H2020 5Growth Project
Grant No. 856709

D3.1: ICT-17 facilities Gap analysis

Abstract

The basic needs, performance requirements and constrains expressed by 5Growth Vertical partners in relation to the Use Cases they are planning to validate along 5Growth project are collected and summarized in a uniform way.

With the goal of meeting those requirements a set of specific technology and architectural solutions are sketched and proposed, and the potential role that ICT-17 platforms may play for within those solutions is also studied for each of the use cases and selected locations.

The feasibility of such proposals is assessed and the main gap areas to be addressed in 5Growth project are identified. Besides that, a first study and outlook into the further analysis to be performed at project level on the feasible integration models of 5Growth with the selected ICT-17 platforms under consideration is also captured in this report.

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Disclaimer

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Contents

List of Figures

List of Tables

List of Acronyms

5Gr-RL – 5Growth Resource Layer

5Gr-SO – 5Growth Service Orchestrator

5Gr-VS – 5Growth Vertical Slicer

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

EPC – Evolved Packet Core

HSS – Home Subscriber Server

LTE – Long Term Evolution

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

RRU – Remote Radio Unit

SAIDI - System Average Interruption Duration Index

SCADA – Supervisory Control and Data Acquisition

SIL – System Integrity Level

vEPC – virtual EPC

ZDM – Zero Defect Manufacturing

Executive Summary and Key Contributions

5Growth intent is to address the wide range of needs related to the extensive validation and trialing of 5G-enabled vertical applications developed by the key agents of four specific industry sectors involved in 5Growth consortium, namely:

- COMAU and INNOVALIA for Industry 4.0,
- EFACEC_S for Transport, and
- EFACEC_E for Energy.

All those participant verticals plan to validate their 5G-ready applications, by deploying them in an environment expected to be -as much as possible- equivalent to the target 5G commercial environments where they will deploy them as part of their new businesses or services they will launch. With that approach in mind, for each Use Case in the 5Growth portfolio, two decisions have been taken:

- a specific location and facility have been proposed for hosting, on premises, the validation activities and,
- an associated ICT-17 platform and specific site facility has been selected for supporting, at different stages, the lifecycle of innovation and validation of such Use Case.

That set of decisions are summarized here:

- COMAU plans to carry out their validation activities on Industry 4.0 use cases at their own factory premises in Turin area, and has selected ICT-17 Platform 5G EVE, and more specifically its facility in Turin, for supporting that process.
- EFACEC_E and EFACEC_S plan to perform their validation campaigns on Energy and Transport Use Cases in the field itself, in concrete areas of Aveiro, and have selected ICT-17 platform 5G-VINNI, and its facility in Aveiro, for backing such campaigns.
- INNOVALIA plans to perform their validation activities on Industry 4.0 use cases both at 5TONIC site in Madrid and at their R&D premises in Bilbao, and thus has selected ICT-17 5G EVE platform, and its facility in Madrid for enabling those activities.

The performed analysis of the verticals' requirements vs. the required capabilities and services expected to be available at the hosting sites delivers, for each analyzed use case, a set of actionable gaps which constitute formal requirements on further activities in 5Growth project at each facility hosting the validation tests of those use cases. Those identified gaps fall into four different categories:

a) 5G Capabilities to be deployed -at the hosting facility and/or at the associated ICT-17 facility- in order to cope with the critical performance requirements of 5Growth Use Cases.

b) New, or additional, HW equipment to be deployed -at the hosting facility and/or at the associated ICT-17 facility- in order to scale infrastructure components to the levels that the Test Cases demand.

c) New, or improved, validation testing services and tools to become available -at the hosting facility and/or at the associated ICT-17 facility- in order to meet the validation needs that the Test Cases demand.

d) Selected 5Growth innovations -at the hosting facility and/or at the associated ICT-17 facility- in order to support specific needs of 5Growth Use Cases.

When we focus on each of the specific facilities hosting the validation activities, the key gap areas identified can be summarized as follows:

1) For COMAU Use Cases validation support:
   a) Deployment of all the necessary 5G infrastructure at COMAU factory premises for trialing COMAU's Industry 4.0 use cases in scope.
   b) Integration of COMAU Factory premises environment with 5G EVE facility in Turin.
   c) Availability of specific validation tools of 5Growth platform at COMAU factory premises.
   d) Availability of specific innovative features of 5Growth platform at COMAU factory premises.
2) For EFACEC_E Use Cases validation support:
   a) Deployment of all the necessary 5G infrastructure in the field, at the specific edge locations selected for trialing EFACEC_E Energy use cases in scope.
   b) Integration of those selected locations' environments with 5G-VINNI facility in Aveiro.
   c) Availability of specific validation tools of 5Growth and 5G-VINNI platform at the selected locations' environments.
   d) Availability of specific innovative features of 5Growth platform at the selected locations' environments.
3) For EFACEC_S Use Cases validation support:
   a) Deployment of all the necessary 5G infrastructure in the field, at the specific edge locations selected for trialing EFACEC_S Transport use cases in scope.
   b) Integration of those selected locations' environments with 5G-VINNI experimental facility in Aveiro.
   c) Availability of specific validation tools of 5Growth and 5G-VINNI platform at the selected locations' environments.
   d) Availability of specific innovative features of 5Growth platform at the selected locations' environments.
4) For INNOVALIA Use Cases validation support:

a) Deployment of all the necessary 5G infrastructure, first at 5G EVE Madrid site facility, and then at INNOVALIA R&D premises in Bilbao, for validating and trialing INNOVALIA's Industry 4.0 use cases in scope.
b) Integration INNOVALIA environments with 5G EVE platform.
c) Availability of specific validation tools of 5Growth platform at INNOVALIA R&D environment.
d) Availability of specific innovative features of 5Growth platform at INNOVALIA R&D environment.

Finally, the report also provides a first study and outlook on the potential common integration schemes of 5Growth platform with ICT-17 platforms, over a set of preliminary assumptions, and postulates a set of alternative approaches to be taken as input to further analysis work in 5Growth Task 3.2.

Introduction

The goal of 5Growth Task 3.1 (T3.1) is to detect and analyses the gap in the ICT-17 platforms for deploying and executing the four different 5Growth vertical pilot use cases. The gap analysis scope is to detect the need of additional resources, such as additional hardware or capacity expansion or activation of additional features in each ICT-17 platform. An additional goal of this task is to select the innovations defined in WP2 to be deployed in 5Growth.

The main input of this task comes from WP1, from the analysis of the vertical use cases, and WP2. Also, it has an external dependency from ICT-17 platforms availability.

This deliverable presents the results of the gap analysis and a proposed set of innovations as the result of task T3.1, which constitutes a major input for further activities of the project, more specifically to Task 3.2, devoted to 5Growth platform implementation and deployment in ICT-17 and vertical premises.

The performed analysis of identification of gaps of ICT-17 platforms vs 5Growth needs, in the following structured way:

First, the basic needs, performance requirements and constrains expressed by 5Growth Vertical partners in relation to the Use Cases they are planning to validate along 5Growth project are collected and summarized in a uniform way in Section 1.

Next, the technology and architectural solution approaches considered and proposed for each of the relevant locations for 5Growth deployment so that the abovementioned requirements can be satisfied, are briefed in Section 2. Moreover, in that section, the potential role of ICT-17 platforms for each of the use cases and selected locations is also studied, and a preliminary proposal is outlined for further analysis.

Then, in Section 3, the ICT-17 platforms selected as baseline for the range of 5Growth Use Cases (5G EVE facilities in Madrid, Spain and Turin, Italy; and 5G-VINNI facility in Aveiro, Portugal) are analyzed and assessed against the input requirements from 5Growth Verticals captured in Section 1 and assuming the proposed architecture outlined for each testing facility in Section 2. Such analysis yields the main gap areas to be addressed in 5Growth project. Besides that, a first study and outlook into the further analysis to be performed at project level -and more specifically at 5Growth Task 3.2-, on the feasible integration models of 5Growth with the selected ICT-17 platforms under consideration is also captured in this Section 3.

Finally, the specific identified gaps, listed per use case, and per facility, are classified and formally described in Section 4, and a set of guidelines about the implementation plan ahead needed in order to fill those gaps is introduced in Section 5.

1. Input Requirements from 5Growth Verticals

This section provides performance requirements and constrains expressed by 5Growth Vertical partners in relation to the Use Cases they are planning to validate along 5Growth project. In the following, such requirements are described per Use Case per Vertical Pilot.

1.1. COMAU Use Case 1: Digital Twin Apps

1.1.1. Overview

The Digital Twin is essentially a virtual representation of something which exists in the real world as physical assets, processes, people, places, systems and devices. Consider a thousand robots, all coordinated in real time across a production line. If something unexpected happens in the production flow for instance a component delivered out of sequence, several alternative scenarios can be simulated in parallel in the virtual environment of the digital twin and the most appropriate alternative can be applied to the "real" twin.

To make this possible, the real machinery is outfitted with a massive number of sensors that send status data to the virtual reproductions on a constant basis. A requirement management system functions 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. The digital twin can also be used to predict bottlenecks in the production/assembly line.

In order to have an actual and exact representation, a continuous stream of data, coming from the field (e.g. reading cycle time from PLCs and monitored parameters from sparse sensors), is needed. This requires a huge throughput and very low latency to avoid delays in the digital representation.

More details are reported in 5Growth's Deliverable D1.1 [15].

1.1.2. 5G Network KPIs and Targets

Table 1 reports the initial KPI requirements of UC1 in the COMAU pilot. The low latency requirement of 15 msec is imposed by the need to read data from PLCs and feed the digital model with such data. The broadband connectivity is required because cameras are also used to shape the twin. Finally, the device density refers to the cumulative number of connected devices which is dominated by a plethora of sparse sensors. Note that the device density does not necessarily refers to devices that contribute to the digital twin construction.

TABLE 1: COMAU USE CASE 1 - TARGET KPI'S

Latency RTT	msec	15
Data Rate	Mbps	250
Reliability	%	99.9999%
Availability	%	99.9999%
Mobility	Km/h	3-50
Broadband Connectivity		Y
Network Slicing		Y
Security		N
Capacity	Mbps/m^2	50
Device Density	Dev/ Km^2	5000

1.1.3. Critical Testing Needs

E2E tests will be done to assess latency RTT and Data Rate. Such tests will require having a preliminary test on the infrastructure.

As network performance indicators are verified, tests will focus on the vertical application assessing the real time of the digital replica with respect to the real robot-system on the shop floor. Critical test will verify that the actions performed on the robot are synchronized with the view in the digital environment.

1.1.4. Test Campaign Plan

Initial test will be done on infrastructure related to the mobile network segment (RRU-vEPC) for the Phase 1 (LTE) and then for Phase 2 (5G NR) to verify that latency values are compliant with the use case purposes, and check quality of transmission. An E2E test will also include performance evaluations of the applications running in the cloud on premises.

1.1.5. Specific Restriction/Constrains

No restrictions are expected at the release date of the current deliverable.

1.1.6. Logical Architecture for the Vertical application

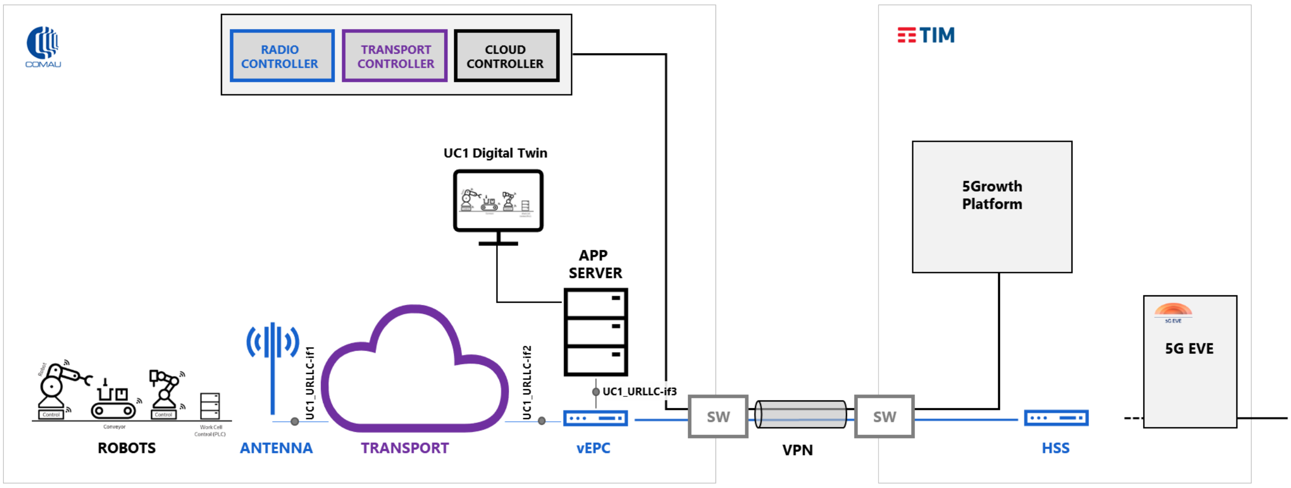

FIGURE 1: LOGICAL ARCHITECTURE UC1-COMAU

TABLE 2: UC1-COMAU LOGICAL ARCHITECTURE COMPONENTS

Component	Description	Location
Robotic line	Production line including robots and other systems which will be virtually replicated in the digital twin.	COMAU site
Antenna System	Ericsson antenna system for LTE (Phase 1) and 5G NR (Phase 2)	COMAU site
vEPC	Ericsson Virtual Evolved Packet Core providing core radio functionalities on COMAU premises (Phase 1) and, partially on TIM premises (Phase 2)	COMAU site only (Phase 1); COMAU site and TIM site (Phase 2)
App Server	Server platform running COMAU applications devoted to build the digital twin of the robotics line to be shown on the display in real time	COMAU site
Controllers	Server where radio, transport, and cloud controllers run	COMAU site
Display	Monitor rendering the digital twin including the required IT hardware for interaction with the technical staff	COMAU site
Transport	Wired connection (in the specific case it is just a point to point link) between the antenna system and the vEPC, through a baseband system	
Switches	Terminals of the connection between the COMAU site and the TIM site	COMAU and TIM sites
HSS	Home Subscriber Server	TIM site
5Growth platform	It is the project platform bases on the three components VS, SO, RL.	TIM site

TABLE 3: UC1-COMAU INTERFACES AND REQUIREMENTS

Interface	Description	Requirements	Slice Type
UC1-URLLC-If1	Antenna to Transport link	Latency <15ms – Up to 250Mbit/s (per device)	URLLC
UC1-URLLC-If2	Transport to vEPC server link	Latency <15ms – Up to 250Mbit/s (per device)	URLLC
UC1-URLLC-If3	vEPC server to App server link	Ethernet based	

NOTE: The end to end latency, which is the sum of the all the latencies of the traversed interfaces, must be less than 15 msec.

The requirements for each interface and component listed in Table 2 and Table 3 will define the location of components and the specific technical requirements of the slice.

1.1.7. Selected ICT-17 platform to support the Test Campaign

For latency and security reason, most of the infrastructure equipment will be placed and deployed on COMAU premises. Possible interaction with 5G EVE infrastructure will be evaluated.

1.1.8. Selected 5Growth innovation to be leveraged/validated

The innovation will refer to the architecture with focus on new RAN orchestration [8] enabled by suitable configuration of resources including RAN, edge, mobile core for support of target KPIs and service quality. Abstraction model and slicing support will be also validated

1.2. COMAU Use Case 2: Telemetry/Monitoring Apps

1.2.1. Overview

In this use case an extensive sensor deployment is in place to monitor and prevent failures of machineries and equipment through massive data collection (i.e. vibration, pressure, temperature and so on). 5G facilitates need to install a wide range of different wireless sensors easy to attach on machineries [15]. 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, addressed by the current use case, is to reinforce the fault predictive capabilities.

More details are reported in 5Growth's Deliverable D1.1 [15].

1.2.2. 5G Network KPIs and Targets

Table 4 reports the initial KPI requirements of UC2 in the COMAU pilot.

TABLE 4: COMAU USE CASE 2 – TARGET KPI'S

Latency RTT	msec	15- 100
Data Rate	Mbps	250
Reliability	%	99.9999%
Availability	%	99.9999%
Mobility	Km/h	3-50
Broadband Connectivity		Y
Network Slicing		Y
Security		N
Capacity	$Mbps/m^2$	50
Device Density	Dev/Km^2	5000

1.2.3. Critical Testing Needs

E2E tests will be done to assess latency RTT and Data Rate.

Such tests will require to have a preliminary test on infrastructure.

As network performances are verified, tests will focus on the vertical application assessing if all critical elements are monitored, alarms are detected and correctly communicated.

1.2.4. Test Campaign Plan

Initial test will be done on infrastructure related to the segment (RRU-vEPC) for the Phase 1 (LTE) and then for Phase 2 (5G NR) to verify that latency values are compliant with the use case purposes, and check quality of transmission. An E2E test will also include performance evaluations of the applications running in cloud.

1.2.5. Specific Restriction/Constrains

No restrictions are expected at the release date of the current deliverable.

1.2.6. Logical Architecture for the Vertical application

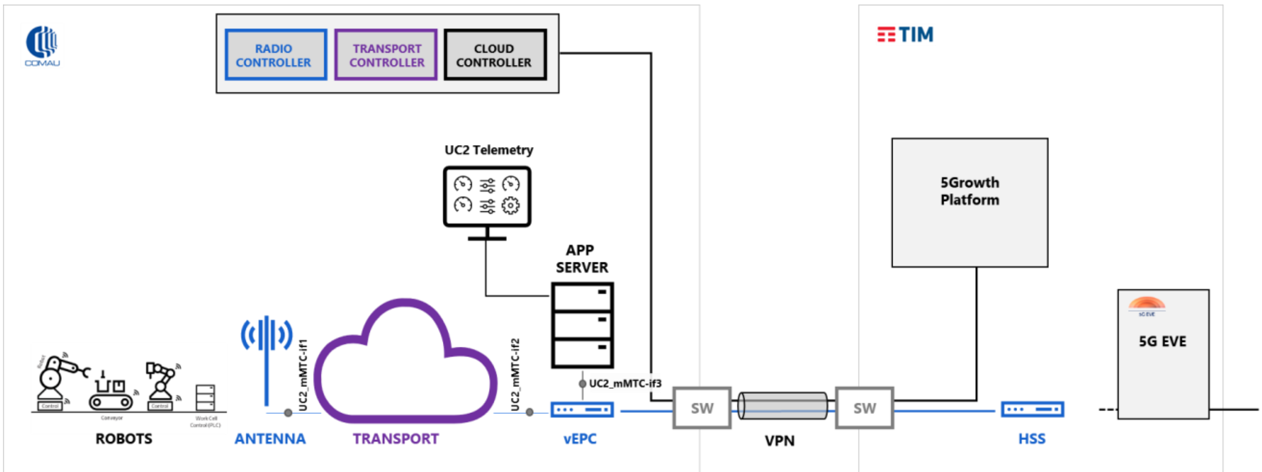

FIGURE 2: LOGICAL ARCHITECTURE COMAU-UC1

TABLE 5: UC2 LOGICAL ARCHITECTURE COMPONENTS

Component	Description	Location
Robotic line	Production line including robots and other systems which will be virtually replicated in the digital twin.	COMAU site
Antenna System	Ericsson antenna system for LTE (Phase 1) and 5G NR (Phase 2)	COMAU site
vEPC	Ericsson Virtual Evolved Packet Core providing core radio functionalities on COMAU premises (Phase 1) and, partially on TIM premises (Phase 2)	COMAU site only (Phase 1); COMAU site and TIM site (Phase 2)
App Server	Server platform running COMAU applications devoted to elaborating the telemetry data taken from the shop floor	COMAU site
Controllers	Server where radio, transport, and cloud controllers run	COMAU site
Display	Monitor rendering the telemetry dashboard and delivering information about preventive maintenance including the required IT hardware for interaction with the technical staff	COMAU site
Transport	Wired connection (in the specific case it is just a point to point link) between the antenna system and the vEPC, through a baseband system	
Switches	Terminals of the connection between the COMAU site and the TIM site	COMAU and TIM sites
HSS	Home Subscriber Server	TIM site
5Growth platform	It is the project platform bases on the three components VS, SO, RL.	TIM site

TABLE 6: UC2-COMAU INTERFACES AND REQUIREMENTS

Interface	Description	Requirements	Slice Type
UC2-mMTC-If1	Antenna to Transport link	Maximum of 5 devices/m^2 each requiring a max of 250 Mbit/s (in case of cameras, for sensors the required bandwidth is significantly lower).	mMTC
UC2-mMTC-If2	Transport to vEPC server link	Maximum of 5 devices/m^2 each requiring a max of 250 Mbit/s (in case of cameras, for sensors the required bandwidth is significantly lower).	mMTC
UC2-mMTC-If3	vEPC server to App server link	Ethernet based	

1.2.7. Selected ICT-17 platform to support the Test Campaign

For latency and security reason, most of the infrastructure equipment will be on COMAU premises. Possible interaction with EVE infrastructure will be evaluated.

1.2.8. Selected 5Growth innovation to be leveraged/validated

The innovation will refer to the architecture with focus on new RAN orchestration [8] enabled by suitable configuration of resources including RAN, edge, mobile core for support of target KPIs and service quality. Abstraction model and slicing support will be also validated. The innovation will refer to the architecture with focus on new RAN orchestration enabled by suitable configuration of resources for support of quality of services.

1.3. COMAU Use Case 3: Digital Tutorial and Remote Support

1.3.1. Overview

This use case aims at providing technicians and maintenance staff with digital tutorials and remote support by means of high definition videos and live connections to remote technical offices. The main objective is to reduce the MTTR (Mean Time Tor Repair) using real-time streaming with a skilled technician in remote locations to support maintenance and repair operations in the production line of the factory. Other advantage is the possibility to access to tutorials and instructions for training purposes.

More details are reported in 5Growth's Deliverable D1.1 [15].

1.3.2. 5G Network KPIs and Targets

Table 7 reports the initial KPI requirements of UC3 in the COMAU pilot.

TABLE 7: COMAU USE CASE 3 – TARGET KPI'S

Latency RTT	msec	50
Data Rate	Mbps	500
Reliability	%	99.9999%
Availability	%	99.9999%
Mobility	Km/h	3
Broadband Connectivity		Y
Network Slicing		Y
Security		N
Capacity	$Mbps/m^2$	50
Device Density	Dev/ Km^2	1000

1.3.3. Critical Testing Needs

E2E tests will be done to assess performances in terms of broadband Data Rate in support of video streaming.

Such tests will require to have a preliminary test on infrastructure.

As network performances are verified, tests will focus on the vertical application assessing if the planned video streaming for remote support and digital tutorial will work smoothly without any interruptions.

1.3.4. Test Campaign Plan

Initial test will be done on infrastructure related to the segment (RRU-vEPC) for the Phase 1 (LTE) and then for Phase 2 (5G NR) to verify that latency values are compliant with the use case purposes, and check quality of transmission. An E2E test will also include performance evaluations of the applications running in cloud.

1.3.5. Specific Restrictions/Constrains

No restrictions are expected at the release date of the current deliverable.

1.3.6. Logical Architecture for the Vertical application

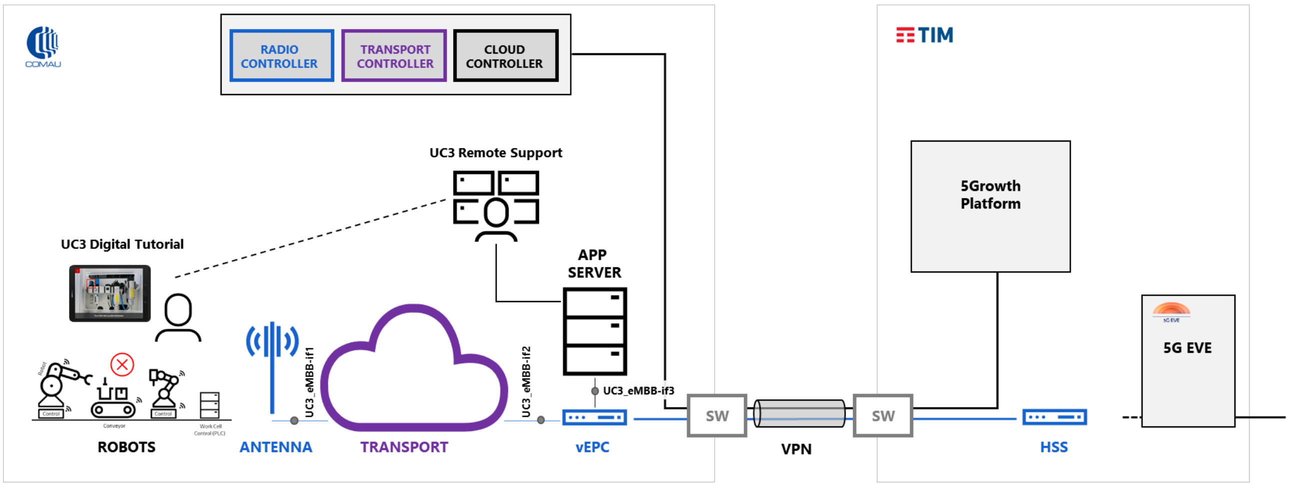

FIGURE 3: LOGICAL ARCHITECTURE COMAU-UC3

TABLE 8: UC3 LOGICAL ARCHITECTURE COMPONENTS

Component	Description	Location
Robotic line	Production line including robots and other systems which will be virtually replicated in the digital twin.	COMAU site
Antenna System	Ericsson antenna system for LTE (Phase 1) and 5G NR (Phase 2)	COMAU site
vEPC	Ericsson Virtual Evolved Packet Core providing core radio functionalities on COMAU premises (Phase 1) and, partially on TIM premises (Phase 2)	COMAU site only (Phase 1); COMAU site and TIM site (Phase 2)
App Server	Server platform running COMAU applications devoted to providing remote support and digital tutorials as foreseen in the use case	COMAU site
Controllers	Server where radio, transport, and cloud controllers run	COMAU site
Transport	Wired connection (in the specific case it is just a point to point link) between the antenna system and the vEPC, through a baseband system	COMAU site
Switches	Terminals of the connection between the COMAU site and the TIM site	COMAU and TIM sites
HSS	Home Subscriber Server	TIM site
Display(s)	Displays in a control room where COMAU personnel deliver support instructions to a remote located specialist who is troubleshooting a problem on the shop floor (e.g. a technician located in an automotive plant which uses COMAU robots)	COMAU site
Tablet	User equipment located on COMAU premises and used to receive data from the remote support specialists including instructions for troubleshooting	COMAU site or COMAU customer's plant
5Growth platform	It is the project platform bases on the three components VS, SO, RL.	TIM site

TABLE 9: UC3-COMAU INTERFACES AND REQUIREMENTS

Interface	Description	Requirements	Slice Type
UC3-eMBB-If1	Antenna to Transport link	Max of 1 device/m^2 (UE) requiring 500Mbit/s	eMBB
UC3-eMBB-If2	Transport to vEPC server link	Max of 1 device/m^2 (UE) requiring 500Mbit/s	eMBB
UC3-eMBB-If3	vEPC server to App server link	Ethernet based	

1.3.7. Selected ICT-17 platform to support the Test Campaign

For latency and security reason, most of the infrastructure equipment will be in COMAU premises. Possible interaction with 5G EVE infrastructure will be evaluated.

1.3.8. Selected 5Growth innovation to be leveraged/validated

The innovation will refer to the architecture with focus on new RAN orchestration [8] enabled by suitable configuration of resources including RAN, edge, mobile core for support of target KPIs and service quality. Abstraction model and slicing support will be validated.

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

1.4.1. Overview

The EFACEC energy use case 1 (Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV distribution substation) aims 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 center and to the mobile devices of the maintenance crew. More details about this Use Case are reported in 5Growth's Deliverable D1.1 [15] .

1.4.2. 5G Network KPIs and Targets

Table 10 describes the 5G KPIs expected by the EFACEC Energy pilot in the UC1. The main highlight here goes to the low latency required to ensure the timely collection of energy monitoring data, and the high bandwidth at high Data Rate (mobility) required to ensure that high quality video can be streamed to the maintenance staff when travelling using a car.

TABLE 10: EFACEC-E USE CASE 1 – TARGET KPI'S

Latency RTT	msec	<5
Data Rate	Mbps	100
Reliability	%	99,99%
Availability	%	99,99%
Mobility	Km/h	120
Broadband Connectivity	Y/N or Mbps	Y
Network Slicing	Y/N	Y
Security	Y/N	Y
Capacity	Mbps/Km2	10
Device Density	Dev/Km2	Low

1.4.3. Critical Testing Needs

The use case tests will assess the Data Rate, Latency, Reliability and Mobility.

The tests will be done by measuring the latency (one-way) for the real time energy data events reported from the installation to the control center. The real time video streaming to the control center operator and for the maintenance crews will need to be tested.

Support to an AR (Augmented Reality) application, that will run in a mobile device used by the maintenance crew, with real time video and real time energy data (currents, voltages, power, etc.) from the installation will be tested.

1.4.4. Test Campaign Plan

The initial test will be focused on the infrastructure performance tests, validating the Data Rate, Latency, Reliability and Mobility. The phase 2 will be to validate the energy real time events reported to the control center. Phase 3 will be focused on the real time video streaming to the control center operator and maintenance crew. The phase 4 will be focused on the real time streaming video along with energy real time information to validate the Augmented Reality application. The final phase will be to validate the full use case.

1.4.5. Specific Restriction/Constrains

The installation of the solution components will be done in an existing private secondary substation of the University of Aveiro. As it is in production, some limitation may occur, but no big impact is expected.

1.4.6. Logical Architecture for the Vertical application

Figure 4 depicts the logical architecture for the connected worker use case, including all the necessary components and labelled interfaces, which are further explained and justified in Table 11 and Table 12, along with the established slice type considering the different test campaign phase. In this case the operator provides and manages the Vertical service in a Slice as a Service model.

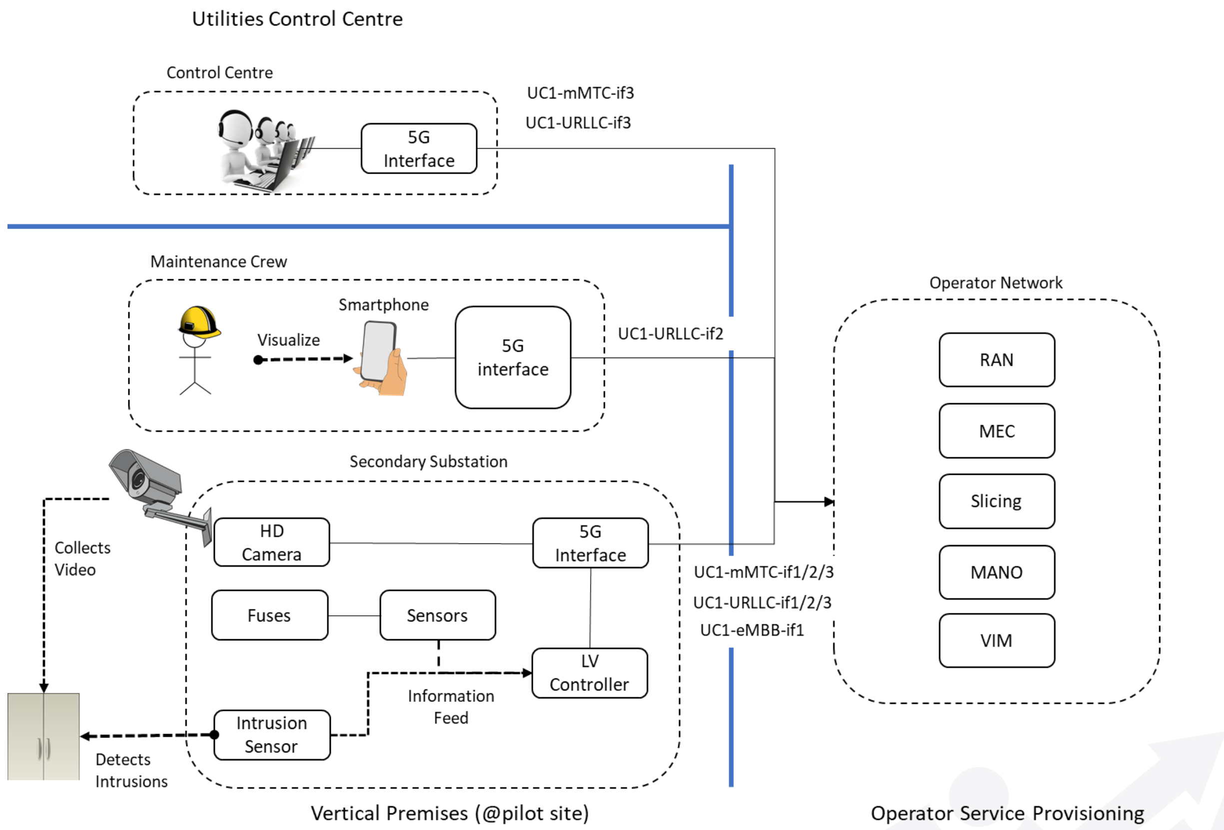

FIGURE 4: LOGICAL ARCHITECTURE EFACEC_E-UC1

TABLE 11: EFACEC_E UC1 LOGICAL ARCHITECTURE COMPONENTS.

Component	Description	Location
Fuses	Components used to protect the low voltage feeder against high currents	Aveiro Campus secondary substation
Sensors	Devices that will be installed in the secondary substation to monitor and detect faults in the low voltage feeders	Aveiro Campus secondary substation
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.	Aveiro Campus secondary substation
HD cameras	Video camera that will be installed in the secondary substation for surveillance.	Aveiro Campus secondary substation
Intrusion Sensor	Device that will be installed in the secondary substation to detects intrusions in the secondary substation	Aveiro Campus secondary substation
Smartphone	Smartphone used by the maintenance team.	With maintenance team
Control Centre	SCADA system to support the operators to monitor and control the installation.	Cloud
5G router	Communication module for the secondary substation	Aveiro Campus secondary substation

TABLE 12: EFACEC_E UC1 INTERFACES AND REQUIREMENTS.

Interface	Services	Requirements (KPIs)	Slice Type
UC1-EMBB-IF1	HD video transmission (near real-time)	14Mbit/s, 100ms, 99.9%, 120Km/h	eMBB
UC1-URLLC-IF1, UC1-MMTC-IF1	Real-time energy data monitoring	1.2Kbit/s, 100ms, 99.99%, -	URLLC
UC1-URLLC-IF2, UC1-URLLC-IF2	Data collection for AR (maintenance)	1.2Kbit/s, 100ms, 99.9%, -	URLLC
UC1-URLLC-IF3, UC1-MMTC-IF3	AR Video delivery (maintenance)	14Mbit/s, 100ms, 99.9%, 120Km/h	URLLC

1.4.7. Selected ICT-17 platform to support the Test Campaign

This Use Case will use the infrastructure of the 5G-VINNI Aveiro Experimentation Site, extending the 5G-NR coverage to the University of Aveiro, the area where the UC1 takes place.

1.4.8. Selected 5Growth innovation to be leveraged/validated

The members of 5Growth involved in the pilots in Aveiro are addressing innovations "C1-I6 Federation and inter-domain" and "C3-I11: Security and auditability", identified in 5Growth's Deliverable D2.1 [8]. Both innovations will be generically developed considering their contribution towards a better capability to provide particular 5G services to verticals. In this specific case, inter-domain capabilities could be employed to retain the necessary network conditions while the maintenance crew is moving to or out of the energy facilities (C1-I6), and security procedures could be used to ensure that instantiated virtualized services are trustworthy (C3-11). Regarding validation, even though the actual realization of the proposed use cases does not actively require the employment of inter-domain or virtualization mechanisms security, it will be assessed how such mechanisms could be deployed and evaluated in such, or similar, use case execution conditions.

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

1.5.1. Overview

The main purpose of this use case is to validate advanced smart grid control solutions across wide smart metering and measurement infrastructure. The smart sensors installed in the low voltage network are continuously monitoring the energy measurements such as currents, voltages, powers, etc. When a power outage occurs, the meter will save the relevant information to memory and send a last-gasp message, before turning off. With the real time information received from the smart meters and sensors, the control center will run a self-healing algorithm 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. More details about this Use Case are reported in 5Growth's Deliverable D1.1 [15] .

1.5.2. 5G Network KPIs and Targets

Table 13 describes the 5G KPIs expected by the EFACEC Energy pilot in the UC2. The main highlight here goes to the low latency required to ensure the timely collection of energy monitoring data and self-healing enforcement, and the high availability/resilience required to maintain the electricity network up and running, reacting to failures.

TABLE 13: EFACEC-E USE CASE 2 – TARGET KPI'S

Latency RTT	msec	<5ms
Data Rate	Kbps	1
Reliability	%	99,99%
Availability	%	99,99%
Mobility	Km/h	N
Broadband Connectivity	Y/N or Mbps	N
Network Slicing	Y/N	Y
Security	Y/N	Y
Capacity	Mbps/Km2	Low
Device Density	Dev/Km2	Low

1.5.3. Critical Testing Needs

The use case tests will assess the Data Rate, Latency and Reliability.

The tests will be done by measuring the latency for the real time energy data events reported from the installation to the control center and for the controls send from the control center to the installation.

Support to an AR (Augmented Reality) application that will run in a mobile device used by the maintenance crew, with real time energy data (currents, voltages, power, etc.) from the installation will be tested.

1.5.4. Test Campaign Plan

The initial test will be focus on the infrastructure performance tests, validating the Data Rate, Latency and Reliability. The phase 2 will be to validate the energy real time events reported to the control center and controls sent by the control center to the infrastructure. Phase 3 will be focus on the energy real time information to validate the Augmented Reality application. The final phase will be to validate the full use case.

1.5.5. Specific Restrictions/Constrains

The installation of the solution components will be done in an existing private secondary substation of the University of Aveiro. As it is in production, some limitation may occur, but no big impact is expected.

1.5.6. Logical Architecture for the Vertical application

Figure 5 depicts the logical architecture for the connected worker use case, including all the necessary components and labelled interfaces, which are further explained and justified in Table 14 and Table 15, along with the established slice type considering the different test campaign phase. In this case the operator provides and manages the Vertical service in a Slice as a Service model.

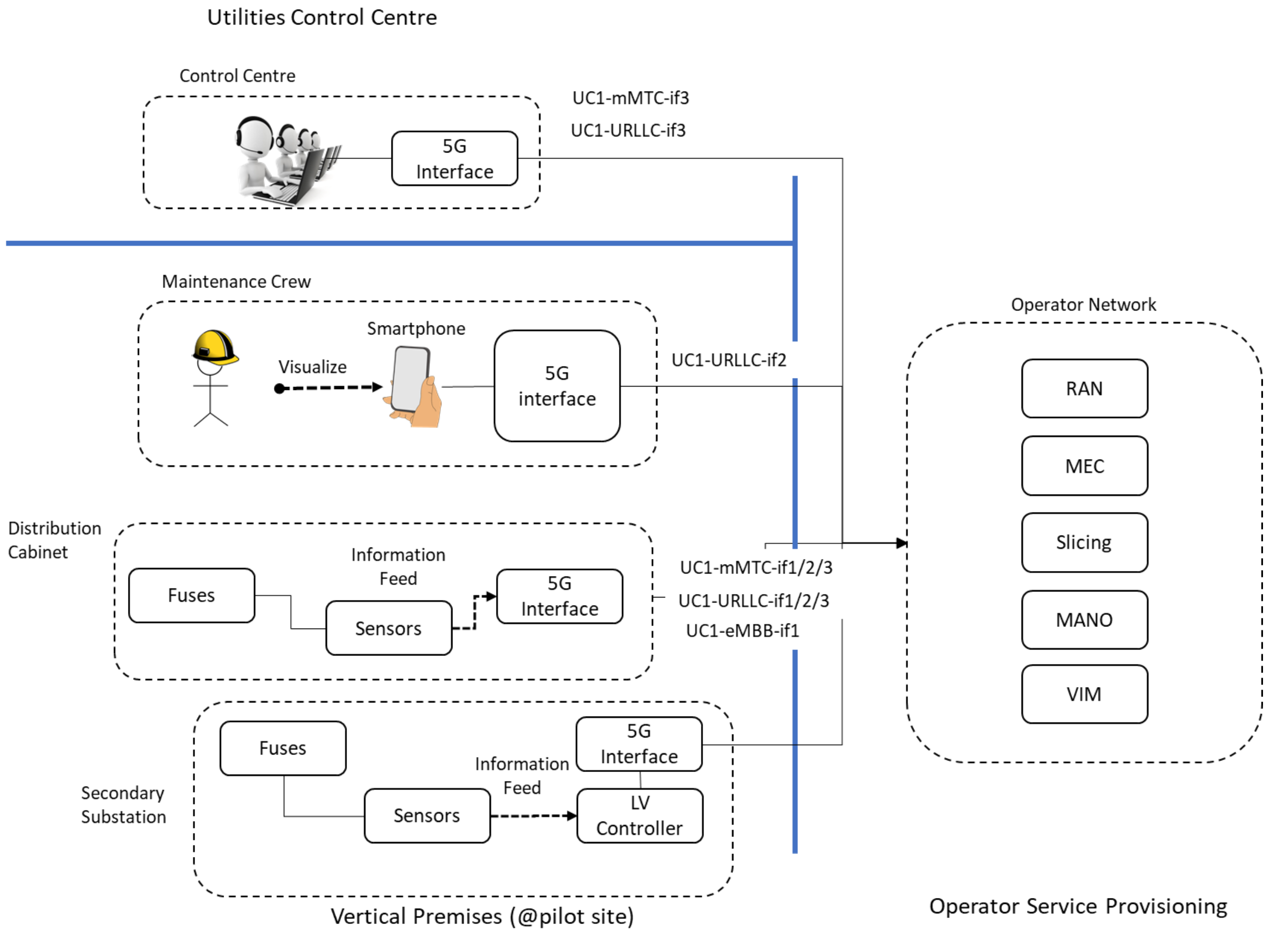

FIGURE 5: LOGICAL ARCHITECTURE EFACEC_E-UC2

TABLE 14: EFACEC_E UC2 LOGICAL ARCHITECTURE COMPONENTS

Component	Description	Location
Fuses	Components used to protect the low voltage feeder against high currents	Aveiro Campus
Meters / Sensors	Devices that will be installed in the secondary substation and distribution cabinets to monitor and detect faults in the low voltage feeders	Aveiro Campus
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.	Aveiro Campus secondary substation
Smartphone	Smartphone used by the maintenance team.	With maintenance team
Control Centre	SCADA system to support the operators to monitor and control the installation.	Cloud
5G router	Communication module for the secondary substation and distribution cabinets	Aveiro Campus

TABLE 15: EFACEC_E UC2 INTERFACES AND REQUIREMENTS.

Interface	Services	Requirements (KPIs)	Slice Type
UC2-URLLC-IF1, UC2-MMTC-IF1	Real-time energy data monitoring	1Kbit/s, 5ms, 99.99%	URLLC
UC2-URLLC-IF2, UC2-MMTC-IF2	Time synchronization (1ms max error)	1Kbit/s, -, 99.99%	URLLC
UC2-MMTC-IF3, UC2-URLLC-IF3	Real-time control (self-healing)	1Kbit/s, 5ms, 99.99%	URLLC

1.5.7. Selected ICT-17 platform to support the Test Campaigns

This Use Case will use the infrastructure of the 5G-VINNI Aveiro Experimentation Site, extending the 5G-NR coverage to the University of Aveiro, the area where the UC2 takes place.

1.5.8. Selected 5Growth innovation to be leveraged/validated

The members of 5Growth involved in the pilots in Aveiro are addressing innovations "C1-I6 Federation and inter-domain" and "C3-I11: Security and auditability". Both innovations will be generically developed considering their contribution towards a better capability to provide particular 5G services to verticals. In this specific case, inter-domain capabilities could be employed to retain the necessary network conditions while the maintenance crew is accessing information originated from different coverage areas provided by different domains (C1-I6), and security procedures could be used to ensure that instantiated virtualized services are trustworthy (C3-11). Regarding validation, even though the actual realization of the proposed use cases does not actively require the employment of inter-domain or virtualization mechanisms security, it will be assessed how such mechanisms could be deployed and evaluated in such, or similar, use case execution conditions.

1.6. EFACEC_S Use Case 1: Safety Critical Communications

1.6.1. Overview

The use case will demonstrate the use of 5G communications for the railway safety critical communications, particularly at Level Crossing systems, supporting data information exchange between the level crossing train detector activation points and the LX (Level Crossing) controller. Since this type of communication is considered critical, the most relevant issues are related to reliability, availability and low latency in order to assure the proper behavior of the system according to railway signaling safety communications standards EN50159-2 class 7. More details about this Use Case are reported in 5Growth's Deliverable D1.1 [15] .

1.6.2. 5G Network KPIs and Targets

The Table 16 describes the 5G KPIs expected by the EFACEC Transportation pilot in the UC1. The main highlight here goes to the low latency required to ensure a properly train detection, as well as the high availability and resilience of the system to ensure all safety conditions and to ensure that train rails and car roads are always mutually protected.

TABLE 16: EFACEC_S USE CASE 1 - TARGET KPI'S.

Latency RTT	msec	<10
Data Rate	Kbps	1.2
Reliability	%	99,99%
Availability	%	99,99%
Mobility	Km/h	N
Broadband Connectivity	Y/N or Mbps	N
Network Slicing	Y/N	Y
Security	Y/N	Y
Capacity	Mbps/Km2	1
Device Density	Dev/Km2	Low

1.6.3. Critical Testing Needs

E2E tests will be done to assess availability, reliability and latency. Such tests will require to have a preliminary test on infrastructure. Once network performances are verified, tests will then focus on the vertical application assessing if all critical elements are properly communicating in accordance with all requirements.

1.6.4. Test Campaign Plan

The initial test will be performed at EFACEC_S premises in order to assure that the complete Level Crossing and its components, devices and modules are properly assembled and communicating, in compliance with the functional requirements. In this stage the network will be based on LTE communication.

The second stage will be performed at vertical site premises (Aveiro Harbor), still using LTE as the communication network infrastructure and focusing functional requirements. Finally, the third stage comprises the use of 5G network assuring the integration with 5G-VINNI platform and E2E service availability. After this stage, the verification and validation campaigns of Transportation EFACEC_S Pilot can be initiated collecting evidence about the fulfilment of the core 5G, Technical requirements and service KPIs in the context of UC1.

1.6.5. Specific Restriction/Constrains

According with the 5Growth plan, the integration at vertical sites will start at M10 and the test campaigns will start at M12. The main identified constraint is related the commercial availability of 5G-CPEs, needed to integrate the Level Crossing components with the 5G network.

1.6.6. Logical Architecture for the Vertical application

Figure 6 depicts the logical architecture for the connected worker use case, including all the necessary components and labelled interfaces, which are further explained and justified in Table 17 and Table 18. In this case the operator provides and manages the Vertical service in a Slice as a Service model.

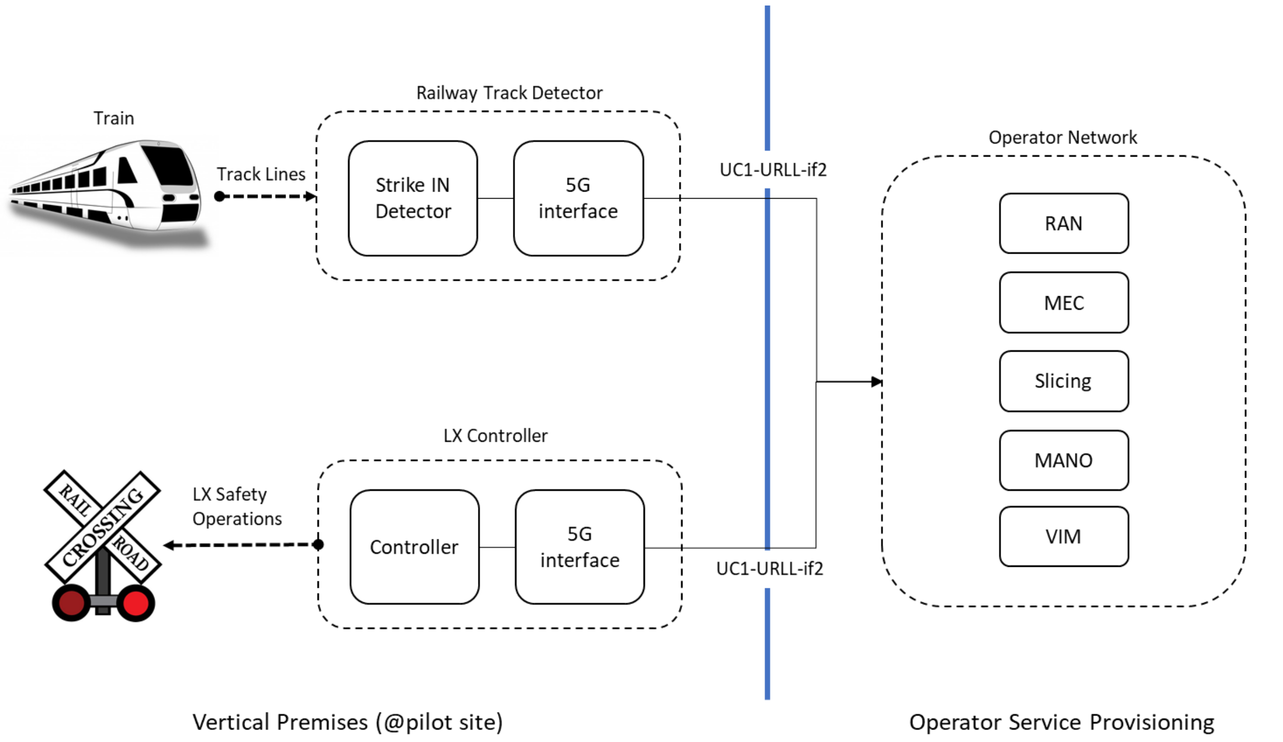

FIGURE 6: LOGICAL ARCHITECTURE EFACEC_S-UC1

TABLE 17: EFACEC_S UC1 LOGICAL ARCHITECTURE COMPONENTS

Component	Description	Location
Train	The machine responsible to transport people or freight.	Aveiro Harbor
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 Harbor
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	Level Crossing area-Aveiro Harbor
Traffic lights	Device that is installed in the Level Crossing area and is responsible to process traffic information	Level Crossing area-Aveiro Harbor
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 Harbor
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 Harbor
Half Barriers	The device that physically protects the Level Crossing against non-authorized entrances.	Level Crossing area-Aveiro Harbor
5G Interface	Mobile network interface able to connect to a 5G mobile network.	Strike IN Detector/LX Controller at the Railway track
Operator Network	5G Mobile network covering the level crossing	Mobile Operator/Altice Labs/Aveiro Harbor
RAN	The RAN portion of the operator's mobile network	Mobile Operator/Altice Labs
MEC	The MEC portion of the mobile operator, allowing for lower latency service provisioning whenever needed.	Mobile Operator/Altice Labs
Slicing	Network slicing capability whenever needed	Mobile Operator/Altice Labs
MANO	Mobile Network Management and Orchestration capability.	Mobile Operator/Altice Labs
VIM	Virtualized Infrastructure Management Capability	Mobile Operator/Altice Labs

TABLE 18: EFACEC_S UC1 INTERFACES AND REQUIREMENTS.

Interface	Services	Requirements (KPIs)	Slice Type
UC1-URLLC-IF1, UC1-URLLC-IF2	Train sensors to LX communications	1.2Kbit/s, 10ms, 99.99%, -	URLLC

1.6.7. Selected ICT-17 platform to support the Test Campaigns

This Use Case will use the infrastructure of the 5G-VINNI Aveiro Experimentation Site, extending the 5G-NR coverage to the Aveiro Harbor, the area where the UC1 takes place.

1.6.8. Selected 5Growth innovation to be leveraged/validated

The members of 5Growth involved in the pilots in Aveiro are addressing the "C3-I11: Security and auditability" innovation. This will be generically developed considering its contribution towards a better capability to provide particular 5G services to verticals. In this specific case, security procedures could be used to ensure that instantiated virtualized services are trustworthy (C3-11). Regarding validation, even though the actual realization of the proposed use cases does not actively require the employment of virtualization mechanisms security, it will be assessed how such mechanisms could be deployed and evaluated in such, or similar, use case execution conditions.

1.7. EFACEC_S Use Case 2: Non-safety Critical Communications

1.7.1. Overview

The use case involves 5G communications to support two main objectives, in Level Crossing environments: (*i*) HD video image transmission from LX surveillance camera to the approaching trains' on-board tablets and/or maintenance agents' hand-held tablets, and (*ii*) Level crossing LX controller status and alarm events transmission to maintenance agents' tablets. This use case will be composed of two slices, one for eMBB and other one to URLLC where the availability of the slices is the main constrain. More details about this Use Case are reported in 5Growth's Deliverable D1.1 [15].

1.7.2. 5G Network KPIs and Targets

The Table 19 describes the 5G KPIs expected by the EFACEC Transportation pilot in the UC2. The main highlight here goes to the low latency and availability/resilience required to ensure a properly visualization of the train approaching, and the high bandwidth at high Data Rate (mobility) required to ensure that high quality video can be streamed to the train driver in order to see the next level crossing area. The low latency and availability/resilience is required to permanently monitor the status (alarms and events) of the Level Crossing.

TABLE 19: EFACEC_S USE CASE 2 - TARGET KPI'S.

Latency RTT	msec	5-100
Data Rate	Mbps	14
Reliability	%	99,99%
Availability	%	99,99%
Mobility	Km/h	160
Broadband Connectivity	Y/N or Mbps	Y
Network Slicing	Y/N	Y
Security	Y/N	Y
Capacity	Mbps/Km2	60
Device Density	Dev/Km2	Low

1.7.3. Critical Testing Needs

E2E tests will be done to assess availability, reliability, latency as well as large bandwidth (HD video transmission) and Mobility (involving the train). Such tests will require to have a preliminary test on infrastructure. Once network performances are verified, tests will then focus on the vertical application assessing if all critical elements are properly communicating in accordance with all requirements.

1.7.4. Test Campaign Plan

The initial test will be performed at EFACEC_S premises in order to assure that the complete Level Crossing and its components, devices and modules are properly assembled and communicating, in compliance with the functional requirements. In this stage the network will be based on LTE communication.

The second stage will be performed at vertical site premises (Aveiro Harbor), still using LTE as the communication network infrastructure and focusing on functional requirements. Finally, the third stage comprises the use of 5G network assuring the integration with 5G-VINNI platform and E2E service availability. After this stage, the verification and validation campaigns of Transportation EFACEC_S Pilot can be initiated collecting evidence about the fulfilment of the core 5G, Technical requirements and service KPIs in the context of UC2.

1.7.5. Specific Restriction/Constraints

According with the 5Growth plan, the integration at vertical sites will start at M10 and the test campaigns will start at M12. The main identified constraint is related the commercial availability of 5G-CPEs, needed to integrate the Level Crossing components with the 5G network.

1.7.6. Logical Architecture for the Vertical application

Figure 7 depicts the logical architecture for the connected worker use case, including all the necessary components and labelled interfaces, which are further explained and justified in Table 20 and Table 21. In this case the operator provides and manages the Vertical service in a Slice as a Service model.

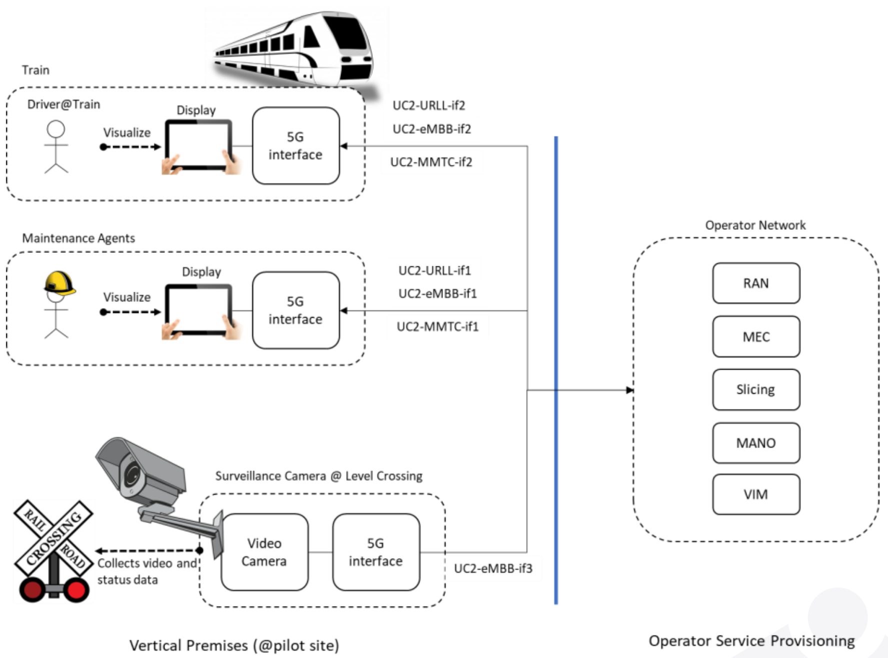

FIGURE 7: LOGICAL ARCHITECTURE EFACEC_S-UC2

TABLE 20: EFACEC_S UC2 LOGICAL ARCHITECTURE COMPONENTS

Component	Description	Location
Train	The machine responsible to transport people or freight.	Aveiro Harbor
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 Harbor
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 Harbor
Command Centre:	Technical and Operation rooms to support the monitor and control of the Level Crossing.	Level Crossing area-Aveiro Harbor
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 Harbor
GPS position system	Device to be installed in the train in order to report its geographical positioning.	Train-Aveiro Harbor
5G Interface	Mobile network interface able to connect to a 5G 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 Harbor
Operator Network	5G Mobile network covering the level crossing	Mobile Operator/Altice Labs/Aveiro Harbor
RAN	The RAN portion of the operator's mobile network	Mobile Operator/Altice Labs/
MEC	The MEC portion of the mobile operator, allowing for lower latency service provisioning whenever needed.	Mobile Operator/Altice Labs/
Slicing	Network slicing capability whenever needed	Mobile Operator/Altice Labs/
MANO	Mobile Network Management and Orchestration capability.	Mobile Operator/Altice Labs/
VIM	Virtualized Infrastructure Management Capability	Mobile Operator/Altice Labs/

TABLE 21: EFACEC_S UC2 INTERFACES AND REQUEIREMENTS

Interface	Services	Requirements (KPIs)	Slice Type
UC2-eMBB-IF1, UC2-eMBB-IF2, UC2-eMBB-IF3	HD video on the train (near real-time), sent from the surveillance camera at the level crossing	14Mbit/s, 5-100ms, 99.9%, 160Km/h	eMBB
UC2-URLLC-IF1, UC2-MMTC-IF1, UC2-URLLC-IF2, UC2-MMTC-IF2	Real-time sensors data monitoring	1.2Kbit/s, 10ms, 99.99%	URLLC

1.7.7. Selected ICT-17 platform to support the Test Campaigns

This Use Case will use the infrastructure of the 5G-VINNI Aveiro Experimentation Site, extending the 5G-NR coverage to the Aveiro Harbor, the area where the UC2 takes place.

1.7.8. Selected 5Growth innovation to be leveraged/validated

The members of 5Growth involved in the pilots in Aveiro are addressing innovations "C1-I6 Federation and inter-domain" and "C3-I11: Security and auditability". Both innovations will be generically developed considering their contribution towards a better capability to provide particular 5G services to verticals. In this specific case, inter-domain capabilities could be employed to retain the necessary network conditions while the video is being sent to the incoming train (C1-I6), and security procedures could be used to ensure that instantiated virtualized services are trustworthy (C3-11). Regarding validation, even though the actual realization of the proposed use cases does not actively require the employment of inter-domain or virtualization mechanisms security, it will be assessed how such mechanisms could be deployed and evaluated in such, or similar, use case execution conditions.

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

1.8.1. Overview

The Coordinate Measuring Machine (CMM) can measure autonomously but must be programmed previously by an operator measuring a hardware piece with the same sizes. In this case, the operator programs the CMM remotely using a virtual joystick in a mobile device, which at the same moment a live video of the CMM is displayed giving feedback to the operator. The use case will be composed of two non-permanent slices (always running at the same time, i.e. the same life-cycle management will be applied on both slices), one for eMBB and URLLC, where the availability of the slices will be determined by the necessity to measure an industrial part during a specific time slot. For the URLLC slice the critical parameter is the reliability, however the latency will play an important role between the synchronization of the video stream and the virtual joystick.

1.8.2. 5G Network KPIs and Targets

Table 22 provides the KPI to be measured and specific use case requirements for the connected worker INNOVALIA UC1.

TABLE 22 : INNOVALIA USE CASE 1 – TARGET KPI'S

Latency RTT	msec	5
Data Rate	Mbps	10
Reliability	%	99.99%
Availability	%	99.99%
Mobility	Km/h	3
Broadband Connectivity		Y
Network Slicing		Y
Security		Y
Capacity	Mbps/km^2	20
Device Density	Dev/Km2	1000

1.8.3. Critical Testing Needs

- A remote connection must be enabled on the M3Box device, which is an Edge device that hosts the services that translate the instructions from M3 metrology software to the control of the CMM (Robotlink and DataAssembler).
- Synchronization between the video stream and the Joystick instructions is a must, the operator must be able to operate the joystick with a video stream that corresponds to no more than the defined operational RTT KPI (Table 22 : INNOVALIA Use Case 1 – Target KPI'sof the use case, which corresponds to the delay between the video feed being displayed and the time the virtual joystick is able to execute the instruction in the CMM.

- Feedback video from the CMM and optical sensor should comply with low latency(<5ms) requirement, as the user (the INNOVALIA expert) must control the CMM based on the video stream received.

1.8.4. Test Campaign Plan

The Test Case for this use case is composed of an operator and an CMM machine, as there is only going to be a single operator managing a single CMM machine at a time. In order to test the use case, the vertical is exploring the possibility to bring all the necessary equipment to 5TONIC to test and validate the theoretical KPIs by using 5G technologies and the 5G EVE platform extracting the experimental KPIs. Table 23 describes how the testing campaign is planned in three phases. The first phase of the testing campaign will allow the vertical to validate on premises the functional requirements of each of the components defined in the logical architecture, using 4G technologies available. The second phase of the testing campaign will focus on the integration of the components defined in the logical architecture at 5TONIC experimental facility. Finally, the third and last phase will leverage from the results of the second phase to further test the vertical pilot at their site using the components that has been integrated on the second phase.

TABLE 23: TESTING CAMPAIGN INNO_UC1

Phase	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
1	■	■	■							
2			■	■	■	■	■	■		
3							■	■	■	■

1.8.5. Specific Restriction/Constrains

No restrictions or constrains have been identified.

1.8.6. Logical Architecture for the Vertical application

Figure 8 depicts the logical architecture for the connected worker use case, including all the necessary components and labelled interfaces, which are further explained and justified in Table 24 and Table 25.

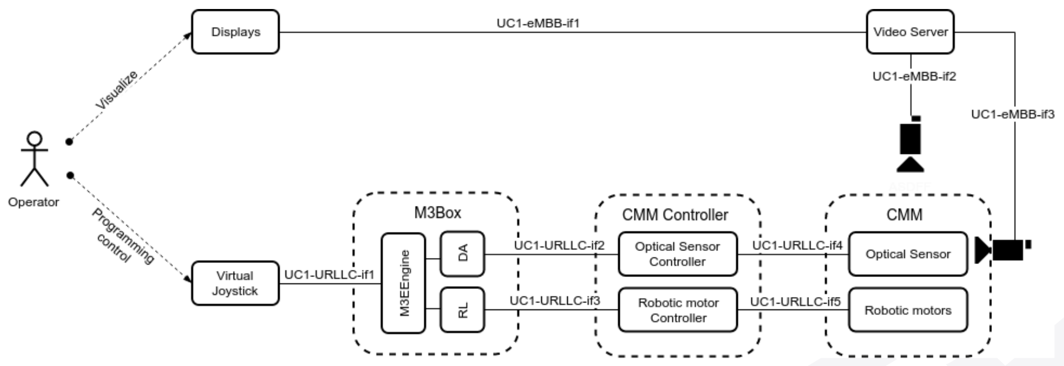

FIGURE 8: LOGICAL ARCHITECTURE INNO-UC1

TABLE 24: UC1 LOGICAL ARCHITECTURE COMPONENTS

Component	Description	Location
Displays	Two displays rendering the live video streams from two cameras installed in the CMM.	Innovalia control center
Video Server	Translate RAW video to bytes-based video.	Factory/Innovalia control center
Overall HD Camera	Capture CMM movements and position.	Factory
Sensor pointing HD Camera	Monitor the CMM's robot measuring sensor. This camera must be lightweight because it must be mounted on the actual sensor.	Factory
Virtual Joystick	Virtual joystick application, which can be installed in a 5G smart phone. On a first step the joystick could be emulated via command line.	Innovalia control center
M3ExecutionEngine	The main function of the M3EE is the sizing of a hardware piece autonomously so, the M3EE must be programmed to size a model hardware piece. M3EE controls both, Robotlink and DataAssembler	M3Box (Factory)
RobotLink	Commands the CMM's Robotic Motor Controller to move the robotic sensor in three axes (X, Y, Z).	M3Box (Factory)
DataAssembler	Commands the Optical Sensor Controller to controls the optical sensor, receive the data and filter data.	M3Box (Factory)
Optical Sensor Controller	Control the sensor that position and dimensions.	Factory
Robotic Motor Controller	Control the robotic arm moving the sensor	Factory
Optical Sensor	Used to size the hardware pieces	CMM (Factory
Robotics motors	Move the robotic arm sensor and the pieces to scan.	CMM (Factory)
M3Box	Device that hosts the services used to control the CMM through its corresponding controllers	Factory
CMM Controller	Translates instructions between the M3Box and the CMM itself. The CMM controller always must be side by side with the CMM.	Factory
CMM	Coordinate Measuring Machine. It contains an optical sensor and some electric motors and servomotors to move a robotic arm sensor.	Factory

TABLE 25: UC1-INNO LOGICAL ARCHITECTURE INTERFACES

Interface	Description	Requirements
UC1-eMBB-If1	RTP format video from the video server to be displayed under an IP connection.	RTP 10Mbps
UC1-eMBB-If2	RAW video from the camera to the video server.	Uncompressed video, 24-bit, 1080p @ 60 fps = 2.98 Gbit/s. HDMI, DVI and HD-SDI inputs.
UC1-eMBB-If3	RAW video from the camera to the video server.	Uncompressed video, 24-bit, 1080p @ 60 fps = 2.98 Gbit/s. HDMI, DVI and HD-SDI inputs.
UC1-URLLC-If1	Joystick CMM control traffic IP based.	TCP based Protocol, 128 – 400 Kbps. 5G connectivity 99.99% Reliability.
UC1-URLLC-If2	DataAssembler communication with the Optical Sensor Controller (CMM controller)	Ethernet based
UC1-URLLC-If3	RobotLink communication with the Robotic Motor Sensor Controller (CMM controller)	Ethernet based
UC1-URLLC-If4	Optical sensor data between Optical Sensor Controller and the actual optical sensor.	Optical sensor data proprietary protocol
UC1-URLLC-If5	Robotic motor control data between Robotic Sensor controller and the robotic motors	Robotic motor control data proprietary protocol

Note that components of the logical architecture depicted in Figure 8 do not map 1:1 to physical architecture. E.g. the Video server could be embedded in the camera directly or the Joystick CMM controller could also be embedded at the joystick or at the CMM.

The requirements for each interface and component listed in Table 24 and Table 25 will define the location of components, which currently can be located in more than one place and the specific technical requirements of the slice.

1.8.7. Selected ICT-17 platform to support the Test Campaign

5G EVE facility in Leganés, Madrid (5TONIC lab).

1.8.8. Selected 5Growth innovation to be leveraged/validated

This use case will leverage the 5Growth innovations related to monitoring, i.e. *"I2: Vertical-oriented Monitoring System"* and *"I3: Orchestration of Monitoring functions"*, in order to provide the vertical with real-time monitoring information about the health status of the deployed service. Furthermore, *"I4: Control-loops stability"* and *"I8: Smart Orchestration and Resource Control"* will be employed to perform automatic orchestration, with the purpose of ensuring SLAs and service availability. Finally, *"I6: Federation and inter-domain"* will be leveraged to validate the radius of operation of the service, which must span across different administrative domains around Europe.

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

1.9.1. Overview

This use case leverages 5G edge infrastructure to deploy the required components closer to the machines using them. The use case will enable the collaboration between two initially isolated systems, by exploiting M2M communication across multiple machines, for the sake of this use case AVG and CMM control systems will be coordinated to share a single CMM machine across multiple production lines [15].

1.9.2. 5G Network KPIs and Targets

Table 26 provides the KPI to be measured and specific use case requirements for the connected worker INNOVALIA UC2.

TABLE 26 : INNOVALIA USE CASE 1 – TARGET KPI'S

Latency RTT	msec	5
Data Rate	Gbps	1
Reliability	%	99.99%
Availability	%	99.99%
Mobility	Km/h	3-50km/h
Broadband Connectivity		Y
Network Slicing		N
Security		Y
Capacity	Mbps/km^2	200
Device Density	Dev/Km2	Low

1.9.3. Critical Testing Needs

- Permanent eMBB slice, were industrial parts are scanned sequentially, uploaded to the edge application which compares the scanned model with the original. Later, the results (deviations from the original model) are displayed to the factory operator.
- 5G communication between scanned part model–to-edge and operator-to-edge
- Transport of the pieces by an Automated Guide Vehicle which is an industrial robot that will help to move hardware between the CMM and the production line.
- Industrial control systems controlling the CMM and the AGV, installed at the edge.

The M2M communication between the AGV and the CMM across the edge.

1.9.4. Test Campaign Plan

The Test Case for this use case is composed of a CMM machine an AGV and the necessary industrial control systems, for the testing campaign one CMM and multiple AGVs will be provided. In order to test the use case, the vertical is exploring the possibility to bring all the necessary equipment to 5TONIC to test and validate the theoretical KPIs by using the 5G EVE platform extracting the experimental KPIs. Table 27, describes how the testing campaign is planned, three testing phases are used. For the first phase of the testing campaign, the vertical will validate on premises the functional requirements of each of the components defined in the logical architecture, using 4G technologies available. The second phase of the testing campaign will focus on the integration of the components defined in the logical architecture at 5TONIC experimental facility. Finally, the third and last phase will leverage from the results of the second phase to further test the vertical pilot at their site using the components that has been integrated on the second phase.

TABLE 27: TESTING CAMPAIGN INNO_UC2

Phase	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
1	■	■	■							
2			■	■	■	■	■	■		
3							■	■	■	■

1.9.5. Specific Restrictions/Constrains

No restrictions or constrains have been identified.

1.9.6. Logical Architecture for the Vertical application

Edge is going to be placed in the operator infrastructure and managed by the operator. A M3Box and an AGV Controller is will be virtualized inside.

Figure 9 depicts the logical architecture for the connected worker use case, including all the necessary components and labelled interfaces, which are further explained and justified in Table 28 and Table 29.

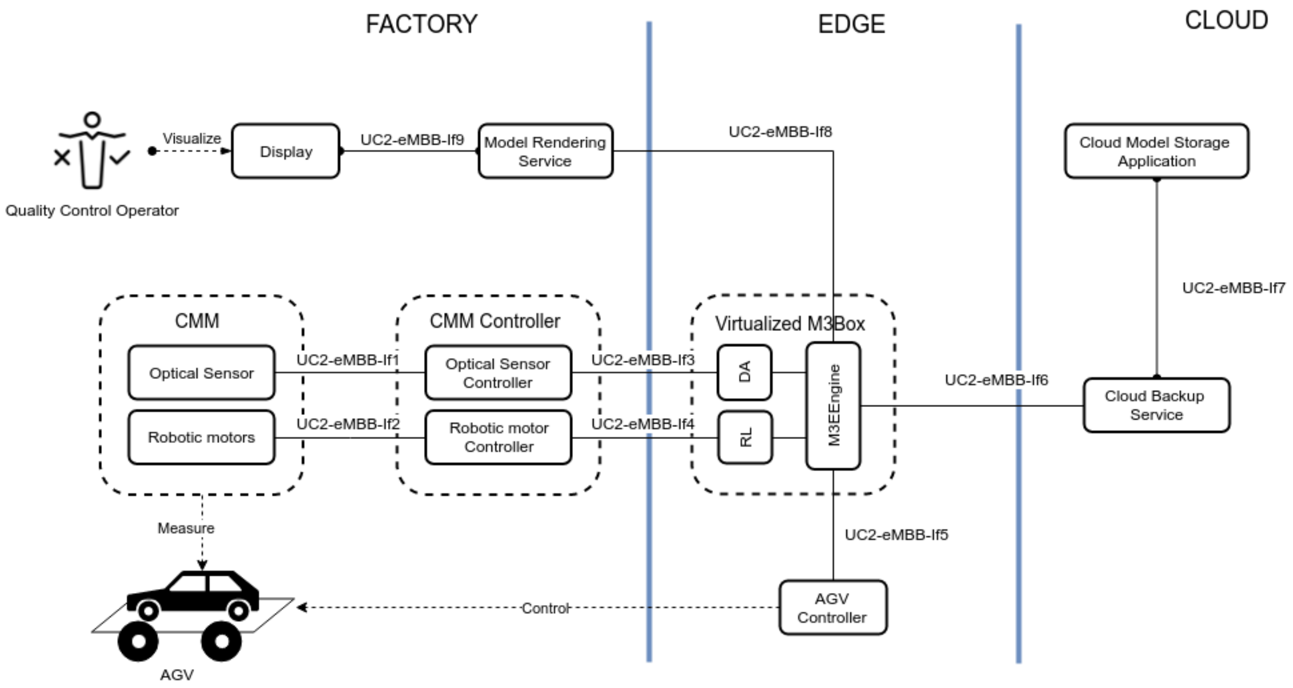

FIGURE 9: LOGICAL ARCHITECTURE INNO-UC2

TABLE 28: LOGICAL ARCHITECTURE COMPONENTS INNO-UC2

Component	Description	Location	Limitation
CMM	Coordinate Measuring Machine.	Innovalia Factory	Area/Volume scanned by unit time.
CMM Controller	Translates instructions between the CMM and Robotlink, DataAssembler and M3ExecutionEngine	Innovalia Factory	Area/Volume scanned by unit time.
M3ExecutionEngine	Execute a previously programmed sizing. It controls both, Robotlink and DataAssembler.	Edge	Time to process model (MB/s) (cm3/s) (cm2/s). Storage needed – ~ 10 TB (tbc)
Robotlink	Moves the CMM robot in three axes (XYZ) through the Robotic Motor Controller	Edge	Numbers of movements per second
DataAssembler	Controls the optical sensor, receive the data and realize a first filtering.	Edge	Storage needed – ~ 10 TB (tbc)
Optical Sensor Controller	Control the sensor that size.	Factory	Number of orders per second
Robotic Motor Controller	Control the robots that move the sensor	Factory	Number of orders per second
Optical Sensor	Used to size the hardware pieces	CMM (Factory)	Number of sizes per second
Robotics motors	Move the sensor and the pieces to scan	CMM (Factory)	Number of movements per second
Model Rendering Service	Renders the final resulting model. Either it can render it as a CAD model or images/video.	Edge	Video processing capabilities
Display	Displays the resulting model.	Operator workstation (Innovalia Factory)	Screen resolution
AGV Controller	Control the AGV	Edge	Latency
Cloud Backup Service	Proxy between the cloud and the edge.	Cloud	Cost of data transfer
Cloud Model Storage Application	Permanent storage of the resulting model with known defects at the cloud.	Cloud	Storage cost

TABLE 29: LOGICAL ARCHITECTURE INTERFACES INNO-UC2

Interface	Description	Requirements
UC2-eMBB-If1	Optical sensor data between Optical Sensor Controller and the actual optical sensor.	Optical sensor data proprietary protocol
UC2-eMBB-If2	Robotic motor control data between Robotic Sensor controller and the robotic motors	Robotic motor control data proprietary protocol
UC2-eMBB-If3	DataAssembler communication with the Optical Sensor Controller (CMM controller)	IP Based. 5G connectivity. 99.99% Reliability.
UC2-eMBB-If4	RobotLink communication with the Robotic Motor Sensor Controller (CMM controller)	IP Based. 5G connectivity. 99.99% Reliability.
UC2-eMBB-If5	M3EE and AGVC communication	Inter-Process Communication
UC2-eMBB-If6	Resulting model with known defects	1Gbps
UC2-eMBB-If7	Resulting model with known defects	1Gbps
UC2-eMBB-If8	Resulting model with known defects	TCP Protocol. 99.99% Reliability.
UC2-eMBB-If9	Rendered model with known defects to be displayed	Ip Protocol. 99.99% Reliability.

1.9.7. Selected ICT-17 platform to support the Test Campaign

5G EVE facility in Leganés, Madrid (5TONIC lab).

1.9.8. Selected 5Growth innovation to be leveraged/validated

This use case will leverage the 5Growth innovations related to monitoring, i.e. *"I2: Vertical-oriented Monitoring System"* and *"I3: Orchestration of Monitoring functions"*, in order to provide the vertical with real-time monitoring information about the health status of the deployed service. Furthermore, *"I4: Control-loops stability"* and *"I8: Smart Orchestration and Resource Control"* will be employed to perform automatic orchestration, with the purpose of ensuring SLAs and service availability.

2. Technical Solution Approaches

2.1. General Technical Solution principles

The benefits of 5G technologies has raised the interest of several entities on the use of 5G networks in private environments, usually designated as non-public networks (NPN), in collaboration or not with traditional network operators. Typically, large players such as industrial plants (e.g. oil, gas, manufacturing), campus (e.g. universities, large company headquarters), or big communication infrastructures (airports, harbors), are willing to manage those networks; however, smaller organizations can also take advantage of NPN.

NPN 5G networks can offer several advantages:

(a) **Quality of Service (QoS)**, using proprietary network (and spectrum), QoS can be ensured with a higher degree of confidence;

(b) **Security**, credentials databases are proprietary and custom security mechanisms can be used;

(c) **Isolation**, providing protection from malfunctions in public networks, alongside better performance, security, privacy, and safety reasons;

(d) **Accountability**, a private network increases the ability to identify responsibilities for availability, maintenance, performance and operation.

The 5G NPN topic has been addressed by multiple standard developing organizations (SDOs). 3GPP has studied this topic, for example in [10], targeting related issues in several documents such as [11]. The 5G Alliance for Connected Industries and Automation (5G-ACIA) [12] has been very active in this field, being the most representative vertical association. Driven by the powerful German Industry, 5G-ACIA aims to ensure the best application of 5G, raising attention for the industrial specific spectrum needs, and suggesting new models like operating a private 5G network within a plant or factory. 5G-ACIA has been lobbying on the German Government for assigning licensed spectrum directly to industries.

The 5G-ACIA association, in his "5G for Connected Industries and Automation" White Paper [13] proposes four scenarios of 5G NPN deployments, one standalone 5G private networks and three in conjunction with public networks. In the NPN shared with public network scenarios, the NPN network is not fully standalone, but partially reusing some network functions from a public network. The shared scenarios intend to reduce the total cost of ownership (TCO), while still ensuring acceptable levels of quality of service, isolation and security. The higher the levels of sharing, the lower the costs and the lower the network guarantees and isolation.

Figure 10 depicts the four scenarios proposed (from right to left): (1) Standalone; (2) Shared RAN; (3) Shared RAN and CP; and, (4) Shared RAN, CP and UP.

In the standalone NPN scenario, depicted in Figure 10 (1), a fully 5G isolated network is deployed within the private perimeter to cover the desired area (e.g. factory). Dedicated and independent network functions are required for the RAN and 5G Core. The management layer is also dedicated and independent.

In the shared RAN scenario (Figure 10 (2)), the RAN part is shared between the NPN and the public network. The NPN may have its own spectrum (unusual) or use spectrum of the network operator (more often). The traffic generated by terminals (control and user plane) is forwarded to network functions within the NPN perimeter. Here it is the operator that takes care of RAN management.

In the shared RAN and control plane (CP) scenario (Figure 10 (3)), the RAN is shared and the NPN control plane is handled by the public network. The user plane (UP) traffic from NPN terminals is forwarded to the network functions within the private perimeter. This should be implemented using network slices. Here it is the operator that takes care of RAN and CP management.

Finally, in the NPN hosted by the public network scenario (Figure 10 (4)), the RAN and CP is shared with the public network. The user plane (UP) traffic is forwarded externally to the public network. This scenario implies an NPN network slice instance at the public network. End-to-end latencies should increase as services and core are far from the terminals.

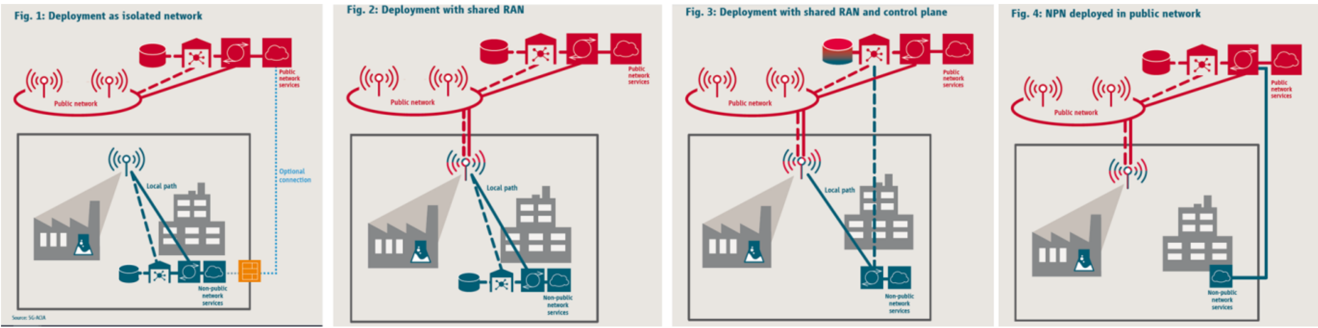

FIGURE 10: NPN DEPLOYMENT ALTERNATIVES (5G-ACIA)

2.2. Specific Technical Solutions

2.2.1. Technical Solution for COMAU Use Cases in Turin Environment

COMAU use cases will be deployed in COMAU and TIM premises that will be connected through a VPN.

Due to latency critical requirements and for security reasons, COMAU vertical applications will run in COMAU premises, corresponding to the first option in the 5GACIA framework illustrated in Figure 10. Hence the Radio Access Network (RAN), from Radio Remote Unit to vEPC, will be in COMAU premises, while the other core network components (e.g. HSS) and the 5Growth platform for orchestration will be in TIM premises.

Two phases are planned for the infrastructure deployment. In the first phase, the use cases in the pilot are deployed starting to connect them with an LTE network. In the second phase the pilot is fully migrated to a 5G NR network.

Phase 1

Phase 1, illustrated in Figure 11, is deployed connecting the systems with LTE. and a leveraging on a unique vEPC located on COMAU premises. Radio (except HSS), transport, and cloud equipment, including the relevant controllers, are similarly located in COMAU. The HSS function, which is required to allow access to the TIM licensed spectrum, is located on TIM premises and connected with the COMAU site through a VPN established between the two sites. It's worth to notice that actual remains bounded inside the COMAU building as the connectivity with TIM is established just to authorize the transmission over the TIM spectrum which is completely reserved by TIM for the experiments (i.e. not used for other commercial traffic).

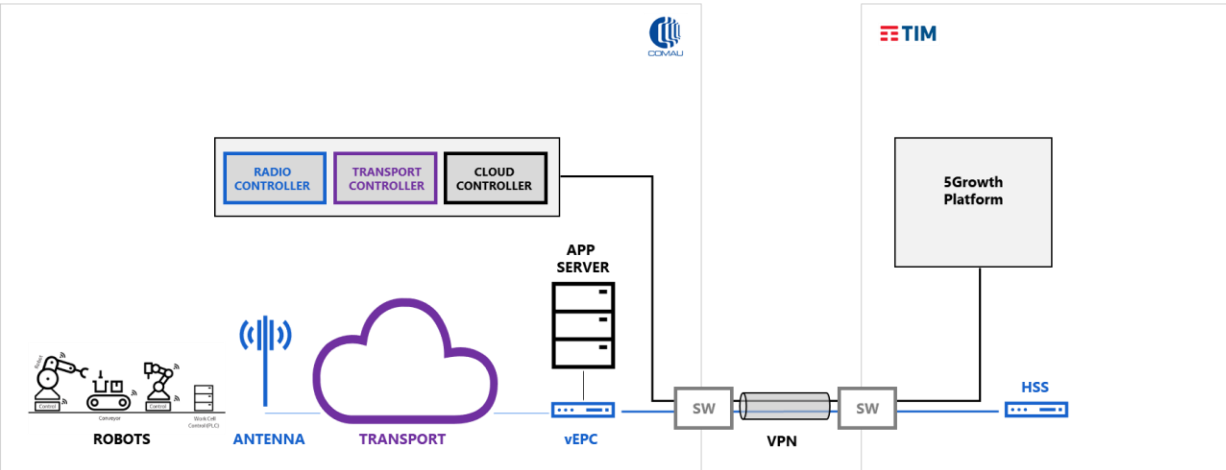

FIGURE 11: COMAU TECHNICAL SOLUTION APPROACH – PHASE 1

This network setup belongs to the "option 1" type among the canonical options of the network deployment scenarios in 5GACIA. In this "option 1" scenario, the Non-Public Network (NPN) is deployed as an independent, standalone network where all network functions are located inside the logical perimeter of the defined premises (i.e. the COMAU site) and the NPN is separate from the public network. The only communication path between the NPN and the public network is via a firewall which is a clearly defined and identifiable demarcation point. The vertical company (i.e. COMAU) has sole and exclusive responsibility for operating the NPN and for all service attributes up to the demarcation point.

Phase 2

The Ericsson vEPC has two important features: the ability to smoothly upgrade from LTE to 5G NR (named "dual mode" functionality) and the possibility to separate the User Plane (UP) from the Control Plane (CP) with maximum topology flexibility and completely independent capacity scaling of control and user planes. Leveraging on these capabilities, the pilot will be evolved in a Phase 2, illustrated in Figure 12. Here the radio network will be a 5G NR one. In this setup, the UC gateway (UP-GW), is located on COMAU premises and connected to the associated CP gateway (CP-GW) located on TIM premises. The 5Growth platform is in TIM, and is connected to the radio, transport and Cloud domains by means of a REST API directed linked to the corresponding controller. The HSS functionalities is still in TIM.

Phase 2, illustrated in Figure 12, is based on 5G NR. Here the user plane component of vEPC (UP-GW) is in COMAU while the control plane component (CP-GW) is in TIM.

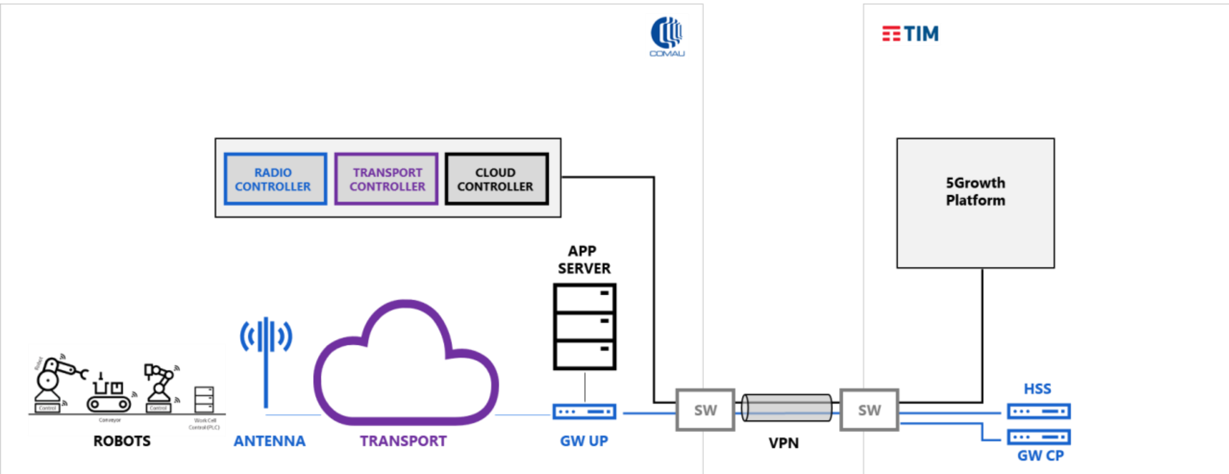

FIGURE 12: COMAU TECHNICAL SOLUTION APPROACH – PHASE II

Phase 2 is near to a realistic commercial solution where the operator has a centralized CP and many UPs deployed in multiple vertical sites. This network setup belongs to the "option 3" type among the canonical options of the network deployment scenarios in 5GACIA. In this "option 3" scenario, the NPN and the public network share the radio access network for the defined premises (i.e. COMAU site), and besides the network control tasks (i.e. control plane functions) are performed in the public network (i.e. control on TIM premises).

Nevertheless, all NPN traffic flows remain within the logical perimeter of the vertical premises: it is an important requirement for the vertical that prefers the maximum confidentiality level for its own plant data.

Relation with 5G EVE

The relation with 5G EVE is related to the coexistence of the 5Growth Platform elements and of the 5G EVE infrastructure terminal on the TIM premises. Sharing of functional blocks (e.g., HSS) among the two projects elements is planned in the COMAU pilot implementation.

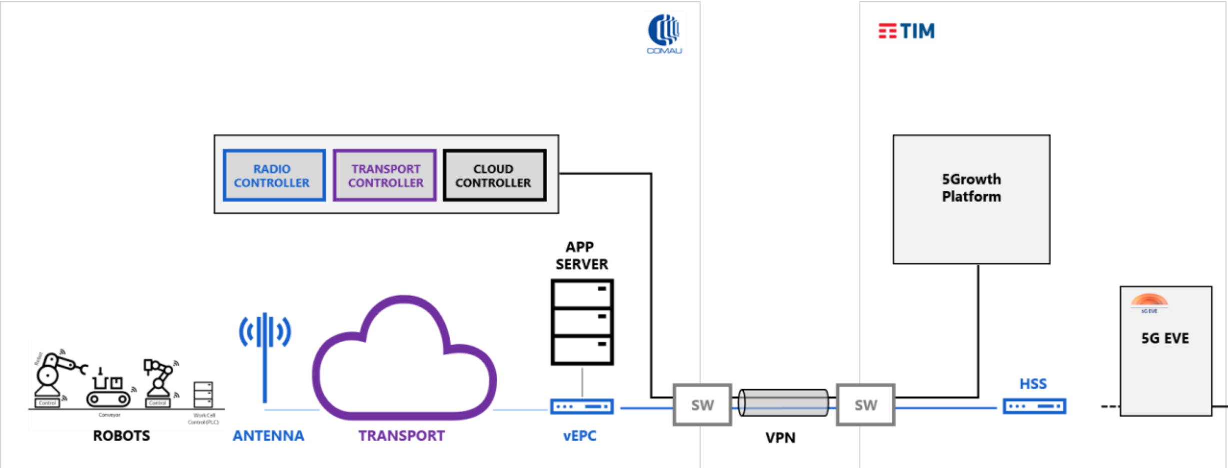

FIGURE 13: COMAU TECHNICAL SOLUTION APPROACH AND RELATION WITH 5G EVE

2.2.2. Technical Solution for EFACEC_E Use Cases in Aveiro Environment

Figure 14 diagram illustrates the preliminary technical solution concept for EFACEC_E use cases.

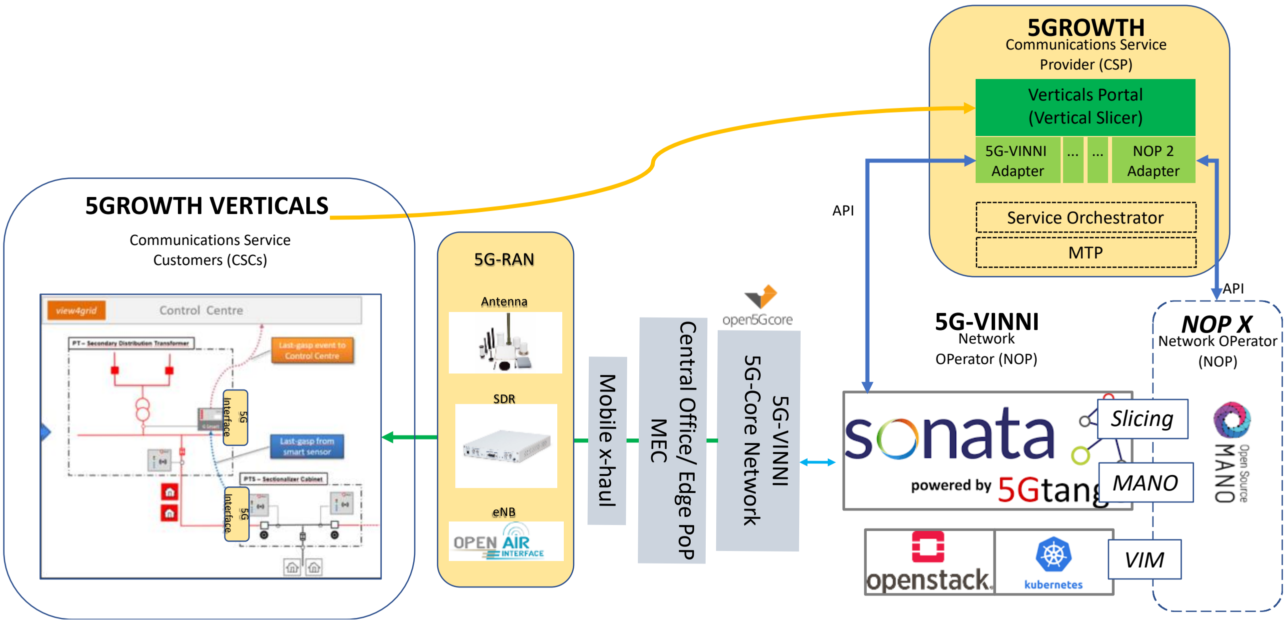

FIGURE 14: TECHNICAL SOLUTION FOR EFACE-E USE CASES IN AVEIRO ENVIRONMENT (UC1 AND UC2)

In this environment, the vertical has enhanced the connectivity of their customer's energy cabinets and transformers with 5G-NR capable interfaces. This allows it to access a 5G coverage provided by the network operator. For the purposes of this pilot, the 5G coverage will be deployed over the Santiago Campus of the University of Aveiro, as an extension to the ICT-17 project 5G-VINNI experimental site in Aveiro, whose components are described next.

- The 5G-RAN will consist of an antenna deployed over the rooftop of the Instituto de Telecomunicações, in the University of Aveiro campus, using an USRP N310 SDR from Ettus Research, served by an OpenAirInterface (OAI) based gNB.
- The RAN's cell site reaches the operator's core through a NG-PON2 Mobile x-haul (e.g., Front, Mid and Backhaul), a technology developed in-house by Altice Labs.
- The operator's 5G core is composed by an Open5GCore deployment from the Fraunhofer Institute, instantiated on top of a virtualization infrastructure, managed by Openstack and Kubernetes, for virtual machine and container-based deployments, respectively.
- The Management and Orchestration (MANO) of resources, as well as the network slicing operations, are handled by the open source SONATA platform [14] which is the result of the H2020 Phase I and II, SONATA and 5GTANGO projects, respectively.

Figure 15 depicts the geographical location of the Use Case in the campus of the University of Aveiro, the same location where the Edge PoP will be deployed. The Transformation unit to be considered in around 50 meters away from the building (datacenter) where the edge PoP will be deployed.

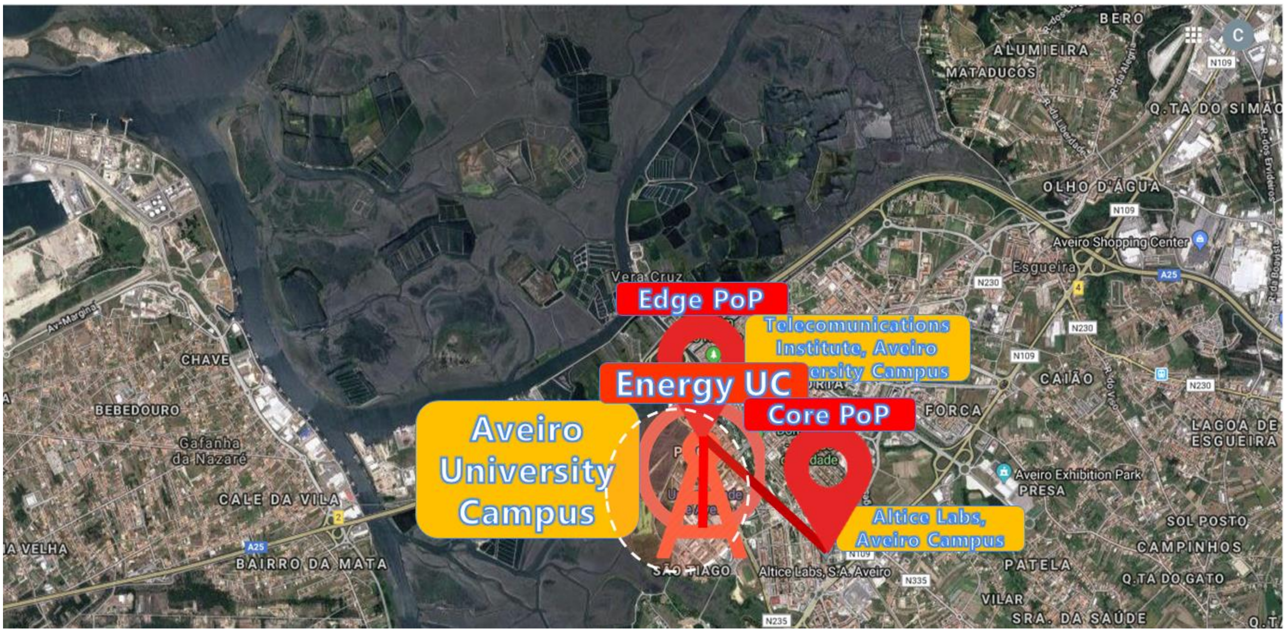

FIGURE 15: EFAFEC-E GEOGRAPHICAL LOCATION.

This pilot will rely on 5Growth's capability of allowing Vertical Users (e.g., Communications Services Customers – CSCs) to request 5G network service provisioning on-demand, tailored to their services requirements. To support this, 5Growth will act as a Communications Service Provider (CSP), offering them a vertical- "friendly" interface, composed by the Verticals Portal of the Vertical Slicer (VS) component. This component, developed by the H2020 Phase II 5G-TRANSFORMER project, will be enhanced with adapters, enabling the CSC's provisioning requests towards the ICT-17 5G-VINNI infrastructure in Aveiro. Additionally, it will explore optional advanced capabilities (currently being explored as innovations in the scope of WP2), allowing inter-domain service provisioning involving multiple network operator scenarios, by having the necessary adapters whenever required. Such adapters will allow the VS to transform CSCs' requirements towards the orchestration entities belonging to each of the operators.

The solution to be deployed for this use case follows the "option 4" scenario, i.e., "NPN hosted and deployed in public network" model as defined by 5G-ACIA (see section 2.1 for reference). In this option, it is the operator that manages the 5G network to be provided to the vertical, including both control plane and data plane, providing a tailored slice according to the customer network requirements. The operator will also provide edge computing capabilities, enabling the deployment of use cases services on the edge in case they require low latencies.

The reason why this vertical prefers this model is twofold: (1) on one side, EFACEC is a relatively small company that is not interested in having a large number of network specialists, capable of managing the network, preferring to focus on his core business and outsourcing the network service, on the other side (2) the coverage required for this use case would be nation-wide to connect energy plants along the country, needing a nation-wide 5G private networks, which is unmanageable for the company.

2.2.3. Technical Solution for EFACEC_S Use Cases in Aveiro Environment

Figure 16 diagram illustrates the preliminary technical solution concept for EFACEC_S use cases.

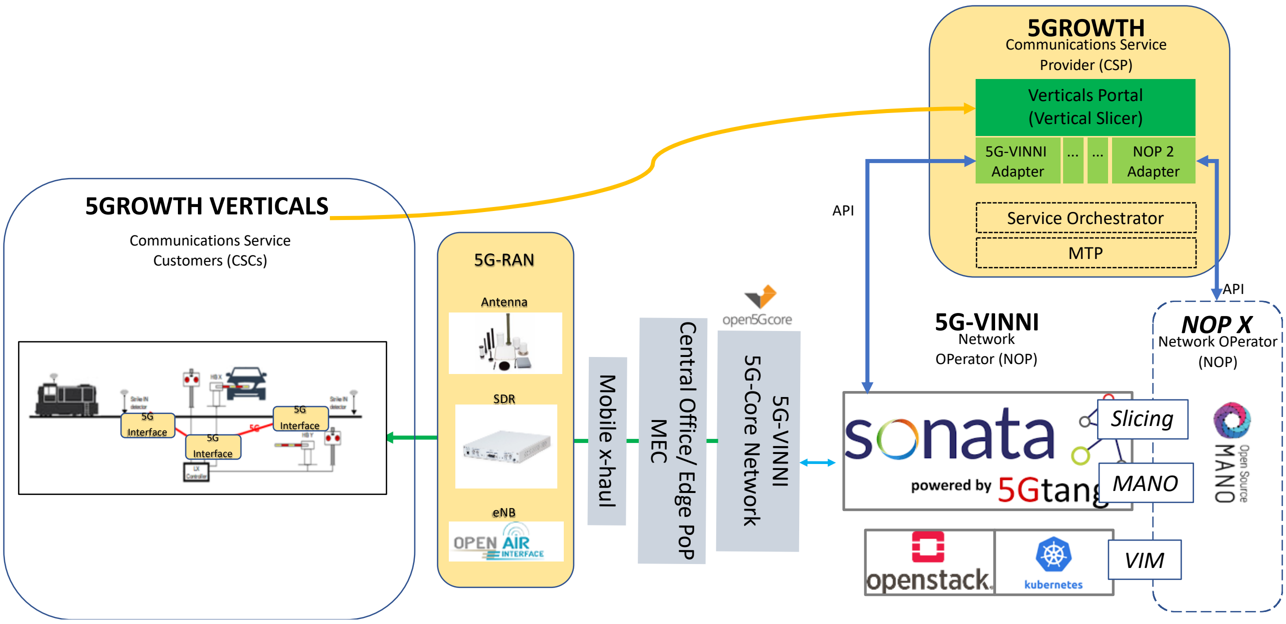

FIGURE 16: TECHNICAL SOLUTION FOR EFACEC_S USE CASES IN AVEIRO ENVIRONMENT (UC1 AND UC2)

The environment replicates the same deployment as presented for EFACEC_E's use case described in the previous section. The railway cross level to be considered is located within the perimeter of the Aveiro Harbor, several kilometers away from the Santiago Campus of the University of Aveiro, where the edge node will be deployed (and the EFACEC_E UC). The coverage is still under study but must be done in the surrounding of this area. This coverage will have the following details.

- The 5G-RAN will consist of an antenna deployed either inside the Aveiro Harbor facilities or using the closest commercial site around the Harbor location, using an USRP N310 SDR from Ettus Research, served by an OpenAirInterface (OAI) based gNB.
- The RAN's cell site reaches the operator's core through a NG-PON2 Mobile x-haul (e.g., Front, Mid and Backhaul), a technology developed in-house by Altice Labs.
- The operator's 5G core consists of an Open5GCore deployment from the Fraunhofer Institute, instantiated on top of a virtualization infrastructure, managed by Openstack and Kubernetes, for virtual machine and container-based deployments, respectively.
- The Management and Orchestration (MANO) of resources, as well as the network slicing operations, are handled by the open source SONATA platform [14], which is the result of the H2020 Phase I and II, SONATA and 5GTANGO projects, respectively.

Figure 17 depicts the geographical location of the Use Case in the Aveiro Harbor. The Level Cross to be considered in around 5Km away from the building (datacenter) where the edge PoP will be deployed.

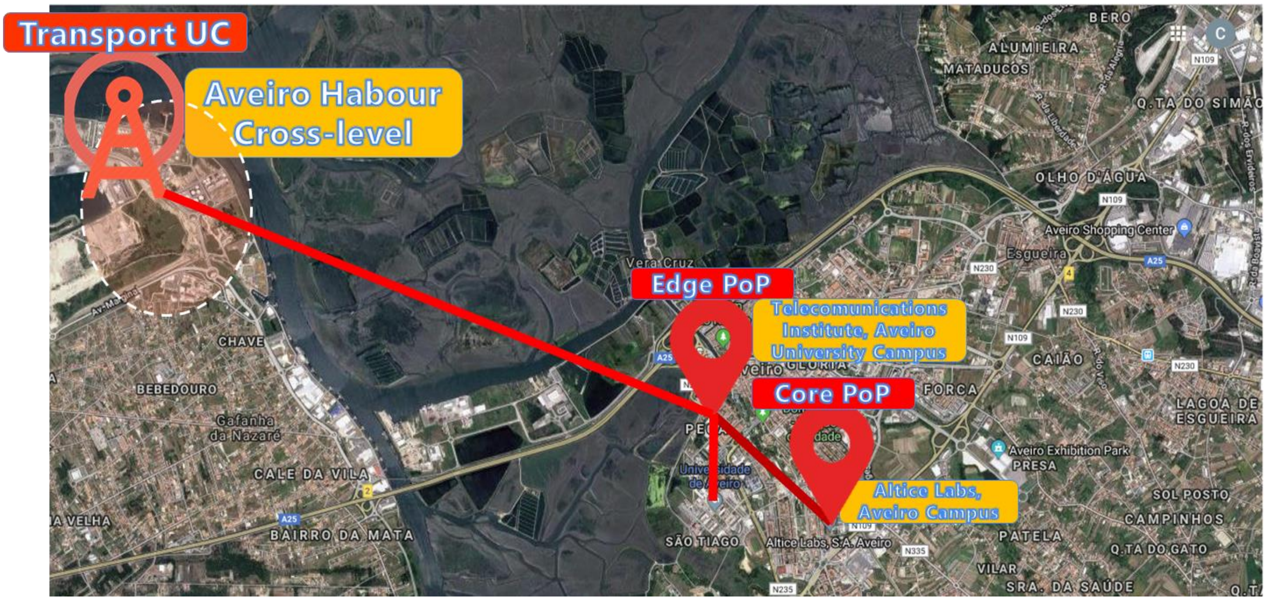

FIGURE 17: EFACEC_S GEOGRAFICAL LOCATION.

This pilot, similarly to the previous one (EFACEC_S), relies on 5Growth's capability of allowing Vertical Users to request 5G network service provisioning on-demand, tailored to their services requirements. As such, 5Growth will act as CSP, offering them a vertical- "friendly" interface, composed by the Verticals Portal of the Vertical Slicer (VS) component.

The solution to be deployed for this use case follows the "NPN deployed in public network" model as defined by 5G-ACIA (see section 2.1 for reference). The reason why this vertical prefers this model is twofold: (1) on one hand, EFACEC is a relatively small company that is not interested in having a large number of network specialists, capable to manage the network, preferring to focus on his core business and outsource the network service, on the other (2) the coverage required for this use case would be nation-wide to connect level cross locations along the country, needing a nation-wide 5G private networks, which is unmanageable for the company.

2.2.4. Technical Solution for INNOVALIA Use Cases in Madrid-Bilbao Environment

This section contains the technical solution for the INNOVALIA Use Cases. We propose two phases for the validation of the use cases.

The first phase is a validation in the 5G EVE Spanish premise, 5TONIC. The main goal of this phase is to validate the technical solution using the 5G EVE framework, focused in the following aspects:

- Feasibility of the technical solution.
- Measurement of the impact of network KPIs in the Use Cases.

The phase I is described in detail in the Figure 18. The proposed solution includes a Network Slice of URLLC/eMBB for providing the connectivity between the UC elements and the cloud application.

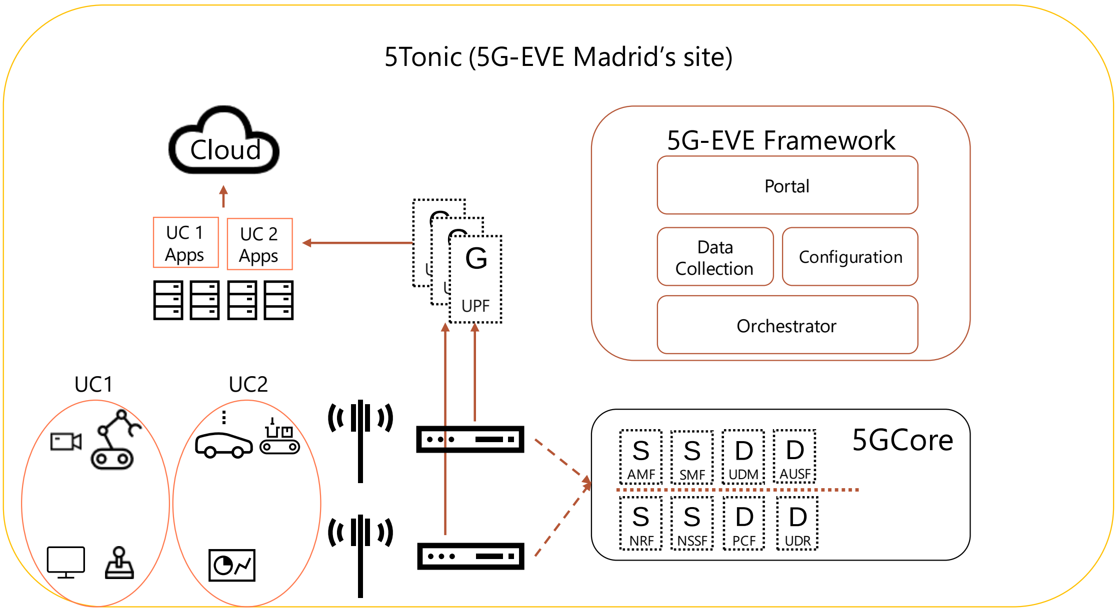

FIGURE 18: INNOVALIA USES CASE DEPLOYMENT IN 5G EVE PREMISES (PHASE I)

Also, it is included the 5G EVE Framework for supporting the deployment and validation of the use case. One of the key aspects to validate is the impact of network KPIs over the Use Cases, specially the reliability and latency KPIs. For that, we propose to define a set of 5G EVE experiments with variations of the latency and reliability parameters and use the 5G EVE data collection framework for verifying the impact. Since it might happen that some of the INNOVALIA equipment cannot be moved to the 5TONIC premise, the deployment in 5TONIC should include emulators of the equipment for the verification.

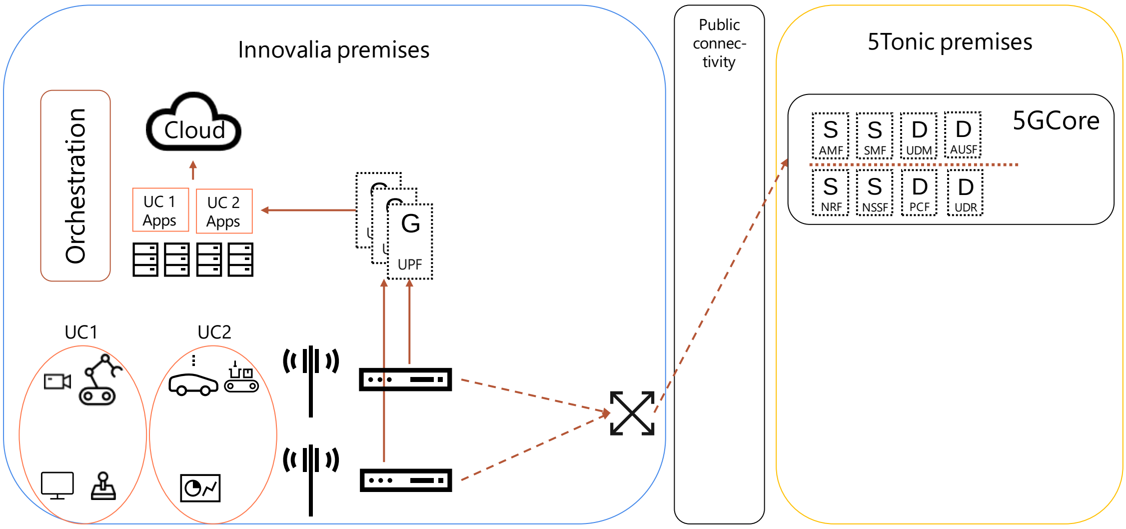

FIGURE 19: INNOVALIA USE CASES DEPLOYMENT AT INNOVALIA PREMISES

Once the basic technical solution is verified, we propose the phase II with the deployment of the use cases in the INNOVALIA premises, as described in Figure 19. The philosophy of this solution is to reuse as much as possible the setup of the phase I, and for that we propose to use the 5G Core from 5TONIC. This approach is aligned with the 5G-ACIA deployments described in section General Technical Solution principles, with a deployment with *shared radio access network and control plane*. Also, it is aligned with the *NPN deployed in public network* scenario, although the User Plane is in INNOVALIA premises, instead of public operator premises, due to practical reasons.

The main goal of this phase is to validate the INNOVALIA use cases using the final equipment in a real environment. Additionally, innovations coming from WP2 can be validated in this phase.

In the INNOVALIA use case, the integration of 5Growth platform with 5G EVE platform follows the approach described in Figure 30: the 5Growth Vertical Slicer interacts with the 5G EVE portal using the REST API provided by 5G EVE and the 5Growth Service Orchestrator is integrated with the 5G EVE IWL using a dedicated driver. The integration is explained in the following figure for both phases:

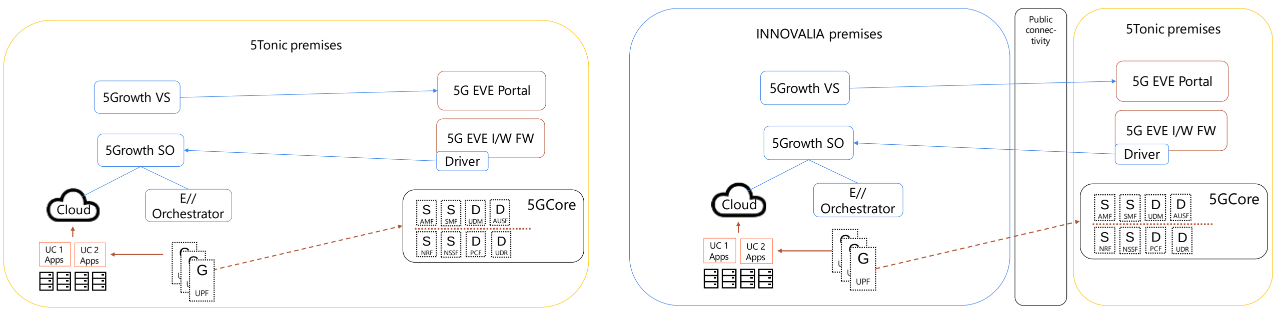

FIGURE 20: 5GROWTH INTEGRATION WITH 5G EVE FOR PHASE 1 (LEFT) AND PHASE 2 (RIGHT)

2.3. Analysis and Conclusions

As can be seen in previous section 2.2, each of proposed technical solutions for supporting the various clusters of use cases under analysis can be classified as one (maybe two) possible scenarios of the introduced 5G-ACIA framework for NPN.

More specifically we can conclude that, facility by facility, these are the implicit selections of scenarios:

- For COMAU Use Cases the scenario selected is that of *Deployment as Isolated Network* (NPN Scenario 1)
- For both EFACEC_S and EFACEC_E Use Cases the scenario selected is that of *NPN hosted and deployed in public network* (NPN Scenario 4)
- For INNOVALIA Use Cases the scenario selected is that of either *Deployment with Shared RAN and Control* Plane (NPN Scenario 3) or even that of *NPN hosted and deployed in Public Network* (NPN Scenario 4).

So, as a first conclusion, 5Growth has the challenge (and the opportunity) to create a platform that can cater for the needs of such a wide range of NPN deployments. And there's, consequently, the possibility for 5Growth participant verticals to not only validate their applications over a one selected scenario but also over a set of them. That should provide them with a deeper insight on the business model alternatives and their impact on exploitation.

Then, the selection of NPN scenarios also has relevant implications not only in the distribution of 5G capabilities but also in the availability of services and tools for 5G validation purposes offered by ICT-17 platforms. If we take the case of 5G EVE, it can be seen (Table 30) that regardless the specific Use Case under analysis it is the NPN selection what really conditions the level of reuse of ICT-19 platforms' capabilities and services.

TABLE 30: DISTRIBUTION OF RESPONSIBILITIES (5G EVE CASE)

Scenario	5G EVE Orchestration	5G EVE KPI framework	5G EVE Runtime Configuration	On-site network elements management
Deployment as isolated network	None	None	None	On-premise orchestrator
Deployment with shared RAN	Only RAN	Only RAN KPIs	Only RAN	On-premise orchestrator (except RAN)
Deployment with shared RAN and control plane	RAN and Control Plane	RAN and Control Plane	RAN/Control Plane	On-premise orchestrator (Data plane except RAN)
NPN deployed in public network	All network elements	Network Slice KPIs	All network elements	On-premise orchestrator (only for vertical App)

A similar analysis on 5G-VINNI platform would lead to the same conclusion. Therefore, a second conclusion is that there's the possibility for 5Growth to define a *limited* set of common architectures for the integration of ICT-17 platforms with vertical premises environments where the considered NPN scenarios are supported and the capabilities and services that can be leveraged from ICT-17 platforms are known and clear (beforehand) and common to 5G EVE and 5G VININI.

3. Assessment of ICT-17 Platforms

This section provides an assessment of the selected ICT-17 platforms, namely 5G EVE and 5G-VINNI, which goal is threefold: (*i*) to identify how they support the requirements of each specific vertical use case considered in the scope of 5Growth project; (*ii*) identify which are the functionalities, features and open APIs offered by the ICT-17 platforms that can be exploited to integrate the 5Growth platform and to validate its innovations; and finally (*iii*) to provide an initial study on ICT-17 integration with 5Growth.

3.1. Overview of ICT-17 platforms

In the following is provided an overview of both 5G EVE and 5G-VINNI, ICT-17 platforms that have been selected for the field trials to demonstrate the 5Growth specific vertical use cases. This high-level analysis will be the entry point for a better understanding of each platform, and it will pave the way for their assessment regarding each of the use cases considered in 5Growth.

Before going into the specific aspects of each ICT-17 platform, it is necessary to remark their common aspects in terms of purpose, vision and approach.

First, both platforms are meant for, and only for, the execution of extensive validation tests of 5G-ready (vertical) applications. With that purpose in mind, the end-user of the platform is a Vertical Experimenter, and, in consequence, a set of processes and tools are created and offered to it.

Then, each of those platforms concentrates several 5G capabilities and testing and validation framework on a limited set of locations in Europe. The assumed interaction model with vertical is that the extensive validation tests are to be carried out on-site at any of their specific locations where they have a footprint. The reason behind is economy-efficiency, based on the guiding principle that it makes more sense to concentrate expensive investments in technology and supporting tools in just a few well-equipped sites, rather than spreading to several least supported locations or even geographical areas.

Finally, both platforms also share the approach of offering generic services like the definition and scheduling of validation tests, KPI monitoring, etc. to verticals of a wide range of sectors, and offer them to as many vertical users as feasible, instead of customizing the platform to specific requirements of specific verticals.

The common aspects of ICT-17 platforms are introduced, tabulated and regularly updated at the 5G PPP IA web page ([1]), over a common time-line. Please see the 5GPPP Trials Roadmap ([2]) for the latest update on the common set of capabilities and features supported by these platforms.

3.1.1. 5G EVE

The 5G EVE concept is based on further developing and interconnecting existing European sites to form a unique 5G end-to-end (E2E) facility (Figure 21). The four interworking sites are in France, Greece, Italy and Spain (Figure 22) and provide both indoor and outdoor facilities. They are complemented by advanced labs, e.g. the Ericsson lab in Kista, Sweden. The French site is composed of a cluster of sites located in Paris, Nice, and Rennes. Each site is operated by a telecoms network operator, i.e. Orange in France, OTE in Greece, TIM in Italy, and Telefonica in Spain. The four sites will be interconnected to provide a seamless single platform experience for experimenters from vertical industries. The 5G EVE end-to-end facility will enable experimentation and validation with full sets of 5G capabilities – initially Release 15 compliant and by the end of the project Release 16 compliant.

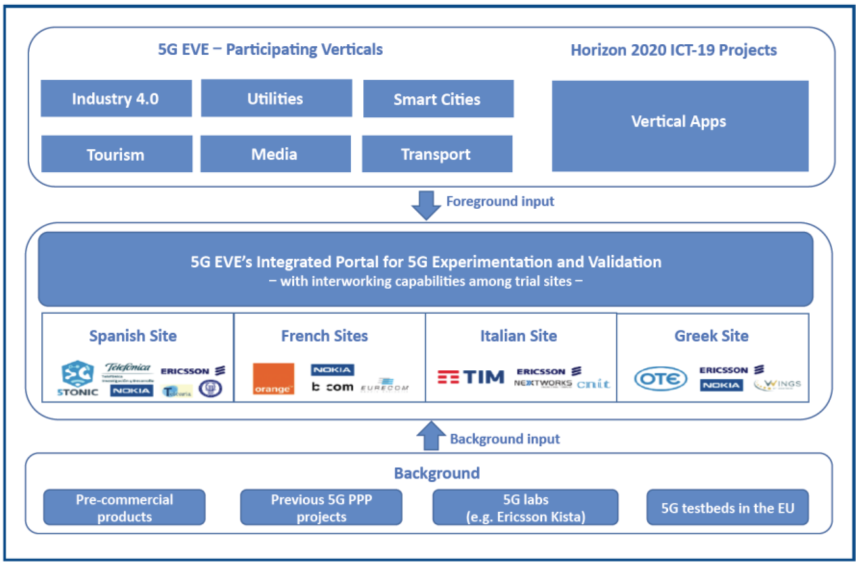

FIGURE 21: 5G EVE END-TO-END FACILITY – FUNCTIONAL ARCHITECTURE

FIGURE 22: 5G EVE FACILITY SITES

Specifically, the technical objectives include:

1. Implementing Release 16 compatible technologies in the four sites, starting from the evolutions of current Release 15. Specific pilots will validate that 5G KPIs can be achieved;

2. Creating intent-based interfaces to simplify access to the 5G end-to-end facility;
3. Designing and implementing site interworking and multi-x slicing and orchestration mechanisms;
4. Implementing a vertical-oriented open framework;
5. Creating advanced 5G testing and measurement mechanisms to validate advanced 5G features and KPIs;
6. Advanced data analytics on the output of monitoring processes for anticipating network operations.

Started in July 2018, 5G EVE project has already established the foundations for meeting its objectives. The focus for its first year of project was on four major lines of actions: (i) Detailed analysis of the first six 5G use cases to be addressed by 5G EVE in 2019; (ii) Planning and initial deployment of the required 4G and 5G capabilities at each 5G EVE site for 2019; (iii) Design of advanced features for supporting E2E validation tests from 2020 onwards; (iv) Dissemination and outreach for attracting more vertical sector players to the 5G EVE innovation ecosystem from 2019 onwards.

5G EVE has already open its E2E facility to the verticals within the project consortium in May 2019 so they can start implementing and validating their 5G-ready applications. To this purpose the project has already analyzed the capabilities of the four 5G EVE site facilities and planned/started the deployment of the 4G and 5G capabilities required for the testing activities to be carried out in 2019. For each site facility, 5G EVE provides a description of its architecture with all technical features at several levels and a roadmap (Figure 23) with the dates of availability for each component of the integrated site facility.

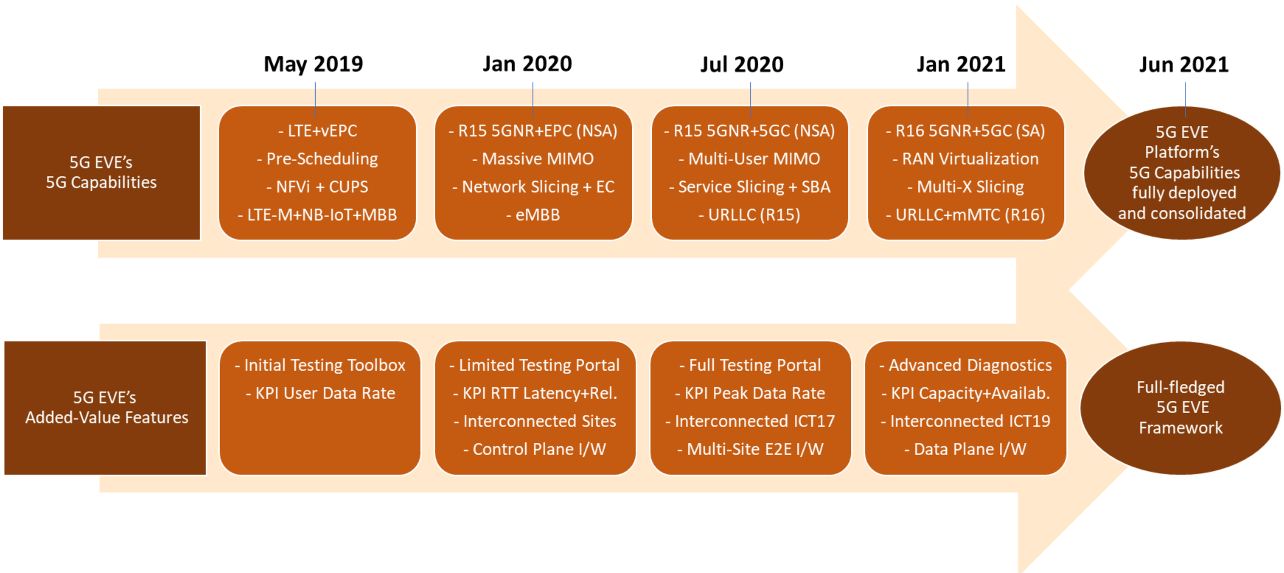

FIGURE 23: 5G EVE TIME PLAN

In the following, we describe with more detail the 5G EVE site facilities in Spain and Italy, due to their relevance for the trials of INNOVALIA and COMAU vertical use cases, respectively.

3.1.1.1. Spain Site

The 5G EVE facility site in Spain is located in Madrid. It is in the premises of IMDEA Networks in Leganés/Madrid and it relies on the 5TONIC Open 5G Lab.

The experimentation activities to be carried out in Spain are mainly related with the implementation of conceptual showcases on Media & Entertainment, Industry 4.0 and Smart Tourism.

Figure 24 depicts a high-level view of the Spain's facility site. This figure shows a general overview of the 5TONIC site facility, highlighting the main technologies to be experimented and the main use cases.

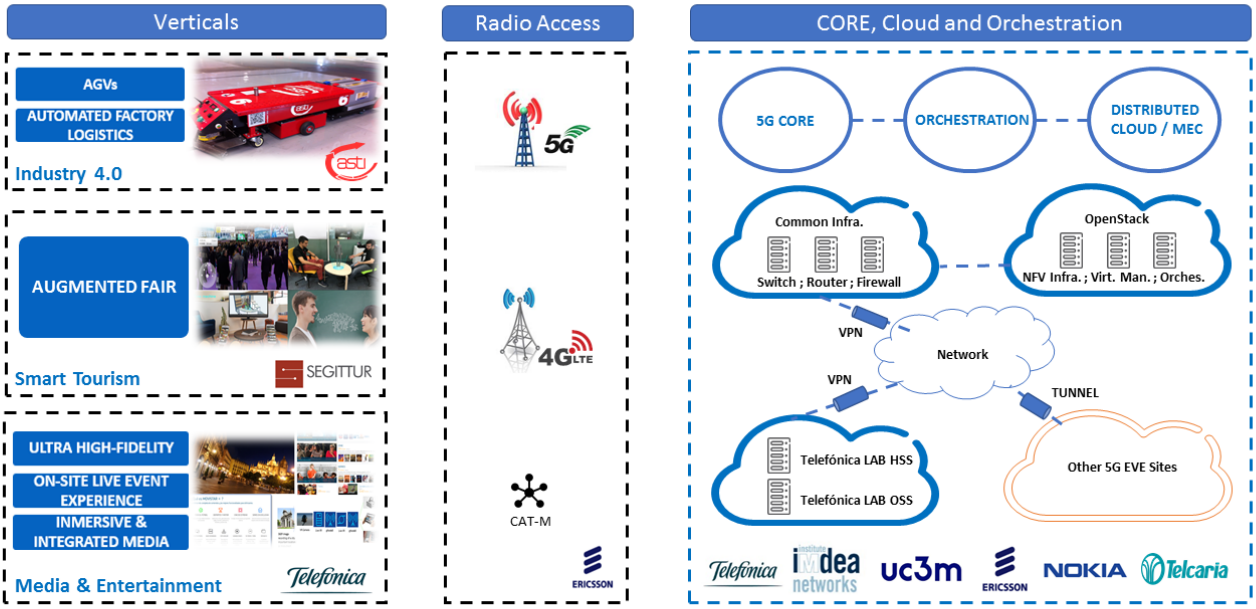

FIGURE 24: 5G EVE SPAIN FACILITY SITE

3.1.1.2. Italy Site

The 5G EVE facility site in Italy is located in Turin, where an initiative called "Torino 5G" has been already started to experimentally evaluate 5G systems and services.

The experimentation activities to be carried out in Italy are mainly related with the implementation of conceptual showcases on Smart Transportation and Smart Cities.

Figure 25 depicts a high-level view of the 5G EVE facility site in Turin. This figure shows the different locations (core and edge), as well as the technologies to be experimented.

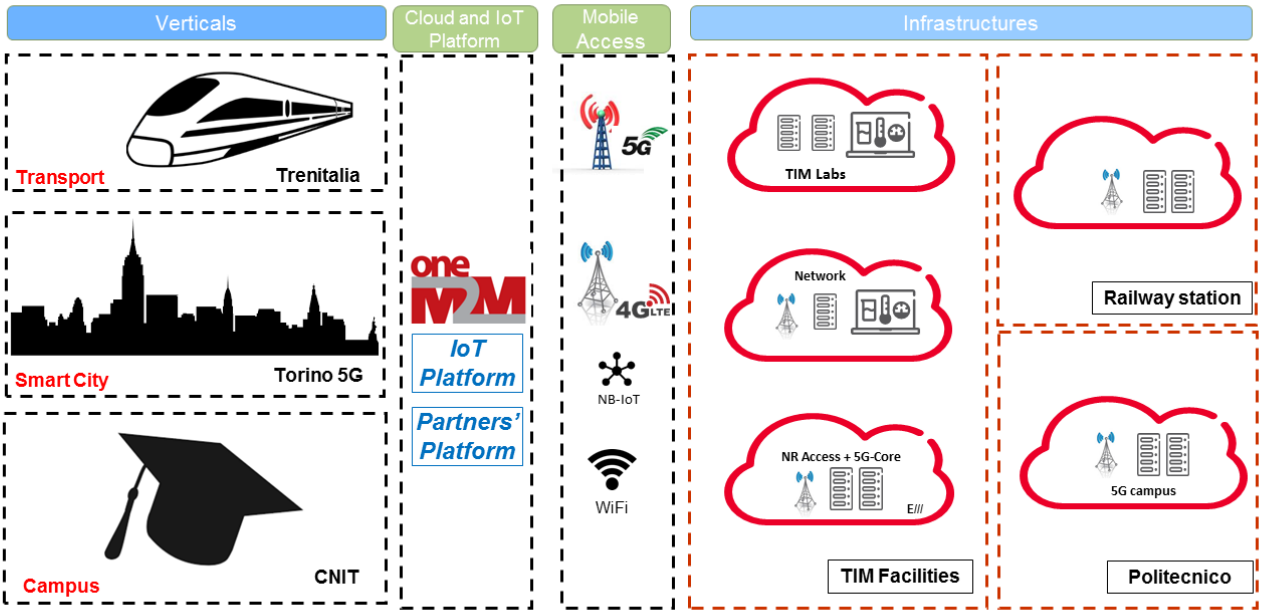

FIGURE 25: 5G EVE ITALY FACILITY SITE

3.1.2. 5G-VINNI

5G-VINNI (5G Verticals INNovation Infrastructure) is an ICT-17 project which intends to accelerate the 5G adoption in Europe, by providing end-to-end (E2E) infrastructure that vertical industries can use to develop and validate their pilots, lowering the entry barriers and fostering 5G utilization.

5G-VINNI is responsible to design and build several 5G facility sites, comprising 5G radio and core components, as well as management and orchestration tools to enable zero-touch management mechanisms. 5G-VINNI intends to validate the 5G KPIs in several testing campaigns and support the execution of trials of verticals, namely use cases coming from ICT-19 projects. 5G-VINNI also intends to develop business and management models during and beyond the project and demonstrate the value of 5G and influence standards and open source organizations.

The 5G-VINNI facility sites are classified into two different types: *main facility sites*, which are facilities that offer 5G services to ICT-18-19-22 projects with well-defined SLAs; and *experimentation facility sites*, which are sites devoted to providing environments for advanced experimentation, namely on software and hardware components, architecture, optimizations, models, specific standard validation etc. The seven 5G-VINNI facility sites are illustrated in the Figure 26, with Norway, UK, Spain and Greece as main facility sites, and Portugal, Germany/Munich and Germany/Berlin as experimentation facility sites. In addition, there is a mobile experimentation facility site in the form of a rapid response vehicle for public protection and disaster relief (PPDR).

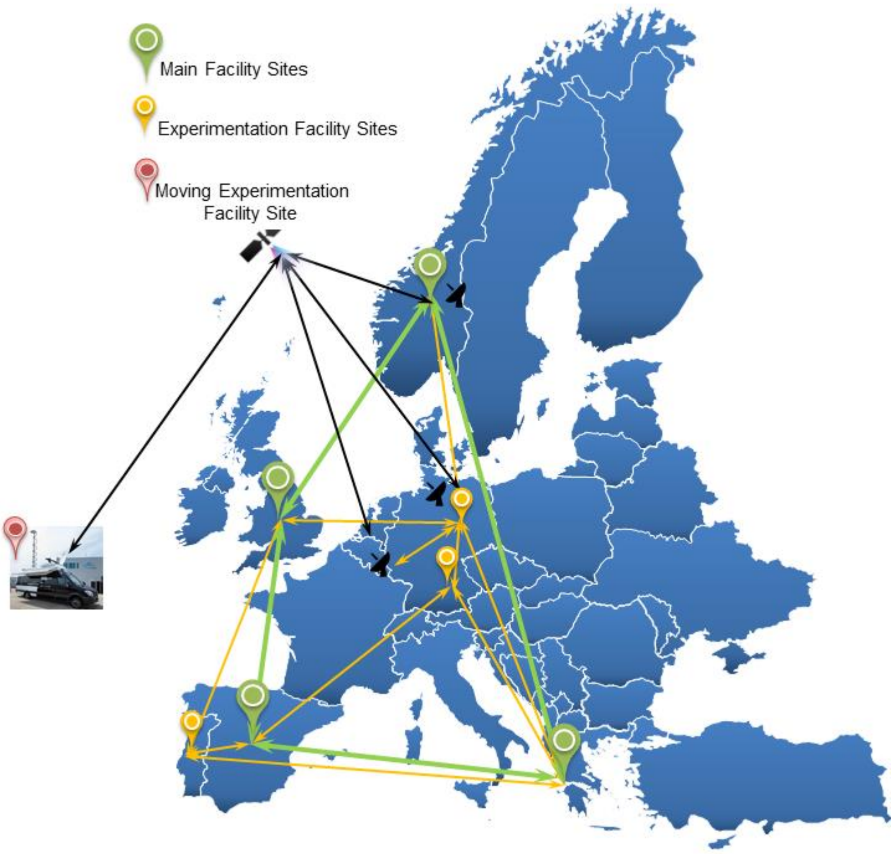

FIGURE 26: 5G-VINNI FACILITY SITES.

Figure 27 shows the 5G-VINNI project time plan together with other relevant activities, such as 5G-PPP, 3GPP Releases and other ICT projects.

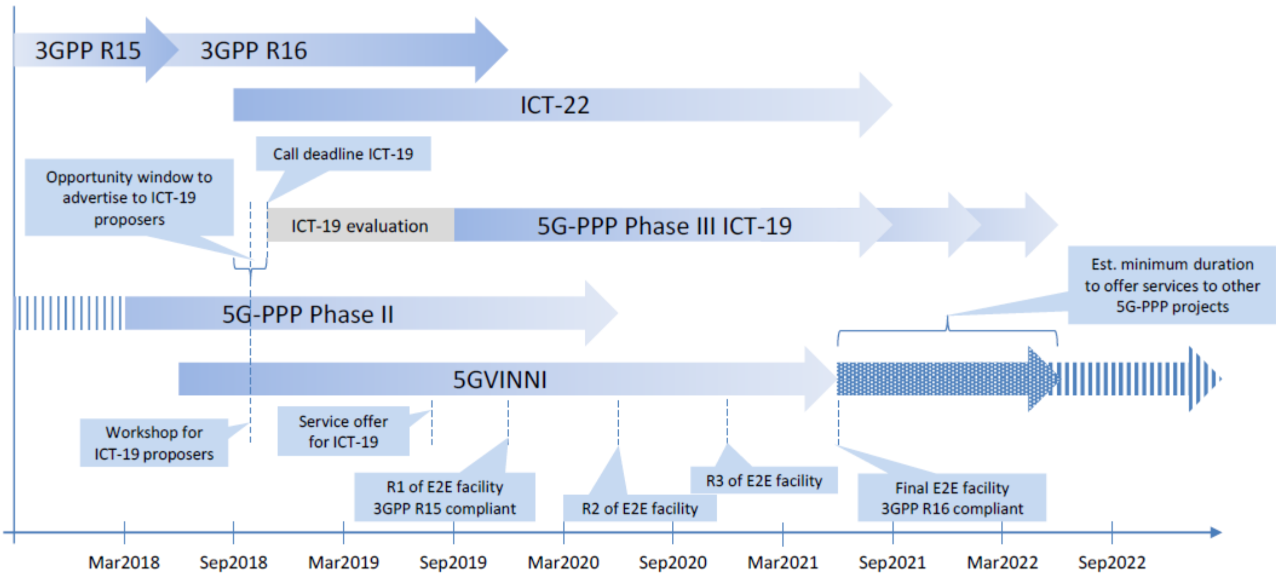

FIGURE 27: 5G-VINNI TIME PLAN

In the following, we describe with more detail the Aveiro Experimental Site of 5G-VINNI, due to its relevance to the 5Growth trials of both EFACEC_S and EFACEC_E vertical use cases.

3.1.2.1. Aveiro Experimental Site

The 5G-VINNI experimental facility site in Portugal is located in Aveiro. It is based on an extensive computational and networking infrastructure available in two different city locations, Altice Labs (ALB) and Instituto de Telecomunicações (IT). The facility is integrated in the "Aveiro 5G City" initiative, including multiple 5G-related activities and projects, both national and international, in which Altice Labs is playing the leading role.

The experimentation activities to be carried out in Portugal (leaded by Altice Labs) are: (1) NG-PON2-based 5G front-hauling & backhauling, focusing in throughput capacity, fixed/mobile convergence and cost reduction; (2) OSS layer, focusing on network slice lifecycle management, autonomic and self-organizing networks, service reliability and agility; (3) Edge Computing, with focus on low latency and bandwidth efficiency.

The Figure 28 depicts a high-level view of the Aveiro's experimental facility site. This figure shows the different locations (core and edge), as well as the technologies to be experimented.

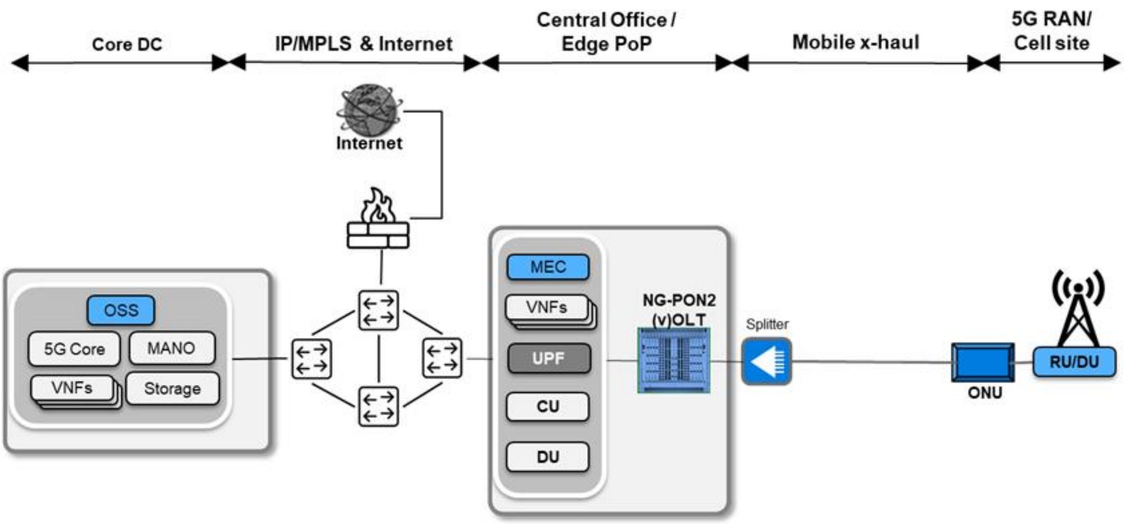

FIGURE 28: 5G-VINNI PORTUGAL EXPERIMENTAL FACILITY SITE

3.2. Support for 5Growth Vertical Requirements

This section provides an analysis on how 5G EVE and 5G-VINNI platforms support the requirements (both service and technical requirements) of each specific vertical use case considered in the scope of 5Growth project, aiming to identify the existing gap within the ICT-17 platforms.

The time-line considered for the analysis establishes as first check-point (*as-is)* the date of 1 July 2020, since that is the common date of first general availability of ICT-17 platform services to ICT-19 associated projects (as well as to other external verticals to the ICT-17's original verticals ecosystem). That said, after 1 July 2020, both platforms are not frozen. On the contrary they keep evolving their 5G Capabilities and Framework services towards their end delivery on 30 June 2021, according to their respective project plans, and over the harmonized and anticipated roadmap published and updated by the 5GPPP IA at [1].

The analysis of each use case will be done regarding the selected ICT-17 platform to support the test campaign as identified in Section 1, as also summarized in Table 31.

TABLE 31: SELECTED ICT-17 PLATFORM TO SUPPORT THE TEST CAMPAIGN

Pilot	Use case	5G EVE	5G-VINNI
COMAU	Digital Twin Apps	X	
	Telemetry/Monitoring Apps	X	
	Digital Tutorial and Remote Support	X	
EFACEC_E	Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV distribution substation		X
	Advanced critical signal and data exchange across wide smart metering and measurement infrastructures		X
EFACEC_S	Safety Critical Communications		X
	Non-Safety Critical Communications		X
INNOVALIA	Connected Worker Remote Operation of Quality Equipment	X	
	Connected Worker Augmented ZDM Decision Support System (DSS)	X	

3.2.1. COMAU use cases

The COMAU pilot is composed by three main use cases: (i) Digital Twin Apps; (ii) Telemetry/Monitoring Apps; and (iii) Digital Tutorial and Remote Support.

The three proposed use cases will interact / integrate with 5G EVE platform.

3.2.1.1. Digital Twin Apps

Table 32 presents the vertical requirements assessment for the digital twin apps use case.

TABLE 32: COMAU - DIGITAL TWIN APPS USE CASE REQUIREMENT ASSESSMENT

Use Case 1: Digital Twin Apps			5G EVE
Service Requirements	Bandwidth	250 Mbits/s	Not completely: DL: 100Mbps UL: 50Mbps
	Latency	15ms	Supported
	Reliability	99.999%	Under discussion
	Mobility	3-50 Km/h	As of 2020 Jul, up to pedestrian mobility will be supported (10 km/h) Planned for the Rel-16 in Jan 2021)
	Availability	99.999%	NA
	Broadband Connectivity	needed	Planned for the Rel-16 in Jan 2021
	Network Slicing	needed	Supported
	Capacity (Mbps/m^2 or Km^2)	50	To be verified (10 Mb/s/m2 planned for Rel. 16 in Jan.2021)
	Device Density	5000	To be verified

3.2.1.2. Telemetry/Monitoring Apps

Table 33 presents the vertical requirements assessment for the telemetry/monitoring apps use case.

TABLE 33: COMAU - TELEMETRY/MONITORING APPS USE CASE REQUIREMENT ASSESSMENT

Use Case 2: Telemetry/Monitoring Apps			5G EVE
Service Requirements	Bandwidth	250 Mbits/s	Not completely: DL: 100Mbps UL: 50Mbps
	Latency	15 - 100ms	Supported
	Reliability	99.999%	Under discussion
	Mobility	3-50 Km/h	As of 2020 Jul, up to pedestrian mobility will be supported (10 km/h) Planned for the Rel-16 in Jan 2021

	Availability	99.999%	NA
	Broadband Connectivity	needed	Planned for the Rel-16 in Jan 2021
	Network Slicing	needed	Supported
	Capacity (Mbps/m^2 or Km^2)	50	To be verified (10 Mb/s/m2 planned for Rel. 16 in Jan.2021)
	Device Density	5000	To be verified

3.2.1.3. Digital Tutorial and Remote Support

Table 34 presents the vertical requirements assessment for the digital tutorial and remote support use case.

TABLE 34: COMAU - DIGITAL TUTORIAL AND REMOTE SUPPORT USE CASE REQUIREMENT ASSESSMENT

Use Case 3: Digital Tutorial and Remote Support			5G EVE
Service Requirements	Bandwidth	500 Mbits/s	Not completely: DL: 100Mbps UL: 50Mbps
	Latency	50ms	Supported
	Reliability	99.999%	Under discussion
	Mobility	3 Km/h	Supported
	Availability	99.999%	NA
	Broadband Connectivity	needed	Planned for the Rel-16 in Jan 2021
	Network Slicing	needed	Supported
	Capacity (Mbps/m^2 or Km^2)	50	To be verified (10 Mb/s/m2 planned for Rel. 16 in Jan.2021)
	Device Density	5000	To be verified

3.2.2. EFACEC_E use cases

The EFACEC_E pilot is composed by two main use cases: (i) advanced Monitoring and Maintenance Support for Secondary Substation MV/LV distribution substation; and (ii) advanced critical signal and data exchange across wide smart metering and measurement infrastructures.

Both use cases will interact / integrate with 5G-VINNI platform.

3.2.2.1. Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV distribution substation

Table 35 presents the vertical requirements assessment for the advanced monitoring and maintenance support for secondary substation MV/LV distribution substation use case.

TABLE 35: EFACEC_E - ADVANCED MONITORING AND MAINTENANCE SUPPORT FOR SECONDARY SUBSTATION MV/LV DISTRIBUTION SUBSTATION USE CASE REQUIREMENT ASSESSMENT

Use Case 1: Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV distribution substation			5G-VINNI[1]
Service Requirements	Latency RTT	<5 msec	Supported
	Data Rate	100 Kbps	Supported
	Reliability	99,99%	Supported
	Availability	99,99%	To be verified
	Mobility	120 Km/h	Supported
	Broadband Connectivity	Needed	To be verified
	Network Slicing	Needed	Supported
	Security	Needed	To be verified
	Capacity	10 Mbps/m2	Supported
	Device Density	Low	Supported
Technical requirements	5G coverage in Santiago Campus of the University of Aveiro		To be added in the future

3.2.2.2. Advanced critical signal and data exchange across wide smart metering and measurement infrastructures

Table 36 presents the vertical requirements assessment for the advanced critical signal and data exchange across wide smart metering and measurement infrastructures use case.

TABLE 36: EFACEC_E - ADVANCED CRITICAL SIGNAL AND DATA EXCHANGE ACROSS WIDE SMART METERING AND MEASUREMENT INFRASTRUCTURES USE CASE REQUIREMENT ASSESSMENT

Use Case 1: Advanced Monitoring and Maintenance Support for Secondary Substation MV/LV distribution substation			5G-VINNI[2]
Service Requirements	Latency RTT	<5 msec	Supported
	Data Rate	1 Kbps	Supported
	Reliability	99,99%	Supported
	Availability	99,99%	To be verified
	Mobility	No needed	N/A
	Broadband Connectivity	No needed	N/A

[1] This assessment concerns the main facility sites, since the information for the experimental facility sites (namely, the one in Aveiro) is not yet available

[2] This assessment concerns the main facility sites, since the information for the experimental facility sites (namely, the one in Aveiro) is not yet available

	Network Slicing	Needed	Supported
	Security	Needed	To be verified
	Capacity	Low	Supported
	Device Density	Low	Supported
Technical requirements	5G coverage in Santiago Campus of the University of Aveiro		To be added in the future

3.2.3. EFACEC_S use cases

The EFACEC_S pilot is composed by two main use cases: (i) Safety Critical Communications; and (ii) Non-Safety Critical Communications.

Both use cases will interact / integrate with 5G-VINNI platform.

3.2.3.1. Safety Critical Communications

Table 37 presents the vertical requirements assessment for the safety critical communications use case.

TABLE 37: EFACEC_S - SAFETY CRITICAL COMMUNICATIONS USE CASE REQUIREMENT ASSESSMENT

Use Case 1: Safety Critical Communications			5G-VINNI[3]
Service Requirements	Latency RTT	<10 msec	Supported
	Data Rate	1.2 Kbps	Supported
	Reliability	99,99%	Supported
	Availability	99,99%	To be verified
	Mobility	No needed	N/A
	Broadband Connectivity	No needed	N/A
	Network Slicing	Needed	Supported
	Security	Needed	To be verified
	Capacity	1	Supported
	Device Density	Low	Supported
Technical requirements	5G coverage in Santiago Campus of the University of Aveiro		To be added in the future
	5G coverage in Aveiro Harbor		To be added in the future

[3] This assessment concerns the main facility sites, since the information for the experimental facility sites (namely, the one in Aveiro) is not yet available

3.2.3.2. Non-Safety Critical Communications

Table 38 presents the vertical requirements assessment for the non-safety critical communications use case.

TABLE 38: EFACEC_S NON-SAFETY CRITICAL COMMUNICATIONS USE CASE REQUIREMENT ASSESSMENT

Use Case 2: Non-Safety Critical Communications			5G-VINNI[4]
Service Requirements	Latency RTT	5-100 msec	Supported
	Data Rate	12 Mbps	Supported
	Reliability	99,99%	Supported
	Availability	99,99%	To be verified
	Mobility	160 Km/h	Supported
	Broadband Connectivity	Needed	To be verified
	Network Slicing	Needed	Supported
	Security	Needed	To be verified
	Capacity	60 Mbps/m2	To be verified
	Device Density	Low	Supported
Technical requirements	5G coverage in Santiago Campus of the University of Aveiro		To be added in the future
	5G coverage in Aveiro Harbor		To be added in the future
	Link deployment between University of Aveiro and Aveiro Harbor sites		To be added in the future

3.2.4. INNOVALIA use cases

The INNOVALIA pilot is composed by two main use cases: (i) Connected Worker Remote Operation of Quality Equipment and (ii) Connected Worker Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS).

The two proposed use cases will interact / integrate with 5G EVE platform.

3.2.4.1. Connected Worker Remote Operation of Quality Equipment

Table 39 presents the vertical requirements assessment for the Connected Worker Remote Operation of Quality Equipment use case.

[4] This assessment concerns the main facility sites, since the information for the experimental facility sites (namely, the one in Aveiro) is not yet available

TABLE 39: INNOVALIA - CONNECTED WORKER REMOTE OPERATION OF QUALITY EQUIPMENT

Use Case 1: Connected Worker Remote Operation of Quality Equipment			5G EVE
Service Requirements	Bandwidth	10Mbps	Supported
	Latency	5ms	Supported
	Reliability	99.99%	Under discussion
	Mobility	3 km/h	Supported
	Availability	99.99%	NA
	Broadband Connectivity	needed	Planned for the Rel-16 in Jan 2021
	Network Slicing	needed	Supported
	Capacity (Mbps/km^2)	20	To be verified (10 Mb/s/m2 planned for Rel. 16 in Jan.2021)
	Device Density (Dev/km^2)	1000	To be verified

3.2.4.2. Connected Worker Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS)

Table 40 presents the vertical requirements assessment for the Connected Worker Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS) use case.

TABLE 40: INNOVALIA - CONNECTED WORKER AUGMENTED ZERO DEFECT MANUFACTURING (ZDM) DECISION SUPPORT SYSTEM (DSS)

Use Case 2: Connected Worker Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS)			5G EVE
Service Requirements	Bandwidth	1Gbps	Not completely: DL: 100Mbps UL: 50Mbps
	Latency	5ms	Supported
	Reliability	99.99%	Under discussion
	Mobility	3-50 km/h	As of 2020 Jul, up to pedestrian mobility will be supported (10 km/h) Planned for the Rel-16 in Jan 2021
	Availability	99.99%	NA
	Broadband Connectivity	needed	Planned for the Rel-16 in Jan 2021
	Network Slicing	needed	Supported
	Capacity (Mbps/km^2)	200	To be verified (10 Mb/s/m2 planned

			for Rel. 16 in Jan.2021)
	Device Density	low	Supported

3.3. Support for 5Growth innovations integration

5Growth WP2 activities seek for defining the set of innovations to foster efficiently and effectively the deployment and management of network slices ensuring their specific SLAs over the 5Growth architecture. Thereby, the purpose of this section is to identify and analyses how the candidate options enabling the integration of 5Growth architecture (VS, SO and RL) and ICT-platforms (i.e., 5G EVE and 5G-VINNI) lead to adopt such planned WP2 innovations. To this end, reference scenarios and options dealing with the integration of both 5Growth architecture and ICT-17 platforms are considered for the targeted analysis.

From the overall set of innovations being discussed in WP2, a subset has been selected to be firstly (i.e., chronologically) addressed in the so-called release 1 (R1). For the sake of completeness, a brief description of each of these innovations is provided:

I. *RAN segment in network slices*: when creating demanding/requesting a network slice entailing radio network technologies, this innovation deals with the capability of defining specific features such as coverage, bandwidth, delay, etc.

II. *Vertical Service Monitoring*: this innovation focuses on providing a monitoring system entailing the metrics that allow checking that vertical services SLAs are being satisfied. It is worth to note that this monitoring system is complementary to the regular one devoted on monitoring specific infrastructure functions and/or components, since it enables the collection and elaboration of application and service level metrics.

III. *Control-loops stability:* the focus of this innovation is to adopt “closed loops” throughout the different 5Growth building blocks (VS, SO and RL) entailing the processing of monitored information (related to each of the architectural 5Growth layers), and come up with transversal orchestration decisions to attain better optimization of resources, effective fault-tolerance mechanisms, etc. ensuring the automatically SLA lifecycle management.

IV. *Smart orchestration and resource control algorithms:* for supporting required network slice lifecycle management to continuously ensure SLAs, advanced orchestration mechanisms achieving tailored and adaptive resource decisions are needed. To this end and leveraging the collected monitored information, this innovation focuses on exploring effective AI/ML strategies aiming at achieving such advanced orchestration and resource control mechanisms.

3.3.1. RAN segment in network slices

The first innovation (RAN segment in network slices) is related to the actual service ordering / deployment. To deal with that it is needed that both 5Growth architecture (i.e., particularly VS) and ICT-17 frontend elements (i.e., portals at both 5G EVE and 5G-VINNI) enhance their blueprint service description to process and ensure the specific RAN segment-related requirements in term of coverage, delay, bandwidth, etc. Alternatively, the 5Growth VS becomes the single frontend with the vertical and an API (for programmability purposes) between the 5Growth VS and the respective ICT-17 Portals is used to end up with the targeted RAN segment features of network slice.

3.3.2. Vertical Service Monitoring

Both ICT-17 platforms (5G EVE and 5Growth) support mechanisms via their Portal GUIs to retrieve experimental results and present them to the Vertical (or experimenter) requesting the service. The monitored information should be specified in the corresponding blueprints and the gathering of the information is done during the so-called service operation. Depending on how 5Growth VS and ICT-17 Portals are interworked (either independently via a common Vertical reference point or using a well-defined API), the collection of the monitored information and its processing functionality could be done separately (i.e., part at the 5Growth VS and Monitoring Platform and part at the ICT-17 platform) focusing exclusively on their own network slice partition. Alternatively, if 5Growth VS (or Monitoring Platform) interacts with the ICT-17 platform monitoring tools for retrieving the collected metrics, the monitoring, processing and potential decisions related to the entire end-to-end Vertical service can be done at the 5Growth VS.

3.3.3. Control-loops stability

As said above, for the control-loop stability innovation the aim is that the different layers in the 5Growth system (i.e., VS, SO and RL) are cooperating to achieve automated SLA lifecycle management. When deploying network slices encompassing different domains governed by the 5Growth architecture and ICT-17 platforms, a potential solution (being at the time of writing under discussion) for that innovation seeks for defining orchestration-oriented APIs (i.e., at the SO/NFVO level) between both 5Growth and ICT-17 domains. This would allow achieving such closed-loops stability for ensuring SLAs, reflected on appealing functionalities for the automated and adaptive resource orchestration (e.g., auto-scaling, self-healing, traffic management). This would require carefully definition of the functionalities to be supported at each building blocks of both 5Growth and ICT-17 platforms, the workflow enabling the communication of both as well as the API contents determining the sort of operations and information to be exchanged.

At the time of writing, since the target ICT-17 platforms do not currently provide open APIs to interact with their internal orchestrators, 5Growth is also investigating alternative approaches. In particular, the possibility to adopt partial solutions is under analysis, where the control-loops stability feature offered by 5Growth platform is applied and evaluated in the local pilot sites, operating over the subset of resources entirely under the control of the 5Growth RL.

3.3.4. Smart orchestration and resource control algorithms

Finally, the innovation addressing smart orchestration and resource control algorithms is related to the discussion made above for the closed-loop stability. The objective of the innovation is to exploit as much as possible the advantages of AI/ML mechanisms. This requires extensive data sets (e.g., monitored information) for the training and tuning of the AI/ML algorithms. Therefore, collecting information from both 5Growth and ICT-17 platforms domains within a unique dataset may lead to attain better decisions for ensuring SLA lifecycle management. One option to achieve this common data set could be to rely on APIs enabling the communication between the orchestrators at the 5Growth system and at the ICT-17 platforms. However, the considerations done in the previous section about the internal nature of ICT-17 orchestrators are applicable also in this context.

Alternatively, these AI/ML mechanisms could be handled at the VS but issues with the resource details constituting the data sets could arise.

3.4. Initial study on ICT-17 integration with 5Growth

This section provides a preliminary study and analysis of possible options for the integration of 5Growth with the two ICT-17 platforms (5G EVE and 5G-VINNI). It is to be considered as a first input for further refinement and development in upcoming 5Growth Tasks such as, mainly, Task T3.2.

3.4.1. Pilot Deployment Scenarios

Based on the planned deployment of the vertical pilot use cases, as described in Section 2, the common scenarios considered -in this preliminary analysis- for 5Growth will consist of (1) a Non-Public Network (NPN), and (2) public network(s) which are usually owned by one or multiple network operators who is responsible for providing E2E service and infrastructures for the verticals. As shown in Figure 29, the verticals (as the role of clients), request the public network operators (as the role of the service and infrastructure providers) to partly or entirely operate their NPN at their premises, and also to deploy the vertical service End-to-End (E2E) by building a customized network slices tailored for the vertical service requirements. In the context of the project, the E2E infrastructure may partly or entirely use the ICT-17 platform infrastructures, from 5G EVE and 5G-VINNI. In this sense, the operators also need to take care of the connections to the vertical sites and how to connect them to their networks as well as to the ICT-17 platforms.

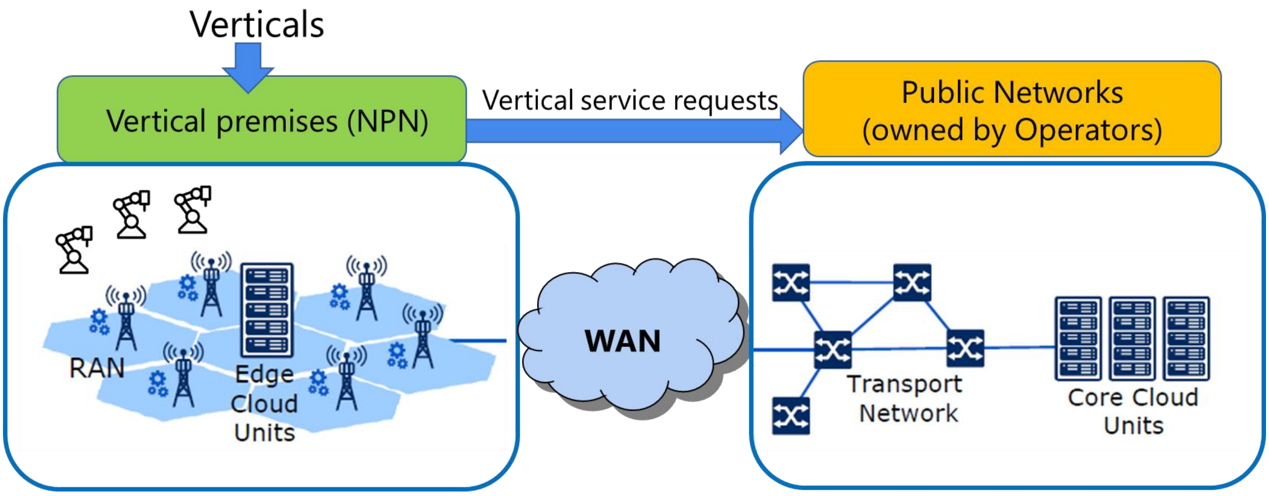

FIGURE 29: PILOT DEPLOYMENT SCENARIOS

3.4.2. Preliminary architectural considerations about interworking with ICT-17 platforms

In the scope of integration with the ICT-17 platforms, we shall consider, for the time being, the following architectural decisions regarding the roles of 5Growth system and ICT-17 platforms.

- 5Growth system is the entry point for the industrial verticals to request the deployment of their services.

- At the resource level, everything (e.g. infrastructure of RAN, or edge resources) that will be deployed at the vertical premises, as well as the WAN connections to the ICT-17, will be managed by the 5Growth Resource Layer, whereas the resources at the ICT-17 sites will be managed through their own systems.
- At the orchestration and service management level, the interworking solution will be specifically designed on a per-pilot basis, according to the interworking model offered by the target ICT-17 platforms.
- 5Growth system is also responsible for specifying the external interfaces to interact with other domains/platforms (e.g. ICT-17 platform), which can be tailored to the Portal/APIs exposed by other domains or platforms.

At the high-level conceptual level, the 5Growth system relies on the capability of the ICT-17 platforms to deliver customizable network slices built over 5G infrastructures. However, it is important to note that the two ICT-17 platforms adopt different approaches for the network slice management. For example, they provide different information models and levels of granularity for the specification of the required capabilities, and they offer different mechanisms to manage, control and monitor the slices. In particular, it should be noted that not all the ICT-17 platforms provide explicit APIs for creating and managing network slices. For example, 5G EVE follows an experiment-as-a-service approach, more oriented to the delivery of virtual infrastructures for the execution of experiments associated to vertical services, which are implicitly and only internally translated into network slices. For this reason, in 5Growth we are investigating alternative solutions where the 5Growth system, depending on the interfaces and the interworking model offered by the target ICT-17 platform, adopts different models to specify the required network slices, e.g. in the form of vertical-oriented experiment blueprints, vertical service blueprints, network slice templates, etc.

We consider the following two potential scenarios:

- Scenario 1: 5Growth system requests to the ICT-17 platform a network slice covering all network domains (E2E slice) including RAN+TN+CN.
    - 5Growth is responsible for attaching vApps to the provided E2E slice by making use of the defined SAPs and provide the MEC or edge computing system in case some of vApps need to be deployed at the edge at the vertical sites.
- Scenario 2: 5Growth system requests to the ICT-17 platform a network slice covering only a subset of network domains.
    - 5Growth is responsible for implementing the network segments that are out of the ICT-17 network slice as well as the network connections to the ICT-17 platform.
    - For example, if 5Growth system requests the ICT-17 facility a slice consisting of TN (backhaul) + CN, then 5Growth shall bring, install and maintain all the

RAN part (including any front-/mid-haul links that could exist in case functional split in the radio protocol stack is applied).

The specific approaches offered by 5G EVE and 5G-VINNI to enable the interworking with a generic ICT-19 platform is represented in Figure 30 and Figure 31 respectively.

In particular, 5G EVE offers a centralized Portal to enable the request of vertical-driven experiments over 5G infrastructures. These experiments can be designed, customized, dynamically instantiated, executed, monitored and assessed by vertical experimenters through the web-based GUI of the 5G EVE Portal. Moreover, a subset of these actions, related to the on-demand instantiation, control of the execution workflow and collection of metrics or experiment results, are also exposed through the REST APIs of the Portal. This approach allows any ICT-19 platform, acting as clients, to interact in a programmable manner with the 5G EVE platform for requesting and managing experiments. Internally, the 5G EVE system translates the experiment specification into a set of end-to-end network slices and NFV network services which are deployed through the internal Interworking Layer (IWL) across multiple site facilities, each of them with their own orchestration and resource management solutions (e.g. OSM, ONAP, proprietary NFVO solutions, etc.). In the 5G EVE model, the Interworking framework can be extended with additional plugins that enable the interaction with external site facilities, e.g. the ICT-19 ones. Following this approach, the end-to-end orchestration is handled at the 5G EVE platform, while the intra-site orchestration and resource allocation logic is delegated to the external facility. This option offers the possibility to integrate the 5Growth remote sites at the vertical premises as "5G EVE interworked sites", exploiting their orchestration capabilities as part of the overall, end-to-end orchestration strategy implemented by the 5G EVE platform.

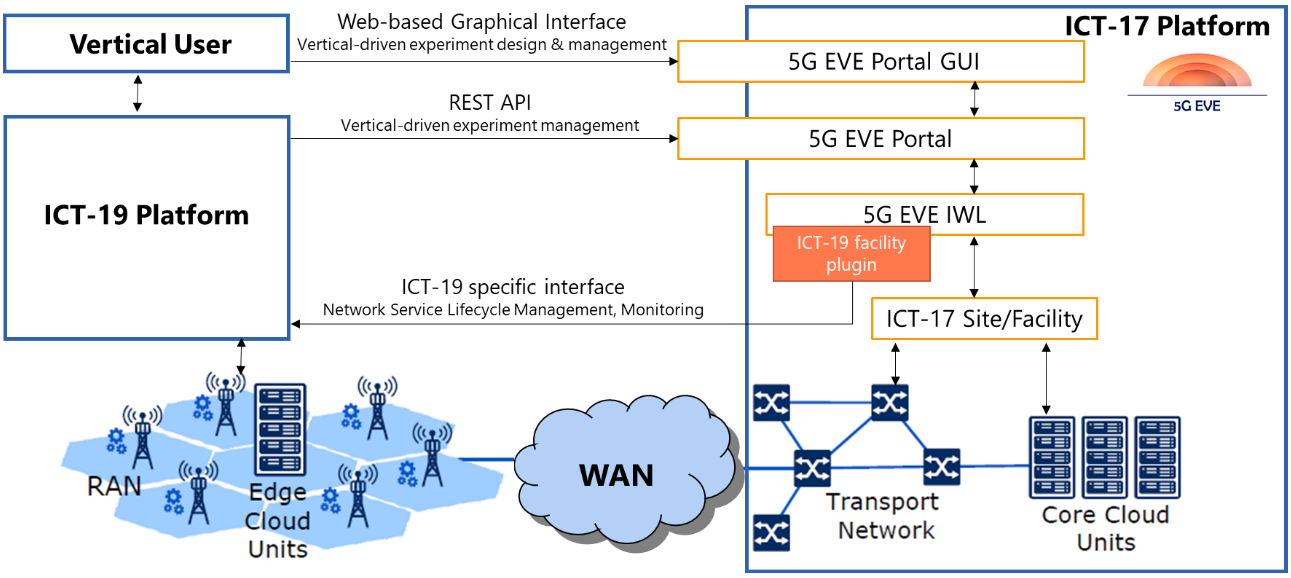

FIGURE 30: 5G EVE INTERWORKING MODEL

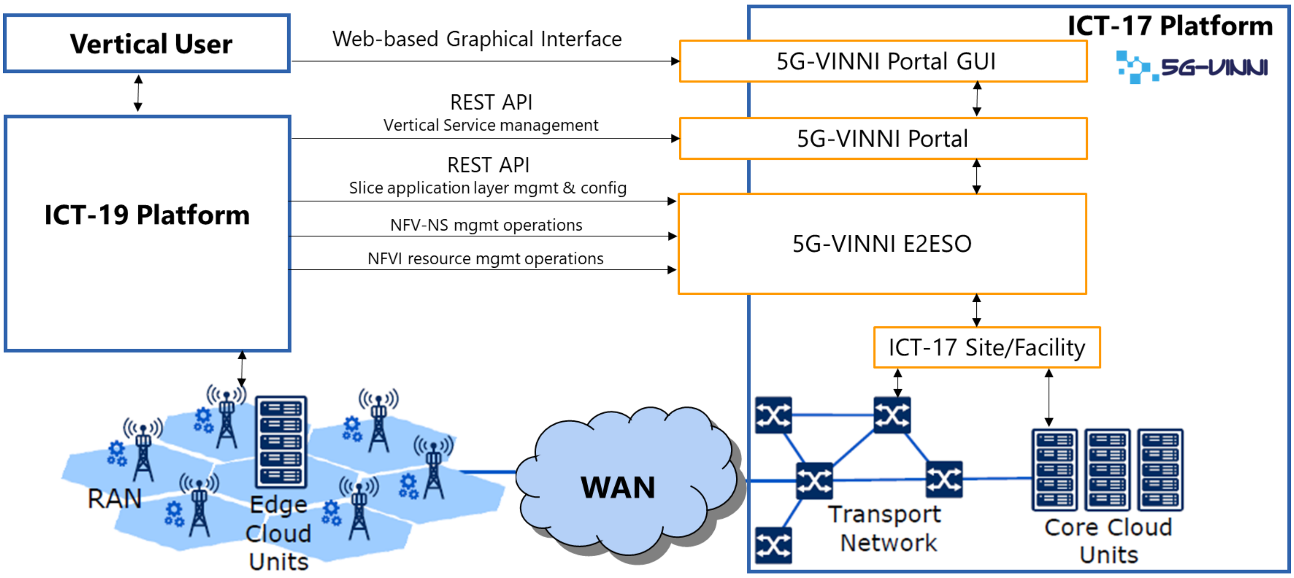

FIGURE 31: 5G-VINNI INTERWORKING MODEL

5G-VINNI, as shown in Figure 31, adopts a different interworking model where the ICT-19 platforms act as clients of the 5G-VINNI system. Depending on the specific 5G-VINNI site, the platform offers REST APIs that enable the management, orchestration, monitoring and control at different "exposure levels", from vertical services, network slices, NFV network services, up to cloud, edge and networking resources, depending on the capabilities and level of openness of the target facility. The possibility to have a certain degree of control over these virtual entities enables the ICT-19 platform to interact with the 5G-VINNI system in a bidirectional manner during the service operation phase.

Thus, it is important to analyze the 5Growth – ICT17 integration at two different phases:

- 1st phase -> Service ordering: A vertical customer (using the 5Growth platform) issues a service request towards an ICT-17 platform. In this sense, the result is a network slice instance deployed in the ICT-17 platform. This slice instance is made available to the vertical according to the information model exposed by the given ICT-17 platform, e.g. as a network slice service instance, as a vertical service instance or as an experiment instance.
- 2nd phase -> Service operation: the vertical customer takes (some degree of control) over the network slice service instance provided by the ICT-17 platform, if feasible and agreed and supported by the ICT-17 platforms.

In the following, we will present the different integration approaches for these two service phases, distinguishing between 5G EVE and 5G-VINNI where needed.

3.4.3. Approaches for Service ordering phase

3.4.3.1. Integration options

So far, we have discussed three major possible options for the integration of 5Growth platform with the ICT-17 platforms for the 1st phase (service ordering or service instantiation/provisioning phase), as shown in Figure 32 (option 1), Figure 33 (option 2), Figure 34 (option 2.a) and Figure 35 (option 3).

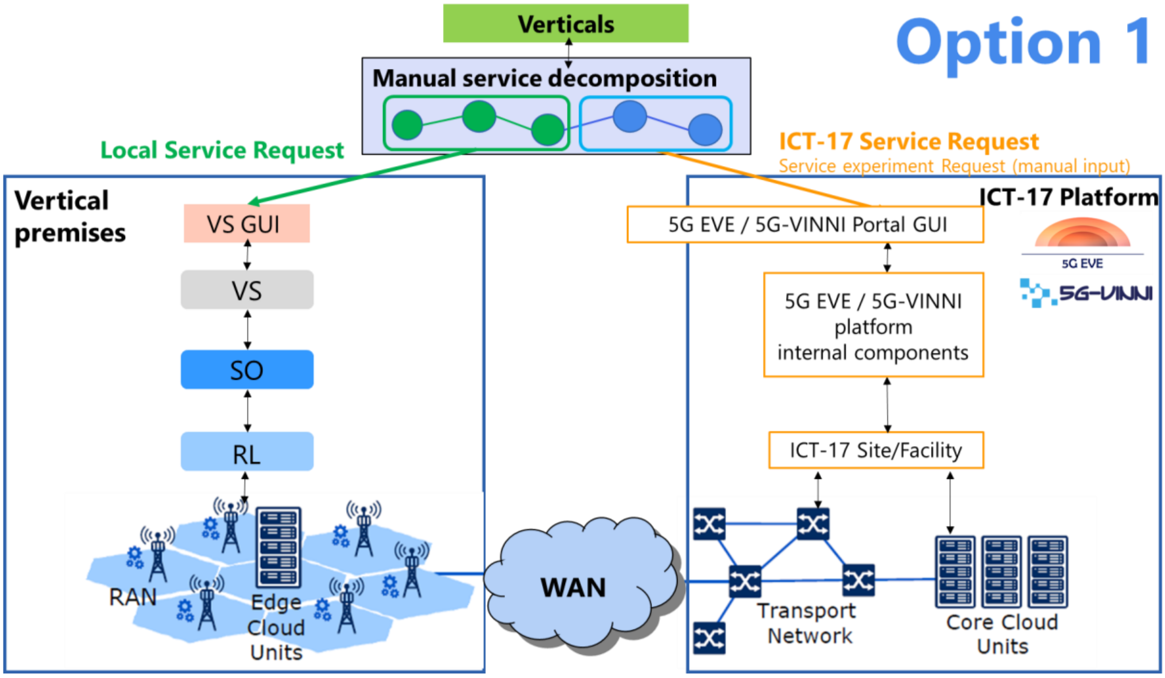

FIGURE 32: 5GROWTH-ICT-17 INTEGRATION IN THE 1ST PHASE. OPTION 1

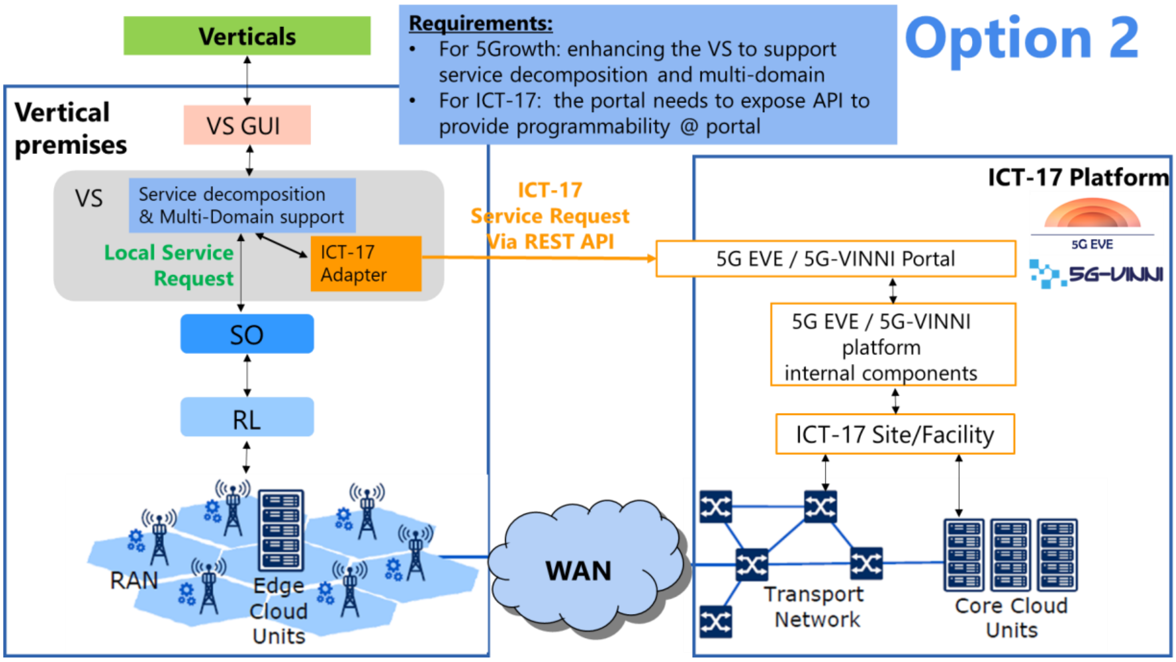

FIGURE 33: 5GROWTH-ICT-17 INTEGRATION IN THE 1ST PHASE. OPTION 2

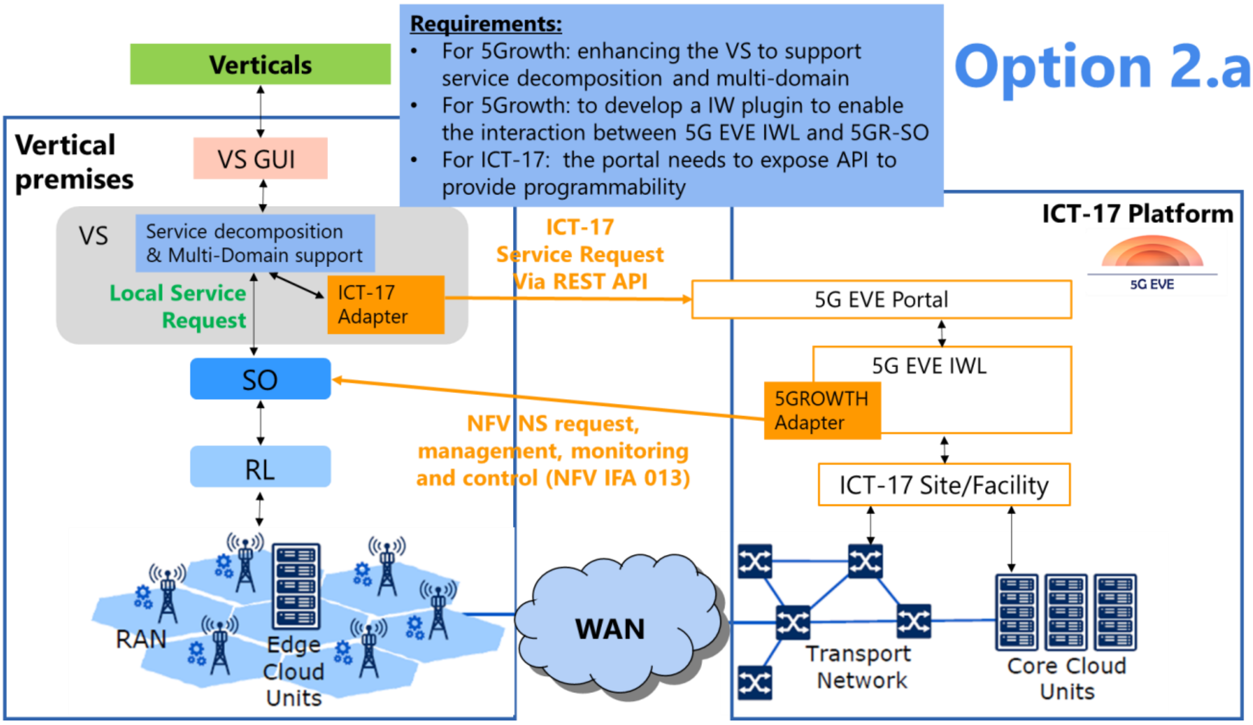

FIGURE 34: 5GROWTH-ICT-17 INTEGRATION IN THE 1ST PHASE. OPTION 2.A. (APPLICABLE TO 5G EVE ONLY)

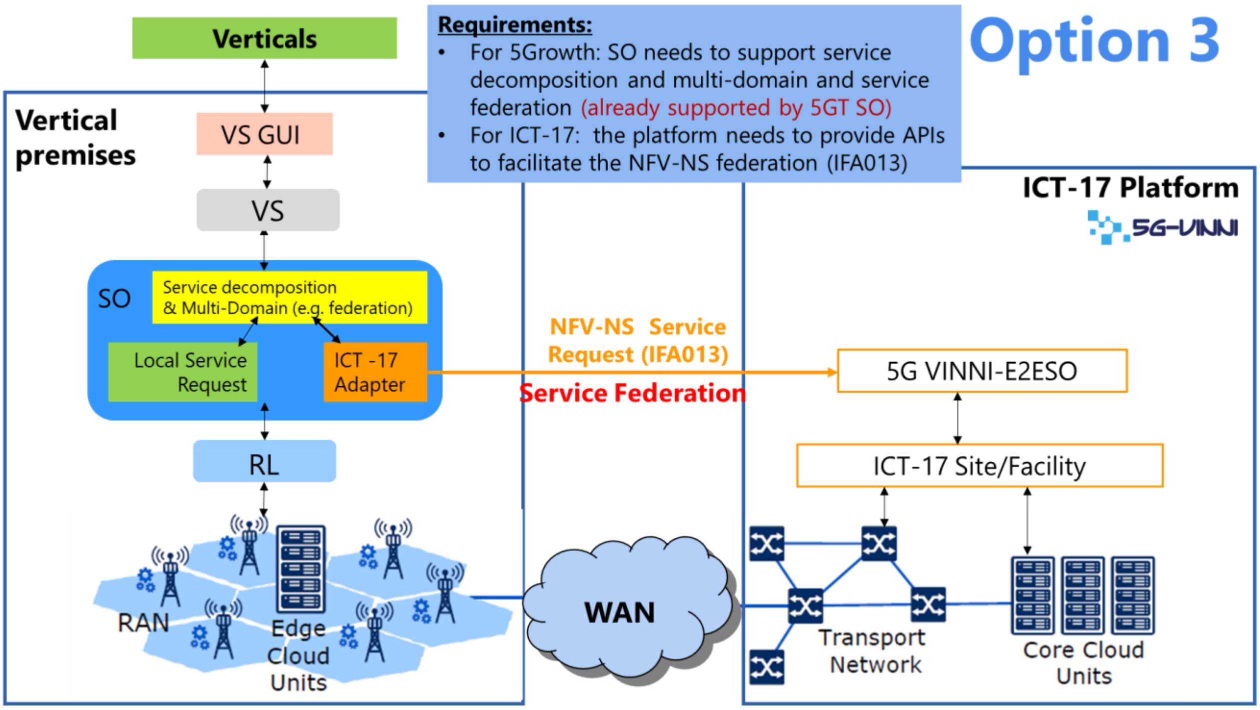

FIGURE 35: 5GROWTH-ICT-17 INTEGRATION IN THE 1ST PHASE. OPTION 3. (APPLICABLE TO 5G-VINNI ONLY)

3.4.3.2. Analysis and Recommendations

From the ICT-17 viewpoint, options 1 and 2 are similar, assuming integration with 5Growth platform at the "vertical service" level. In both scenarios, what comes to the ICT-17 platform is a (vertical-driven) service order that provides a customer-facing service specification. This service order, expressed in the form of an ICT-17 service request, is captured by the ICT-17 portal.

Option 1 is based on the assumption that the vertical interacts manually with the GUI offered by the ICT-17 Portal and the 5Growth Vertical Slicer, requesting a service in each of the domain. Option 2, instead, involves a programmable interaction between 5Growth and the ICT-17 platform, at the portal level. In this option, ICT-17 portals need to provide APIs able to process requests from 5Growth Vertical Slicer (5Gr-VS).

Exploiting the capability of the 5G EVE Interworking framework to interact with external sites, it is also possible to identify an alternative version of option 2, called Option 2.a and applicable only to 5G EVE (see Figure 34). In this option, the 5Growth Vertical Slicer requests the entire end-to-end service to the 5G EVE Portal, specifying the target sites for each of the service segments. The 5G EVE Multi-Site Orchestrator at the Interworking Layer will coordinate the end-to-end provisioning, interacting with the orchestrators available in each site (i.e. in 5Growth vertical premises and in the target 5G EVE site facility) to request the intra-site network service provisioning. This option would require the development of a 5Growth-specific plugin for the 5G EVE Interworking framework, to enable the interaction between the 5G EVE platform and the 5Growth Service Orchestrator.

Option 3, available only for the interactions with 5G-VINNI, assumes integration with 5Growth platform at the "network service" level. Unlike option 1 and 2, what comes to the ICT-17 platform is a service order that provides a resource-facing service specification. This service order, expressed in the form of an NFV-NS Request, is captured by the ICT-17 Service Orchestrator. To enable Option 3, ICT-17 Service Orchestrator needs to provide APIs able to process requests from 5Growth Service Orchestrator (5Gr-SO), e.g. SOL005 compliant APIs. This last option would be currently possible only in the case of integration with 5G-VINNI, but not with 5G EVE, where the NFV orchestrator is an internal component that does not expose APIs to external entities.

3.4.4. Approaches for Service operation phase

3.4.4.1. Options for different service exposure Levels

The filled-in version of the service template sent as part of the service request (1st phase) shall include the specification of the selected capability exposure level. Depending on the selected level, the vertical will be granted with more or less operational capabilities over the provided slice. These capabilities define what the vertical will be allowed to do over the slice at operation time (2nd phase). A brief summary of these capabilities is specified below:

- *Level 1* (see *Figure 36)* -> the vertical is not allowed to make any structural change within the provided slice, but only to perform the re-configuration of some of its parameters. The interaction with the slice is mostly focused on monitoring activities, collecting performance metrics and fault alarms provided by 5G EVE/5G-VINNI. The vertical is only interested in knowing service access points to connect vertical service functions and operate them at run-time (including their re-configuration).

- *Level 2 (see Figure 37)* -> the vertical can manage some of the Service Chains (SCs) at the application layer, but not at the virtualized resource level. The selection of this level would allow the interaction of 5Gr-VS with site-specific RAN/CN/TN controllers, through the VINNI-E2ESO (in the case of 5G-VINNI).
- *Level 3 (see Figure 38)* -> the vertical can manage SCs at the virtualized network service resource level, taking NFV operations over them through the IFA013 interface. The selection of this level would allow the interaction of 5Gr-SO with site-specific NFVO. Since the exposure of site-specific NFVO APIs is not available in 5G EVE, this level is applicable only for the interaction with 5G-VINNI. This scenario corresponds to option 3 for 5Growth-ICT17 integration, as long as NFVO's NBI is SOL005 compliant.
- *Level 4 (see Figure 39)* -> the vertical can directly manage the NFVI resources at the VIM level. In such a case, the vertical would behave as an OpenStack tenant. The selection of this level would allow the interaction of 5Gr-RL with site-specific VIM. This level is also supported only for the interaction with 5G-VINNI.

With the proposed approach based on the selection of one or another exposure level, 5Growth system can interact with ICT-17 stack at different abstraction layers that go beyond the service federation proposed in option 3.

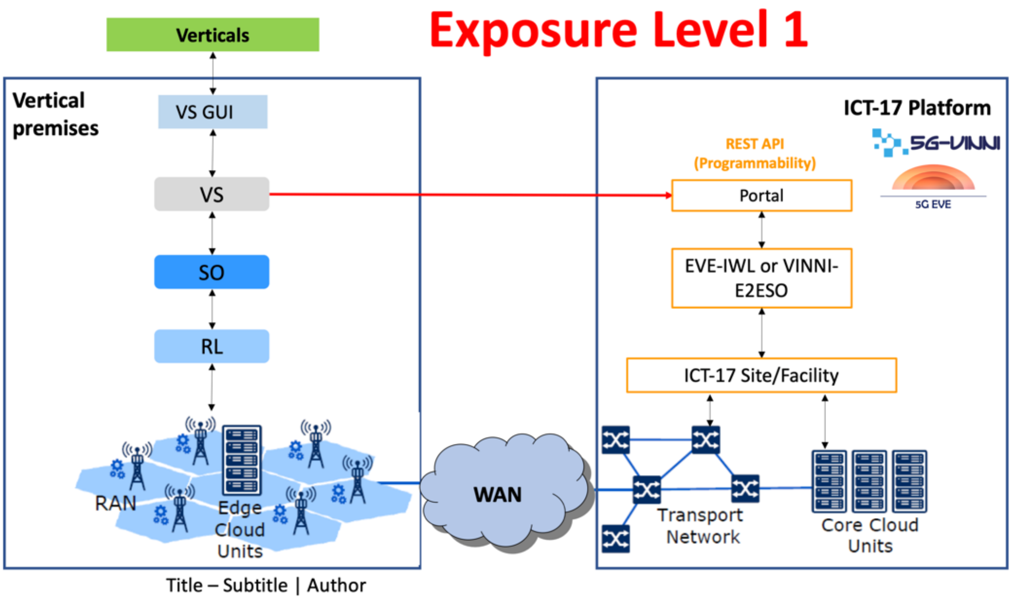

FIGURE 36: 5GROWTH – ICT17 INTEGRATION IN THE 2ND PHASE, IF SELECTED EXPOSURE LEVEL = 1.

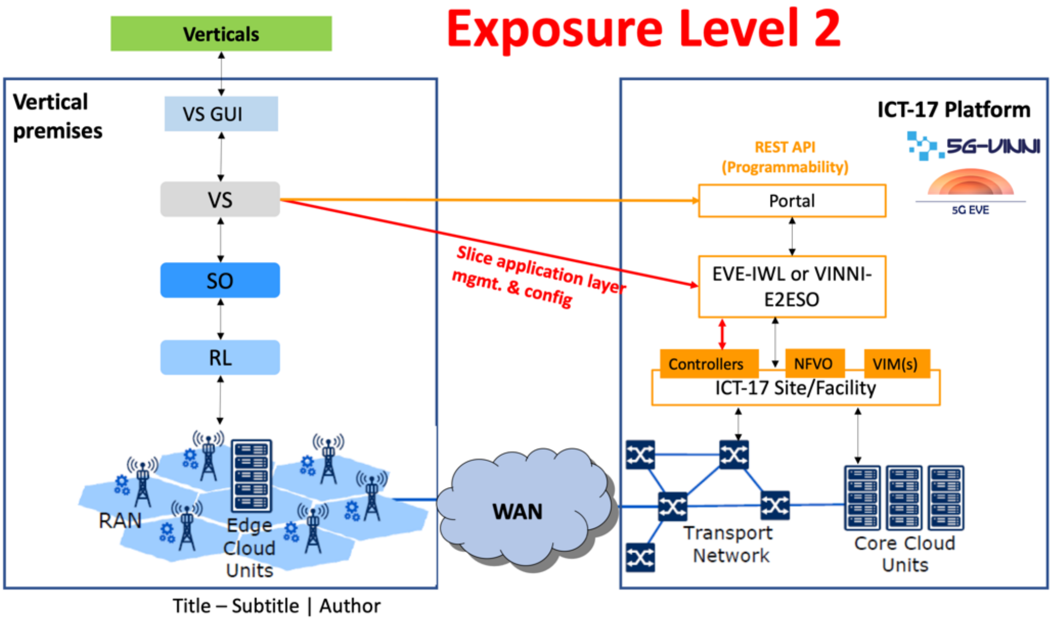

FIGURE 37: 5GROWTH -ICT17 IN THE 2ND PHASE, IF SELECTED EXPOSURE LEVEL = 2.

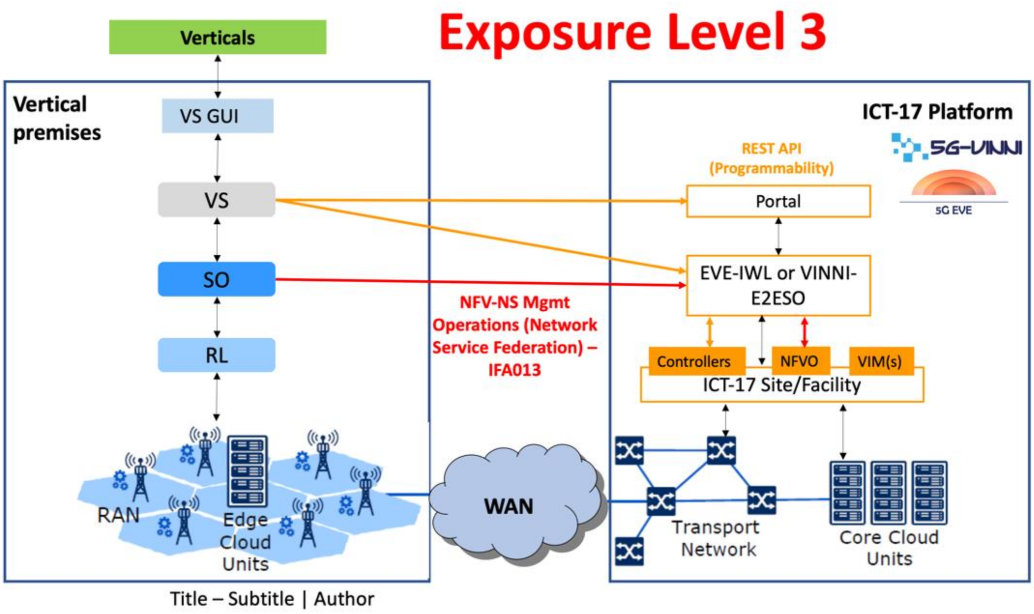

FIGURE 38: 5GROWTH -ICT17 IN THE 2ND PHASE, IF SELECTED EXPOSURE LEVEL = 3.

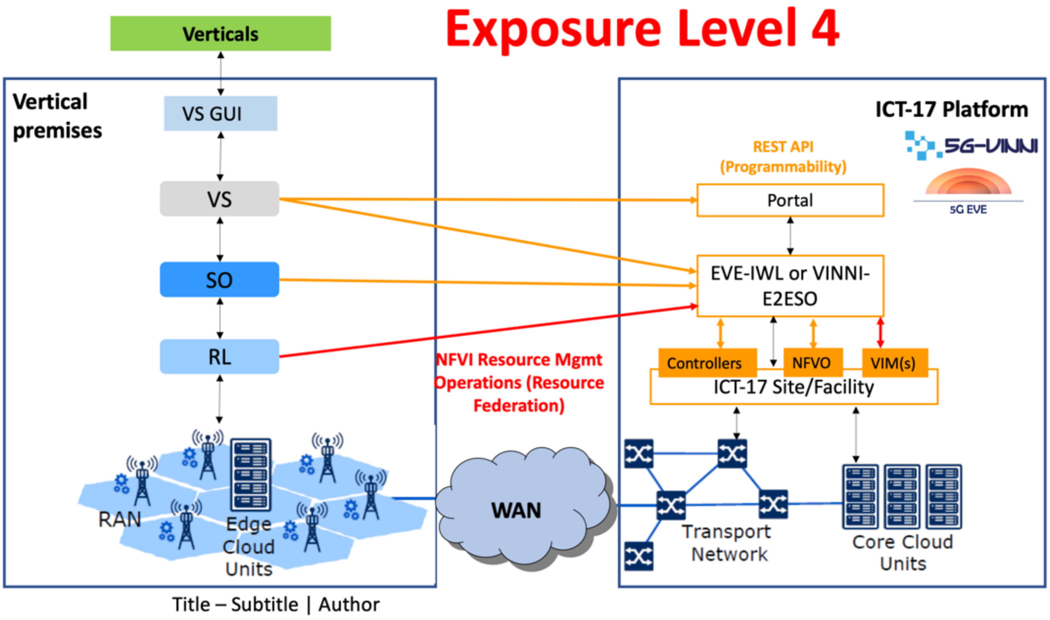

FIGURE 39: 5GROWTH -ICT17 IN THE 2ND PHASE, IF SELECTED EXPOSURE LEVEL = 4.

Taking into account the direction taken by the 5G-VINNI project, 5Growth can explore the feasibility of these different exposure levels in a selected subset of scenarios (mainly related to the pilots planned on 5G-VINNI facilities), relying on open source environments like OSM and OpenStack. For this end, we may look in detail the multi-tenancy support capabilities that OSM and OpenStack claim to have.

3.4.4.2. Analysis and Recommendations

Based on the initial analysis of the offered capacities of the ICT-17 platforms, both 5G EVE and 5G-VINNI will be able to support the exposure level 1. In 5G-VINNI, however, it is possible to explore other exposure levels, which depends on the needs of the use cases. This is still under analysis and study with 5G-VINNI for further discussions.

4. Identified and Actionable Gaps

4.1. List of Identified Gaps related to ICT-17 Platforms

Table 41 lists all identified gaps in the analysis performed in this document, gaps which constitute a formal requirement to 5Growth project. The table shows, for each identified gap, a classification category (Technological Capability, HW Capacity), the relation to the corresponding Use Cases motivating that gap, and the related ICT-17 Platform.

TABLE 41: LIST OF IDENTIFIED GAPS IN ICT-17 PLATFORMS

Gap Id	Gap Name	Category	Use Cases	ICT-17 Platform	Gap Description
PG-01	Reliability KPI Control	Technological Capability	INNO_UC1, INNO_UC2	5G EVE	Currently the capability to emulate reliability levels during the execution of a test case is not implemented
PG-02	CAD model processing and storage at the edge	Technological Capability	INNO_UC2	5G EVE	Innovalia zero defect manufacturing use case requires the deployment of CAD processing and storage capabilities at the edge to support latency requirements
PG-03	Broadband Connectivity	Technological Capability	INNO_UC1	5G EVE	Not supported, planned for the Rel-16 in Jan 2021
PG-04	Capacity	Technological Capability	INNO_UC1	5G EVE	20 Mbps/m2 or km^2. To be verified if it is supported
PG-05	Device Density	Technological Capability	INNO_UC1	5G EVE	1000. To be verified if it is supported
PG-06	Bandwidth	Technological Capability	INNO_UC1	5G EVE	1Gbps. Not supported
PG-02	Broadband Connectivity	Technological Capability	INNO_UC2	5G EVE	1Gbps, Not supported, planned for the Rel-16 in Jan 2021
PG-08	Capacity	Technological Capability	INNO_UC2	5G EVE	200 Mbps/m2 or km^2. Not supported
PG-09	Device Density	Technological Capability	INNO_UC2	5G EVE	Low. To be verified if it is supported

PG-10	Coverage Extension	HW Capacity	EFACEC_E_UC1, EFACEC_E_UC2, EFACEC_T_UC1, EFACEC_T_UC2	5G-VINNI	Extension of 5G coverage (gNBs) to the Use Cases location: EFACEC_E, at the University of Aveiro campus, and EFACEC_T, at the Aveiro Harbor
PG-11	Vertical Portal	Technological Capability	EFACEC_E_UC1, EFACEC_E_UC2, EFACEC_T_UC1, EFACEC_T_UC2	5G-VINNI	Vertical Portal where verticals can go there and provision their services in a self-care mode
PG-12	Real time energy data monitoring mobility	Technological Capability	EFACEC_E_UC1, EFACEC_E_UC2	5G-VINNI	Mobility N/A
PG-13	Data collection for AR	Technological Capability	EFACEC_E_UC1,	5G-VINNI	Mobility N/A
PG-14	Time synchronization Latency	Technological Capability	EFACEC_E_UC2	5G-VINNI	Latency N/A
PG-15	Time synchronization Latency mobility	Technological Capability	EFACEC_E_UC2	5G-VINNI	Mobility N/A
PG-16	Real-time control mobility	Technological Capability	EFACEC_E_UC2	5G-VINNI	Mobility N/A
PG-17	Train Sensors to LX communication mobility	Technological Capability	EFACEC_T_UC1	5G-VINNI	Mobility N/A
PG-18	Bandwidth	Technological Capability	COMAU_UC3	5G EVE	Needed 500Mbps Not completely supported: DL: 100Mbps UL: 50Mbps
PG-19	Bandwidth	Technological Capability	COMAU_UC1, COMAU_UC2	5G EVE	Needed 250Mbits/s (not completely supported) Supported: DL: 100Mbps UL: 50Mbps
PG-20	Reliability KPI Control	Technological Capability	COMAU_UC1, COMAU_UC2	5G EVE	Currently the capability to control reliability during the execution of a test case is not implemented

PG-21	Reliability	Technological Capability	COMAU_UC1, COMAU_UC2, COMAU_UC3	5G EVE	99.999% Not supported
PG-22	Mobility	Technological Capability	COMAU_UC1, COMAU_UC2, COMAU_UC3	5G EVE	As of 2020 Jul, up to pedestrian mobility will be supported (10 km/h) Planned for the Rel-16 in Jan 2021
PG-23	Availability	Technological Capability	COMAU_UC1, COMAU_UC2, COMAU_UC3	5G EVE	99.999% N/A
PG-24	Broadband Connectivity	Technological Capability	COMAU_UC1, COMAU_UC2, COMAU_UC3	5G EVE	Not supported, planned for the Rel-16 in Jan 2021
PG-25	Capacity	Technological Capability	COMAU_UC3	5G EVE	100 Mbps/m2 or km^2. To be verified if it is supported
PG-26	Capacity	Technological Capability	COMAU_UC1, COMAU_UC2	5G EVE	50 Mbps/m2 or km^2. To be verified if it is supported
PG-27	Device Density	Technological Capability	COMAU_UC1, COMAU_UC2	5G EVE	5000. To be verified if it is supported
PG-28	Device Density	Technological Capability	COMAU_UC3	5G EVE	1000. To be verified if it is supported

4.2. List of Identified Gaps related to Vertical/Application Equipment

Table 42 lists several identified gaps on specific verticals' equipment required for fulfilling the use case implementation and piloting. The table shows, for each identified gap, a classification category and the relationship to the corresponding Use Cases motivating the gap.,

It's not an exhaustive list, since a careful and further analysis will be carried out in the project, but it is meant for helping as a basis for early planning and budgeting.

TABLE 42: LIST OF IDENTIFIED GAPS IN 5GROWTH VERTICAL EQUIPMENT

Gap Id	Gap Name	Category	Use Cases	Gap Description
VG-01	Remote worker Hardware	HW Capacity	INNO_UC1	Innovalia remote worker use case require specific hardware equipment, which is currently not available at 5TONIC. The necessary equipment to validate this use case (only one piece of equipment should be shipped) is: - Virtual Joystick - CMM and controllers - Hardware pieces to scan. - Cameras
VG-02	ZDM Hardware	HW Capacity	INNO_UC2	ZDM use case require specific hardware equipment. The necessary equipment to validate this use case (only one piece of equipment should be shipped) is: - CMM and controller. - Industrial parts to be scanned. - Operator workstation. - AGV
VG-03	Energy Hardware	HW Capacity	EFACEC_E_UC1, EFACEC_E_UC2	Deployment of energy equipment, such as low voltage monitors or video cameras to visualize the control panel cabinets
VG-04	Transportation Hardware	HW Capacity	EFACEC_T_UC1, EFACEC_T_UC2	Deployment of transportation equipment, such as train sensors, barriers, video cameras to visualize the cross levels area
VG-05	Energy Edge Computing Applications	Technological Capability	EFACEC_E_UC1, EFACEC_E_UC2	Deployment of applications at the edge to enable the collection of low latency energy monitoring, and augmented reality servers

VG-06	Transportation Edge Computing Applications	Technological Capability	EFACEC_T_UC1, EFACEC_T_UC2	Deployment of applications at the edge to enable the collection sensor data and video streamers for cross level video transmission

5. High-level Considerations for Gap Implementation Planning

The actionable gaps identified in this report constitute a formal set of requirements on 5Growth activities aimed at completing the development and deployment of infrastructure components and services supporting the Use Cases in the scope of the project.

It is the responsibility of further tasks in WP3 (more precisely Task 3.2) to define and operationalize an implementation plan to be hand-shaken by all concurring partners at the locations hosting those use cases.

A few guidelines are provided below for consideration at these further planning and implementation tasks.

First, when it comes to deployment of new 5G technologies, it is worth leveraging the analysis jointly performed by ICT-17 projects, and 5GPPP TB, on 5G industry standards evolution and expected pre-commercial (and commercial) availability of systems adopting them. The practical expression of such analysis is enclosed in [2] in the form of a yearly roadmap of E2E 5G features, that has already undergone a risk assessment, and thus represents a safe base timeline for planning on new 5G technology availability dates in ICT-19 projects such as 5Growth.

Next, regarding the provisioning of new HW for supporting test cases validation at the demanded scale, the recommendation is that a careful dimensioning of both ICT-17 supporting facilities and 5Growth vertical locations is performed. On the one hand ICT-17 platforms benefit from economies of scale since they serve several use cases and therefore can be optimized. On the other hand, dedicated 5Growth facilities must be dimensioned for the "peak" requirements of the involved test cases.

And even more importantly, with applicability to both new technology deployments and HW additions, it is strongly recommended that the involved partners carefully assess the necessary investment plan against the allocated budget at 5Growth for cost of equipment, before moving into implementation.

Then, on the aspect of services and tools required for an extensive validation of 5Growth Use Cases, it is strongly recommended that those services and tools offered as a service by ICT-17 platforms be considered as the default option to leverage by 5Growth in order to minimize investments and avoid duplication of efforts at 5GPPP Phase III projects, as a whole. That said the on-premises nature of most deployments foreseen in 5Growth project shall involve the procurement and readiness of expensive instrumentation equipment and the availability of several tools locally. This is, budget-wise, an area that can pose relevant risks to be analyzed before moving into implementation.

Finally, the exploration of additional innovate features to be developed within 5Growth project should be linked to the actual endorsement of concrete use cases whose validation of execution may clearly benefit from them. That will help streamlining the implementation activities and its outcomes at just the cost of a necessary preliminary analysis and coordination. So, having identified those synergies before moving into implementation may be a key success factor for the project goals.

Last, but not least, the quest for efficiencies in the project also urges for identifying common approaches for integration schemes of 5Growth with the selected ICT-17 platforms. In this report a framework for further analysis is just outlined and needs special attention at tasks like T3.2. And since this activity transcends the original scope of ongoing 5G EVE and 5G-VINNI projects, platforms also supporting several other ICT-19 projects and vertical use cases, it is advisable to find commonalities with other ICT-19 projects, also leveraging the network of connections enabled by 5GPPP TB.

6. Conclusions

Each of proposed technical solutions for supporting the various clusters of use cases under analysis can be classified into one possible scenario of the introduced 5G ACIA framework for NPN. More specifically we can conclude that, facility by facility, these are the implicit selections of scenarios:

- For COMAU Use Cases the scenario selected is that of *Deployment as Isolated Network* (NPN Scenario 1).
- For both EFACEC_S and EFACEC_E Use Cases the scenario selected is that of *NPN deployed in Public Network* (NPN Scenario 3).
- For INNOVALIA Use Cases the scenario selected is that of either *Deployment with Shared RAN and Control* Plane or even that of *NPN deployed in Public Network* (NPN Scenario 4).

The key gap areas identified can be summarized as follows:

1) For COMAU Use Cases validation support:
    a) Deployment of all the necessary 5G infrastructure at COMAU factory premises for trialing COMAU's Industry 4.0 use cases in scope.
    b) Integration of COMAU Factory premises environment with 5G EVE facility in Turin.
    c) Availability of specific validation tools of 5Growth platform at COMAU factory premises.
    d) Availability of specific innovative features of 5Growth platform at COMAU factory premises.
2) For EFACEC_E Use Cases validation support:
    a) Deployment of all the necessary 5G infrastructure in the field, at the specific edge locations selected for trialing EFACEC_E Energy use cases in scope.
    b) Integration of those selected locations' environments with 5G-VINNI facility in Aveiro.
    c) Availability of specific validation tools of 5Growth and 5G-VINNI platform at the selected locations' environments.
    d) Availability of specific innovative features of 5Growth platform at the selected locations' environments.
3) For EFACEC_S Use Cases validation support:
    a) Deployment of all the necessary 5G infrastructure in the field, at the specific edge locations selected for trialing EFACEC_S Transport use cases in scope.
    b) Integration of those selected locations' environments with 5G-VINNI experimental facility in Aveiro.
    c) Availability of specific validation tools of 5Growth and 5G-VINNI platform at the selected locations' environments.

   d) Availability of specific innovative features of 5Growth platform at the selected locations' environments.

4) For INNOVALIA Use Cases validation support:

   a) Deployment of all the necessary 5G infrastructure, first at 5G EVE Madrid site facility, and then at INNOVALIA R&D premises in Bilbao, for validating and trialing INNOVALIA's Industry 4.0 use cases in scope.

   b) Integration INNOVALIA environments with 5G EVE platform.

   c) Availability of specific validation tools of 5Growth platform at INNOVALIA R&D environment.

   d) Availability of specific innovative features of 5Growth platform at INNOVALIA R&D environment.

Finally, the report also provides an outlook on the potential common integration schemes of 5Growth platform with ICT-17 platforms, over a set of preliminary assumptions, and postulating a set of alternative approaches to be taken as input to further analysis work at 5Growth Task 3.2.

References

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