H2020 5Growth Project
Grant No. 856709

D3.4: Plan for pilot deployments

Abstract

This deliverable reports the step by step approach to the deployment of the pilots in vertical industries premises. It provides the status of each pilot in November 2020 (M18), a timeline of the deployments towards the end of the project and includes an update with respect to the COVID-19 contingency plan reported in D3.2.

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Disclaimer

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List of Acronyms

5G-NR – 5G New Radio

5Gr-RL – 5Growth Resource Layer

5Gr-SO – 5Growth Service Orchestrator

5Gr-VS – 5Growth Vertical Slicer

AGV – Automated Guided Vehicle

AMI – Advanced Metering Infrastructure

API – Application Programming Interface

AR – Augmented Reality

BB – Baseband

CMM – Coordinate-Measuring Machine

CP – Control Plane

CU – Centralized Unit

CPE – Customer Premises Equipment

DSS – Decision Support System

DU – Distributed Unit

eCPRI – enhanced Common Public Radio Interface

eMBB – enhanced Mobile Broadband

GPS – Global Positioning System

GUI – Graphical User Interface

HSS – Home Subscriber Server

HW - Hardware

IMU – Inertial Measurement Unit

IIoT – Industrial Internet of Things

IRU – Indoor Radio Units

KPI – Key Performance Indicator

LTE – Long Term Evolution

LV – Low-Voltage

LVS3 – Low Voltage Sensor

LX – Level Crossing

MANO – Mobile Network Management and Orchestration

mMTC – massive Machine Type Communications

MTTR – Mean Time To Repair

MTU - Maximum Transmission Unit

NFVO – Network Functions Virtualization Orchestrator

NSA – Non-standalone

NSD – Network Service Descriptor

OMS – Outage Management System

PLC - Programmable Logic Controller

PNF- Physical Network Function

RAN – Radio Access Network

RU – Radio Unit

SA – Stand Alone

SLA – Service Level Agreement

SO – Service Orchestrator

SW - Software

UP – User Plane

URLLC – Ultra-Reliable Low Latency Communication

vEPC – virtual Evolved Packet Core

VIM – Virtualized Infrastructure Management

VM – Virtual Machine

VNF – Virtual Network Function

VPN – Virtual Private Network

VS – Vertical Service

VSB – Vertical Service Blueprint

VSD – Vertical Service Descriptor

WDM - Wavelength Division Multiplexing

WIM – WAN Infrastructure Manager

ZDM – Zero Defect Manufacturing

Executive Summary and Key Contributions

5Growth targets the technological and business validation of 5G technologies from a vertical's point of view through four real life pilots, centered around three specific industry sectors involved, namely: Industry 4.0 (i.e., INNOVALIA and COMAU), energy (i.e., EFACEC_E) and transportation (i.e., EFACEC_S).

D3.2 [1] provided a mature definition of the technical solution of each vertical pilot under the scope of 5Growth, as well as the integration options of 5Growth platform with the selected ICT-17 platforms (namely, 5G-EVE and 5G-VINNI). D3.2 also included an analysis of the impact of COVID-19 on the plans and related roadmaps for the execution of the vertical pilots, along with appropriate contingency plans for mitigating such impact. COVID-19 has, in fact, delayed the planned installations and deployments at vertical premises for the limited access to the experimental areas and for the restrictions to travel among the partner's sites. To mitigate the effects on the different pilots, all the partners involved in the deployments of the use cases have focused their efforts to software deployments and on simulations in virtual environments, being these still possible when a direct access to the vertical premises was severely restricted. Most of the in-field activities were restored in September 2020 (M16) allowing to absorb part of the delays with an extra-effort demonstrated by all the involved partners.

The current deliverable D3.4 reports the status of the pilots in November 2020 (M18) and an update on the related plans towards the end of the project following a step-by-step approach to the deployment of said pilots in the vertical industries premises. This update is particularly important to clarify how the project has managed the impact of COVID-19 in coherence with the mentioned contingency plans.

Specifically, this deliverable is organized in four main sections, one for each pilot: Section 2 for the INNOVALIA pilot, Section 3 for the COMAU pilot, Section 4 for the EFACEC_E pilot, and Section 5 for the EFACEC_S pilot.

Each section reports, for the relevant pilot:

- A short description of the **communication infrastructure** (radio access and core, transport, 5Growth platform) with the related schemes and pictures. The full description is available in D3.2. This also reports the status of the infrastructure at November 2020 (M18) and the deployment towards the end of the project.
- A short description of the **use cases** with the related schemes and pictures. This also reports the status of each use case in November 2020 (M18) and the deployment plan towards the end of the project.

The timelines reported in this deliverable also includes test and validation campaigns which follows the deployments of infrastructures and of use cases in all the four pilots. Details on measurements methods, tools, and test results are reported in D4.2 [2].

1. Introduction

5Growth project aims at integrating the 5Growth service platform with the selected ICT-17 platforms (namely 5G-EVE and 5G-VINNI), along with its deployment into complementary trial sites on the premises of verticals, to provide an extensive validation and trialing of 5G-enabled vertical applications. These 5G-enabled applications are demonstrated through nine use cases across four pilots (comprising Industry 4.0, energy, and transportation vertical sectors) that will be deployed in a TRL6/TRL7-comparable environment as close as possible to a real 5G commercial environment.

D3.2 [1] reported the initial details regarding the deployment of the 5G infrastructure in the vertical premises. It also reported the progress related to the use case modelling, the identification of the hardware and software components and the set of experiments for the initial validation of different components of the use cases. D3.2 also provided an initial planning and roadmaps for the deployment, experimentation and for supporting the validation of each of the nine use cases in their respective vertical pilots. Finally, D3.2 reported an analysis of the impact of COVID-19 on the planned execution timelines.

The current deliverable D3.4 recalls the main elements of the infrastructure and of the systems used in the vertical use cases, for which initial details were provided in D3.2. For each pilot, this deliverable also reports a summary of the current status in November 2020 (M18), constituting a significant update with respect to the status reported in April 2020 (M11) in D3.2. Starting from the November 2020 (M18) baseline, this deliverable illustrates the roadmaps for the completion of the planned activities. Specifically, each pilot reports a chart representing the timeline associated to the main deployment steps. Each chart is complemented with a numbered list of steps that will be undertaken towards the completion of the planned implementations.

Moreover, the deployment of the infrastructure (radio access and core, transport, 5Growth platform) has proceeded in parallel with the deployments of the related vertical use cases. In doing so, this deliverable also details the plans for the integration of the vertical systems (like for example a robotic cell) with the infrastructure that provides the related connectivity. This is crucial to verify to what extent 5G can support the requirements imposed by the vertical use cases and to validate the related KPIs.

The status and plan for the integration of the 5Growth platform in the pilots is reported in pilot's roadmaps. With the integration of the 5Growth platform in the pilot's infrastructure, each use case will exploit some of the innovations carried out in WP2, as indicated in D3.1 [2]. The innovation's releases are detailed in D2.1 [4].

2. INNOVALIA Vertical Pilot

This section describes the evolution of the INNOVALIA pilot plans, departing from the initial ones reported in D3.2 [1] Section 2.4. To avoid repeating content from D3.2, this section summarizes the aspects that remain unchanged while detailing the modified aspects from the initial plan.

2.1. Infrastructure

As planned from the beginning of the project, the INNOVALIA pilot is structured in two phases. In Phase I (currently ongoing), the deployment and integration of all the components is taking place at 5TONIC lab. In Phase II, leveraging the expertise acquired during the previous phase, several components will be deployed at INNOVALIA premises in order to build a closer to real-life scenario. The latter will be the deployment scenario that we will be leveraged for the final testing.

Phase I

At this phase, the entire infrastructure has been deployed at 5TONIC lab. Figure 1 shows an evolved representation of the common infrastructure needed for INNOVALIA pilot. In summary, the infrastructure includes:

- General purpose servers for holding the 5Growth platform;
- The 5G network, which includes RAN and CORE components;
- Connectivity to the 5G-EVE platform.

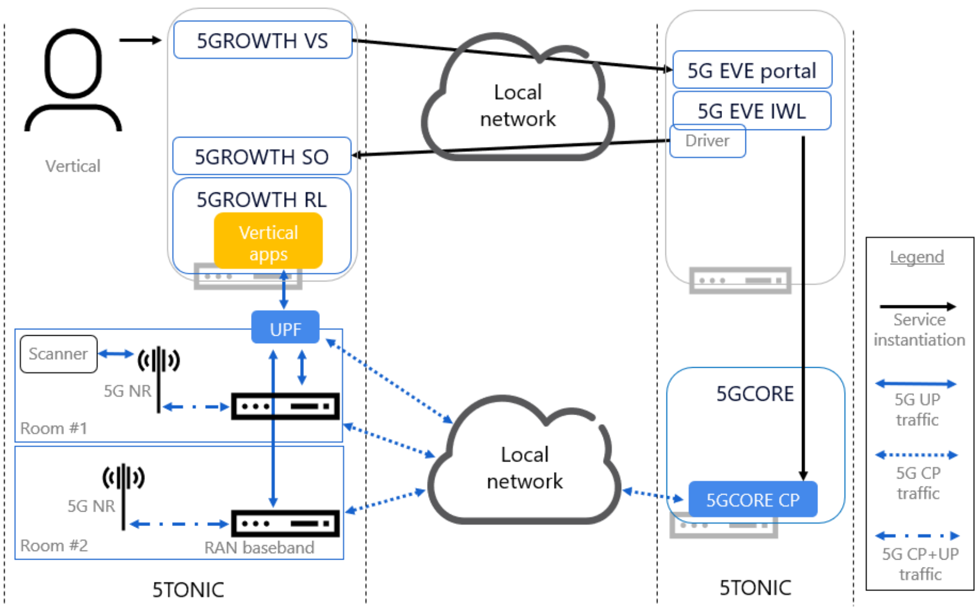


FIGURE 1: INNOVALIA - PHASE I SETUP (5TONIC LAB)

One of the evolved aspects is that there will be two different rooms with separate 5G coverage, which allow a better emulation of the network access conditions for the use cases that require coverage in two locations (such as, INNOVALIA-UC1, later detailed in Section 2.2). Other improvements, depicted in the previous figure, are the interconnectivity between components and the separation between interaction domains, which are better illustrated.

Regarding the specific infrastructure equipment, the 3D scanner device used in both use cases has changed from the originally planned one. The model installed and used in the 5TONIC lab is a Vulkan-type Coordinate-Measuring Machine (CMM). Figure 2 shows a picture of the Vulkan CMM. Its basic installation is composed by the CMM, a reduced-size controller, a joystick which is connected directly to the controller, and a PC running the software solution that runs the quality tests, called M3. This is the starting point from where the team is moving towards the final target setup that enables the operation envisioned in the use cases, namely connecting the INNOVALIA devices through the 5G. Moreover, a vertical application called M3Box is introduced. The M3Box runs the M3 services that move the robot and control the sensors. This component must run at the network edge, near to the CMM end.

FIGURE 2: INNOVALIA - VULKAN CMM

Regarding the rest of the infrastructure components, there are no changes from what was reported in D3.2 [1] Section 2.4.1.

Phase II

For the second phase, Figure 3 shows which components will be deployed at INNOVALIA premises.

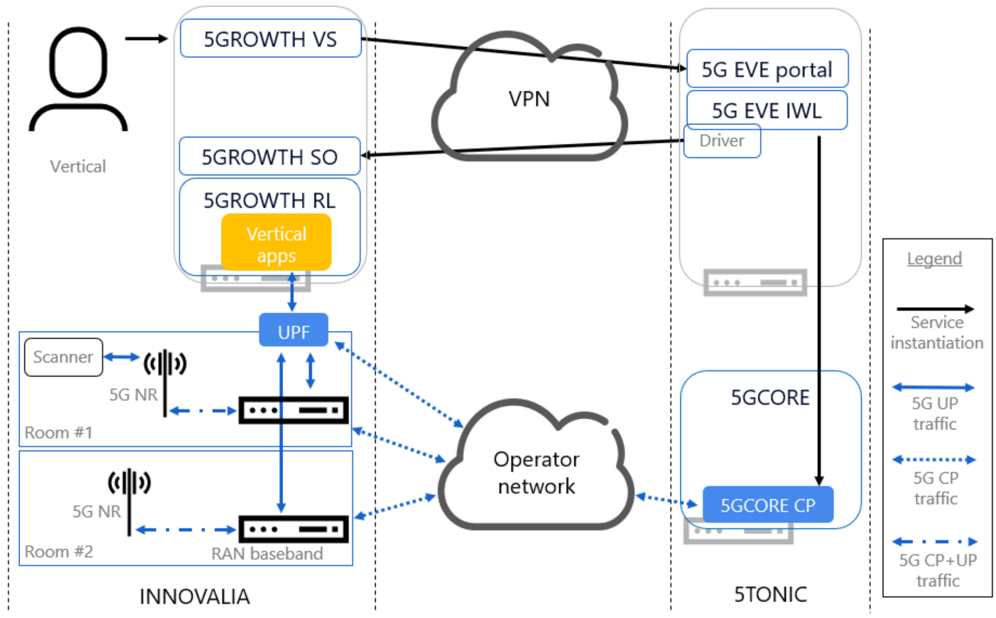


FIGURE 3: INNOVALIA - PHASE II SETUP (INNOVALIA PREMISES)

At INNOVALIA premises, two areas of coverage are needed: one is the room where the 3D-scanner is placed and the other is the control room. This is better depicted in Figure 3. The connectivity between distant 5G components is granted by the Mobile Operator Network, while the connectivity between 5Growth and 5G-EVE platforms must be established through a VPN (it can be done through Internet).

The CMM that will most likely be used in this second phase is still the Vulkan-type. Even if the model used is changed, the rest of services and components involved will be the same as they use the same controllers, thus they are easily interchangeable.

For details about the rest of the infrastructure, see D3.2 [1] Section 2.4.1.

2.1.1. Status

Regarding the infrastructure, COVID-19 has delayed the planned installations and deployments. However, currently most of the common infrastructure required by the use cases of the pilot is available at 5TONIC lab.

The INNOVALIA 3D-scanner was installed in 5TONIC lab and is available for experimentation, as seen in Figure 4. The way on how to connect the device to the 5G network for the different experimentation stages has been discussed.

FIGURE 4: INNOVALIA - CMM AT 5TONIC LAB

Besides the 5G NSA network available at 5TONIC, the 5G Stand Alone (SA) network is now running at 5TONIC lab as well. This achievement meant the deployment and configuration of a full 5GCore, activating the 5G RAN features for SA operation, and acquiring suitable SA-capable CPE routers. The network performance testing is ongoing to confirm the expected values. So, this technology is currently ready at the lab to be used by the pilot.

The second room with separate 5G coverage is not yet fully operational at the time of writing this report. The final setup is as shown in Figure 5. The full deployment will is expected to be completed by early December 2020.

FIGURE 5: INNOVALIA - SECOND ROOM OF COVERAGE

The development work of the software drivers for the integration of 5Growth platform with 5G-EVE platform has progressed according to plan and the first version of the software code has been released in November 2020 (M18). Individual testing of the software has been performed also.

Testing and debugging phases of these drivers in a fully integrated environment will start in December 2020, allowing the deployment of vertical services through the integrated platforms.

2.1.2. Plan for pilot deployment

Figure 6 reports the details on when each of the required infrastructure components for the INNOVALIA pilot will be available.

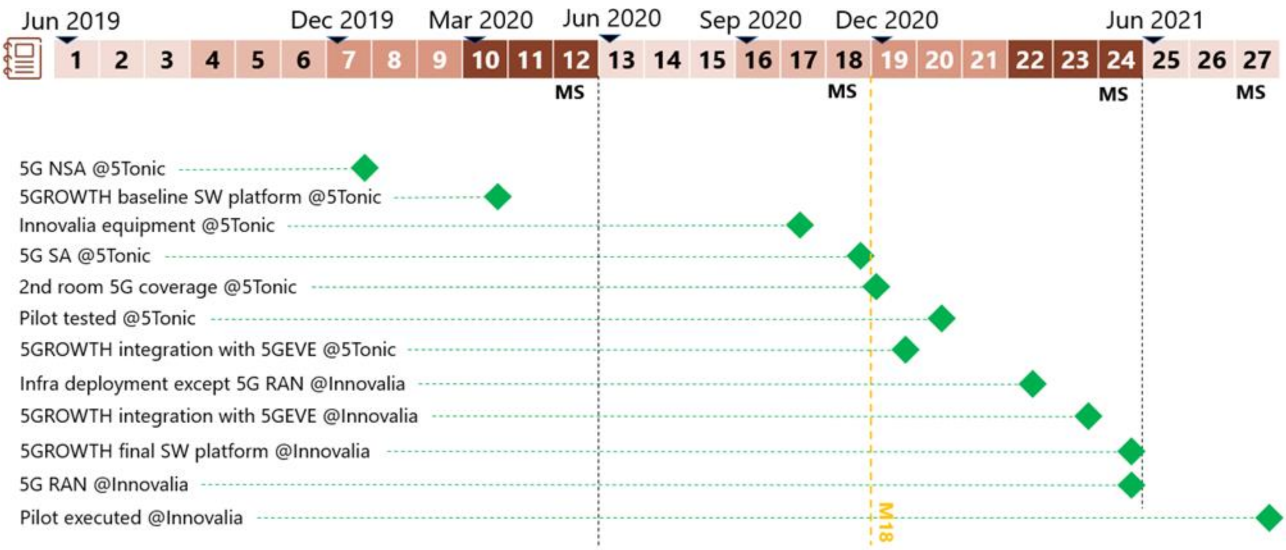


FIGURE 6: INNOVALIA - 5G NETWORK INFRASTRUCTURE ROADMAP

These steps are explained in more detail as follows:

1) In March 2020 (M10), the 5Growth baseline SW platform was deployed at 5TONIC lab. Since then, discussions and progress have been done to integrate 5Growth with the ICT-17 platforms and to define the NSDs needed for all use cases.
2) In October 2020 (M17), the INNOVALIA 3-D scanner and service application was installed.
3) In November 2020 (M18), the 5G RAN and CORE with Stand Alone option deployment was completed at 5TONIC lab.
4) By early December 2020 (M19), 5G coverage will be activated at the second room at 5TONIC building, which is useful to emulate connectivity between two different locations. It is only missing a few cables needed for the deployment and it will be completed as soon as possible.
5) By the end of December 2020 (M19), the 5Growth components installed at 5TONIC lab will be integrated with 5G-EVE. The first release of the SW interfaces has been released in November 2020 (M18), so they are now ready to be used.
6) By the end of April 2021 (M23), the infrastructure, with the exception of the 5G RAN, will be deployed at INNOVALIA premises.
7) By the end of May 2021 (M24), the 5Growth final SW platform and interfaces will be deployed, including the final innovations developed.
8) By the end of May 2021 (M24), the 5G RAN will be installed at INNOVALIA premises. The 5G Core Control Plane used is the one available at 5TONIC lab.

2.2. Use Case 1: Connected Worker Remote Operation of Quality Equipment

INNOVALIA Pilot Use Case 1 is depicted in Figure 7. The description of the use case can be checked in D3.2 [1] Section 2.4.2. As additional information, the virtualized application needed in this use case is a single VNF that contains two software functionalities: (i) the Robot Link (RL), which is the one that controls the moves of the CMM, and (ii) the Data Assembler (DA), which gathers the information of the 3D position of the scanner arm.

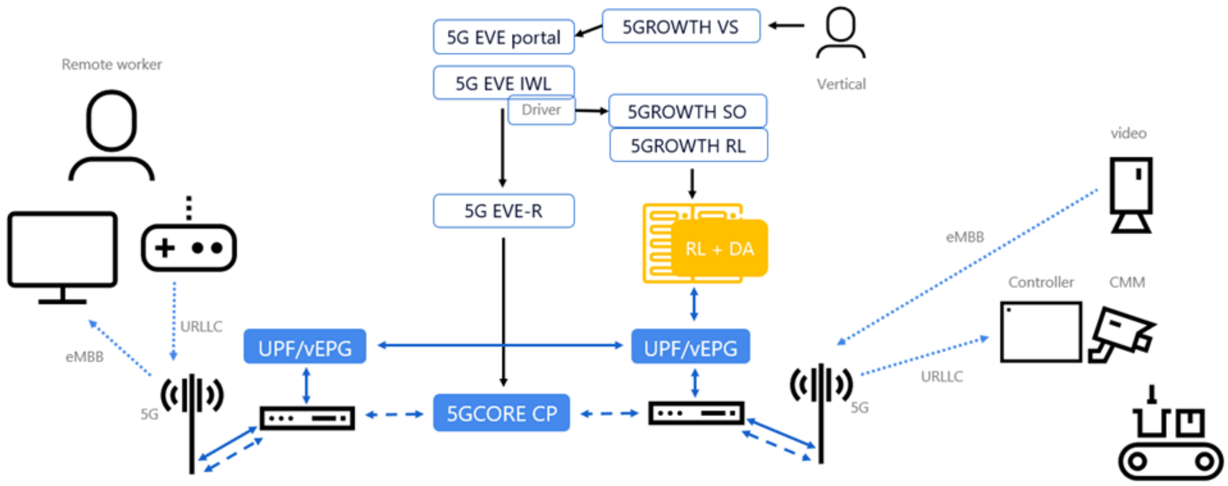


FIGURE 7: INNOVALIA-UC1 - OVERVIEW

2.2.1. Status

This use case has been executed, so far, over a fully static deployment. The application is not yet deployed as a virtualized application in the Edge. In the first experimenting stage of the use case, the following conditions have been considered:

- The devices on each end were connected to a different 5G Customer Premises Equipment (5G CPE).
- At the time of these tests, the lab had only one 5G cell, so both 5G CPEs were connected to the same cell. This means that the same radio resources are shared when both CPEs are transmitting at the same time.
- Joystick and scanner devices were emulated by software applications on regular PCs.
- The application was embedded in the CMM.

In the second experimenting stage of the use case, which is currently ongoing, the following conditions have been changed:

- The scanner is the actual machine installed in 5TONIC lab.
- The application has been virtualized and it is running on a separate PC cabled to the CMM.

Once the virtualized application is validated in previous environment, in a future experimenting stage, it will run on a server at the network Edge.

The final video solution with a low latency camera designed by Interdigital is not yet available at 5TONIC, due to the travel restrictions imposed by COVID-19. Such video solution is being tested in an independent 5G lab in UK, so that results can validate the solution to be used for the pilot in the future. Alternatively, at 5TONIC lab experiments, a simple Raspberry Pi video-camera has been used to be able to test the full end-to-end INNOVALIA-UC1.

Work has been done to be able to deploy dynamically the vertical service on the network Edge using the 5Growth platform, specifically, interacting with 5Gr-VS. The definition of the required blueprints and the descriptors, as well as experimentation, for deploying the application on the Edge is ongoing. In the near future, the use case will be executed having this virtualized application dynamically deployed and also having the network slice selected dynamically at deployment time.

2.2.2. Plan for pilot deployment

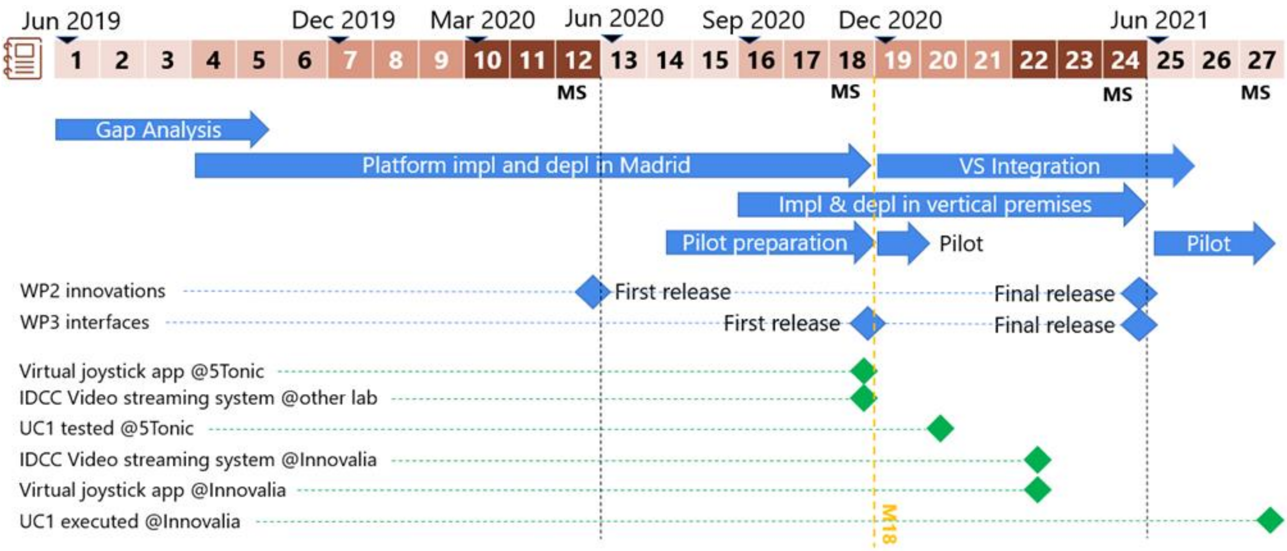


FIGURE 8: INNOVALIA-UC1 - DEPLOYMENT PLAN

As shown in Figure 8, the main steps of the plan for this use case are:

1) The INNOVALIA virtual joystick application is currently (M18) being tested in 5TONIC.
2) The Interdigital video streaming system was implemented and tested in an independent lab in November 2020 (M18).
3) The use case will be tested, with the available features so far, by the end of January 2021 (M20).
4) The video streaming system is planned to be implemented at INNOVALIA premises by the end of March 2021 (M22).
5) The CMM and the INNOVALIA virtual joystick application will be available for project use at INNOVALIA premises by the end of March 2021 (M22).

A correction is reported regarding what is stated on the HW/SW tables reported in D3.2 Section 2.4.2.2. The M3 Execution Engine SW component is not used in INNOVALIA-UC1, as it covers image processing functionalities that are only used in INNOVALIA-UC2.

Regarding future experimenting of INNOVALIA-UC1, as soon as components are available, deployed and fully tested, they will be added to the use case setup for further validation. Thus, the future steps will be:

1) The use case will be validated having the end devices in two different rooms with independent 5G coverage available, still with the application deployed on the user device end.
2) The virtualized application will be then deployed on the network Edge using only the 5Gr-SO. For this, the NSD and the VNF for the application must be built and then onboarded on the 5Gr-SO. The performance of the use case will be validated again under these conditions.
3) Finally, the full integrated path involving 5Growth and 5G-EVE platforms will be used to deploy the vertical services. At this point, all the blueprints and descriptors described in previous deliverables (VSB, VSD, NSD, VNF and others) will be needed.

2.3. Use Case 2: Connected Worker - Augmented ZDM Decision Support System (DSS)

The INNOVALIA pilot Use Case 2 is depicted in Figure 9. A more extensive description of the use case can be checked in D3.2 [1] Section 2.4.3. As additional components for this use case, besides the virtualized application needed in INNOVALIA-UC1, it will be required: (i) the M3 Execution Engine, which manages the images obtained from the CMM and (ii) the AGV controller, which handles the movement of the AGVs.

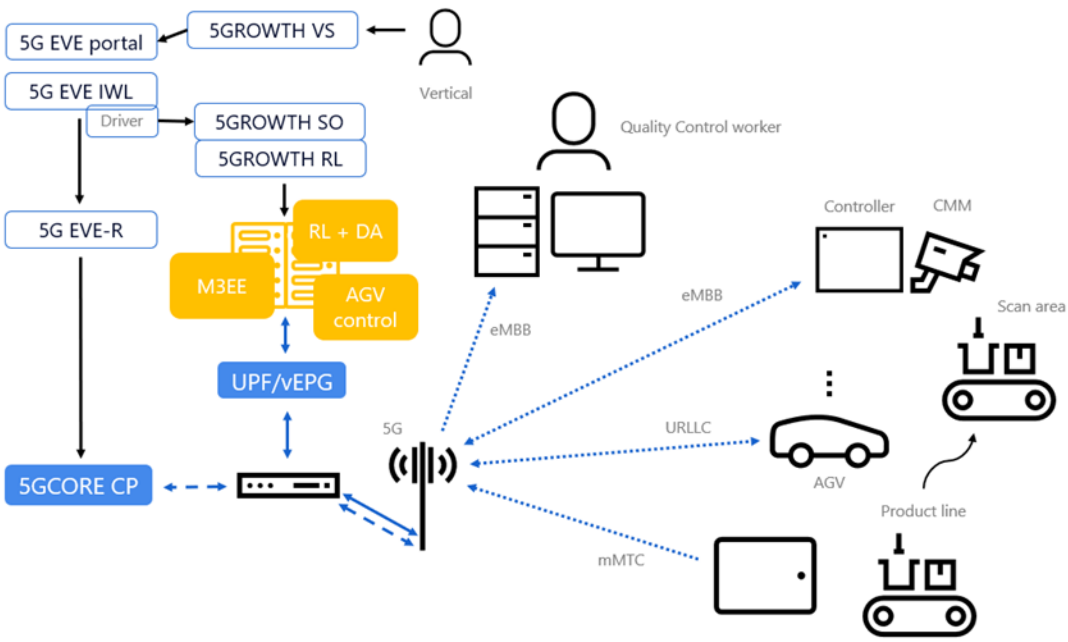


FIGURE 9: INNOVALIA-UC2 - OVERVIEW

2.3.1. Status

Due to delays caused by COVID-19, the project is focusing on progressing first in INNOVALIA-UC1, so there is no progress yet specifically for INNOVALIA-UC2. However, the work done in the project regarding the infrastructure is valid for setting up INNOVALIA-UC2 on top of it. In that sense, the infrastructure is ready for experimenting with INNOVALIA-UC2. Furthermore, the work currently ongoing for INNOVALIA-UC1 of designing and building the blueprints and descriptors needed to deploy the vertical services through the 5Growth platform will be useful for the partners to gain expertise to quickly replicate these tasks over INNOVALIA-UC2.

The extra virtualized application M3 Execution Engine and the coordination with the AGV controller needed for this use case are still under development by INNOVALIA and are not yet ready. As soon as a version of INNOVALIA-UC1 with its applications deployed at the network Edge using the 5Growth stack is tested and the extra virtualized application is available, specific experimentation with INNOVALIA-UC2 can be started.

2.3.2. Plan for pilot deployment

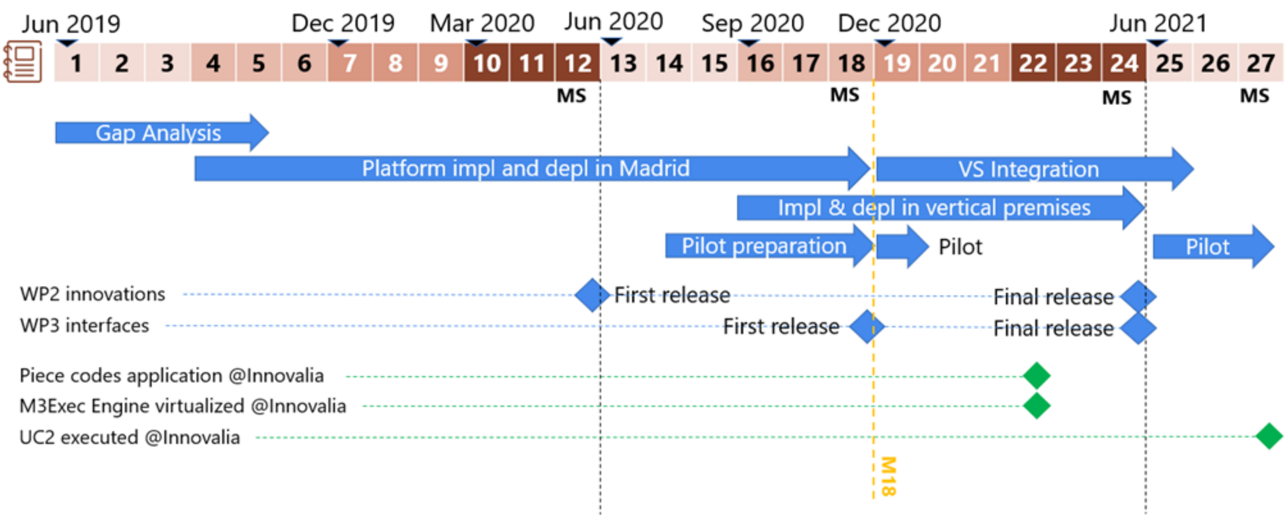


FIGURE 10: INNOVALIA-UC2 - DEPLOYMENT PLAN

As shown in Figure 10, the highlights of the plan for this use case are:

1) The required applications will be available for project use at INNOVALIA premises by the end of March 2021 (M22). Due to the impact of COVID-19, the pilot has focused their efforts on INNOVALIA-UC1, so INNOVALIA-UC2 will be implemented directly at INNOVALIA premises.
2) The UC2 should be fully executed at the final validation stage by the end of the project.

There are no modifications to report regarding what is stated on the HW/SW tables reported in D3.2 [1].

The experimentation plan for INNOVALIA-UC2 will follow a different approach than for INNOVALIA-UC1. Since the different components of INNOVALIA-UC1 are being validated, the required applications for INNOVALIA-UC2 (when available) are going to be directly deployed using the integrated 5Growth and 5G-EVE platforms. This means adapting the blueprints and descriptors (VSB, VSD, NSD, VNF and others) for INNOVALIA-UC2 and experimenting directly in the final environment.

3. COMAU vertical pilot

3.1. Infrastructure

Figure 11 illustrates the logical architecture of the COMAU pilot which is hosted at the COMAU site in Turin, Italy. The three use cases deployed in the pilot leverage on a 5G network operating on TIM spectrum and supported by an optical-based transport infrastructure which connects the baseband (BB) node to the antenna side. This network guarantees stringent industry-grade performance and provides the security level required for critical data. The COMAU site is connected to the TIM site through a VPN. The TIM site hosts the 5Growth platform, including the orchestrator, the HSS, the COMAU IIoT application in.Grid which is used in the second use case of the pilot.

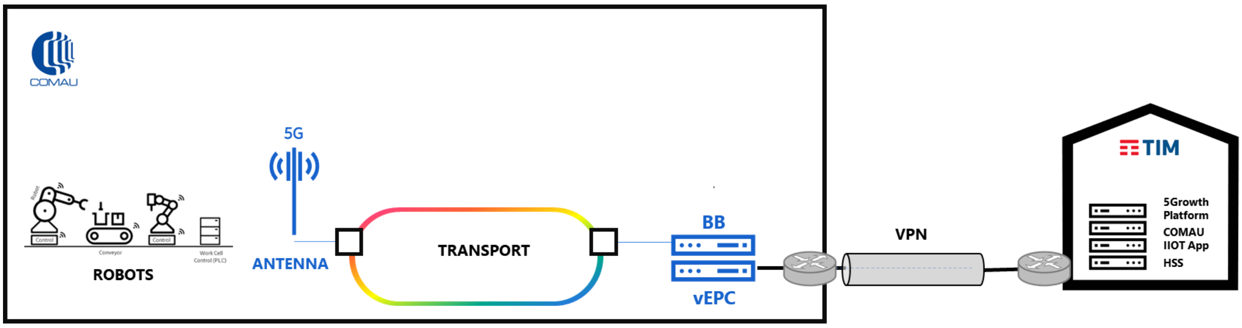


FIGURE 11: COMAU - PILOT HIGH-LEVEL ARCHITECTURE

Figure 12 provides more details on the 5G NSA (Non-Standalone) radio infrastructure based on Ericsson radio nodes and antennas. Specific 5G terminals and 5G pocket routers are used to connect the various components of the pilot (robots, controllers, AR glasses, sensors, etc) to the cellular network.

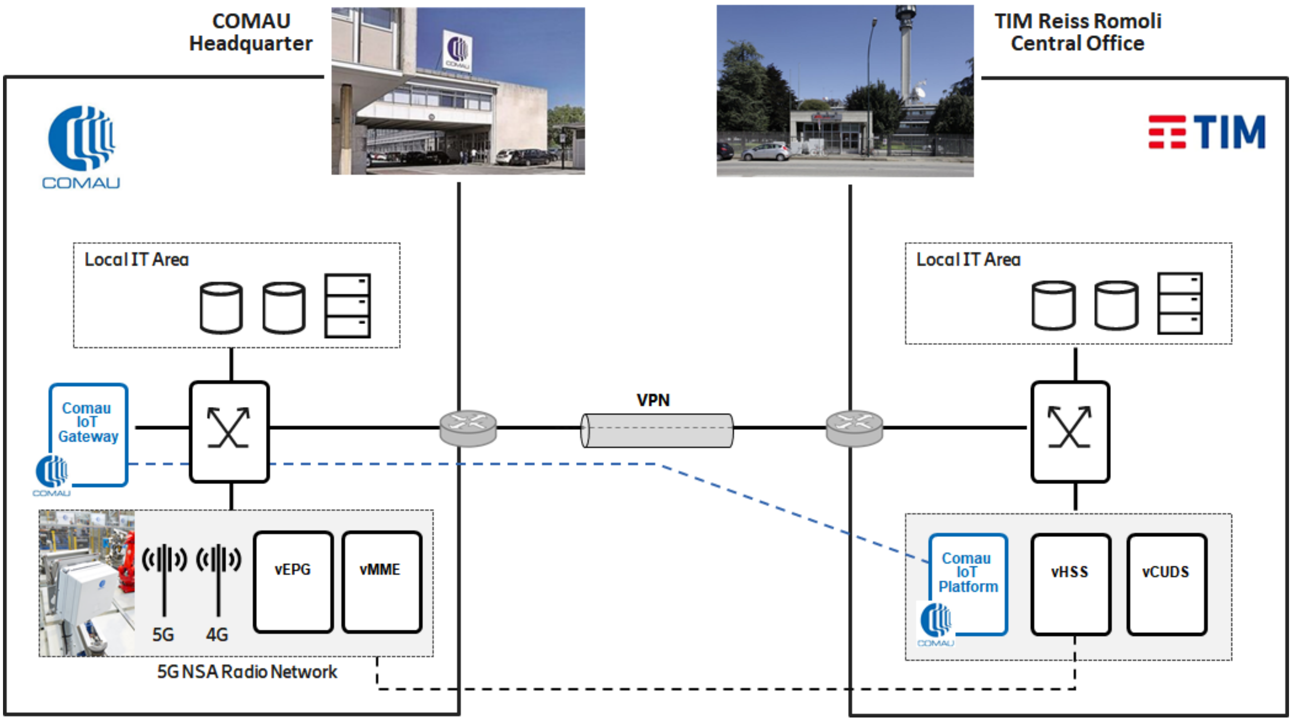


FIGURE 12: COMAU - PILOT RADIO INFRASTRUCTURE

3.1.1. Status

Figure 13 illustrates the various components of the pilot infrastructure (mobile, transport, 5Growth platform) and the related timelines considering the end of November 2020 (M18) as the current time at the publication of this deliverable. Such components are located at the COMAU and TIM sites. For completeness and better understanding, Figure 13 also includes the high-level timelines related to the UCs (for which further details are reported in the following Section 3.2). The considered time frame spans across all the project life, including the past periods. The pilot activities in WP3 started in September 2019 (M4) after three months of system design.

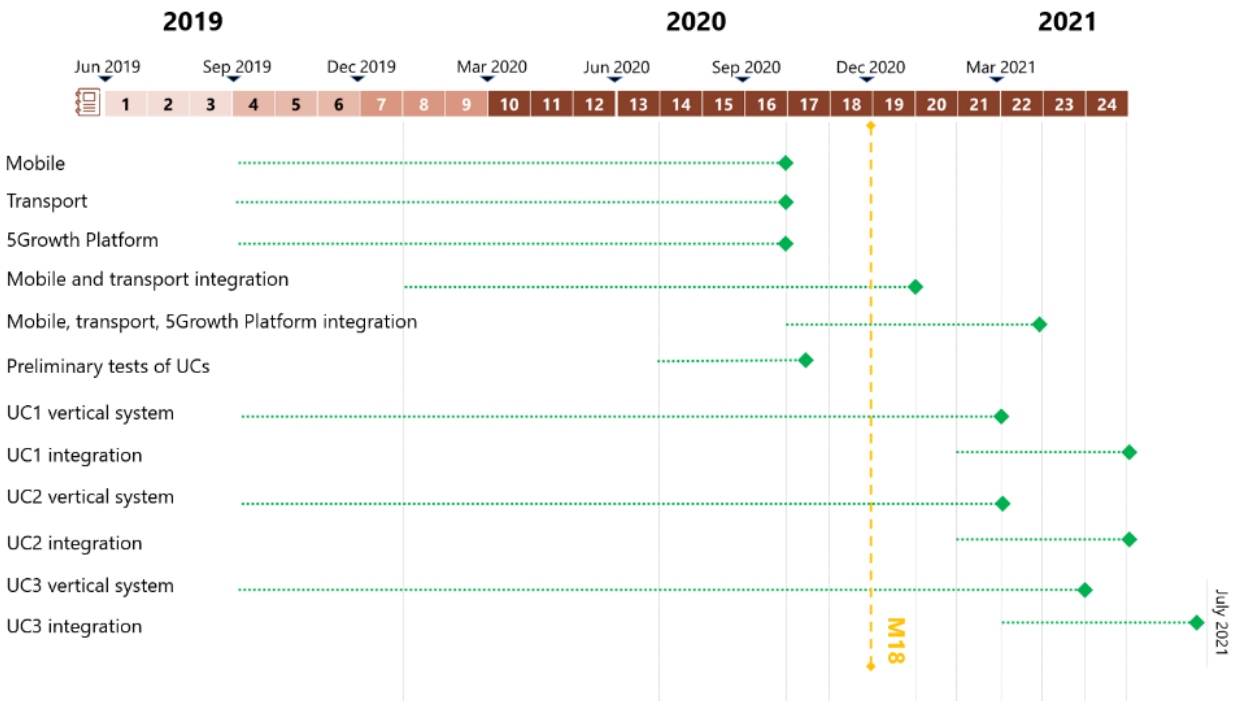


FIGURE 13: COMAU - 5G NETWORK INFRASTRUCTURE ROADMAP

Due to the restriction related to the COVID-19, the access to the vertical premises has not been possible for several months. In addition, partner companies involved in the pilot deployment have applied tight restrictions to the mobility of their employees. However, part of the deployment has been carried out working from home (e.g. the software developments). In D3.2 [1], partners had considered and reported a worst-case scenario of four months of limitations for on-site activities in the COMAU premises, in the TIM premises, in the laboratories of Ericsson, and in the academic institutions involved in the pilot (SSSA and POLITO). At the time of the current deliverable, it can be affirmed that the revised and adjusted plan, reported in D3.2, has been realistic and a concrete progress has been possible despite COVID-19.

The installation of the 5G network has been completed in the COMAU premises by end of September 2020 (M16). The network, operating on the TIM spectrum, has been tested in operation and preliminary performance results are reported in D4.2 [2]. Further tuning of the 5G network will continue beyond November 2020 (M18) to achieve the best possible trade-off between throughput and low latency by acting on the pre-scheduler and on the Maximum Transmission Unit (MTU) size.

The transport layer is used to connect the BB unit with the antenna by conveying the enhanced Common Public Radio Interface (eCPRI) interface protocol. A specific framer to wrap eCPRI on an optical channel (i.e. a wavelength in a WDM flow) has been deployed by May 2020 (M12). The overall transport network, operating on a ring of optical fiber, has been installed to replace the simple point-to-point fiber link that was preliminary used.

According to the time-plan, Release 1 of 5Growth platform is ready and available for usage. It includes the support for RAN slice feature to partition radio resources for different use case traffic and the automated network slice lifecycle management. Such initial release does not cover yet all the features needed for the final validation of the pilot use cases, since some functionalities, like PNF support, ICT17 integration with 5GEVE and service monitoring, will be made available progressively in future releases during the execution of the project. For this reason, the roadmap includes an activity dedicated to the integration of the 5Growth platform that will specifically focus on the maintenance of the platform deployment and its continuous update with the features that will be made available from the other project tasks.

3.1.2. Plan for pilot deployment

From November 2020 (M18) on, the following steps are foreseen, as illustrated in Figure 13:

1) The final integration between mobile and transport, by moving the eCPRI flow over the new optical ring, will be completed within December 2020 (M19)
2) Then the integration of the mobile-transport infrastructure with the overall 5Growth platform is planned within March 2021 (M22). Hosted in TIM site, the 5Growth platform will include the 5Gr-VS, the 5Gr-SO and the 5Gr-RL, enabling the full automation of the instantiation and configuration of vertical services and corresponding network slices by coordinating the resource allocation of mobile, transport, and cloud.
3) Preliminary tests on the infrastructure (related to radio and transport as separate entities) have been performed by October 2020 (M17), as better detailed in D4.2 [2]. In parallel, the deployment of the three UCs is moving on to start the integration with the complete infrastructure at the beginning of February 2021 (M21), for COMAU-UC1 and COMAU-UC2, with a planned conclusion within May 2021 (M24). The integration of COMAU-UC3 with the infrastructure will start on March 2021 (M22) with a planned completion within July 2021 (M26).

There are no modifications to report regarding what is stated on the HW/SW tables reported in D3.2 [1].

3.2. Use Case 1: Digital Twin Apps

The first use case, which is illustrated in Figure 14, aims at demonstrating the capability of the 5G technology, supported by the 5Growth platform, to ensure ultra-reliable low latency communication (URLLC) performances for industrial applications.

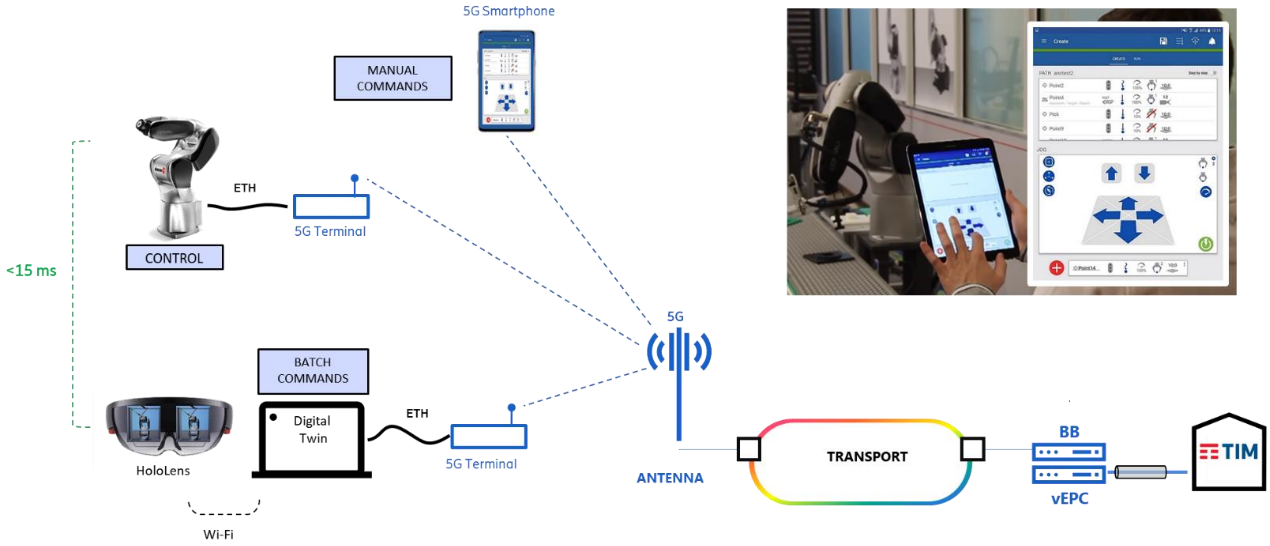


FIGURE 14: COMAU-UC1 - OVERVIEW

The 5G-connected industrial robot can receive manual commands from the COMAU application PickApp, installed on a 5G smartphone, or can receive a predetermined sequence of commands from a computer connected to the robot through 5G.

The robot controller, which performs the motion control function, is co-located with the robot. The controller executes the commands sent to the robot and estimates the actual position of the robot components via the encoders installed on the axes' motors. Through the low latency 5G links, this data is continuously sent to the smartphone or to the computer. The computer exploits this data to build a real-time digital replica (i.e. the "digital twin") of the robot and to feed specific HoloLens glasses with information presented to a human supervisor in the form of AR. The perfect alignment between the real world and the digital replica is possible thanks to a latency lower than 15 ms in the round trip.

Figure 15 presents a picture with the digital twin of the robot placed side by side with the real robot. As it can be seen, the quality of the digital representation is extremely high as a very realistic rendering is utilized to build the 3D-like digital robot starting from the positioning data coming from field.

FIGURE 15: COMAU-UC1 – DIGITAL TWIN OF THE RACER 3 ROBOT IN COMAU PREMISES

3.2.1. Status

Figure 16 illustrates the timeline for the deployment of this use case. As detailed in D3.2 [1], COMAU has initially used a robot model e.Do to start deploying the main functionalities of the use case. It is a modular small "educational" robot having the same multi-axis movements capabilities of a commercial "industrial" robot. Later, e.DO has been replaced by a Racer3 model (the one depicted in the Figure 14), which is a robot designed for quick applications in restricted spaces, including handling, assembly and pick-and-place operations. The Racer3 robot can also be instructed with the PickApp application which runs on a smartphone, with the purpose to drive the robot manually. In addition, the full 3D model of the Racer robot has been deployed between April 2020 (M11) and November 2020 (M18) and connected to the real robot so that it is now possible to have a preliminary digital twin demonstrator. According to the plan reported in the next section, it will be further evolved to a fully synchronized digital twin over 5G and complemented with the AR experience.

The COMAU-UC1 deployment has been partially impacted by the limitations imposed by COVID-19 since a large part of the software deployments has been possible in a simulated environment and later transferred in the Racer3 robot.

3.2.2. Plan for pilot deployment

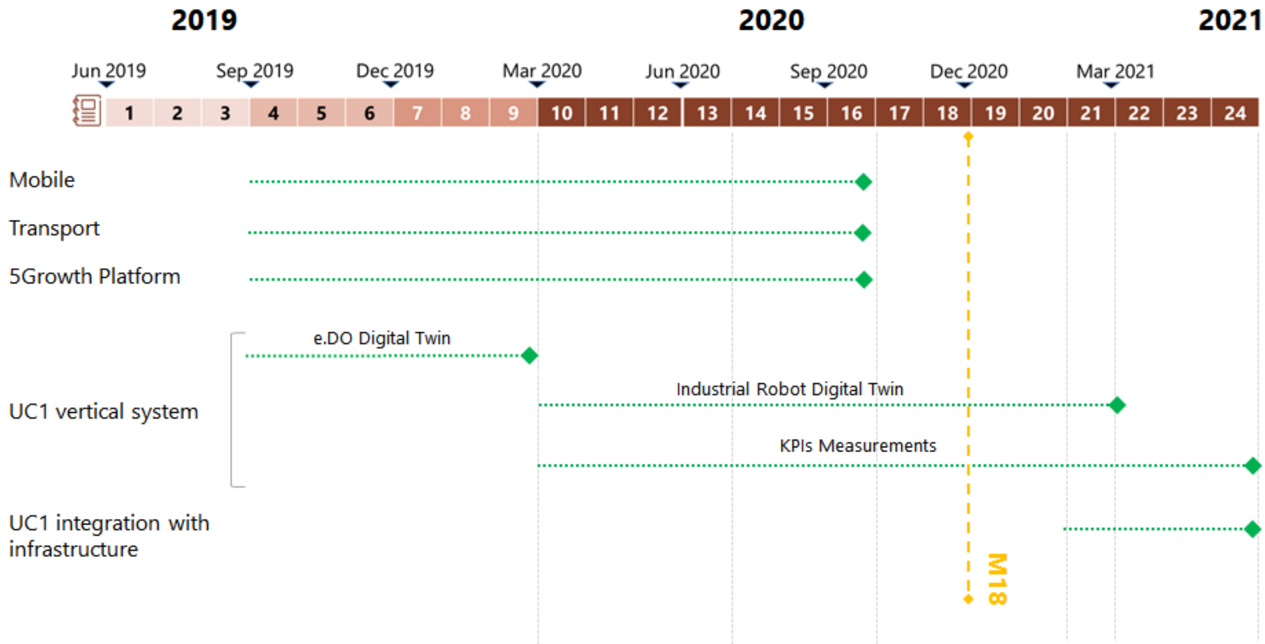


FIGURE 16: COMAU-UC1 - DEPLOYMENT PLAN

As shown in the Figure 16, the deployment of the use case with the industrial robot Racer and all the other functionalities will continue until the end of February 2021 (M21). Specifically:

1) The digital twin will be integrated in the AR environment by connecting the digital twin engine with the HoloLens
2) The 5G network will be tuned to fit the optimal latency for the AR experience (tuning of scheduler)
3) COMAU-UC1 should be fully executed at the final validation stage by the end of the project.

Measurements related to the KPI assessment have been already done and reported in D4.2 for some KPIs related to the network performances and, specifically, to the target latency that enables this use case. The integration with the overall infrastructure (mobile, transport, 5Growth platform) will start at February 2021 (M21) to be concluded in May 2021 (M24) as expected in the original plan.

There are no modifications to report regarding what is stated on the HW/SW tables reported in D3.2 [1].

3.3. Use Case 2: Telemetry/Monitoring Apps

The second use case, represented in Figure 17, has the objective to collect data directly from robots, sensors, and other machineries (e.g. conveyor, PLC…), and to send this data to a specific software platform, namely COMAU in.Grid, running on a cloud environment located in the central office of TIM. This platform gathers and analyses data, possibly sending alerts to technicians through a dashboard asking for corrective actions. Detailed downtime analysis and failure reports are generated for a holistic view of future maintenance needs. For data collection, when scaled on a real plant, the massive Machine Type Communication (mMTC) of 5G is required for the high density of connected devices.

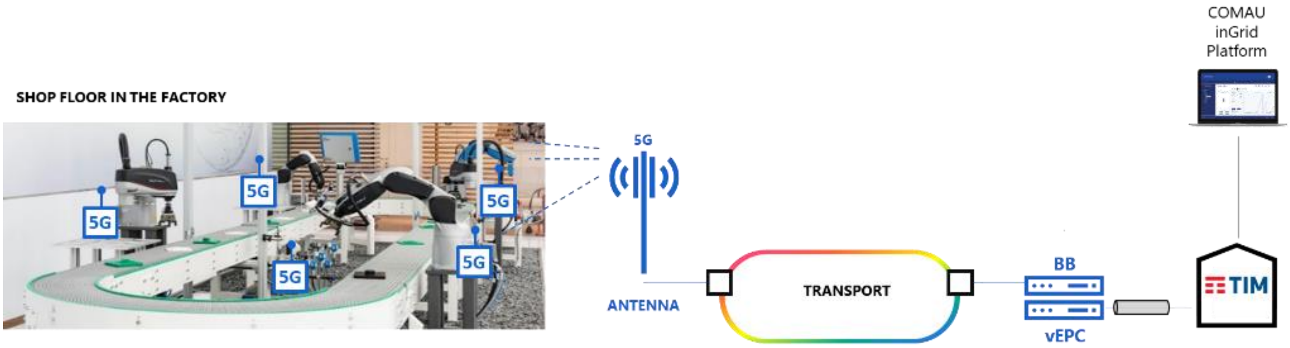


FIGURE 17: COMAU-UC2 – OVERVIEW

Figure 18 reports to pictures of the robotic cell under deployment at the COMAU premises. On the left picture are visible the Racer3 robots and the circular conveyor where the robots will execute a sequence of pick and place actions. The right picture shows the area from a different angle from which the 5G antenna, mounted on a dedicate pole, is visible.

FIGURE 18: COMAU-UC2 - ROBOTIC CELL AND 5G ANTENNA

Figure 19 reports a screen capture of the COMAU in.Grid platform. Many parameters related to the various components of the robotic cell are analyzed and warnings or alarms are presented in case of detected problems. This platform will also be used for trend analysis of data coming from sensors like, for example, vibrations patterns monitored through Inertial Measurement Units (IMU).

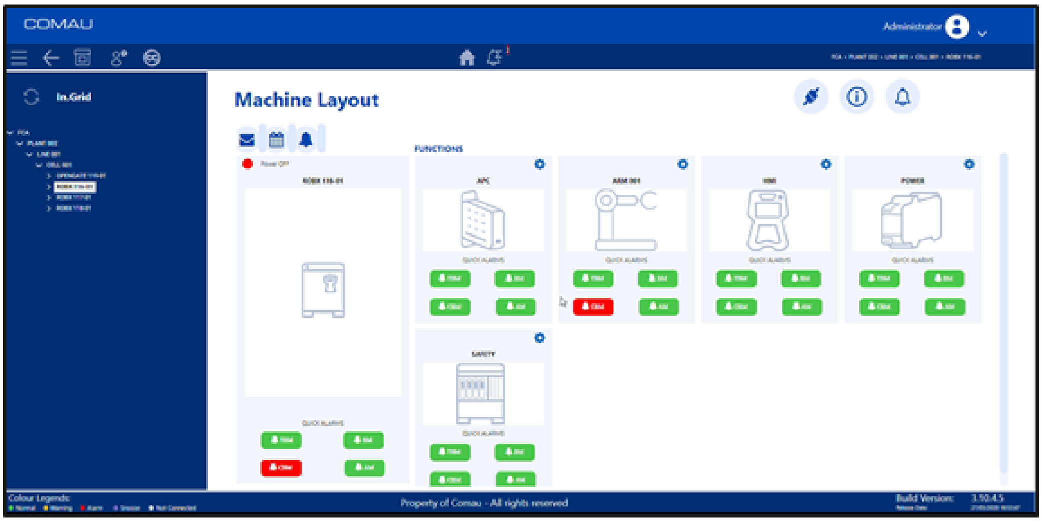


FIGURE 19: COMAU-UC2 – IN.GRID IIOT PLATFORM

3.3.1. Status

Figure 20 summarizes the expected timeline for the deployment of this second use case. As detailed in D3.2 [1], COMAU has designed and it is currently developing a small robotized line from which data are captured and sent to the IIoT platform in.Grid, located on TIM premises. At November 2020 (M18), this line (which constitutes a realistic replica of manufacturing line on a small scale) is under deployment. The target architecture includes three robots operating with a conveyor and coordinated by a PLC which performs the task control. The COMAU site and the TIM site are connected through a VPN that ensure a secure and confidential flow of data from the sensors installed on the robotized line towards in.Grid.

The COMAU-UC2 deployment has been partially impacted by the limitations imposed by COVID-19 because it is largely based on robotic hardware deployments, hence the physical access to labs is required. However, it has been possible to contain the delay by focusing, as much as possible, the work on the software aspects of the use case related to data collection in the IIoT platform.

3.3.2. Plan for pilot deployment

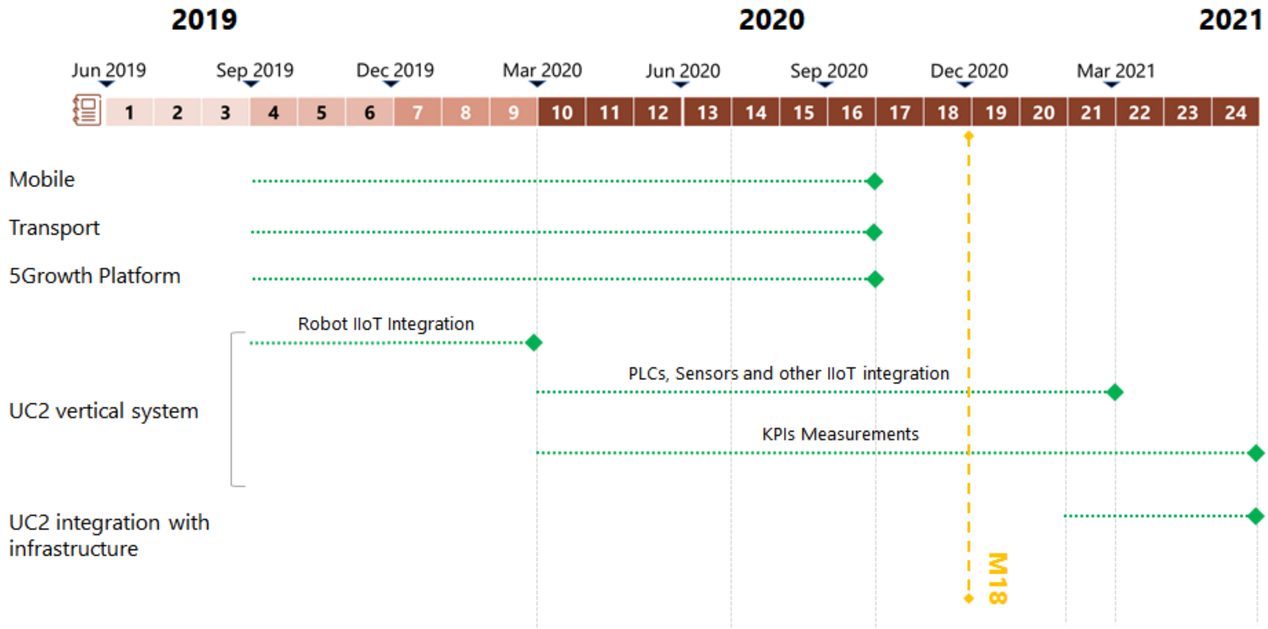


FIGURE 20: COMAU-UC2 - DEPLOYMENT PLAN

As shown in the Figure 20, the deployment of the use case and all the other functionalities will continue until the end of February 2021 (M21). Specifically:

1) The deployment of the robotic cell, including three robots and a conveyor, will be completed
2) The in.Grid platform, located in TIM premises, will receive the data from the robotic cell to perform the statistics and diagnosis on the operating status of the cell. A tuning activity will be performed to fix the optimal performance of the platform for preventive maintenance purposes.

As shown in Figure 20, the deployment of the use case will continue until the end of February 2021 (M21). The integration with the overall infrastructure (mobile, transport, 5Growth platform) will start in February 2021 (M21) to be concluded in May 2021 (M24) as expected in the original plan.

There are no modifications to report regarding what is stated on the HW/SW tables reported in D3.2 [1].

3.4. Use Case 3: Digital Tutorial and Remote Support

This third use case, illustrated in Figure 21, aims at providing technicians and maintenance staff with remote support and digital tutorials by means of high definition videos and live connections to remote technical offices. The main objective is to reduce the MTTR using real-time streaming with a skilled technician in a remote location to support maintenance and repair operations in the production line of the factory. Another advantage achieved with this use case is the possibility to access to step-by-step digital tutorials and instructions for training purposes.

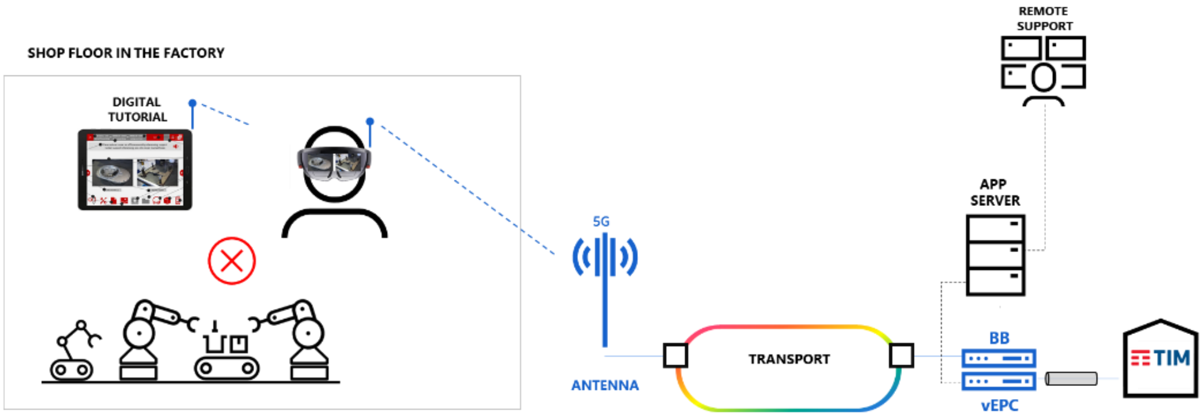


FIGURE 21: COMAU-UC3 - OVERVIEW

In the scenario reported in Figure 21, machinery in a factory is affected by a fault, but the local staff requires advanced support to rapidly fix the problem. In-field technician sent to the remote factory can use a tablet or AR devices connected via 5G. On the other side of the connection, geographically far from the factory where the fault occurred, there is an expert with a remote maintenance application. Such expert has the "full picture" of the fault and can provide remote support to the in-field technician.

Use Case 3 will also benefit of the interaction with the 5G EVE platform which is related to the COMAU pilot according to the scheme in Figure 22.

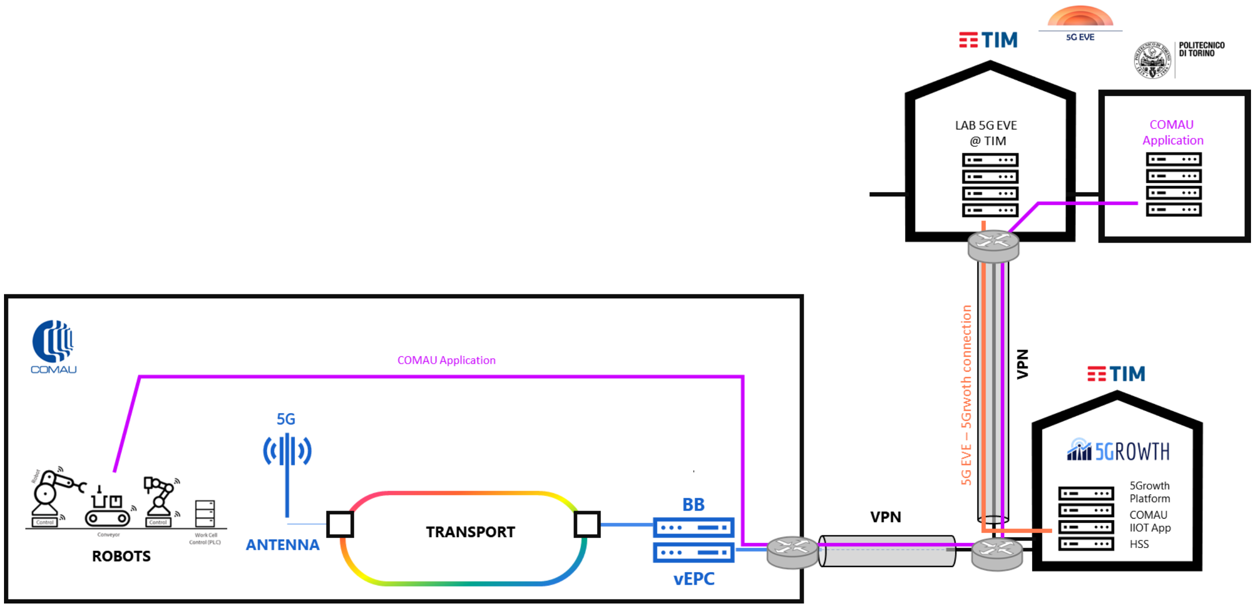


FIGURE 22: COMAU-UC3 – 5G GROWTH - 5G EVE INTERACTION

Specifically, the 5G EVE lab hosted in the TIM site located in via Borgaro is connected to the TIM site located in via Reiss Romoli where the 5Growth platform is hosted. The COMAU application related with COMAU-UC3 is installed on a server located in the Politecnico di Torino which is similarly part of the mentioned 5G EVE network. Through this setup, it is possible to connect (as indicated by a purple line in figure) the robotic area in COMAU with the application running in Politecnico di Torino thanks to the interworking of 5G EVE with 5Growth.

3.4.1. Status

Figure 23 summarizes the expected timeline for the deployment of the third use case. The use case implementation was planned to start later, in comparison with to the other two use cases in the pilot. More specifically, for this use case, the design phase was completed in February 2020 (M9). Despite COVID-19, it has been possible to work at the setting up of the video streaming using the AR glasses integrating the possibility to voice interaction between the in-field technician and the remote support.

3.4.2. Plan for pilot deployment

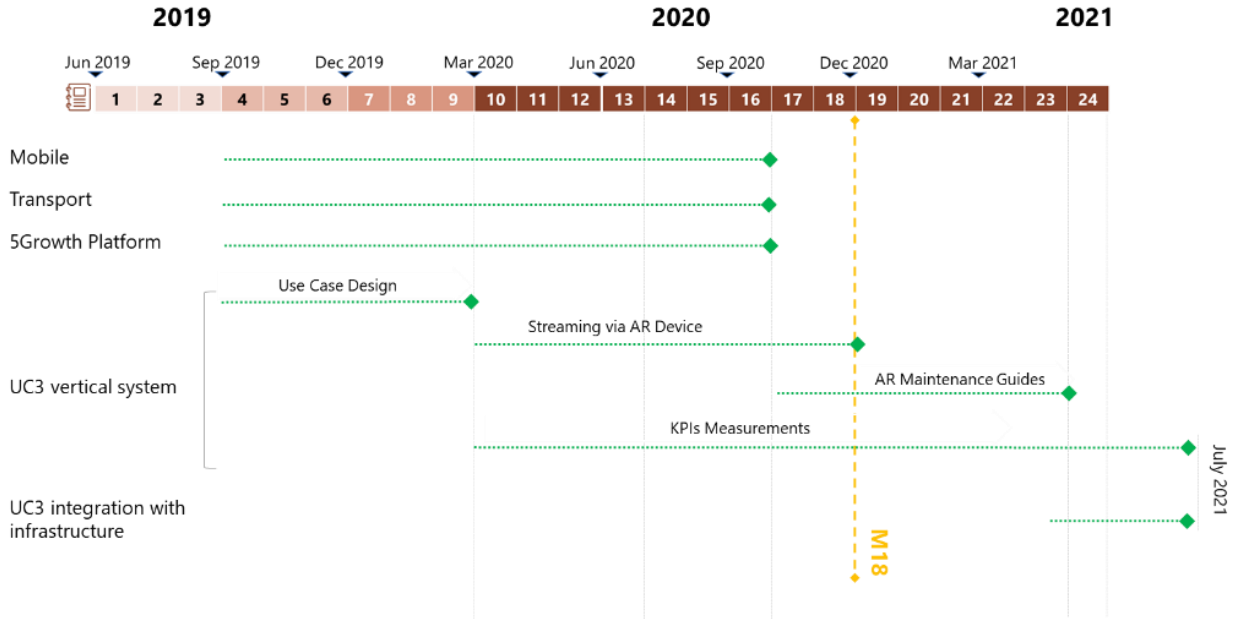


FIGURE 23: COMAU-UC3 - DEPLOYMENT PLAN

As shown in the Figure 23, the deployment of the use case and all the other functionalities will continue until the end of April 2021 (M23). Specifically:

1) Test of the VPN between COMAU and TIM to enable communication between 5Growth site and 5G EVE sites.
2) Test of the interworking layer of 5G EVE platform and 5Growth platform on the Italian site.
3) Deployment of the video streaming with virtual maintenance procedures with the scope to provide and show step-by-step instructions to the in-field technician. This functionality is indicated as "digital tutorial".
4) Integration of the digital tutorial with the AR HoloLens glasses.

While some KPI verifications, which have parameters in common with the other use case, are already on going, the complete KPI assessment will be concluded by July 2021 (M26).

There are no modifications to report regarding what is stated on the HW/SW tables reported in D3.2 [1].

4. EFACEC_E Vertical Pilot

4.1. Infrastructure

Task 3.6, related to EFACEC_E, has two phases: Phase 1 and Phase 2. Phase 1 concerns all the activities targeting the availability of a fully functional 5G infrastructure (RAN and Core) in a Lab environment where it is integrated with the use cases and tested: interoperability and performance tests (KPIs). Phase 1 intends to guarantee that all the use cases requirements are met before the deployment on the pilot sites, which is a more demanding environment. During Phase 2 are also accomplished the activities that will provide network slicing in first place and finally full network orchestration that will guarantee the vertical use cases KPIs requirements.

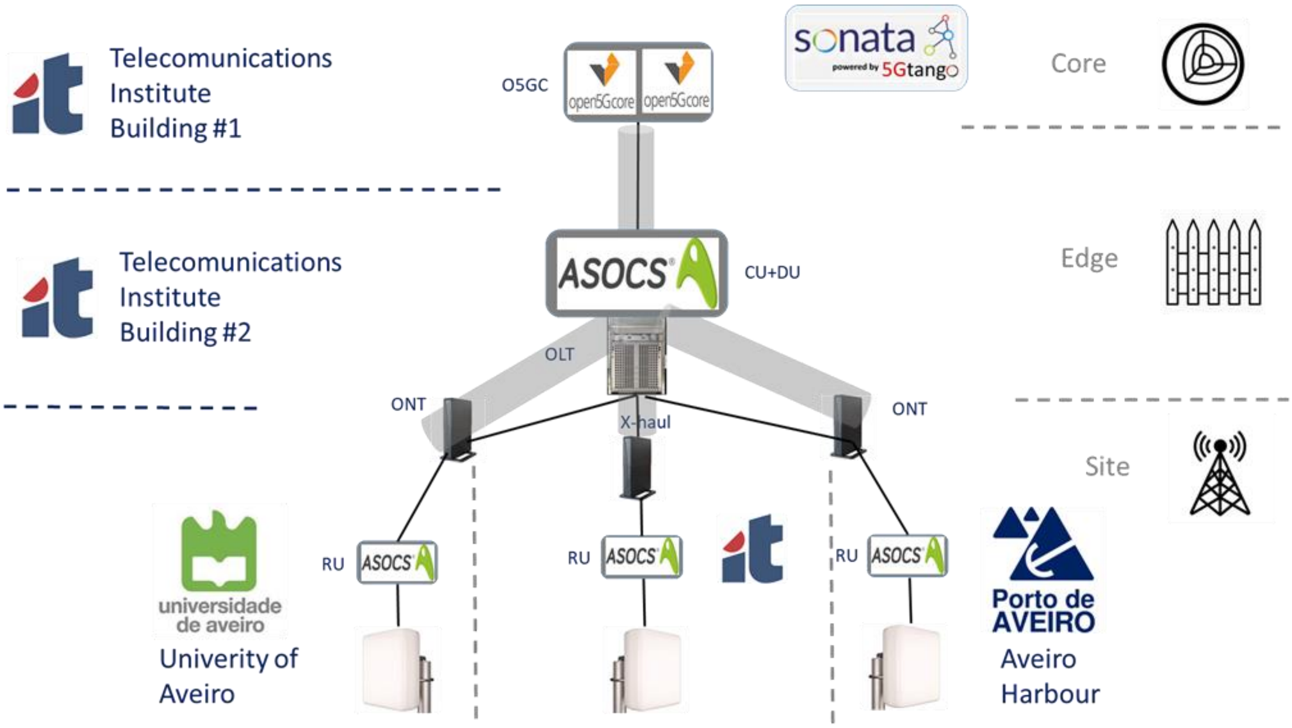


FIGURE 24: EFACEC_E AND EFACEC_S - 5G NETWORK (M26)

Figure 30 depicts the status the EFACEC_E and EFACEC_S pilots on sites at July 2021 (M26), when all the components will be on place. Both pilots are supported by the same 5G Core network (Open 5G Core) located at IT Aveiro building 1 and SA RAN, Centralized Unit (CU) plus Distributed Unit (DU), located at IT Aveiro building 2.

The Energy pilot has two sites: a secondary substation in the Aveiro University and the IT Aveiro building 1 that will be served by a 5G SA Radio Unit (RU) each.

The 5Growth integration with ICT17 5G-VINNI, will be finished and all slicing and orchestration functionalities will be available for evaluation and demonstration.

FIGURE 25: EFACEC_E - SITE 1- UNIVERSITY ENERGY SUBSTATION

FIGURE 26: EFACEC_E - SITE 2 - IT AVEIRO ELECTRICAL BOARDS

The figures above show the pilot sites 1 and 2 where will be deployed the EFACEC_E Use Case 1 and 2, respectively.

4.1.1. Status

According to the contingency scenario defined on D3.2 [1] for November 2020 (M18), there is a fully functional 5G SA network encompassing an Open 5G Core and 5G SA RAN ASOCs (CU+DU, RU) deployed in IT Labs. In order to overcome the unavailability of the OpenAirInterface RAN, as planed on D3.2, it was decided to acquire a 5G SA RAN development kit from ASOCS (https://www.asocscloud.com/). Because ASOCS RAN native 5G SA core is based on a Metaswitch (https://www.metaswitch.com/) solution integration between ASOCS RAN and O5GCORE was carried out, with the cooperation of Altice Labs, Fraunhofer Fokus and ASOCS. ALB is using ASOCS development kit to develop its own 5G indoor and outdoor 5G SA RAN commercial solution. This solution does not provide network slicing capabilities.

In addition, the EFACEC Energy pilot setup including all the components necessary to evaluate the use case 1 are on place in the IT Labs, and the first KPIs measurements were carried out. Further details are provided in the following section.

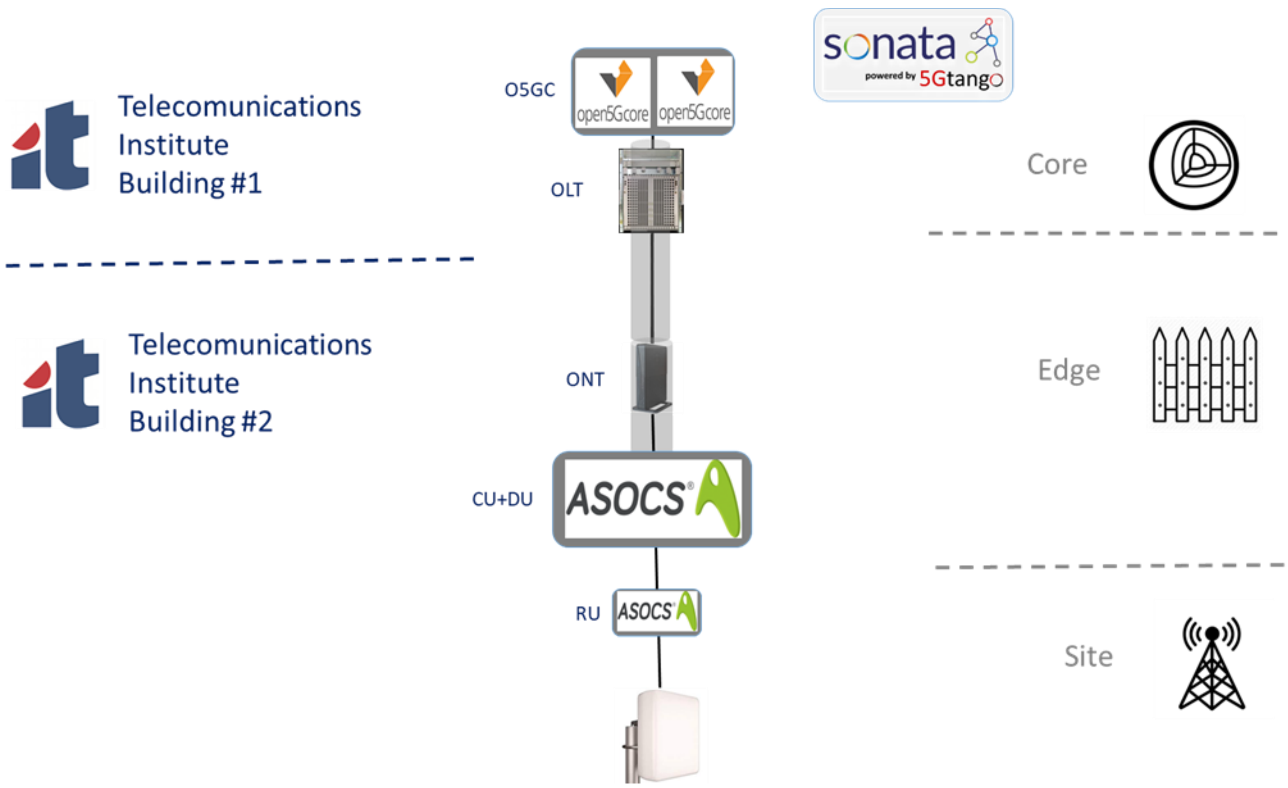
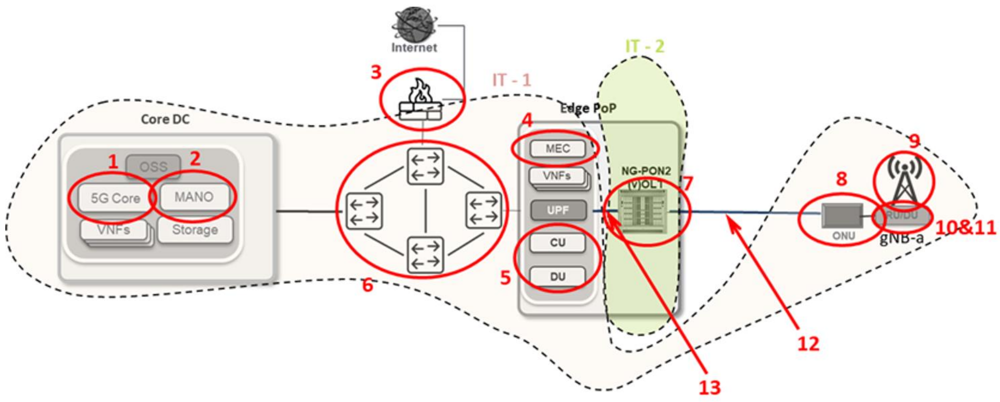


FIGURE 27: EFACEC_E AND EFACEC_S - 5G NETWORK @ LAB (M18)

Figure 28 and Figure 29 show respectively details of the 5G infrastructure and the pictures of the most relevant components at IT Labs. The 5G infrastructure available in November 2020 (M18) is the same that will be on the pilot's sites (phase 2) with the exception that the RUs will be moved from the Lab environment to pilot sites.



	Component	Hardware	Status
1	Open5GCore	Server	OK
2	SONATA NFV orchestrator	Server	OK
3	Firewall / VPN termination	Server	OK
4	Edge Computing components	Server	OK
5	CU/DU	ASOCS	OK
6	IP network	IT internal network	OK
7	OLT	OLT2T2	OK
8	ONT	NG-PON2 ONT-SFU	OK
9	Antenna	ASOCS	OK
10	gNB	ASOCS	OK
11	RU/DU	ASOCS	OK
12	Fiber OLT/ONT connection	Dedicated fiber	OK
13	Fiber OLT/PoP connection	Dedicated fiber	OK

FIGURE 28: EFACEC_E AND EFACEC_S - 5G INFRASCTRUTURE DETAILS

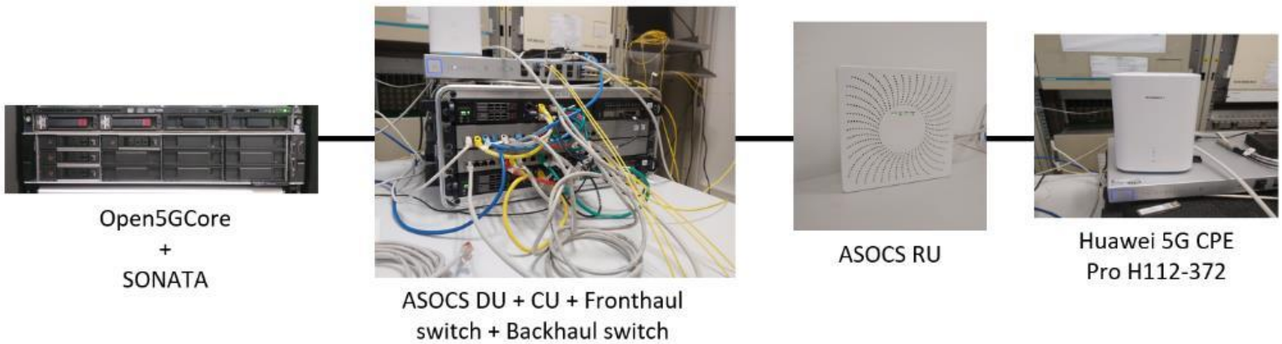


FIGURE 29: EFACEC_E AND EFACEC_S - 5G INFRASCTRUTURE AT IT LABS

The RAN is based on a remote radio RU solution, meaning that no 5G premises are present close to the user radio access, what makes the implementation of a MEC solution not feasible. On the other hand, the 5G RU solution is an important technology for the radio network densification that otherwise has only to rely on the traditional gNodeBs, what makes the densification too expensive for broad adoption.

4.1.2. Plan for pilot deployment

Figure 30 shows the EFACEC_E 5G network road map.

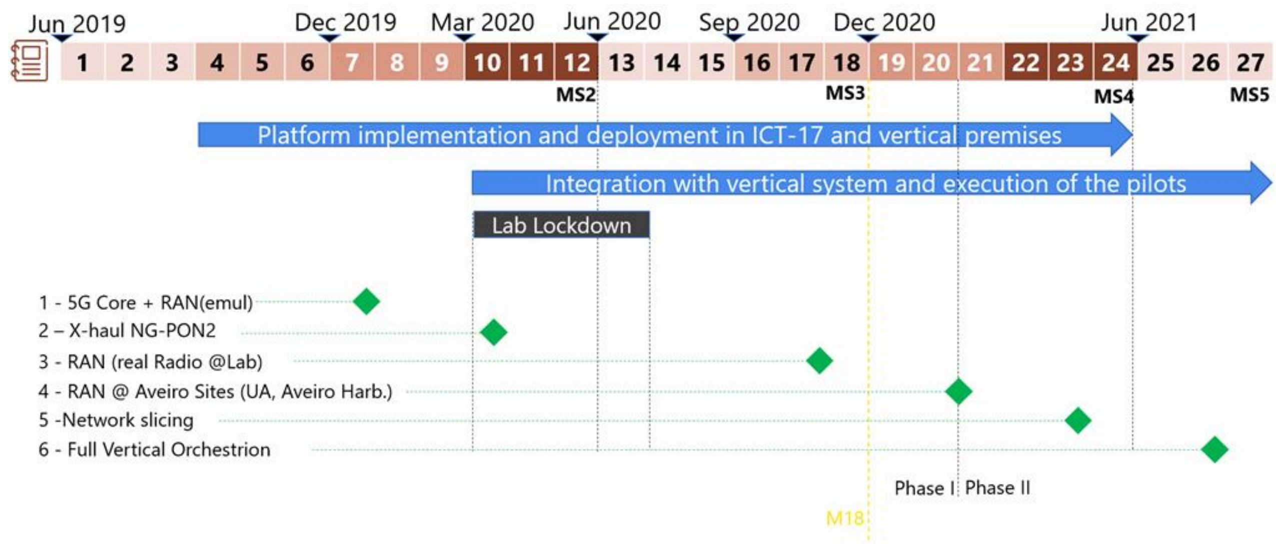


FIGURE 30: EFACEC_E - 5G NETWORK INFRASTRUCTURE ROADMAP

During October 2020 (M17) the emulated RAN component was replaced by a real radio hardware (ASOCS, CU+DU and RU), Lab environment. After this milestone, the deployment on site starts, encompassing the following activities:

1) January 2021 (M20), the real RAN solution deployed at the Lab will be extended to the pilot sites, the Secondary Substation in the University of Aveiro;
2) April 2021 (M23), Network Slicing features will be added to the Lab (first) and pilot sites, accommodating the different requirements of the pilots and respective use cases;
3) July 2021 (M26), not only the network, but also vertical components are orchestrated to be deployed on the network, either being placed in the site, edge or core.

4.2. Use Case 1: Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV distribution substation

Figure 31 depicts the modelling of this use case. Its description in detail can be consulted in Section 2.2.2 of D3.2 [1].

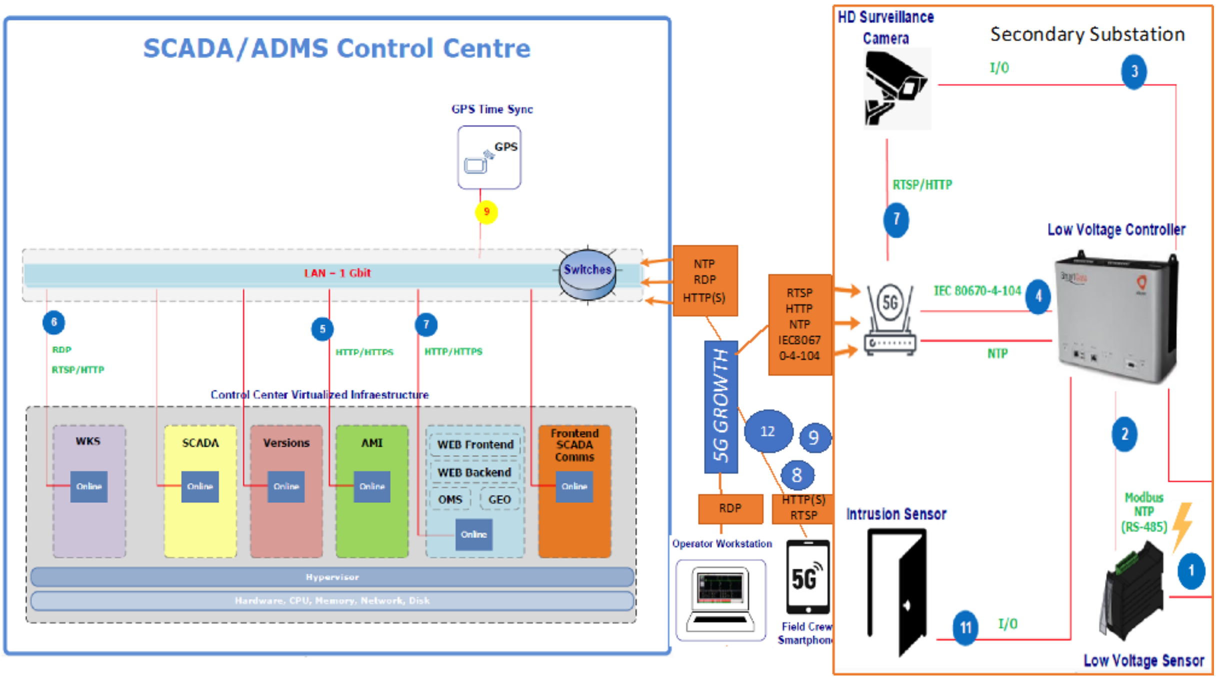


FIGURE 31: EFACEC_E-UC1 - OVERVIEW

4.2.1. Status

As described in D3.2 [1], the plan for November 2020 (M18) is considering the 5G network and a real 5G radio integrated and fully functional but at Lab environment level. Thus, the needed components to implement EFACEC_E-UC1 are being deployed and tested in IT Aveiro Labs according the plan.

The purchasing of components for the pilot was heavily impacted. Nevertheless, considering what was planned to be available in November 2020 (M18) everything is already deployed on IT Lab, except the 5G CPE that is still in transit to EFACEC Energy, and shall be deployed in IT lab shortly.

- GSmart configuration database was created, including all the direct I/O and the Secondary Substation I/O.
- Implementations were made on the GSmart to enable the possibility to remotely perform some of the tests, this way allowing to reduce the physical presence of people involved in the IT Lab.
- Some changes were made in the firmware of the LVS3 to support remote testing.
- The network configurations on Gsmart side were adjusted to cope firstly with the emulated 5G network in the IT Lab, and then with the 5G SA network with ASOCS RAN and Open5GCore.
- A Video IP camera was mounted in the IT Lab and wired connected to the GSmart; At this stage for the first testing experiments, H264 codec is selected in the camera.

- An intrusion detector was mounted and connected to the GSmart.

The Control Center software – ScateX# - is already deployed in the IT datacenter in Aveiro and its specific implementation and configuration to support the secondary substation telemetry and video streaming scenarios belonging to Use Case 1 are fully developed.

- The ScateX# configuration was created including all SCADA I/O concerning the Secondary Substation. A single-line diagram of the Secondary Substation was created providing a GUI to the EFACEC_E-UC1 exposing all real-time telemetry data concerning the secondary substation.
- The ScateX# model configuration was created in order to provide graphical connectivity between all relevant graphical interfaces to support EFACEC_E-UC1 stories (alarm list, event list, substation diagram, camera streaming window).
- The IT Av virtualization infrastructure in the datacenter was prepared to host the ScateX# VMs and, on the other side, at EFACEC, the ScateX# VMs were prepared in order to be deployed with IT Av datacenter and cope with the virtualization technology in place.
- Upon deployment, the network configurations on ScateX# side were adjusted to cope firstly with the emulated 5G network in the IT Lab, and then with the 5G SA network with ASOCS RAN and Open5GCore.

The current status, as detailed above, is in line with the November 2020 (M18) re-planning due to COVID-19 constraints that heavily affected the project execution, as described in D3.2 [1].

The remaining deployments of EFACEC_E-UC1, including all the interactions with the maintenance crew mobile interface will be deployed and preliminary tested by the end of April 2021.

Figure 32 show the setup in IT Labs Aveiro concerning all the Energy Vertical components of EFACEC_E-UC1. The substation equipment will be moved to the pilot site at the selected Secondary Substation in Aveiro University during the second phase in November 2020 (M18) of this task, according to the EFACEC_E-UC1 roadmap depicted in Figure 34.

FIGURE 32: EFACEC_E-UC1 – SECONDARY SUBSTATION AUTOMATION IN IT LAB AND CONTROL CENTER SOFTWARE IN DATACENTER

Figure 33 shows the current perspective of the Workstation Interface, exposing the telemetry transmitted by the GSmart, and the video streaming transmitted by the video IP camera, both currently installed in the IT Lab.

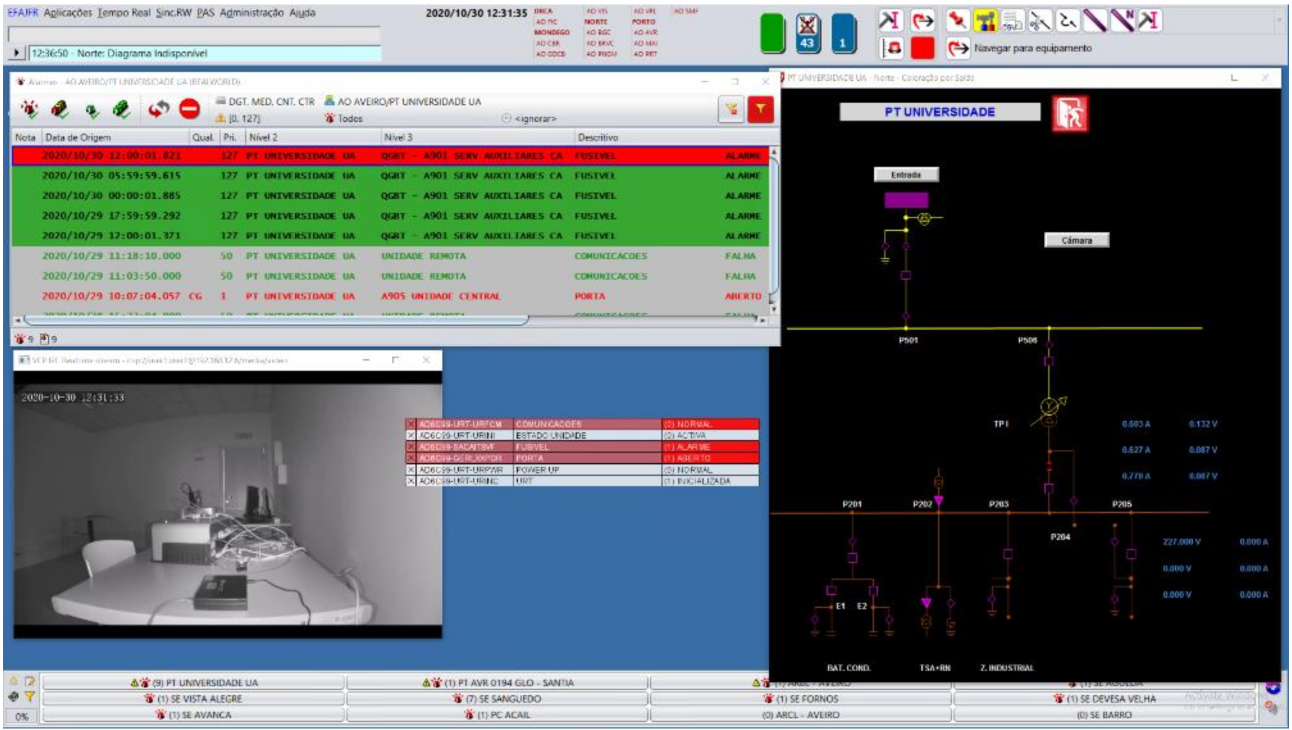


FIGURE 33: EFACEC_E-UC1 – CONTROL CENTER WORKSTATION INTERFACE

4.2.2. Plan for pilot deployment

Besides the rescheduled activities performed in order to achieve a lab environment scenario the plan of EFACEC Energy pilot is being performed according with Option 1 described in section 2.2.4 of the D3.2 [1], and the following roadmap.

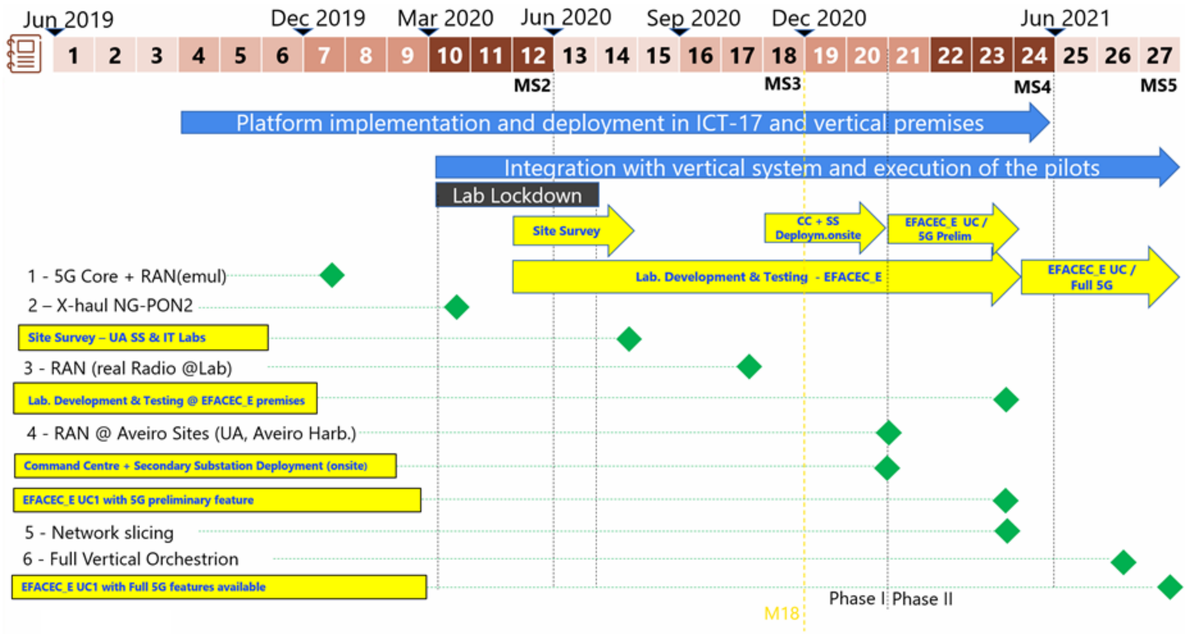


FIGURE 34: EFACEC_E-UC1 – ROADMAP

As shown in Figure 34, the main steps of the plan for this use case are:

1) Development and testing at EFACEC_E premises – This activity runs in parallel with the deployment and testing and shall conclude by the end of April 2021. By that time, the remaining features of the EFACEC_E-UC1, namely Experiment#3 – Video Streaming Exhibition in Mobile Interface and Experiment#4 – Augmented Reality in Mobile Interface, as described in section 2.2.2.4 of D3.2 [1], will be deployed.
2) Command Centre and Secondary Substation deployment on pilot site – This activity is shared by the two Energy Vertical use cases and is equally mentioned in the roadmap of EFACEC_E-UC2. As detailed in the previous section, the ScateX# network management system is already deployed in the ITAV datacentre, and fully functional. The Secondary substation automation, currently deployed in the ITAV lab, will be moved to the Secondary substation in Aveiro University by March 2021 since the 5G RAN covering the area is planned to be in place by the end of February 2021. The full EFACEC_E-UC1 setup will be deployed and working in the final pilot locations by the end of April 2021.
3) EFACEC_E-UC1 5G Preliminary Testing Phase – By the end of April 2021 the EFACEC_E-UC1 will be fully deployed on site, and some 5G functionalities will be ready. From now on and till the end of April, EFACEC_E-UC1 will be tested and validated within these constrains.
4) EFACEC_E-UC1 5G Final Testing Phase – By May 2021 all 5g network functionalities will be available providing the full conditions to verify and validate the business, functional and technical requirements according to what have been specified previously.

There are no modifications to report regarding what is stated on the HW/SW tables reported in D3.2.

4.3. Use Case 2: Advanced Critical Signal and Data Exchange across wide smart metering and measurement infrastructures

Figure 35 depicts the modelling of this use case. Its description in detail can be consulted in Section 2.2.3 of D3.2 [1].

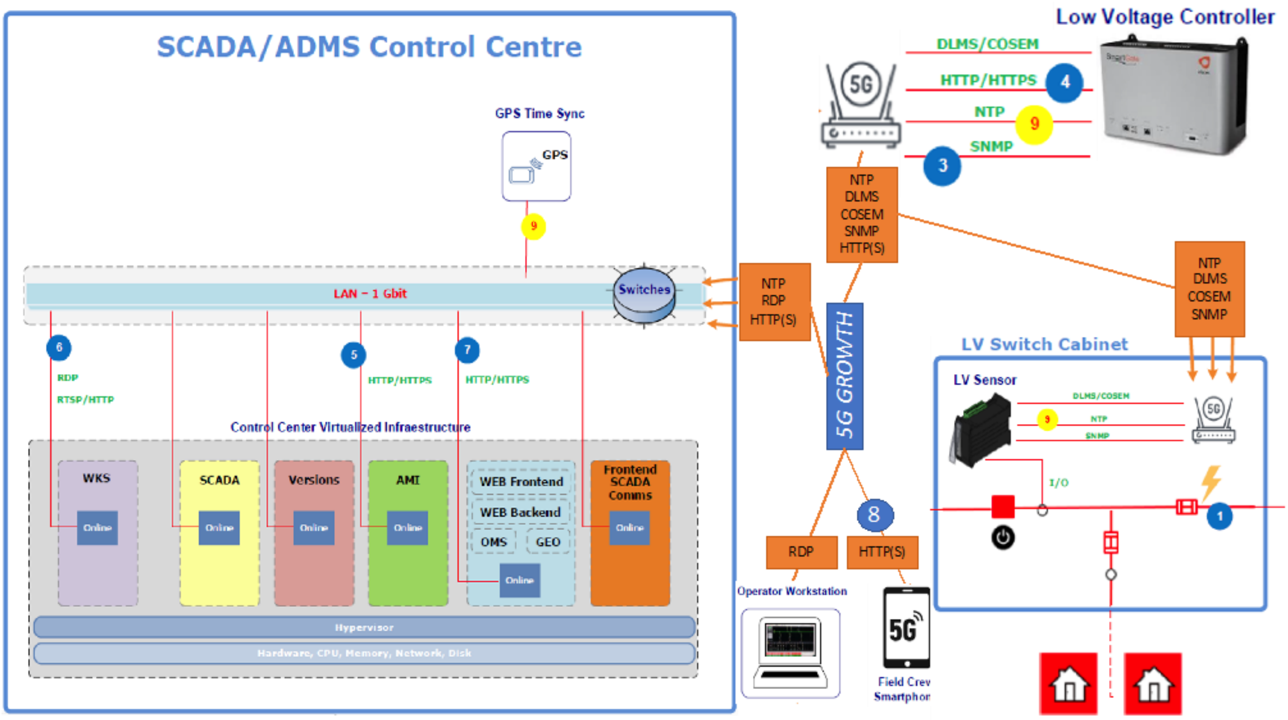


FIGURE 35: EFACEC_E-UC2 - OVERVIEW

4.3.1. Status

As described in D3.2 [1], the first activities concerning EFACEC_E-UC2, such as the HW specific implementation in LVS3 equipment to support the use case are already taking place at EFACEC premises.

The relevant highlights and achievements at November 2020 (M18) are:

- Site survey on Aveiro University and IT buildings took place in mid-July 2020. The secondary substation to deploy the Energy pilot equipment was selected among the available ones, and the lab in IT building to receive the remaining equipment was also determined.
- Currently there are some restrictions in place concerning the schedule of allowed access of EFACEC personnel to the EFACEC Energy premises. Depending on the short-term evolution of COVID-19, stricter measures may be adopted.

- The hardware development activities on LVS3 device are being performed at EFACEC premises at this moment in order to support the EFACEC_E-UC2, namely in what concerns to LVS3 connectivity options and configurations.

At this stage, in November 2020 (M18), there are no further delays.

4.3.2. Plan for pilot deployment

The plan of EFACEC Energy pilot concerning EFACEC_E-UC2 is being performed according with Option 1 described in section 2.2.4 of the D3.2 [1], and the following roadmap.

Figure 36 shows the estimated impact in the deployment plan of EFACEC_E-UC2.

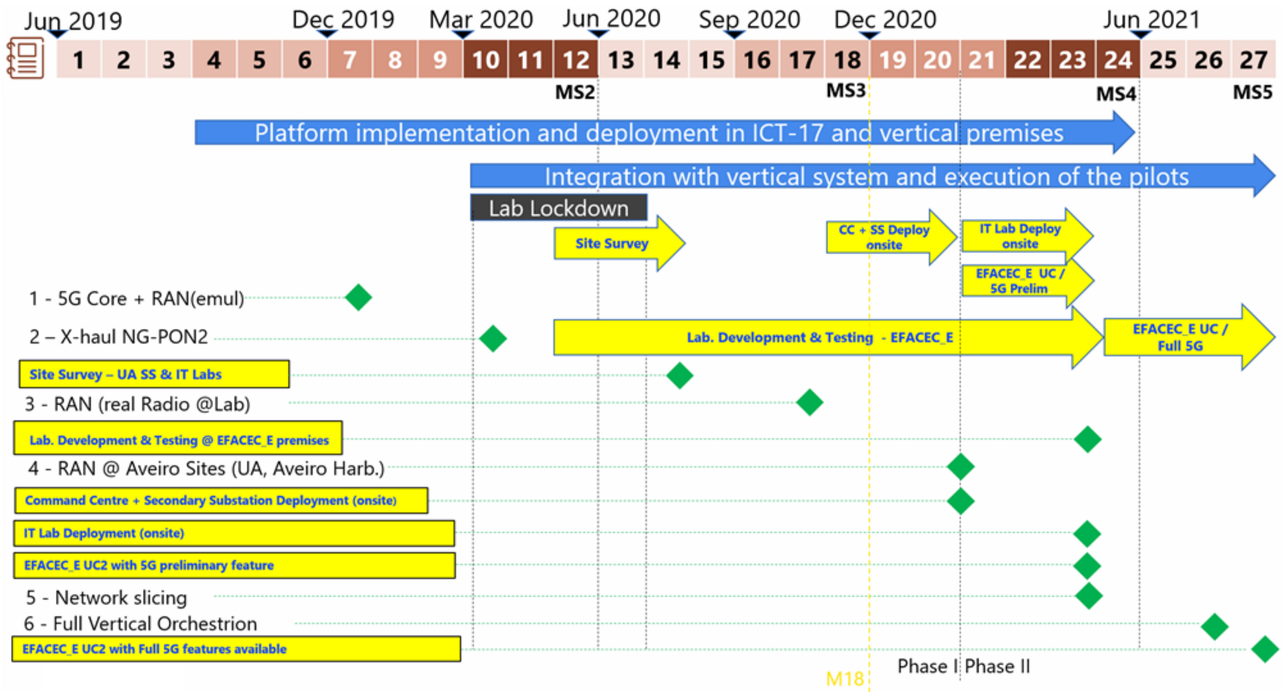


FIGURE 36: EFACEC_E-UC2 - ROADMAP

As shown in Figure 36, the main steps of the plan for this use case are:

1) Development and testing at EFACEC_E premises – This activity runs in parallel with the deployment and testing of the EFACEC_E-UC2 and shall conclude by the end of April 2021. By that time, the planned features of the EFACEC_E-UC2, namely Experiment#1 – Fault Detection – Last Gasp and Experiment#2 – Low Voltage Sensors Synchronization, as described in section 2.2.2.4 of D3.2 deliverable, will be deployed on Aveiro Site locations.
2) Command Centre and Secondary Substation deployment on pilot site – This activity is shared by the two Energy Vertical use cases and is equally mentioned in the roadmap of EFACEC_E-UC1. In this case, the software developments and configurations needed to support EFACEC_E-UC2 will be deployed both in the ScateX# system and in GSmart device till the end of February 2021.
3) University of Aveiro Lab deployment – This activity comprehends the deployment on site of all the pilot components regarding the Low Voltage Grid automation, needed to support the

EFACEC_E-UC2. The LVS3 devices that are currently under implementation of HW and firmware enhancements will be deployed on Aveiro site locations during this activity. These components will be installed in a laboratory and in a low voltage electrical panel inside the IT Building, as already determined during the site survey. By the end of April 2021, the full EFACEC_E-UC2 setup will be deployed.

4) EFACEC_E-UC2 5G Preliminary Testing Phase – By the end of April 2021 the EFACEC_E-UC2 will be fully deployed on site, and some 5G functionalities will be ready. As soon as the EFACEC_E-UC2 deployment begins and till the end of April 2021, EFACEC_E-UC2 will be tested and validated within these constrains.
5) EFACEC_E-UC2 5G Final Testing Phase – By May 2021 all 5G network functionalities will be available providing the full conditions to verify and validate the business, functional and technical requirements of EFACEC_E-UC2, according to what have been specified previously

There are no modifications to report regarding what is stated on the HW/SW tables reported in D3.2.

5. EFACEC_S Vertical Pilot

5.1. Infrastructure

Task 3.5 (EFACEC_S) has two phases: phase 1 and phase 2 .Phase 1 concerns all the activities targeting the availability of a fully functional 5G infrastructure (RAN and Core) in a Lab environment where is integrated with the use cases and tested: interoperability and performance tests (KPIs). Phase 1 intend to guarantee that all the use cases requirements are meet before the deployment on the pilot sites, that is a more demanding environment. During Phase 2 are also finished the activities that will provide network slicing first and finally full network orchestration that will guarantee the vertical use cases KPIs requirements.

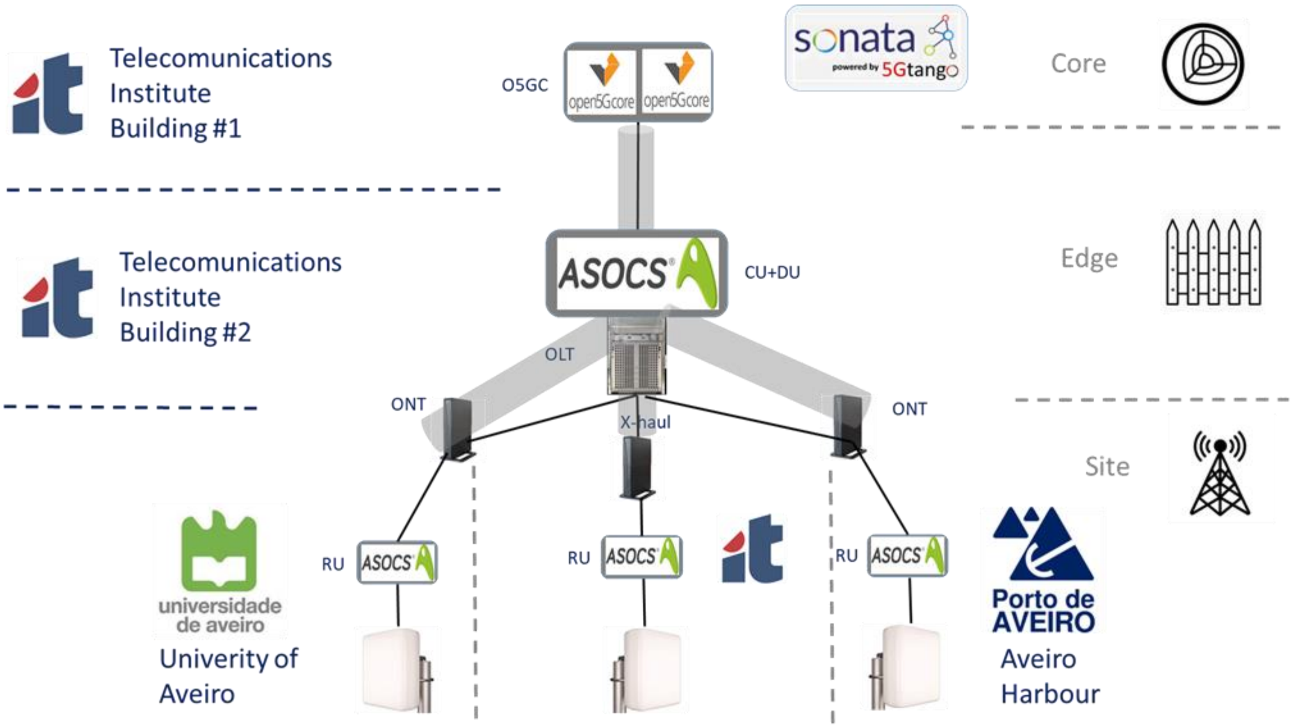


FIGURE 37: EFACEC_E AND EFACEC_S - 5G NETWORK (M26)

Figure 37 depicts the architecture and the status of EFACEC_E (described Section 4) and EFACEC_S pilots on sites at July 2021 (M26), showing all the components deployed in the final environment (Universidade de Aveiro and Aveiro Harbour respectively) . Both pilots are supported by the same 5G Core network (Open 5G Core) located at IT Aveiro building 1 and SA RAN, CU plus DU, located at IT Aveiro building 2. Differently from EFACEC_E pilot, that has two sites (Aveiro university and IT Aveiro), the EFACEC_S pilot has only one site on the Aveiro harbor. Both Pilots will be supported by independent 5G SA RUs. The Integration ICT17-5Growth will be finished at M26 and all slicing and orchestration functionalities will be available for evaluation and demonstration

Figure 35 shows the 5G site. The RU will be installed on the top of the tower and connected by optical fibre to IT, several Kms away. Figure 36 shows the train level crossing where will be deployed the vertical components, described in detail in the following sections.

FIGURE 38: EFACEC_S - 5G SITE

FIGURE 39: EFACEC_S - TRAIN LEVEL CROSSING

5.1.1. Status

According the contingency plan defined on D3.2 [1] for November 2020 (M18) there is a fully functional 5G SA network encompassing an Open 5G Core and 5G SA RAN ASOCs (CU+DU, RU) deployed in IT Labs. Figure 40 illustrates the available network infrastructure in November 2020 (M18). In order to overcome the unavailability of the OpenAirInterface RAN, as planed on D3.2, it was decided to acquire a 5G SA RAN development kit from ASOCS (https://www.asocscloud.com/). Because ASOCS RAN native EPC is based on a Metaswitch (https://www.metaswitch.com/) solution integration between ASOCS RAN and O5GCORE was carried out, with the cooperation of Altice Labs, Fraunhofer Fokus and ASOCS. ALB is using ASOCS development kit to develop its own 5G indoor and outdoor 5G SA RAN commercial solution, the outdoor RU will be installed at Aveiro harbour 5G site This solution does not provide network slicing capabilities.

Also, the EFACEC_S setup, that concerns the main components necessary to evaluate EFACEC_S-UC1 and EFACEC_S-UC2 were deployed and tested and the first KPIs measurements were carried out. More details are provided in the following section.

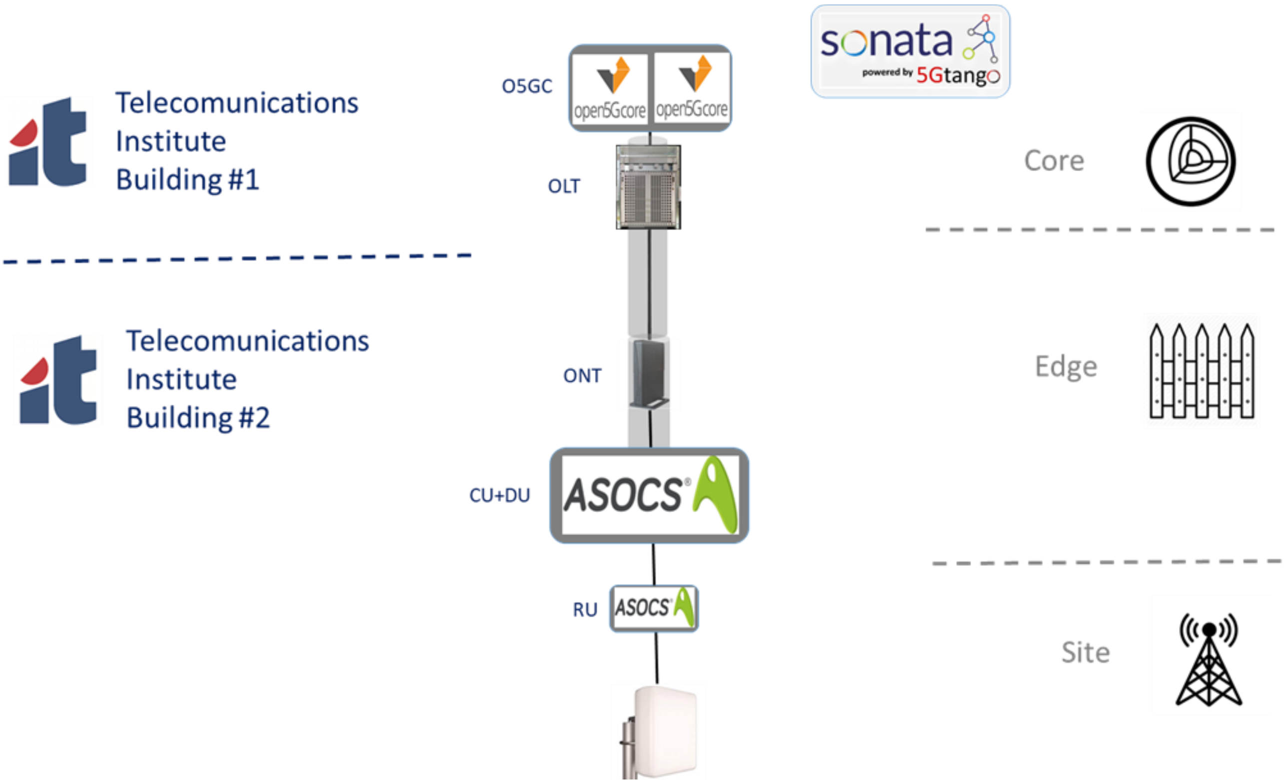
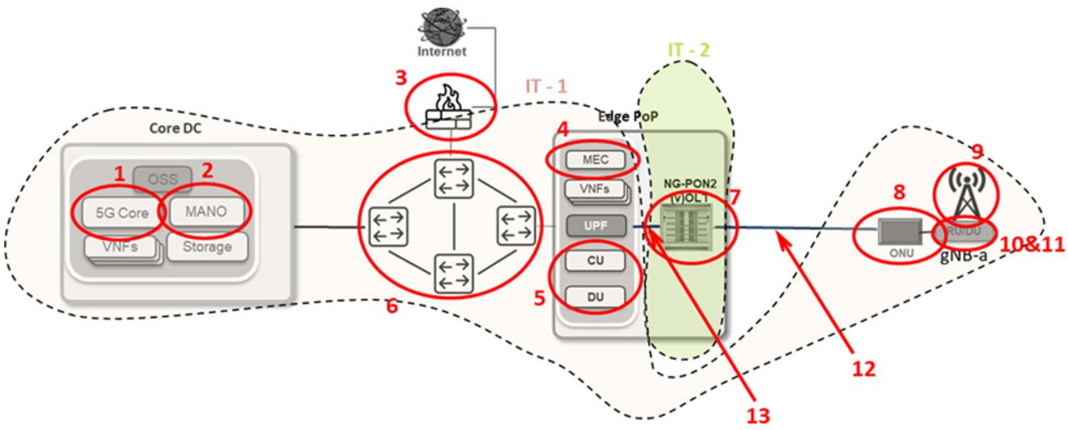


FIGURE 40: EFACEC_E AND EFACEC_S - 5G NETWORK @ LAB (M18)

Figure 41 and Figure 42 show respectively details of the 5G infrastructure and the pictures of the most relevant components at IT Labs. The 5G infrastructure available at November 2020 (M18) is the same that will be on the pilot sites (phase 2). The exception are the RUs that will be moved from the Lab environment to pilot sites.



	Component	Hardware	Status
1	Open5GCore	Server	OK
2	SONATA NFV orchestrator	Server	OK
3	Firewall / VPN termination	Server	OK
4	Edge Computing components	Server	OK
5	CU/DU	ASOCS	OK
6	IP network	IT internal network	OK
7	OLT	OLT2T2	OK
8	ONT	NG-PON2 ONT-SFU	OK
9	Antenna	ASOCS	OK
10	gNB	ASOCS	OK
11	RU/DU	ASOCS	OK
12	Fiber OLT/ONT connection	Dedicated fiber	OK
13	Fiber OLT/PoP connection	Dedicated fiber	OK

FIGURE 41: EFACEC_E AND EFACEC_S - 5G INFRASCTRUTURE DETAILS

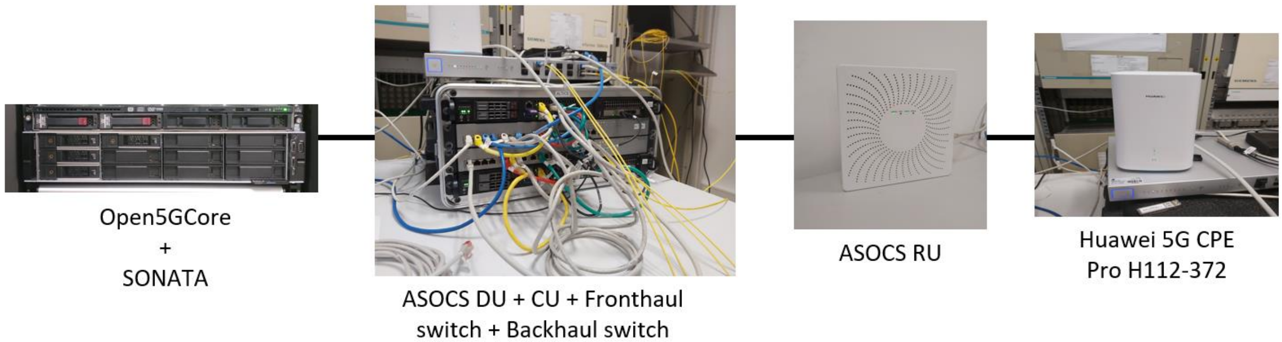


FIGURE 42: EFACEC_E AND EFACEC_S - 5G INFRASCTRUTURE AT IT LABS

The RAN is based in a remote RU solution, meaning that there is no 5G premises close to user radio access, what makes the implementation of a MEC solution not feasible. On the other hand, the 5G RU solution is an important technology for the radio network densification that otherwise has only to rely on the traditional gNodeBs, what makes the densification too expensive for a broad adoption.

5.1.2. Plan for pilot deployment

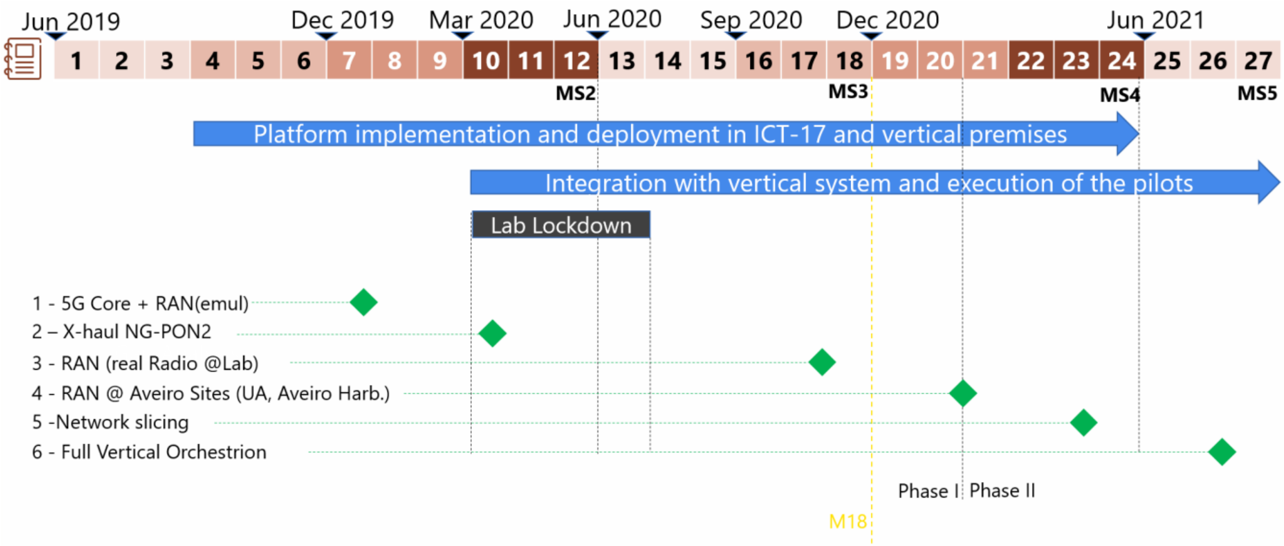


FIGURE 43: EFACEC_S - 5G NETWORK INFRASTRUCTURE ROADMAP

During October 2020 (M17) the emulated RAN component was replaced by a real radio hardware (ASOCS, CU+DU and RU), Lab environment. After this milestone, the deployment on site will start and encompasses the following activities:

1) January 2021 (M20), the real RAN solution deployed at the Lab will be extended to the pilot sites, the University of Aveiro (Energy) and the Aveiro Harbour (Transportation).
2) April 2021 (M23), Network Slicing features will be added to the Lab (first) and pilot sites, accommodating the different requirements of the pilots and respective use cases.
3) July 2021 (M26), not only the network, but also vertical components are orchestrated to be deployed on the network, either they are placed in the site, edge or core.

5.2. Use Case 1: Safety Critical Communications

Figure 44 illustrates the EFACEC_S-UC1, i.e. Fix permanent 5G communications between the train approaching detectors and level crossing (LX) controller.

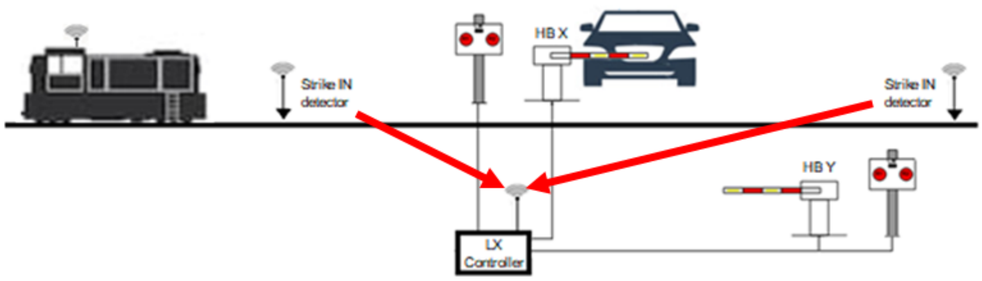


FIGURE 44: EFACEC_S-UC1- OVERVIEW

Figure 45 depicts the modelling of EFACEC_S-UC1, focusing on its components and interfaces.

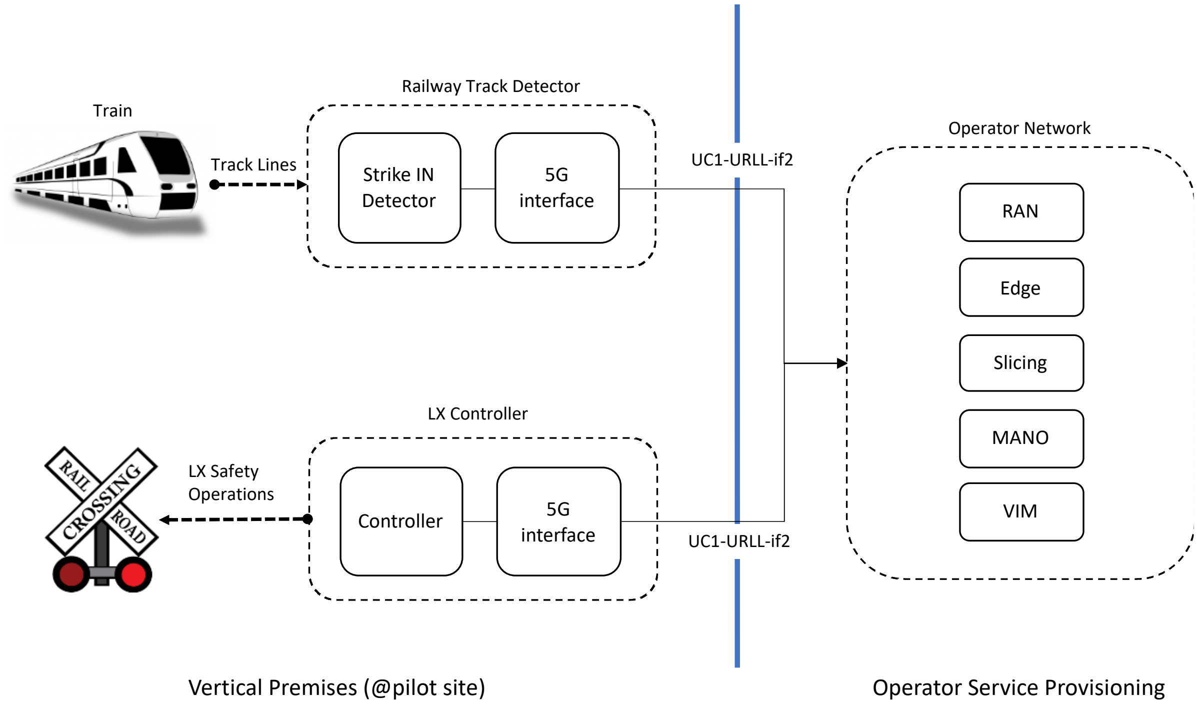


FIGURE 45: EFACEC_S-UC1 - OVERVIEW

EFACEC_S-UC1 considers a 5G-enabled Railway Track Detector with the ability to detect trains passing through a specific point in the railway, and to signal such event (using 5G communication) towards a Level Crossing (LX) Controller, which is in charge of controlling a railroad crossing. A mobile operator network provides the necessary link for the Railway Track Detector and LX Controller to communicate, supported by all the RAN and Core operation service provisioning mechanisms.

Figure 46 shows the solution architecture of the EFACEC_S-UC1, allowing the communication between the train detecting sensors and the LX Controller.

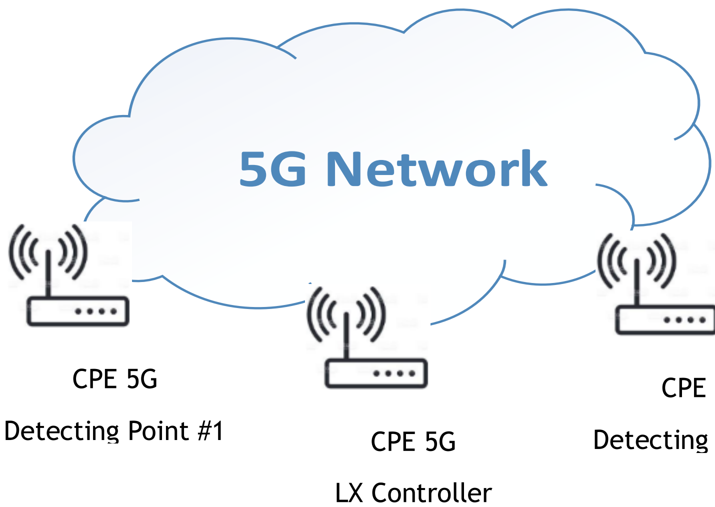


FIGURE 46: EFACEC_S-UC1 - COMMUNICATION BETWEEN THE TRAIN DETECTING SENSORS AND THE LX CONTROLLER

The slice requirements are introduced by the vertical using the Vertical Slicer (5Gr-VS) which interacts with the Aveiro 5G-VINNI testbed through the SONATA orchestrator to instantiate the network service. SONATA will oversee controlling the lifecycle of the network slices that support the use case. Once the connectivity and the service are in place, the use case can be executed as planned. When the process is over, the release of the network slice and respective infrastructure resources can be requested, through the Vertical Slicer again.

5.2.1. Status

As described in D3.2 [1] the plan for November 2020 (M18) is considering the 5G network and a real 5G radio integrated and fully functional but at Lab environment level. Thus, the needed components to implement the use cases are being deployed and tested in IT Aveiro Labs according the plan. Therefore, the Milestones 1, 2 3 regarding 5GCore, Ran Emulation. X-haul NG PON2 and RAN at lab environment are completed allowing to verify the use cases and collect measurements.

The planned HW/SW components was reported in D3.2 (i.e. see Tables 25/26 therein). Some modifications have been required with respect to the original tables. So that, differently from the other pilots, the updated tables for EFACEC_S-UC1 are reported in the following. Deviations refer to different locations for some components of the pilot and on the removal from the table of the Edge Computing HW and SW elements.

TABLE 1: EFACEC_S-UC1 HW COMPONENTS

Component	Description	Location
Train	The machine responsible to transport people or freight	Aveiro Harbour
Strike in detectors/axle counter train detector system	Device (system) that can detect if a train is approaching the level crossing area	Level Crossing area-Aveiro Harbour
Train detectors/axle counter train detector system	Device (system) to detect if the train is occupying the Level Crossing section or to detect the absence of the train in that section	Level Crossing area-Aveiro Harbour
Traffic lights	Device that is installed in the Level Crossing area and is responsible to process traffic information	Level Crossing area-Aveiro Harbour
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)	Level Crossing area-Aveiro Harbour
LX controller	Shelter of devices that receive sensors and equipment information, process this information and assures the LX actions (railways signaling operation)	Level Crossing area-Aveiro Harbour

Component	Description	Location
Half Barriers	The device that physically protects the Level Crossing against non-authorized entrances	Level Crossing area-Aveiro Harbour
5G Interface (CPE)	Mobile network interface able to connect to a 5G mobile network	Strike IN Detector/LX Controller at the Railway track
LTE router	Mobile network interface able to connect to a LTE mobile network	Strike IN Detector/LX Controller at the Railway track
Core 5G	5G Mobile network core elements	IT -Building #1
RAN	The RAN portion of the operator's mobile network	CU + DU IT- Building #2; RU -Aveiro Harbour

TABLE 2: EFACEC_S-UC1 SW COMPONENTS

Component	Description	Location
LX controller (Safety SW application)	Shelter of devices that receive sensors and equipment information, process this information and assures the LX actions (railways signaling operation)	Level Crossing area-Aveiro Harbour
5G Interface (cybersecurity application)	Mobile network interface able to connect to a 5G mobile network	Strike IN Detector/LX Controller at the Railway track
Core 5G	5G Mobile network core elements	IT -Building #1
MANO	Mobile Network Management and Orchestration capability	(IT -Building #1)
VIM	Virtualized Infrastructure Management Capability	(IT -Building #1)

5.2.2. Plan for pilot deployment

Besides the rescheduled activities performed to achieve a lab environment scenario the plan of EFACEC_S pilot is being performed according with the deployment plan summarized in Figure 47.

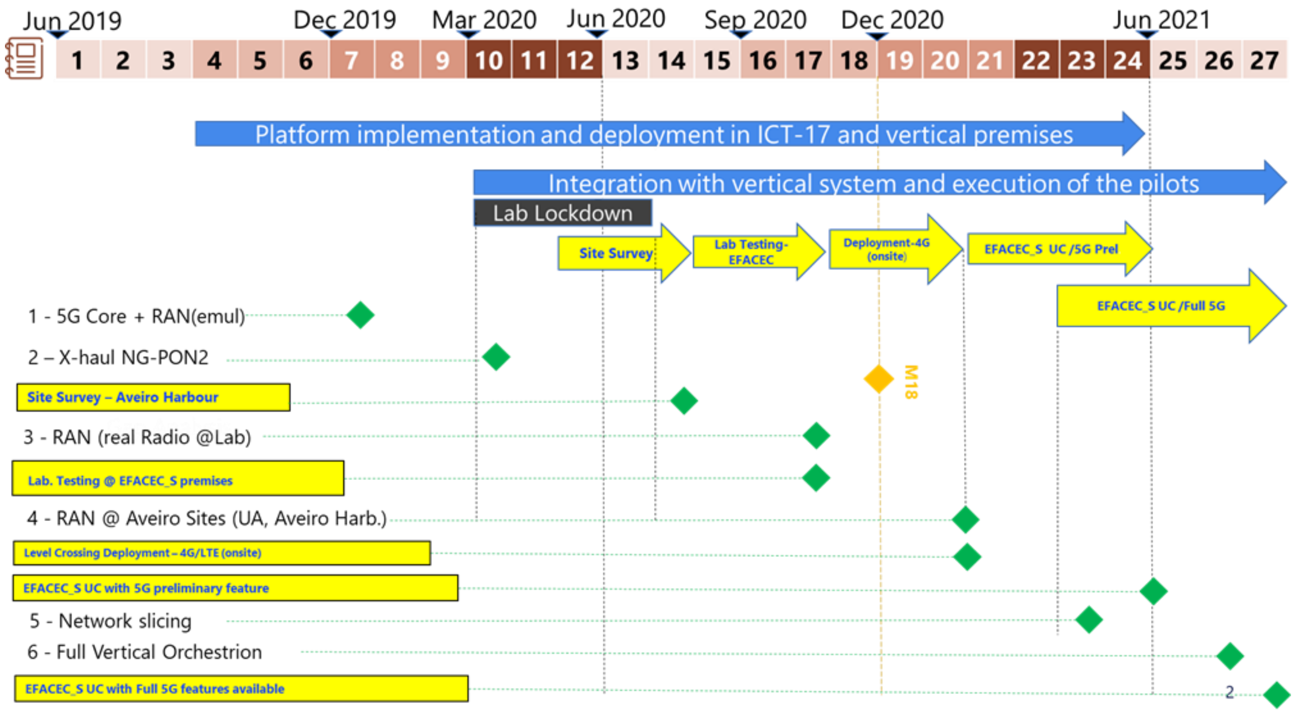


FIGURE 47: EFACEC_S-UC1/UC2 - DEPLOYMENT PLAN

Relevant achievements:

- Site survey on Aveiro harbour was performed at communication, railway at civil works level
- Since September 2020 no restrictions are impacting the access to EFACEC_S premises
- The purchasing of components for the pilot was been impacted causing, in its turn, some delay in the production and testing of the 5G level crossing. However, the goals for November 2020 (M18) have not been impacted since all relevant components (for IT Aveiro lab) were received at EFACEC premises.

5.3. Use Case 2: Non-safety Critical Communications

Figure 48 illustrates EFACEC_S-UC2, i.e. HD video image mobile transmission from LX surveillance camera to Approaching Trains and Maintenance Agents tablets.

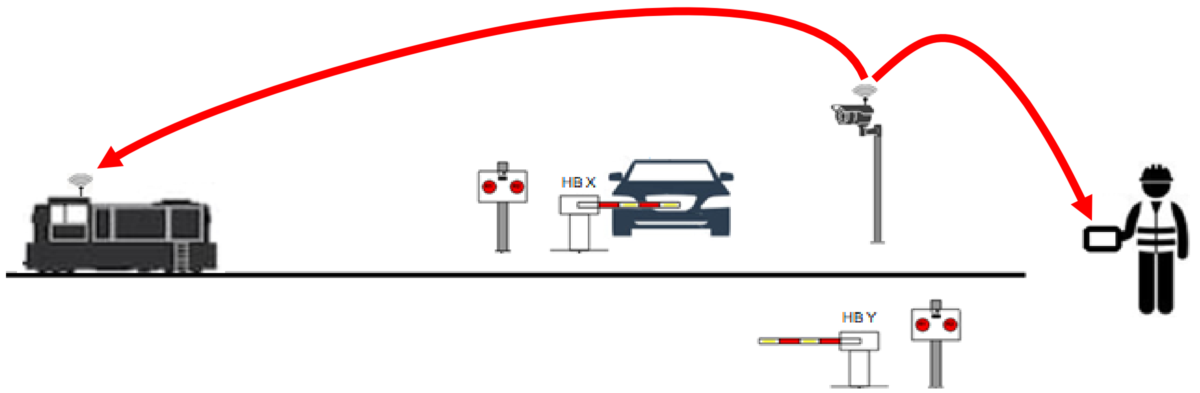


FIGURE 48: EFACEC_S-UC2

Figure 49 depicts the logical architecture for the connected worker EFACEC_S-UC2, including all the necessary components and labelled interfaces.

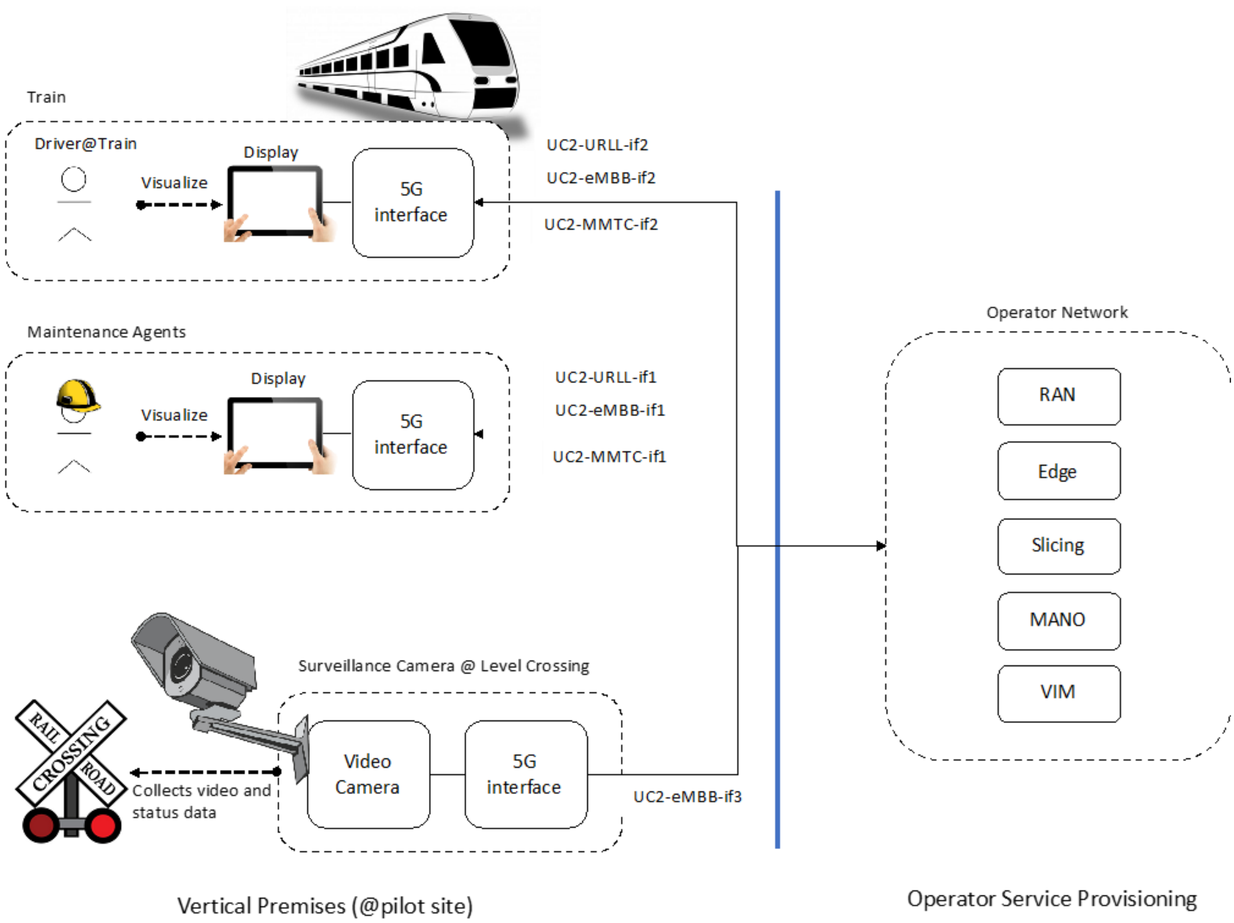


FIGURE 49: EFACEC_S-UC2 OVERVIEW

EFACEC_S-UC2 considers a surveillance camera placed at a railroad crossing, able to broadcast its video feed towards an incoming train and a local maintenance crew, via a 5G network. A mobile operator network provides the necessary link between all three actors, supported by all the RAN and Core operation service provisioning mechanisms.

Figure 50 shows the solution architecture of the EFACEC_S-UC2, allowing the real-time video transmission between the LX site and the train driver/Maintenance staff and Level Crossing Supervision.

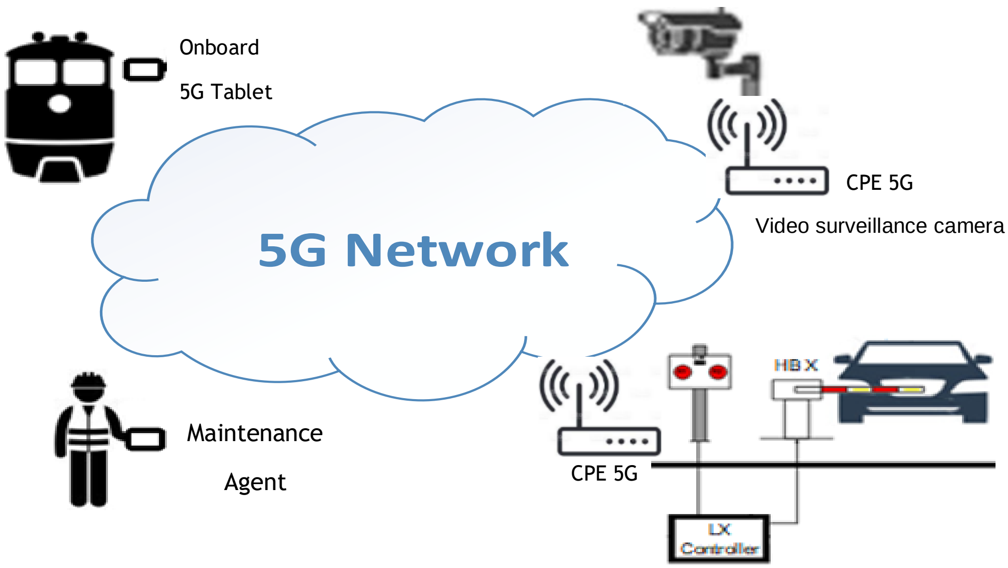


FIGURE 50: EFACEC_S-UC2 REAL-TIME VIDEO TRANSMISSION BETWEEN THE LEVEL CROSSING SITE AND THE TRAIN DRIVER/MAINTENANCE STAFF + LEVEL CROSSING SUPERVISION

As in EFACEC_S-UC1, the 5Gr-VS is used to express the necessary slice requirements for the video feed, which are then used by the SONATA orchestrator at the Aveiro 5G-VINNI testbed to establish the connectivity and service.

5.3.1. Status

As described in D3.2 [1] the plan for November 2020 (M18) is considering the 5G network and a real 5G radio integrated and fully functional but at Lab environment level. Thus, the needed components to implement the use cases are being deployed and tested in IT Aveiro Labs according the plan. Therefore, the Milestones 1, 2 3 (Figure 40) regarding 5GCore, Ran Emulation. X-haul NG PON2 and RAN at lab environment are completed allowing to verify the use cases and collect measurements.

The planned HW/SW components was reported in in D3.2 (i.e. see Tables 25/26 therein). Some modifications have been required with respect to the original tables. So that, differently from the other pilots, the updated tables for EFACEC_S-UC2 are reported in the following. Deviations refer to different locations for some components of the pilot and on the removal from the table of the Edge Computing HW and SW elements.

TABLE 3: EFACEC_S-UC2 HW COMPONENTS

Component	Description	Location / HW/SW
Train	The machine responsible to transport people or freight	Aveiro Harbour
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	Train/Aveiro Harbour
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 center	Level Crossing area-Aveiro Harbour
Command Centre	Technical and Operation rooms to support the monitor and control of the Level Crossing	Level Crossing area-Aveiro Harbour
LX controller	Shelter of devices that receive sensors and equipment information, process this information and assures the LX actions (railways signaling operation)	Level Crossing area-Aveiro Harbour
GPS position system	Device to be installed in the train in order to report its geographical positioning	Train-Aveiro Harbour
5G Interface (CPE)	Mobile network interface able to connect to a 5G mobile network	Train, Maintenance Crew Terminal, Surveillance Camera
LTE router	Mobile network interface able to connect to a LTE mobile network	Train, Maintenance Crew Terminal, Surveillance Camera
Video Camera	HD video camera able to send video stream over a network link	Level Crossing-Aveiro Harbour
Core 5G	Mobile network core elements	IT- Building #1
RAN	The RAN portion of the operator's mobile network	CU + DU IT- Building #2; RU -Aveiro Harbour

TABLE 4: EFACEC_S-UC2 SW COMPONENTS

Component	Description	Location
Command Centre:	Software applications to support the monitor and control of the Level Crossing	Level Crossing area-Aveiro Harbour
LX controller (SW application)	Shelter of devices that receive sensors and equipment information, process this information and assures the LX actions (railways signaling operation)	Level Crossing area-Aveiro Harbour

Component	Description	Location
5G Interface (cybersecurity application)	Mobile network interface able to connect to a 5G mobile network	Train, Maintenance Crew Terminal, Surveillance Camera
Core 5G	Mobile network core elements	IT- Building #1
MANO	Mobile Network Management and Orchestration capability	IT – building #1
VIM	Virtualized Infrastructure Management Capability	IT building #1

5.3.2. Plan for pilot deployment

Besides the rescheduled activities performed to achieve a lab environment scenario the plan of EFACEC_S pilot is being performed according the deployment plan reported in Figure 47.

6. Conclusions

This deliverable reports the status of each of the four pilots in 5Growth and of the relevant nine use cases. It also reports the plan, detailed in timeline, from November 2020 (M18) towards the end of the project.

The structure of D3.4 is organized in four main sections (from Section 2 to Section 5) each organized in a common pattern of subsections. The first subsection details the 5G infrastructure, located at the vertical premises, with the related status at November 2020 (M18) and roadmap. The following subsections refers to the use cases with the relates status at November 2020 (M18) and with specific roadmaps. All roadmaps are complemented with a step-by-step list of deployment milestones for the deployment of the pilots in the vertical industries premises.

It is worth to notice that this deliverable has also the role to provide an update with respect to the COVID-19 contingency plan included in D3.2. The contingency plan was based on alternatives, related to the possibility for the partners to access to laboratories or vertical premises with the planned (or unplanned) restrictions due to the pandemic. The possibility to deploy part of the use cases in home working (e.g. software implementations) was also considered in the contingency plan. In this deliverable, most of those alternatives have been transformed in a clear direction that has been captured in the updated timelines.

References

[1] 5Growth, D3.2, Specification of ICT17 in-house deployment, April 2020.
[2] 5Growth, D4.2, Verification methodology and tool design, November 2020.
[3] 5Growth, D3.1, ICT-17 facilities Gap analysis, October 2019.
[4] 5Growth, D2.1, Initial design of 5G End-to-End Service Platform, November 2019.