 5G network	BR-P3UC1-06 BR-P3UC1-07
FR-P3UC1-11	5G CPE devices must support Ethernet interfaces	BR-P3UC1-07
FR-P3UC1-12	The same Level of safety and security must be assured by the 5G network	BR-P3UC1-06 BR-P3UC1-07
FR-P3UC1-13	The site pilot must be covered by a 5G network	BR-P3UC1-07

3.3.1.9. Technical Requirements

TABLE 18: TECHNICAL REQUIREMENTS (P3UC1)

TR-ID	Description	Notes
TR-P3UC1-01	Strike in detectors and the LX controller must connect to the 5G Network and use it as the communication channel	FR-P3UC1-01 FR-P3UC1-04 FR-P3UC1-10 FR-P3UC1-11 FR-P3UC1-10 FR-P3UC1-12 FR-P3UC1-10 FR-P3UC1-13

TR-P3UC1-02	The 5G New Radio component MUST radiate the coverage of the area where the selected railway devices are located, in the Aveiro harbour	FR-P3UC1-13
TR-P3UC1-03	The gNB MUST have an outdoor reach of around 200-300m (1 macro-cell sector MUST be enough to cover the list of devices selecte	FR-P3UC1-13
TR-P3UC1-04	The gNB MUST use the 3.6MHz band (100MHz bandwidth) assigned temporarily by the Portuguese regulator (ANACOM) for trial and research purposes	FR-P3UC1-13
TR-P3UC1-05	The 5G-Core MUST be deployed in a datacentre and connect to the gNB using a dedicated fiber (GPON)	FR-P3UC1-13
TR-P3UC1-06	The gNB and 5G-Core components MUST comply with 3GPP standards, namely with TS 23.501 and TS 23.502	FR-P3UC1-13
TR-P3UC1-08	The 5G Network MUST support slicing mechanisms to cope with some requirements, such as bandwidth, latency (<10 ms) or reliability (99,99%), over a common 5G infrastructure	FR-P3UC1-12 FR-P3UC1-13
TR-P3UC1-09	The 5G Network MUST support a narrow bandwidth and reliable slices, with URLLC characteristics, to support machine-to-machine (M2M) communications (among level crossing components)	FR-P3UC1-11 FR-P3UC1-12
TR-P3UC1-10	The Management tools MUST be able to dynamically perform life service cycle management actions (e.g. deployment, termination), of gNB and 5G-Core components, as well as 5G Networks as a whole	FR-P3UC1-12 FR-P3UC1-13
TR-P3UC1-11	The Management tools MUST be able to dynamically perform slice life cycle management actions (e.g. creation, termination)	FR-P3UC1-12 FR-P3UC1-13
TR-P3UC1-12	The Management tools MUST be able to create a list of slices based on a set of high-level requirements coming from the verticals (via the Verticals Portal), such as coverage, throughput, latency, resilience, etc.	FR-P3UC1-12 FR-P3UC1-13
TR-P3UC1-13	5G CPE must support router functions between Ethernet and 5G interface	FR-P3UC1-10 FR-P3UC1-11 FR-P3UC1-13
TR-P3UC1-14	The communications must be safe based on FSE (Safe Ethernet) or RaSTA (Rail Safe Transport Application – DIN VDE V 0831-200) protocol in accordance with CENELEC SIL4 and EN 50159 Category 2 – for transmission systems of class 7	FR-P3UC1-01 FR-P3UC1-05
TR-P3UC1-15	Security (cybersecurity) mechanisms shall be implemented for the LX crossing equipment's communications (over communication protocols)	FR-P3UC1-01 FR-P3UC1-05
TR-P3UC1-16	The system must recover automatically from communications failures. The recovery time must be less than 500 ms	FR-P3UC1-01 FR-P3UC1-06

3.3.2. P3UC2: Non-Safety Critical Communications

3.3.2.1. Use Case Description

This use case is broken down to Scenario #2 and Scenario #3 (Figure 21 and Figure 22), involving (*i*) HD video image transmission from LX surveillance camera to the approaching trains' on-board tablets and/or maintenance agents' hand held tablets (Scenario #2), and (*ii*) Level crossing LX controller status and alarm events transmission to maintenance agents' tablets (Scenario#3). Scenario#2 will boost safe level crossing, since the train operator will have the possibility to view the area at the approaching level crossing, thus preventing accidents caused by cars trapped between the level crossing gates. This solution will be a significant safety reinforcement in the overall LX safety. The solution for scenario#3 will enable asset monitoring of the LX system.

The use case will equip a train engine with an on-board 5G tablet, a level crossing with an HD video camera and a server that will connect the LX controller and the camera to the cloud using a 5G. A mobile tablet will allow the monitoring and control of the level crossing systems. An app running in the maintenance agent tablet will allow the remote control of all LX system.

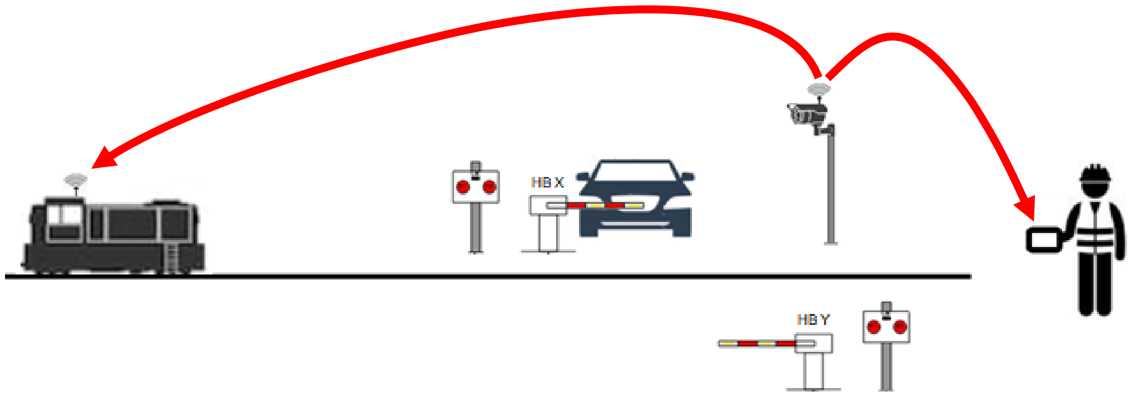

FIGURE 21: P3UC2 – SCENARIO #2 VERTICAL TRANSPORTATION PILOT

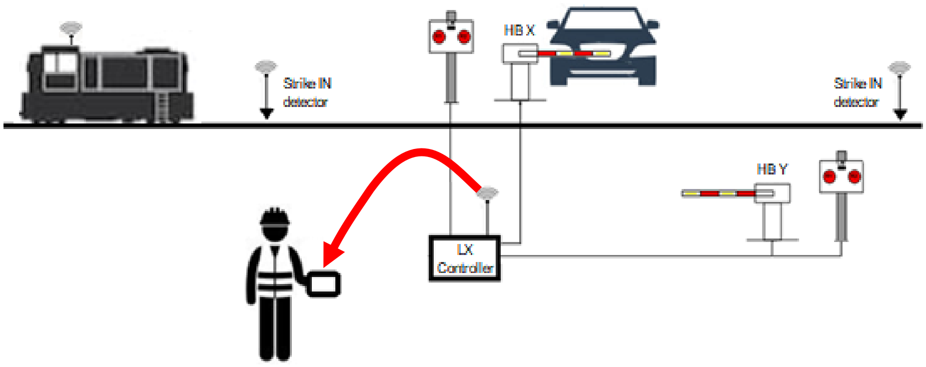

FIGURE 22: P3UC2 – SCENARIO #3 VERTICAL TRANSPORTATION PILOT

3.3.2.2. Use Case Objectives

The main objectives of the use case – scenario #2 is to transmit HD video images to the approaching train, allowing the driver to get images of the level crossing area, thus preventing accidents caused by cars trapped between the level crossing gates. In the scope of this UC it is also desired to transmit the same video images to maintenance agents/Command Centre, providing this way, mechanisms to reinforce the LX safety.

Regarding Scenario #3, the main objective is to allow maintenance agents to monitor (status and alarm event transmission) and manage the level crossing controller, through a tablet device (5G communications).

3.3.2.3. Use Case Conditions

Preconditions

The communication infrastructure must assure video transmission between the level crossing and the trains, the agent's tablet devices and also the command centre. The communication with the LX controller must also be available.

Postconditions

In the presence of an approaching train (GPS positioning), the train driver will receive real-time HD video from the next level crossing video camera that is installed in the next level crossing area. After detecting that the train has left the Level Crossing (passing), the video transmission will be interrupted, in order to not disturb the driver normal activity. The real-time video images will be also transmitted to maintenance tablet's agents and to a command centre. The LX controller status and alarms will be transmitted (5G communication) to the maintenance tablet's agents.

3.3.2.4. Actors Involved

The main actors in this use case are:

1. Train: The machine responsible to transport people or freight.
2. Train Driver: Person who is responsible to drive the train.
3. Maintenance Agent: Person who is responsible to maintain the installations working properly.
4. Tablet/Mobile Devices: Devices to be installed in the train and to be used by maintenance agent to monitor the level crossing area (video) and to assure the proper installation operation.
5. 5G CPEs: device responsible for 5G Machine-to-Machine data exchange.
6. HD Video Camera: Device (video camera) that will be installed in the level crossing area and allows surveillance and image transmission to the train and to a command centre.
7. Command Centre: Technical and Operation rooms to support the monitor and control of the Level Crossing.
8. Command Centre Operator: Person that operates the Command Centre.

9. LX controller: It is a cabinet of devices that receive and process the signalling information including the signalling software and all the interfaces with the peripheral devices.
10. GPS position system: Device to be installed in the train in order to report its geographical positioning.

3.3.2.5. Use Case Flow

Regarding the flow, the scenario can be characterized as follows:

1. The GPS and the onboard train equipment detect that the train is located in the Level Crossing area.
2. Real-time video images (next LX area) start to be transmitted to Tablet Devices (train and maintenance agent).
3. The GPS and the onboard train equipment detect that the train passed the Level Crossing area.
4. The video images transmission to the Tablet Devices is interrupted.
5. Real-time video images are permanently transmitted to the command centre.
6. Equipment status and alarms are permanently transmitted from the LX controller to the maintenance agent tablet device.

3.3.2.6. Use Case Indicators

Following an initial analysis performed during the proposal phase, several business KPIs are provided, used to validate the use cases from a business perspective. The indicators are:

- Safety conditions are reinforced regarding Level crossing area.
- Reduce traffic accidents and damages.

3.3.2.7. Business Requirement

TABLE 19: BUSINESS REQUIREMENTS (P3UC2)

BR-ID	Description	Notes
BR-P3UC2-01	Level Crossing (LX) area must be remotely monitored	
BR-P3UC2-02	Train positioning must be assured	
BR-P3UC2-03	Data communication must be available to the train	
BR-P3UC2-04	Dedicated devices must be available to the train and to maintenance agents	
BR-P3UC2-05	Communication technology (wireless) need to be present to exchange information between the system components	
BR-P3UC2-06	A command centre will be needed to aggregate information	
BR-P3UC2-07	Increase safety and security assuring more information to train drivers and maintenance agents	

3.3.2.8. Function Requirements

TABLE 20: FUNCTIONAL REQUIREMENTS (P3UC2)

FR-ID	Description	BR-ID
FR-P3UC2-01	At least a HD camera must be installed in the LX area	BR-P3UC2-01
FR-P3UC2-02	Geolocation coordinates must be received by GPS	BR-P3UC2-02
FR-P3UC2-03	Tablet devices must support 5G communications	BR-P3UC2-03 BR-P3UC2-04
FR-P3UC2-04	5G communication must available to exchange information between the system components	BR-P3UC2-05
FR-P3UC2-05	Video Images must be visualized in Tablet Devices	BR-P3UC2-04 BR-P3UC2-07
FR-P3UC2-06	Video Camera must support IP protocols and interfaces	BR-P3UC2-01 BR-P3UC2-04 BR-P3UC2-06
FR-P3UC2-07	5G CPE devices will be needed to assure the 5G connectivity of system devices to 5G network	BR-P3UC2-05
FR-P3UC2-08	A command centre will be needed to aggregate information (video images and to broadcast alarms)	BR-P3UC2-06
FR-P3UC2-09	An app for mobile devices (Tablet) must be supplied mainly for supervision purposes and to visualize video images regarding Level Crossing areas	BR-P3UC2-01 BR-P3UC2-04 BR-P3UC2-07
FR-P3UC2-10	The site pilot must be covered by a 5G network	BR-P3UC2-03 BR-P3UC2-05

3.3.2.9. Technical Requirements

TABLE 21: TECHNICAL REQUIREMENTS (P3UC2)

TR-ID	Description	FR-ID
TR-P3UC2-01	All system components (Train, tablets, video camera) must connect to the 5G Network and use it as the communication channel	FR-P3UC2-03 FR-P3UC2-04 FR-P3UC2-07 FR-P3UC2-10
TR-P3UC2-02	The 5G New Radio component MUST radiate the coverage of the area where the selected railway devices are located, in the Aveiro harbour	FR-P3UC2-10
TR-P3UC2-03	The gNB MUST have an outdoor reach of around 200-300m (1 macro-cell sector MUST be enough to cover the list of devices selected)	FR-P3UC2-10
TR-P3UC2-04	The gNB MUST use the 3.6MHz band (100MHz bandwidth) assigned temporarily by the Portuguese regulator (ANACOM) for trial and research purposes	FR-P3UC2-10
TR-P3UC2-05	The 5G-Core MUST be deployed in a datacentre and connect to the gNB using a dedicated fiber (GPON)	FR-P3UC2-10

TR-P3UC2-06	The gNB and 5G-Core components MUST comply with 3GPP standards, namely with TS 23.501 and TS 23.502	FR-P3UC2-10
TR-P3UC2-07	The 5G Network MUST support slicing mechanisms to cope with some requirements, such as bandwidth, latency (<10 ms) or reliability (99,99%), over a common 5G infrastructure	FR-P3UC2-10
TR-P3UC2-08	The 5G Network MUST support a narrow bandwidth and reliable slices, with URLLC characteristics, to support machine-to-machine (M2M) communications	FR-P3UC2-10
TR-P3UC2-09	The Management tools MUST be able to dynamically perform life service cycle management actions (e.g. deployment, termination), of gNB and 5G-Core components, as well as 5G Networks as a whole	FR-P3UC2-10
TR-P3UC2-10	The Management tools MUST be able to dynamically perform slice life cycle management actions (e.g. creation, termination)	FR-P3UC2-10
TR-P3UC2-11	The Management tools MUST be able to create a list of slices based on a set of high-level requirements coming from the verticals (via the Verticals Portal), such as coverage, throughput, latency, resilience, etc.	FR-P3UC2-10
TR-P3UC2-12	5G CPE must support router functions between Ethernet and 5G interface	FR-P3UC2-07 FR-P3UC2-10
TR-P3UC2-13	Security (cybersecurity) mechanisms shall be implemented for communications (over communication protocols)	FR-P3UC2-04 FR-P3UC2-10
TR-P3UC2-14	The system must recover automatically from communications failures. The recovery time must be less than 500 ms.	FR-P3UC2-04
TR-P3UC2-15	The 5G Network MUST support a high bandwidth (at least 120 Mbps) slices, with eMBB (up to 160 Km/h) characteristics, for the delivery of high-quality video to trains, maintenance agents and command centre	FR-P3UC2-04 FR-P3UC2-10

3.4. Energy Pilot - EFACEC Energia

3.4.1. P4UC1: Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV Distribution Substation

3.4.1.1. Use Case Description

The scenario regards advanced monitoring and maintenance support to assist the remote operator and then the crews dispatched to the field to better assess the severity and the impact of the outage they are facing. From the local surveillance systems available in the secondary substation, an HD video signal must be streamed, and monitoring assets, i.e. sensors and meters, should communicate in nearly real-time to the control centre and to the mobile devices of the maintenance crew.

Figure 23 shows the components that will be developed and installed in the field for this use case as well as the interactions between the actors of this use case.

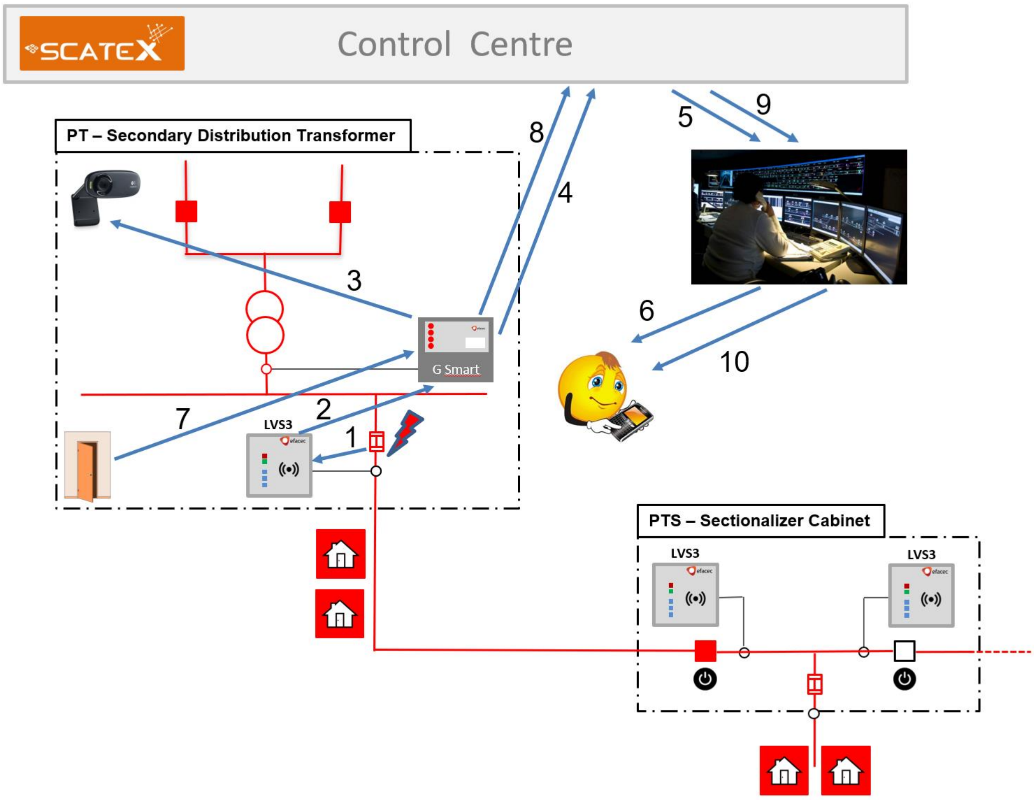

FIGURE 23: ADVANCED MONITORING AND MAINTENANCE SUPPORT OF SECONDARY SUBSTATIONS

In the secondary substation, a set of sensors (intrusion and low voltage feeders), the low voltage controller (G Smart) and an HD video camera will be installed. In the central systems, a Control Centre will be installed to monitor and control the installation and to support the operator and the maintenance crew.

In the sequence of a fault in the low voltage feeder (typically the fuse blows), the sensor detects that fault (1) and reports it to the low voltage controller (2). After that, the low voltage controller sends an order to the video camera to start recording (3) and simultaneously sends an alarm to the control centre (4). The control centre operator detects the alarm (5) and reports the fault to the maintenance team (6). Meanwhile, the control centre operator and the maintenance team can see the installation through the video transmitted by the video camera. When the maintenance team arrives to the installation, the intrusion system is activated (7), an alarm is sent to the control centre (8 and 9), and the technical information of the installation is subsequently made available

3.4.1.2. Use Case Objectives

The purpose of this business scenario is to implement an efficient control system in a secondary substation of the University of Aveiro, addressing the support to the maintenance teams. Video streaming and intrusion detection will be available to the control centre operator and maintenance teams, as well as augmented reality functionality, aiding and optimizing the repair and replacement of damaged equipment.

3.4.1.3. Use Case Conditions

Preconditions

To demonstrate this use case, an HD video camera, the sensors, the low voltage controller and a 5G communication module will be installed in the secondary substation. A control centre must be deployed in the central system, to support the operator and the maintenance team.

With all devices and system deployed, the substation will be in its normal operation, transmitting the electrical data measurements stored in G Smart to the control centre. Access to the substation will be monitored with the intrusion system and the surveillance system that will provide images of the substation equipment for the network operator and maintenance team

Postconditions

After deploying the pilot, a control centre operator and a maintenance team will need to be available to monitor and to ensure that the installation is working without any problem.

3.4.1.4. Actors Involved

The main actors in this use case are:

1. Fuses: components used to protect the low voltage feeder against high currents.
2. Sensors: devices that will be installed in the secondary substation to monitor and detect faults in the low voltage feeders.
3. LV Controller: device that will be installed in the secondary substation to monitor the transformer measures and to concentrate all the information from the substation and low voltage network.
4. HD cameras: video camera that will be installed in the secondary substation for surveillance.
5. Maintenance team: people that are responsible to maintain the installations working.
6. Intrusion Sensor: device that will be installed in the secondary substation to detects intrusions in the secondary substation.
7. Smartphone: Smartphone used by the maintenance team.
8. Control Centre: SCADA system to support the operators to monitor and control the installation.
9. Command Centre Operator: person that will operate the SCADA system.

3.4.1.5. Use Case Flow

Once in normal operation, it is expected that the substation is monitored and any failure in the installation is reported to the control center. The Figure 23 presents the flow for this use case, indicating the sequence of actions described below.

1. A fuse fails and a notification is sent to the control centre.
2. The maintenance team is notified, moving to the location of the fault. They will be supported by HD live streaming video, thus evaluating the severity of the failure.
3. The operator of the control centre will be informed of the entry of the maintenance team through the actuation of the intrusion sensor.
4. To efficiently perform the repair, the maintenance team will be provided with augmented reality devices, collecting technical information of the asset to be replaced, in order to reduce downtime/outage duration.

3.4.1.6. Use Case Indicators

Following an initial analysis performed during the proposal phase, several business KPIs are provided, used to validate the use cases from a business perspective. The indicators are:

- Reduce SAIDI for LV (Low Voltage) by 15%: System Average Interruption Duration Index (SAIDI) measures the average of the total duration of interruptions affecting the average delivery point for a given year;
- Reduce Energy not supplied in 5%.

3.4.1.7. Business Requirements

TABLE 22: BUSINESS REQUIREMENTS (P4UC1)

BR--ID	Description	Notes
BR-P4UC1-01	The system shall monitor the secondary substation measures and detect faults	
BR-P4UC1-02	The system shall send automatically alarms (intrusion, faults, etc.) from the secondary substation to the control centre	
BR-P4UC1-03	A video surveillance system shall be deployed to monitor the secondary substation	
BR-P4UC1-04	A control centre shall be created to aggregate all the information and present it to the operator	
BR-P4UC1-05	A mobile device will be needed to support the maintenance team	
BR-P4UC1-06	A communication technology needs to be present to exchange information between the system components	
BR-P4UC1-07	An augmented reality application must be available to support the maintenance team	
BR-P4UC1-08	The control centre must have an HMI (Human Machine Interface) to present all the information to the control centre operator	
BR-P4UC1-09	An intrusion alarm must be deployed in the secondary substation.	
BR-P4UC1-10	The control centre must have the capacity to send information to the mobile device used by the maintenance team	

3.4.1.8. Functional Requirements

TABLE 23: FUNCTIONAL REQUIREMENTS (P4UC1)

FR-ID	Description	BR-ID
FR-P4UC1-01	The communications between the components (Low voltage sensor, LV controller, and HD video camera) must use standard protocols	BR-P4UC1-06
FR-P4UC1-02	The communication between the LV sensor and LV controller must be RS 485 using Modbus protocol	BR-P4UC1-06
FR-P4UC1-03	The connection between the HD video camera and LV Controller must be Ethernet or wireless	BR-P4UC1-06
FR-P4UC1-04	The LV controller and HD video camera must be connected to a router with 5G communication	BR-P4UC1-06
FR-P4UC1-05	A digital input in the LV controller must be available to receive the intrusion alarm	BR-P4UC1-09
FR-P4UC1-06	The connection between the secondary substation (LV controller and HD video camera) and the control centre must be 5G	BR-P4UC1-02 BR-P4UC1-06
FR-P4UC1-07	5G communication must be used between the smartphone and control centre	BR-P4UC1-06 BR-P4UC1-10
FR-P4UC1-08	The fault detection functionality must be implemented in the low voltage sensor	BR-P4UC1-01
FR-P4UC1-09	The fault must be transmitted to the control centre whenever is detected	BR-P4UC1-01 BR-P4UC1-02
FR-P4UC1-10	Transmission of HD video from the secondary substation to the control centre must be implemented	BR-P4UC1-02 BR-P4UC1-03
FR-P4UC1-11	A SCADA system must be implemented for monitoring and control of the low voltage network	BR-P4UC1-04 BR-P4UC1-08
FR-P4UC1-12	The intrusion sensor must be available	BR-P4UC1-09
FR-P4UC1-13	The intrusion alarm must be transmitted to the control centre whenever is activated	BR-P4UC1-02
FR-P4UC1-14	The control centre must have the capacity to send information to the maintenance crew whenever is needed	BR-P4UC1-10
FR-P4UC1-15	The maintenance crew must have a smartphone with capacity to receive messages from the control centre	BR-P4UC1-05 BR-P4UC1-10
FR-P4UC1-16	The control centre must have the capacity to send a command to the secondary substation to start the transmission of the HD video	BR-P4UC1-03
FR-P4UC1-17	An augmented reality application must be available to be installed in the smartphone for maintenance support	BR-P4UC1-07
FR-P4UC1-18	The LV sensor must be connected to the LV network using Rogowski coils for currents and direct connection for the voltages	BR-P4UC1-01
FR-P4UC1-19	The LV controller must be connected to the LV network using current transformers for currents and direct connection for the voltages	BR-P4UC1-01
FR-P4UC1-20	An intrusion sensor must be installed in the substation door	BR-P4UC1-09

FR-P4UC1-21	The control centre must be installed in the cloud with connectivity to the 5G network	BR-P4UC1-04 BR-P4UC1-06

3.4.1.9. Technical Requirements

TABLE 24: TECHNICAL REQUIREMENTS (P4UC1)

TR-ID	Description	FR-ID
TR-P4UC1-1	Sensors, AR-glasses, surveillance video cameras, or other terminals can connect to the 5G Network and use it as the communication channel	ALL
TR-P4UC1-2	The gNB (5G New Radio component) MUST radiate the coverage of the area where the selected transformers are located, in the University of Aveiro campus	ALL
TR-P4UC1-3	The gNB MUST have an outdoor reach of around 200-300m (1 macro-cell sector MUST be enough to cover the list of transformers selected)	ALL
TR-P4UC1-4	The gNB MUST use the 3.6MHz band (100MHz bandwidth) assigned temporarily by the Portuguese regulator (ANACOM) for trial and research purposes	ALL
TR-P4UC1-5	The 5G-Core MUST be deployed in a datacentre and connect to the gNB using a dedicated fiber (GPON)	ALL
TR-P4UC1-6	The gNB and 5G-Core components MUST comply with 3GPP standards, namely with TS 23.501 and TS 23.502	ALL
TR-P4UC1-7	An Edge Computing solution MUST be provided to enable verticals to address low latency services, hosting video streaming, augmented reality, or control center servers	
TR-P4UC1-8	The 5G Network MUST support slicing mechanisms to cope with some requirements, such as bandwidth, latency or reliability, over a common 5G infrastructure	ALL
TR-P4UC1-9	The 5G Network MUST support a narrow bandwidth and reliable slice, with URLLC characteristics, for the delivery of transformers monitoring and intrusion alerts	FR-P4UC1-14 FR-P4UC1-15 FR-P4UC1-16
TR-P4UC1-10	The 5G Network MUST support a high bandwidth slice, with eMBB characteristics, for the delivery of high-quality video and augmented reality services	FR-P4UC1-10 FR-P4UC1-16
TR-P4UC1-11	The Management tools MUST be able to dynamically perform life service cycle management actions (e.g. deployment, termination), of gNB and 5G-Core components, as well as 5G Networks as a whole	ALL
TR-P4UC1-12	The Management tools MUST be able to dynamically perform slice life cycle management actions (e.g. creation, termination)	ALL
TR-P4UC1-13	The Management tools MUST be able to create a list of slices based on a set of high-level requirements coming from the	ALL

	verticals (via the Verticals Portal), such as coverage, throughput, latency, resilience, etc.	

3.4.2. P4UC2: Advanced Critical Signal and Data Exchange Across Wide Smart Metering and Measurement Infrastructures

3.4.2.1. Use Case Description

The smart meter is continuously monitoring the same bus that powers it. When a power outage occurs, the meter will save the relevant information to memory and send a last-gasp message, before turning off.

It could also broadcast a signal so that some utilities can disconnect customers from the electrical grid during power outages, to reduce problems due to inrush when power is restored.

Therefore, the last-gasp feature of smart devices is essential to detect and locate an electrical grid fault and to help the utility to determine which customers are affected.

Figure 24 shows the components that will be development and installed in the field for this use case as well as the flow between the actors of this use case.

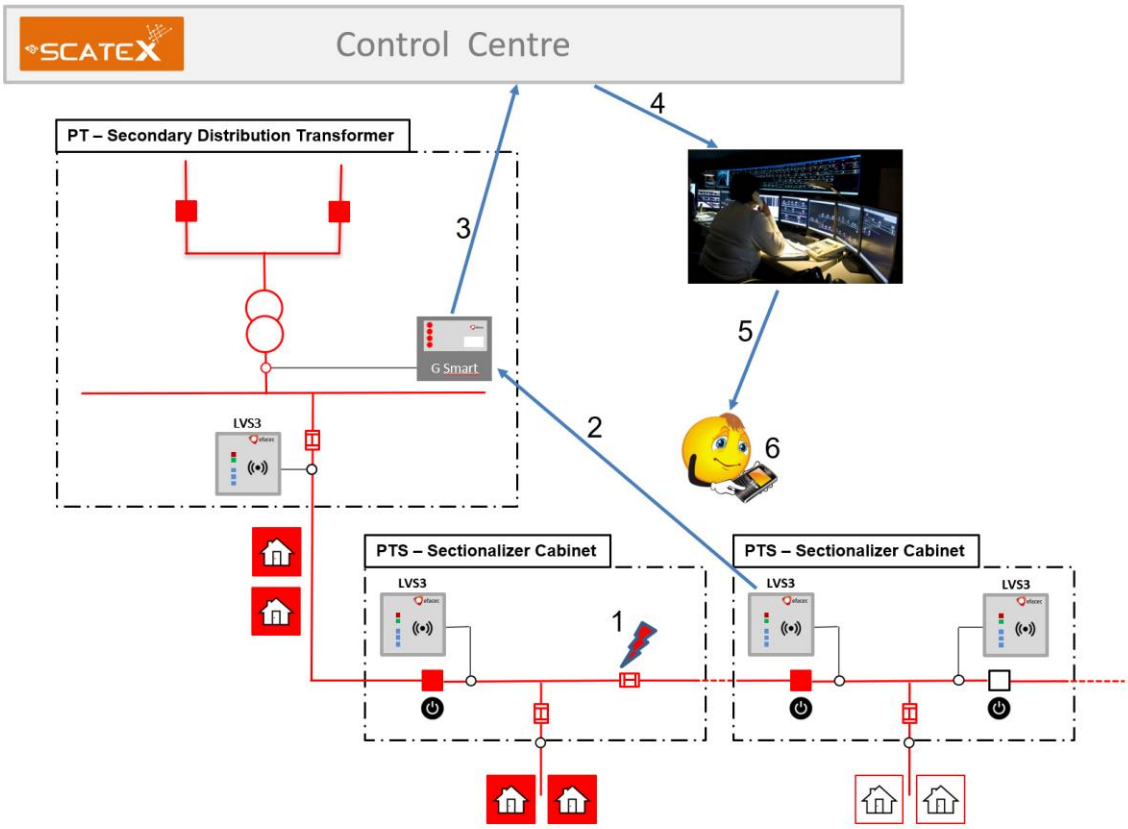

FIGURE 24: FAULT DETECTION IN THE LOW VOLTAGE NETWORK

To demonstrate this use case, a set of low voltage sensors will be installed in the distribution cabinets along the low voltage network, with a 5G communication module. In the secondary substation a low voltage controller (G Smart) will be installed, along with a 5G communication module that will aggregate all the information from the low voltage network and can run advanced algorithms and send information to the control centre. A control centre will be installed to support the operation of the network.

Low latency communications are required immediately after the power outage is detected by the device and it is essential to hold the communication channel active to send the last-gasp message before the device runs out of power (turning off).

Synchronization of the smart devices and data exchange requires even lower latency, which will improve the general quality of the acquired data (currents, voltages, powers, etc), benefiting advanced control applications dependent on correlation analysis and big data processing.

This will result on the one hand in the timely restoration of energy -with advantages to the end users (customers), while on the other hand, utilities will operate more efficiently leading to cost decrease. Low latency communications will also offer the advantage of detecting a partial system failure (e.g. single-phase failure or phase unbalance) with measurements from smart meter.

3.4.2.2. Use Case Objectives

The objective of this use case is to develop a new architecture and algorithms, in order to reduce downtime/outage duration and the number of customers affected by the outage. This new architecture and algorithms will allow to detect and locate an electric grid fault and reconfigure the grid (sending some controls to the grid if possible), in order to identify and reduce the number of customers affected. At the same time, the system will notify the control centre operator, that will send information to the maintenance team identifying the electric grid fault location in order to solve the problem.

3.4.2.3. Use Case Conditions

Preconditions

The communication infrastructure must be provided and validated to ensure system availability and low latency communications. The smart meter / smart sensor must be powered (on the bus) and work in normal operation, without error indication or any other problem.

A 5G router must be available and configured with the correct network properties (IPs, routes, etc.).

The control centre must be active and available for data exchange with the measurement infrastructure and an operator must be prepared to analyse and act accordingly.

Postconditions

After deploying the pilot, a Control Centre operator and a maintenance team will need to be available to monitor and maintain the installation working without any problem.

3.4.2.4. Actors Involved

The main actors in this use case are:

1. Smart meter / Smart sensor: device responsible for data acquisition, detection of the power outages and send the last-gasp messages to the G Smart.
2. G Smart: device responsible for receiving data from smart meters / smart sensors and send to Control Centre, via a router 5G.
3. Router 5G: device responsible for data exchange between G Smart and the control centre, using 5G service available.
4. Control Centre: system that receive data, including the last-gasp message(s) from the meters / sensors.
5. Control Centre Operator: person that verify the location of the failure, based on information from the control centre.
6. Maintenance Team: persons that go to the fault location to evaluate and, if possible, to solve the problem.

3.4.2.5. Use Case Flow

The following diagram shows the relationships among the actors in this scenario, according to the respective functions described above. The numbers represent the actors and the arrows the relationships.

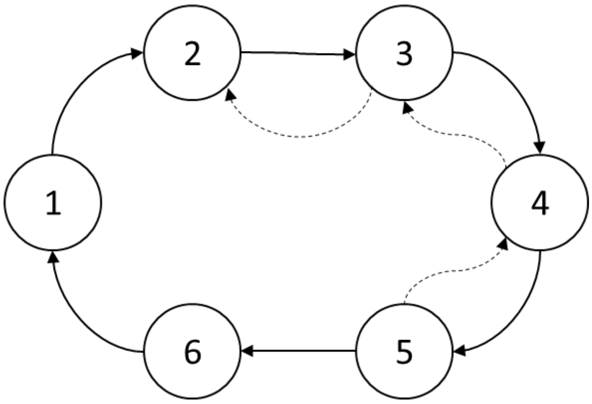

FIGURE 25: USE CASE FLOW FOR USE CASE 2

In the expected scenario flow (continuous line), when the power outage is detected, the last-gasp message is sent from the smart sensor (or from several smart sensors) to the G Smart (1 to 2). The G Smart sends data to the control centre, through a 5G router (2 to 3 and 3 to 4) and a control centre operator will evaluate the information received and act accordingly (4 to 5).

The dashed line shows the scenario when the operator in control centre needs some more information and send a request to G Smart (flow from 5 to 2), before deciding whether to send the operator to solve the problem locally (6 to 1).

3.4.2.6. Use Case Indicators

The main indicator for this use case is the availability and reliability of the system. With this kind of high availability systems, the unavailability time must be as lower as possible (approximately 0). The system availability includes the availability of all the important elements such as the smart meters, the 5G services and the control centre. All of these elements are connected and are mutually dependent.

Based on this approach, the relevant KPIs are the reduction of SAIDI (System Average Interruption Duration Index) for LV (Low Voltage) by 15% and the reduction for the ENS (Energy not supplied) by 5%.

3.4.2.7. Business Requirements

TABLE 25: BUSINESS REQUIREMENTS (P4UC2)

BR-ID	Description	Notes
BR-P4UC2-01	The system shall monitor the distribution cabinets measures and detect faults	
BR-P4UC2-02	The system shall concentrate all the information from the low voltage network in the secondary substation to run the algorithms developed	
BR-P4UC2-03	The system shall send automatically alarms (intrusion, faults, etc.) from the secondary substation to the control centre	
BR-P4UC2-04	A control centre shall be created to aggregate all the information	
BR-P4UC2-05	Communication technology shall be present to exchange information between the system components	
BR-P4UC2-06	An HMI must be developed to present all the information to the control centre operator	
BR-P4UC2-07	The control centre must have a capacity to send information to a mobile device used by the maintenance team	
BR-P4UC2-08	The system must detect and identify the location of the fault	
BR-P4UC2-09	The system must reconfigure the electrical grid in order to minimize the number of customers without energy	

3.4.2.8. Functional Requirements

TABLE 26: FUNCTIONAL REQUIREMENTS (P4UC2)

FR-ID	Description	BR-ID
FR-P4UC2-01	The connection between the distribution cabinet (LV sensor) and LV Controller must be 5G	BR-P4UC2-05 BR-P4UC2-02
FR-P4UC2-02	The control centre must run an algorithm to detect the location of the fault	BR-P4UC2-08
FR-P4UC2-03	The control centre must send controls to the LV sensors in order to reconfigure the LV network	BR-P4UC2-09

FR-P4UC2-04	The control centre must send date and time to all the LV sensors installed in the low voltage network	BR-P4UC2-09
FR-P4UC2-05	The fault detection functionality must be implemented in the low voltage sensors	BR-P4UC2-01 BR-P4UC2-08
FR-P4UC2-06	The fault must be transmitted to the control centre whenever is detected	BR-P4UC2-03
FR-P4UC2-07	A SCADA system must be implemented for monitoring and control of the low voltage network	BR-P4UC2-04 BR-P4UC2-06
FR-P4UC2-08	The SCADA system must have the capacity to send information to the maintenance crew whenever is needed	BR-P4UC2-07
FR-P4UC2-09	The SCADA system must know the low voltage network topology to identify the location of the fault	BR-P4UC2-08
FR-P4UC2-10	The LV sensor must be connected to the low voltage network using Rogowski coils for currents and direct connection for the voltages	BR-P4UC2-01
FR-P4UC2-11	The SCADA system must be installed in the cloud with connectivity to the 5G network	BR-P4UC2-05
FR-P4UC2-12	LV sensor power supply with storage capability to ensure the conditions for the last-gasp message (before turning off)	BR-P4UC2-05
FR-P4UC2-13	5G communication services available	BR-P4UC2-05
FR-P4UC2-14	Low latency communications: a. < 5ms for last gasp b. < 1ms for synchronization c. Control plane latency: < 20ms	BR-P4UC2-08
FR-P4UC2-15	Wide Area Coverage at least 10 km^2	BR-P4UC2-01
FR-P4UC2-16	The self-healing algorithm can run on the edge	BR-P4UC2-09
FR-P4UC2-17	A LV Controller must be installed in the secondary substation to concentrate all the information from the low voltage network	BR-P4UC2-02

3.4.2.9. Technical Requirements

TABLE 27: TECHNICAL REQUIREMENTS (P4UC2)

TR-ID	Description	FR-ID
TR-P4UC2-01	Sensors, AR-glasses, surveillance video cameras, or other terminals MUST connect to the 5G Network and use it as the communication channel	ALL
TR-P4UC2-02	The gNB (5G New Radio component) MUST radiate the coverage of the area where the selected transformers are located, in the University of Aveiro campus	ALL
TR-P4UC2-03	The gNB MUST have an outdoor reach of around 800-1000m (1 macro-cell sector MUST be enough to cover the list of transformers selected)	ALL

TR-P4UC2-04	The gNB MUST use the 3.6MHz band (100MHz bandwidth) assigned temporarily by the Portuguese regulator (ANACOM) for trial and research purposes	ALL
TR-P4UC2-05	The 5G-Core MUST be deployed in a datacentre and connect to the gNB using a dedicated fiber (GPON)	ALL
TR-P4UC2-06	The gNB and 5G-Core components MUST comply with 3GPP standards, namely with TS 23.501 and TS 23.502	ALL, FR-P4UC2-15
TR-P4UC2-07	An Edge Computing solution MUST be provided to enable verticals to address low latency services, hosting video streaming, augmented reality, or control center servers	FR-P4UC2-05 FR-P4UC2-14 FR-P4UC2-16
TR-P4UC2-08	The 5G Network MUST support slicing mechanisms to cope with some requirements, such as bandwidth, latency or reliability, over a common 5G infrastructure	ALL
TR-P4UC2-09	The 5G Network MUST support a narrow bandwidth and reliable slice, with URLLC characteristics, for the delivery of transformers monitoring and intrusion alerts	FR-P4UC2-14 FR-P4UC2-15 FR-P4UC2-16
TR-P4UC2-10	The 5G Network MUST support a high bandwidth slice, with eMBB characteristics, for the delivery of high-quality video and augmented reality services	ALL
TR-P4UC2-11	The Management tools MUST be able to dynamically perform life service cycle management actions (e.g. deployment, termination), of gNB and 5G-Core components, as well as 5G Networks as a whole	ALL
TR-P4UC2-12	The Management tools MUST be able to dynamically perform slice life cycle management actions (e.g. creation, termination)	ALL
TR-P4UC2-13	The Management tools MUST be able to create a list of slices based on a set of high-level requirements coming from the verticals (via the Verticals Portal), such as coverage, throughput, latency, resilience, etc.	ALL

4. Business Model Design

This section aims to gather the first design of the business model that intends to be validated in 5Growth. First, the main stakeholders have to be identified, searching for the commonalities among the different vertical pilots, and their roles will be specified. Then, the relation between these stakeholders and the business flow will be described.

At this stage of the project it is not possible to define the specific value proposition of each stakeholder, as the solutions being deployed in each pilot are still being designed, same as the prices and costs and the necessary equipment. In the coming months, this will be clarified, and it will be possible to describe it in more depth, and it will then be possible to validate these business models.

4.1. Stakeholders & roles

The 5G Infrastructure Public Private Partnership (5GPPP) is working, though collaborative research projects and standardisation bodies, on specifying and developing the main elements in the 5G architecture. In a whitepaper published recently[7] the different stakeholders and roles in the 5G ecosystem are defined. In 5Growth, we have used this definition to identify the main stakeholders involved in each of the pilots.

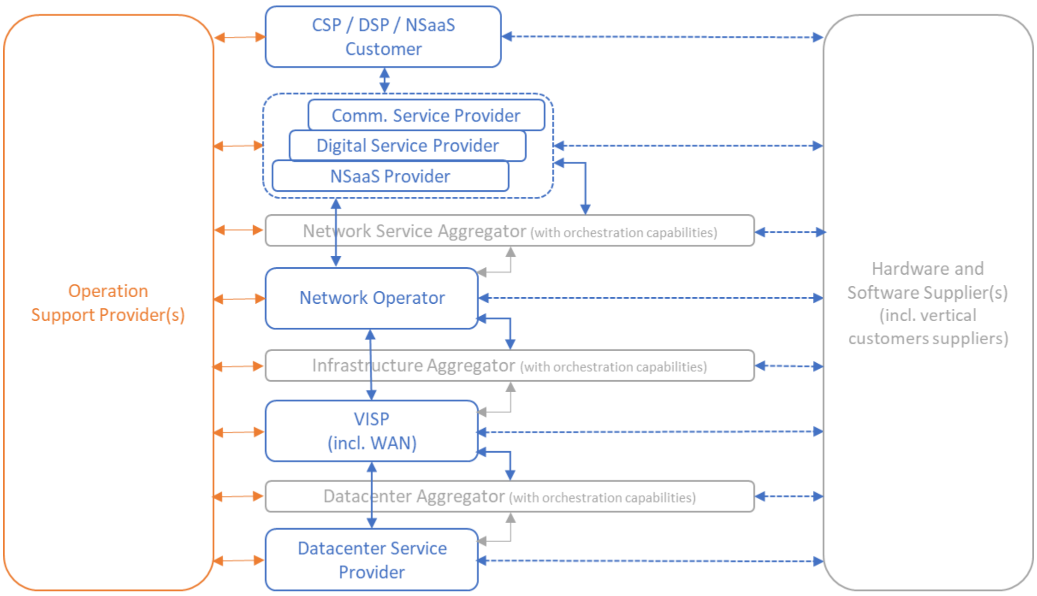

FIGURE 26: STAKEHOLDER ROLES IN THE 5G ECOSYSTEM (SOURCE 5GPPP)

In the referred document, the 5GPPP identifies 5 main stakeholders:

- **Service Costumer (SC)**: is the final user of the services.

[7] *A view on 5G Architecture v3.0* (June 2019) - 5G PPP Architecture Working Group

- **Service Provider (SP)**: can be divided in three sub-roles, depending on the type of service offered: Communication Service Provider (traditional telecom services), Digital Service Provider (digital enhanced services) and Network Slice as a Service (NSaaS) Provider (offers a network slice along with the services that it may support and configure). The SP designs, builds and operates services using aggregated network services.
- **Network Operator (NOP)**: is in charge of the orchestration resources, potentially from multiple virtualised infrastructure providers (VISP). The NOP builds and operates network services, offered to the SP's.
- **Virtualisation Infrastructure Service Provider (VISP):** provides virtualised infrastructure services and designs, builds and operates virtualisation infrastructures. These infrastructures comprise networking and computing resources.
- **Data Centre Service Provider (DCSP):** provides data centre services and design, builds and operates its data centres.

Also, there are two secondary roles, that assist these 5 main roles:

- **Operation Support Provider (OSP)**: provides traditional OSS/BSS and EMS functions, SLA Management and intelligent monitoring.
- **Hardware/Software Supplier**: hardware and software supplier to any of the stakeholders, including the customer.

As described in section 2, in 5Growth pilots these roles are played by the following partners:

TABLE 28: ROLES & STAKEHOLDERS IN 5GROWTH

Role	Pilot 1 INNOVALIA	Pilot 2 COMAU	Pilot 2 EFACEC Engenharia	Pilot 4 EFACEC Energia
SC	INNOVALIA ASTI	COMAU	EFACEC Engenharia	EFACEC Energia
SP	InterDigital Telefonica	Telecom Italia	Altice Labs	Altice Labs
NOP	Telefonica	Telecom Italia	Altice Labs	Altice Labs
VISP	-	-	-	-
DCSP	Telefonica	Telecom Italia	Altice Labs IT Aveiro	Altice Labs IT Aveiro
OSP	Telcaria	Ericsson Italia	IT Aveiro	IT Aveiro
H/SS	Ericsson España	Ericsson Italia	-	-

Other partners are not directly involved in the deployment of the pilots, but on the development of the 5Growth platform, and the new functions and innovations required to create the 5Growth ecosystem. That's why they are not in this table.

4.2. Business Flow per Pilot

Once the stakeholders have been identified and their roles clarified, it is possible to analyse the relationship between them, and that is the object of this section. There are two main kind of relationship: service provision and payment, usually going in opposite directions. There are also other kind of relationship, like indirect service provision (when the provider is paid by a third party), which also appear in one of the pilots.

In this section, these relationships are detailed for each pilot in a simple and graphical way. A very high-level service offering is specified, as there are still certain questions that should be clarified before being able to describe more specifically the offering of the providers. Equally, the payment flow has been pictured, but it is still unclear how these payments are going to be, and which pricing model will be used in each case.

4.2.1. Industry 4.0 Pilot - INNOVALIA

The INNOVALIA pilot is the most complex one, regarding the business flow, as it is the one with more stakeholders playing different roles. Figure 27 depicts the business relationship between the stakeholders involved in the INNOVALIA pilot.

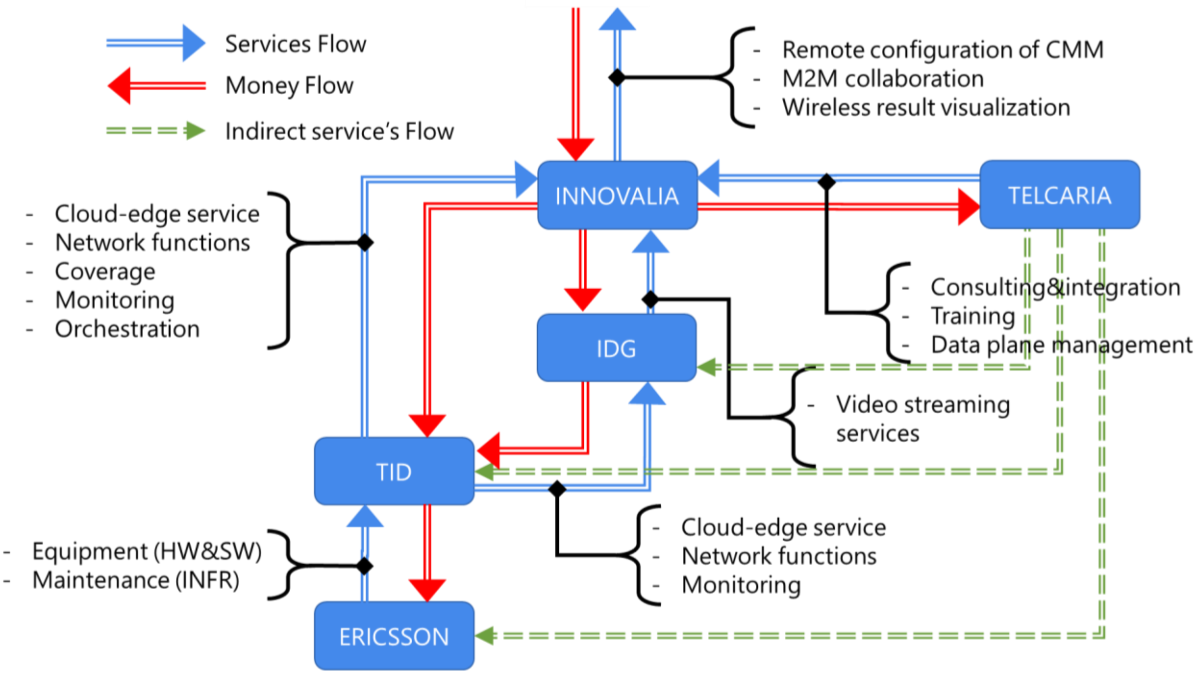

FIGURE 27: INNOVALIA'S PILOT BUSINESS FLOW

INNOVALIA is the Service Consumer of the 5G ecosystem but, somehow, their customers are also Service Consumers, as part of the deployment is going to be in their premises, and they will also use the services.

These services will be provided by two stakeholders: on one hand, Telefonica (TID), who will mainly provide communication services, edge-cloud services, network functions, indoor coverage and also monitoring and orchestration services. On the other hand, there's an intermediate stakeholder, which is InterDigital (IDG), who will provide video streaming services to INNOVALIA and, at the same time, will consume services (network functions, Cloud-Edge and monitoring services) provided by Telefonica (TID).

Ericsson, by its side, will provide Telefonica with the equipment required to provide 5G services, both hardware and software. Also, will take care of the maintenance during operation of this equipment.

Finally, Telcaria will provide INNOVALIA with consulting and integration services, as well as *Data Plane* management and training services. As the services INNOVALIA wants to offer require that every customer deploys a 5G solution, Telcaria will design and integrate the new deployment to make it compatible with the customer's infrastructure.

4.2.2. Industry 4.0 Pilot - COMAU

COMAU itself is the end service consumer, and they require a private network, so they don't rely on public 5G networks.

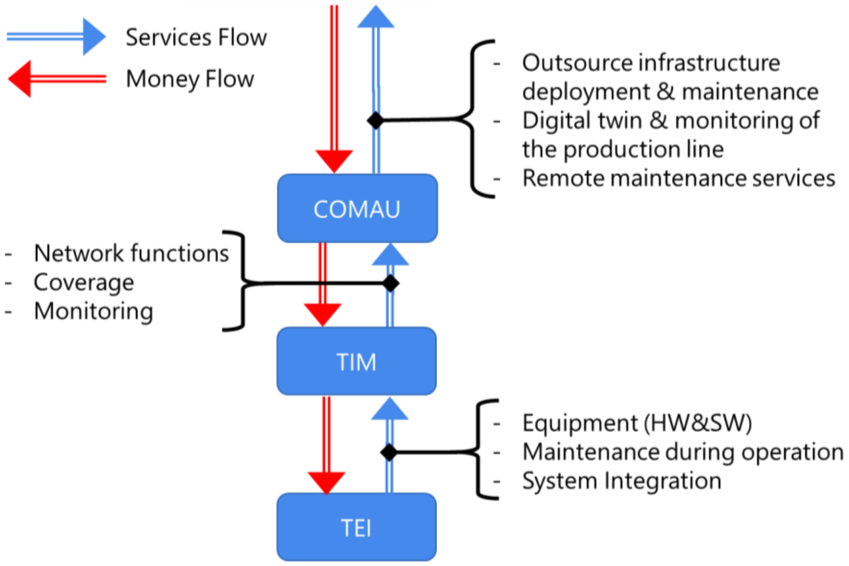

FIGURE 28: COMAU'S PILOT BUSINESS FLOW

COMAU is provided by Telecom Italia (TIM) of indoor coverage, communication services, network functions and monitoring. At the same time, Ericsson Italy (TEI), provides Telecom Italia with the equipment necessary to run the services, the maintenance services during operation and also de system integration.

4.2.3. Transportation Pilot - EFACEC Engenharia e Sistemas and Energy Pilot – EFACEC Energia

Both EFACEC Pilots have the same business model, the same stakeholder and the same business flows, although they target different verticals.

EFACEC Engenharia e Sistemas addresses to the transportation vertical, specifically, to the railway market. It offers to their customers (which could be the owner of the infrastructure or others, like town halls) the deployment and operation of signalling systems for railway crossing.

EFACEC Energia focuses on the energy vertical and offers the deployment and operation of energy monitoring systems for secondary substations of the electrical distribution networks. The customer and even the services they offer are slightly different, but the business flows are the same in both cases, as depicted in Figure 29.

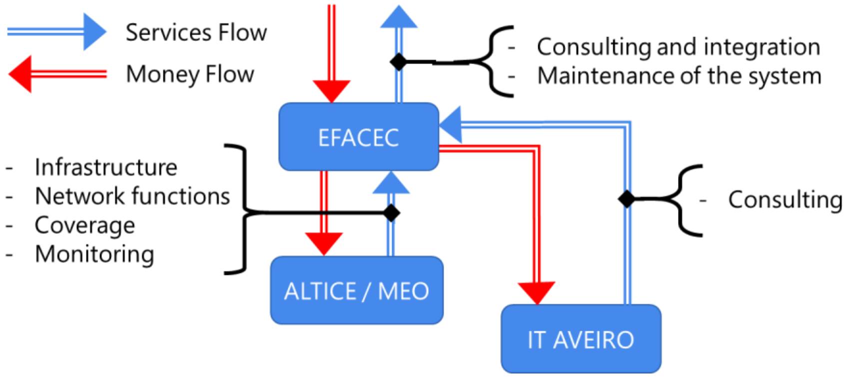

FIGURE 29: EFACEC ENGENHARIA E SISTEMAS & EFACEC ENERGIA PILOTS BUSINESS FLOW

The provider of the 5G network is Altice Labs which is the R&D company of MEO, the main telecommunication operator in Portugal. They provide both EFACEC companies with network functions, monitoring and the usage of the public 5G network.

Also, there is IT Aveiro, which provides consulting and integration services to EFACEC, and are in charge of the design of new implementations, and also when dealing with foreign operators (in case they sell the new developed services to customers abroad).

5. Conclusions

This document has presented the first steps on the business model validation that is being performed within WP1, which are the definition of the pilots and the use cases, and the designing of the business model that will be then validated.

In first place, the definition of the final use cases and the new technologies that will be deployed in each of the pilots allows to specify the business, functional and technical requirements for each of these use cases, and then to identify the main necessities of the verticals. In this task, the communication between the pilot owners and the technical partners is fundamental, as it is essential to find the correspondence between the needs of the verticals and the services and innovations that will be deployed by the technical partners.

Then, with the pilots defined, the main stakeholders have been identified and their roles have been clarified. In this task, we have focused on identifying the business stakeholders, even if more partners are involved in the deployment of the pilots. As the objective is to define the business models in order to be validated, the partners involved in developing the innovations and in charge of other tasks that will not be needed in a commercialization phase, have not been included among these stakeholders.

Finally, the main business relationship and the service offering from the different stakeholders has been designed. This is the furthest we can go right now in terms of the design of the business model, since the rest of the factors that define it, such as the cost structure or the flow of income cannot be defined until the implementation of the Pilots are more advanced in their deployment.

This is precisely what should be done next. Within Task 1.2 (T1.2), a techno-economic study that will evaluate the total cost of the ownership, including the enhanced functionalities provided, the benefits that are expected, etc., and a methodology to validate these business models and flows has to be selected, and will be reported in the next deliverable D1.2, due on M15.