Smart5Grid

Demonstration of **5G** solutions for **SMART** energy **GRID**s of the future

Deliverable **2.1**

Elaboration of UCs and System Requirements Analysis

Version **2.0** - Date **24/02/2022**

D2.1 – Elaboration of UCs and System Requirements Analysis

Document Information

Programme	Horizon 2020 Framework Programme – Information and Communication Technologies
Project acronym	Smart5Grid
Grant agreement number	101016912
Number of the Deliverable	**D2.1**
WP/Task related	[WP2 / T2.1]
Type (distribution level)	PU Public
Date of delivery	[24-02-2022]
Status and Version	Version 2.0
Number of pages	**131** pages
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Revision History

Version	Date	Author/Reviewer	Notes
0.1	03/03/2021	Irina Ciornei	Table of content (first draft)
0.2	07/04/2021	Irina Ciornei	Update ToC
0.3	14/04/2021	Irina Ciornei	Drafting Ch1 and Ch2
0.4	30/04/2021	Irina Ciornei	Drafting Ch2 and Ch3 and update ToC
0.5	05/05/2021	Irina Ciornei	Address comments from Sonia (ATOS)
0.6	10/05/2021	Irina Ciornei	Drafting Ch3
0.7	14/05/2021	Irina Ciornei	Updates on Ch1, Ch2 and drafting Ch4
0.8	18/05/2021	Irina Ciornei	Updates on Ch1-Ch4
0.9	20/05/2021	Irina Ciornei	Updates from partners on Ch4
0.10	21/05/2021	Vasiliki Vlachodimitropoulou	Updates on Ch1 and Ch2
0.11	22/05/2021	Irina Ciornei	Executive summary, Conclusions, corrections on Ch1-Ch3 and updates from partners on Ch4
0.12	26/05/2021	Irina Ciornei	revisions over the entire document
0.12	02/06/2021	Sonia Castro	Review
0.12	02/06/2021	Ioannis Chochliouros	Review
0.12	02/06/2021	Markos Asprou and Christos Panayiotou	Review
0.12	02/06/2021	Elisavet Grigoriou	Review
0.12	02/06/2021	Theoni Dounia	Review
0.13	10/06/2021	Irina Ciornei	Integration of all comments and revisions from internal reviewers and from contributors
0.14	20/06/2021	George Ellinas	Review
0.15	20/062021	Emmanouil Zoulias	Review
0.15	30/06/2021	Irina Ciornei	Final addressing of comments
1.0	30/06/2021	Irina Ciornei	Submission to EC
1.01	14/02/2022	Daniele Porcu, Fabrizio Battista, Daniele Porcou, Inmaculada Prieto Borrero , Athanasios Bachoumis, Ralitsa Rumenova, Demetrios Brodimas, George	Updates UC1, UC2, UC3 and UC4

		Kontopoulos, Irina Ciornei, Lenos Hadjudemetriou	
1.02	14/02/2022	Irina Ciornei, Athanasios Bachoumis, George Kontopoulos, Inmaculada Prieto Borrero, Daniele Porcou	updates on the tables related to business KPIs, review and editing for the latest contributions
1.03	18/02/2022	Irina Ciornei	editing, formatting and updating a clean version for internal review
1.04	22/02/2022	Sonia Castro	internal review
1.05	23/02/2022	Irina Ciornei, Sonia Castro, Daniele Porcu	clarification of comments in UC1 and final editing and formatting
2.0	24/02/2022	Irina Ciornei	Version ready for sumbission

Executive summary

Smart5Grid is focused on boosting innovation for the highly critical and challenging energy vertical, by providing an open 5G enabled experimentation platform customized to support the smart grid vision. The Open Smart5Grid experimental platform aims to be an ecosystem where stakeholders in the energy vertical, ICT integrators, Network Applications (NetApps) developers, actors in the telecom industry and/or network service providers in general could come together fostering collaboration and innovation. The final goal of the project is to validate, both at the technical and business levels, the opportunities offered by 5G technology to the energy vertical, to be demonstrated in four meaningful use-cases, relevant to real scenarios of use. The use-cases were specifically chosen in order to capture a wide range of operation scenarios for the power systems.

This deliverable elaborates on the requirements expressed in relation to the use-cases and the Smart5Grid platform. The use-cases requirements, such as technical, regulatory, environmental or compliance to specific standards for the energy vertical, are collected and summarized in a uniform and standardised way. The goal was to "map" those requirements to specific architectural solutions and the potential role to be played by the Smart5Grid platform for further business exploitation beyond the demonstrators of the specific use cases. In this respect, the main goal of the Smart5Grid platform is to facilitate the development and the testing of NetApps. Furthermore, Smart5Grid aims to capitalize on several architectural features enabled by the network softwarisation principles, such as: adoption of Service-Based Architecture (SBA), functional split in Radio Access Network (RAN), Multiaccess Edge Computing (MEC), network slicing, and distributed orchestration of network resources (both hardware and software).

This deliverable is two-fold: on the one hand, it elaborates on the four meaningful Smart5Grid use-cases and on their associated 5G network requirements; and, on the other hand, it derives the first layer of guidance for the design of the Smart5Grid platform in terms of functional and non-functional requirements of the three major architectural blocks identified.

The four use-cases (UC) cover a broad range of operations for the power grids such as: (i) advanced fault-detection, isolation, and self-healing for the power distribution grids (UC#1 - Italy); (ii) enhanced safety tools for maintenance workers in high-voltage power substations (UC#2 - Spain); (iii) advanced and remote monitoring with millisecond precision for dispersed renewable-based power generation units (UC#3 - Bulgaria); and (iv) wide area monitoring of cross-border transmission power grids (UC#4 - Greece-Bulgaria). The use-cases were specifically chosen to reflect scalable business needs at the European level for all stakeholders operating in the power distribution grids (e.g., electricity suppliers and distribution system operators), European Transmission System Operators, owners, aggregators or operators of distributed, renewable-based power generation.

The main outcomes from the use-cases analysis are a set of technical, business, and regulatory related requirements which are specific for the highly regulated and standardised energy vertical; and, a set of 5G network requirements which are particular to the Smart5Grid use cases. The requirements of these use cases also addressed the scope of the dedicated NetApps and their service objectives, the sequence diagrams of these services, as well as conditions and technologies involved, per case.

In what concerns the Smart5Grid architecture, three layers were identified as major architectural blocks, and their high-level functional and non-functional requirements were collected. The three layers are: (i) the Open Service Repository; (ii) the Validation and Verification Layer for the use-case specific and 3rd party NetApps; and, (iii) the Management and Orchestration Layer. Specifically, the platform will allow developers to upload vertical specific NetApps to be hosted on the Open Service Repository for discovery and consumption by 3rd parties. Before these NetApps are available in the repository, they would have been extensively tested by the Validation & Verification framework. The necessary telecommunication and computing resources support this validation step to execute a fully featured NetApp so as to perform a comprehensive suite of tests.

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Notations, abbreviations and acronyms

Table 1: List of acronyms

Acronym	Description
2D	Two Dimensional
3D	Three Dimensional
3G	The Third Generation of Mobile Communications
3GPP	The Third Generation Partnership Project
4G	The Fourth Generation of Mobile Communications
5G	The Fifth Generation of Mobile Communications
5GCN	5G Core Network
5G-NR	5G New Radio
5G-PPP	5G Public Private Partnership
AC, a.c.	Alternating Current
ACER	European Union Agency for the Cooperation of Energy Regulators
AI	Artificial Intelligence
AIS	Air Insulated Substation
AMF	Access and mobility Management Function
API	Application Programming Interface
ARIB	Association of Radio Industries and Businesses
ATIS	Automatic Terminal Information Service
AUSF	AUthentication Server Function
BRP	Balancing Responsible Party
BSP	Balancing Service Provider
BUC	Business Use-Case
CAPEX	Capital Expenses
CCSA	Committee for the Coordination of Statistical Activities
CE	Marking for production within EEA (see below), which reads as "Conformité Européenne"
CENELEC	European committee for Electrotechnical Standardization
CN	Core Network
CO	regional COntrol room
COTS	Commercial Off-The-Shelf
CPEs	Customer Premises Equipment (wireless broadband access device)
CPRI	Common Public Radio Interface
CPU	Central Processing Unit
DC, d.c.	Direct Current
DER	Distributed Energy Resources
DevOps	Development and Operations
DNS	Domain Name System
DoW	Description of Work
DRAM	Dynamic Random Access Memory
DSO	Distribution System Operator

Acronym	Description
DSS	Dynamic Spectrum Sharing
E2E	End-to-End
EDI	E-Distribuzione, Italy
EEA	European Economic Area
eMBB	enhanced Mobile Broadband
EMC	Electro-Magnetic Compatibility
EN	European Norm
ENTSO-e	European Network of Transmission System Operators for Electricity
ESD	Electrostatic Discharge
ETSI	European Telecommunications Standards Institute
fps	frames per second
FSL	Italian acronym for "Funzionalità di Selettività Logica" meaning Logic Fault Selection
GA	Grant Agreement
GDS	Global Digital Services
GIS	Gas Insulated Substation
GPS	Global Positioning System
GPU	Graphics Processing Unit
gNB	Next Generation NodeB Radio Network Base Station
H2020	Horizon 2020
HEMP	High-Altitude Electromagnetic Pulse
HUB	Central device which manages the traffic exchange between the SCADA systems and the field devices and between neighbouring field devices.
HV	High Voltage
HW	Hardware
i2SM	i2CAT's Slicing Management
ICT	Information and Communication Technology
ID	Identification
IEC	International Electrotechnical Commission
IETF	Internet Engineering Task Force
IMT	International Mobile Telecommunications
IoT	Internet of Things
IP	Internet Protocol
IPv4	Internet Protocol version 4
ISG	Industry specification Group
ITU	International Telecommunication Union
ITU-T	ITU's Telecommunication Standardization Sector
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LTE	Long-Term Evolution
LV	Low Voltage
M&O	Management and Orchestration
MANO	Management and Orchestration (an ETSI architectural framework)
MEC	Multi-access Edge Computing
MiFi	Mobile WIFI (a portable broadband device)

Acronym	Description
mMTC	massive Machine Type Communication
MV	Medium Voltage
NB-IoT	Narrow Band Internet of Things
NetApp	Network Application
NFV	Network Function Virtualization
NFVI	Network Function Virtualization Infrastructure
NFVO	Network Function Virtualization Orchestrator
NGMN	Next Generation Mobile Networks Alliance
NILB	Italian acronym for Number of long and short interruption per customer
NR	New Radio
NRA	National Regulatory Authorities
NS	Network Service
NSD	Network Service Descriptor
NSO	Network Service Orchestrator
nZTP	Near Zero Touch Provisioning
O&M	Operation & Maintenance
O-RAN	Open Radio Access Network [an Alliance]
OPC	Open Platform Communications
OSM	Open-Source MANO
OSR	Open Service Repository
PC	Personal Computer
PCF	Policy Control Function
PDC	Phasor Data Concentrator
PLC	Programmable Logic Controller
PMU	Phasor Measurement Unit
PNF	Physical Network Function
PS	Primary Substation
QoE	Quality of Experience
QoS	Quality of Service
QR	Quick Response
RAN	Radio Access Network
RES	Renewable Energy Sources
RF	Radio-Frequency
RFC	Updated Specifications for the IP4
RLT	Real-Life Test
RoCoF	Rate of Change of Frequency
RPC	Remote Procedure Call
RSC	Regional Security Coordinator
RTLS	Real Time Location System
RTU	Remote Terminal Unit
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SB	Service Blueprint
SBA	Service-Based Architecture

Acronym	Description
SCADA	Supervisory Control And Data Acquisition
SDN	Software Defined Network
SDO	Standards Developing Organization
SFS	Smart Fault Selection
SGAM	Smart Grid Architecture Model
SLA	Service Level Agreement
SLI	Service Level Indicator (same as KPI)
SLO	Service Level Objective
SM	Slice Manager
SME	Small-Medium Enterprise
SMF	Session Management Function
SOS	Save Our Souls
SS	Secondary Substation
SUC	System Use-Case
SW	Software
TEM	Transverse Electromagnetic
TELCO	Telecom Operator
TLC	TeLeCommunication
TRL	Technology Readiness Level
TS	Technical Specification
TSDSI	Telecommunications Standards Development Society, India
TSO(s)	Transmission System Operator(s)
TTA	Telecommunications Technology Association
TTC	Telecommunications Technology Committee
UC	Use-Case
UDM	Unified Data Management
UE	User Equipment
UI	User Interface
UMTS	Universal Mobile Telecommunications System
UPF	User Plane Function
URLLC	Ultra-Reliable and Low Latency Communication
UWB	Ultra-Wide Band
V&V	Validation and Verification Framework
VIM	Virtual Infrastructure Manager
VM	Virtual Machine
VNF	Virtual Network Function
VNFD	Virtual Network Function Descriptor
vPDC	Virtual Phasor Data Concentrator
WAM	Wide Area Monitoring
Wi-FI, WiFi	Wireless Fidelity
WP	Work Package
WWW, www	World Wide Web
XML	Extensive Markup Language

1. Introduction

Large and interconnected power systems are seen as the backbone of the critical infrastructures in any society. They are complex cyber-physical systems for which the communication layer plays an important role in monitoring, control and automation of the grid. So far, the communication networks dedicated to power systems' control and automation were hosted and managed by the electric utility itself. At the same time, telecom providers played little or no role in the communication infrastructure of the power grids, especially upstream the meter of the electricity consumers. However, this status quo is expected to drastically change in the smart grid era, a phase which has already started. The smart grid concept and its deployment environment(s) are aiming to increase efficiency, resilience, reliability and security of the evolved, and greener power grids, by means of increased digital automation and control. In this respect, the traditional power grids need to be complemented with advanced communication and information technologies ([1], [2]) targeting to achieve efficiency and security, in a way that will "reshape" the modern landscape in the energy vertical.

The European vision for Green Deal[1] has set the path for replacing large thermal power plants with hundreds of thousands of smaller and dispersed, renewable-based generation units, able to cover the same or greater power capacity. The renewable-based distributed power generation uses power-electronics converters as an interface with the grid. However, they also contribute to faster power system dynamics, that require advanced monitoring and control tools on top of seamless coordination between many stakeholders and actors in the electricity chain. These are well recognized needs of the energy vertical, requiring flexible, reliable, high-available, and low-latency communication on top of scalability in diversely populated areas.

The fifth Generation (5G) of communication networks appears to possess the right features to allow the power grid to tackle the above-mentioned challenges. It is envisioned that 5G networks will play a significant role in the power grid transformation to enable better efficiency, observability, and controllability of the power system, especially at the distribution side [3], where the number of monitoring devices and remote automation equipment is expected to dramatically increase[2]. Specifications, such as high data rates and low latency across wide areas of coverage, flexible massive Machine Type Communication (mMTC) specific for dense urban areas, and Ultra-Reliable and Low Latency (URLL) communication are those which could enable a significant shift for the smart grid's communication layer. The flexibility of the 5G technology is the most valuable feature along with modularity and full programmability, allowing fast deployment of services to be tailored to the unique requirements of the energy vertical. This transition from a "horizontal" service model, specific for past mobile network versions such as 3G, 4G and LTE, towards a "vertical" dedicated service model opens the path for a plethora of innovative applications across a variety of industry- or community-related verticals, including the energy vertical.

5G vertical trials in Europe have been performed through several 5G Infrastructure Public Private Partnership (5G-PPP) projects. The 5G-PPP[3] is a joint initiative between the European Commission and the

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[1] The European Green Deal is about improving the well-being of people. Making Europe climate-neutral and protecting our natural habitat will be good for people, planet and economy. More details can be found at: https://ec.europa.eu/commission/presscorner/detail/en/fs_19_6714

[2] The vision for 5G is to not only provide better broadband with higher capacity and higher data rates at much lower cost, but also to address entirely new challenges, to enable new services, empower new types of user experiences, and connect new industries.

[3] For more details also see: https://5g-ppp.eu/

European Information and Communication Technology (ICT) industry (ICT manufacturers, telecommunications operators, service providers, SMEs, and research institutions). The 5G-PPP is now in its third phase[4], with projects launched initially in June 2018 and more followed in 2019 and 2020. The 5G-PPP will deliver solutions, architectures, technologies, and standards for the ubiquitous next generation communication infrastructures of the coming decade. The challenge for 5G-PPP is to secure Europe's leadership in the areas where Europe is strong or where there is potential for creating new markets such as smart cities, e-health, intelligent transport, education, or entertainment & media.

It is important to highlight that, a significant part of the Smart5Grid project is the utilization of the published results by research projects at European level, which have already been considered for their concepts in the scope of the 5G-PPP program, that will contribute to the definition of a viable roadmap for SMEs and third-party experimentation in the energy industry.

For instance, Smart5Grid will leverage the results of the H2020 NRG-5 [4] regarding the management and monitoring of power grid assets, the communication requirements, as well as the integration analytics in the ETSI-MANO procedures[5]. Also, other projects whose results will be taken under consideration are VirtuWind [5], 5G-ESSENCE [6], 5G-TANGO [7], and 5G-VICTORI [8].

The Smart5Grid architecture, which will accommodate and mediate the validation process of the demonstrators, revolves around the Network Function Virtualisation (NFV) concept. The design targets an open experimentation facility for 3rd party NetApps developers, fully softwarised, and which integrates an Open Service Repository (OSR), a framework for Validation and Verification (V&V), and a flexible and modularized Management and Orchestration (M&O) framework.

In the context of Smart5Grid, a NetApp is defined as a vertical application, composed of a chain of cloud-native virtual network functions (VNFs), able to leverage 5G and edge infrastructure by formally specifying its deployment and performance requirements in its so-called NetApp descriptor. Its main goal is to abstract the complexity of the underlying 5G network, facilitating the development of applications for the smart grid.

This document details the high-level functional and non-functional requirements for all these relevant architectural layers and components. Furthermore, the Smart5Grid Project takes a step further and aims to develop innovative NetApps dedicated to the highly critical and challenging energy vertical. As part of this mission, the Smart5Grid will administer four meaningful use cases for the aforementioned vertical in Europe using real energy infrastructure and under actual operational conditions. These four use-cases (UC) are:

- **UC#1: Automatic Power Distribution Grid Fault Detection** (Olbia Region, Italy) aims to demonstrate how a 5G network could ensure the performance of the advanced grid fault detection, isolation, and self-healing automation system developed by E-Distribuzione (EDI),

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[4] Further information about the 5G-PPP phase-3 can be found at: https://5g-ppp.eu/5g-ppp-phase-3-projects/

[5] NFV MANO is a framework developed by a working group of the same name within the European Telecommunications Standards Institute (ETSI) Industry Specification Group for NFV (ETSI ISG NFV). Over time, the framework became more commonly referred to as just NFV management and orchestration Management and orchestration (MANO) is a key element of the ETSI network functions virtualization (NFV) architecture. MANO is an architectural framework that coordinates network resources for cloud-based applications and the lifecycle management of virtual network functions (VNFs) and network services.

especially in highly populated geographical areas. Monitoring the digital communication layer of this advanced automation system is crucial to ensure that, when a fault in the grid occurs, the system can perform as expected.

- **UC#2: Remote Inspection of Automatically Delimited Working Areas at Distribution Level** (Barcelona area, Spain) aims to reduce the safety risks for workers performing activities in high voltage power substations by introducing an automated process for the detection of workers and their working tools which might go through / traverse the borders of a delimited safe working area. The detection process requires reliable and ultra-low latency communication for the data originated from the cameras and wearable sensors that will be used. A private 5G network will be implemented.

- **UC#3: Millisecond Level Precise Distributed Generation Monitoring** (Sliven region, Bulgaria) aims to demonstrate a wind farm's advanced real-time monitoring system with millisecond level precision by using the emerging capabilities of 5G telecommunication networks. Real-time monitoring is vital for the proper operation of the wind farms and for the observability purposes of the grid operators, as well as for the optimal portfolio setting of third-party aggregators providing real-time services for balancing electricity markets. The strict requirements set by power system operators for the services to be provided by the distributed renewable resources such as wind farms render essential the utilization of a highly reliable and secure telecommunication connection between the physical asset (wind farm) and the dispatch centre of the grid operator.

- **UC#4: Real-time Wide Area Monitoring** (cross border between Greece and Bulgaria) aims to demonstrate how 5G network communication could be used to monitor power and energy exchanges within a geographical wide area (i.e.: between two countries) in real-time and a reliable and accurate way. This function will be executed from the newly established Regional Security Coordinator (RSC) located in Thessaloniki, Greece. A Virtual Phasor Data Concentrator (vPDC) will be developed for the data gathering process. The Phasor Measurement Units (PMUs), located at the High Voltage (HV) network of Northern Greece (responsible to monitor the cross-border power flow) and the vPDC will be connected using a 5G network, which will offer offers the low latency and high reliability needed for this critical operation.

All four use cases will be detailed as part of this Deliverable (D2.1), aiming to extract UC specific requirements, such as energy vertical related and 5G network related. This first set of requirements will guide the project particularities at the deployment sites in the later work packages (i.e., WP5 and WP6). They will also used for deriving general high-level functional and non-functional requirements of the Smart5Grid architecture which is briefly introduced in this deliverable but that will be further elaborated in a follow-up deliverable of WP2 (i.e., D2.2).

1.1. Scope of the document

This document represents the first technical deliverable submitted by the project, and the first in the series of three inter-related deliverables of the second work package (WP2) of the Smart5Grid project. Specifically, D2.1 aims to elaborate on the use cases as well as to extract the high-level functional and non-functional requirements of the Smart5Grid open experimentation platform. This deliverable covers the

activities performed as part of Task 2.1 and directly contributes to the overall vision of the WP2. The next technical deliverable of the WP2, D2.2, will summarize the work of two tasks, T2.2 and T2.3, which run in parallel and are interdependent with T2.1. Specifically, D2.2, due on M09, will further elaborate on the design details of the Smart5Grid Open Experimental Platform, together with the specifications for the NetApps, and it will detail the system level technical specifications along with the technological choices enabling 5G communication for smart energy grids. The last deliverable of the WP2, D2.3, will align the Smart5Grid platform with previous 5G-PPP Phases and it will derive the strategy and the roadmap for third party experimentation. It is worth mentioning that the output of the WP2 will be used as input for all the other WPs of the project that follow. A block diagram showing the interdependencies of this specific deliverable, D2.1 with the rest of the tasks and work packages of the Smart5Grid project is presented in Figure 1 below.
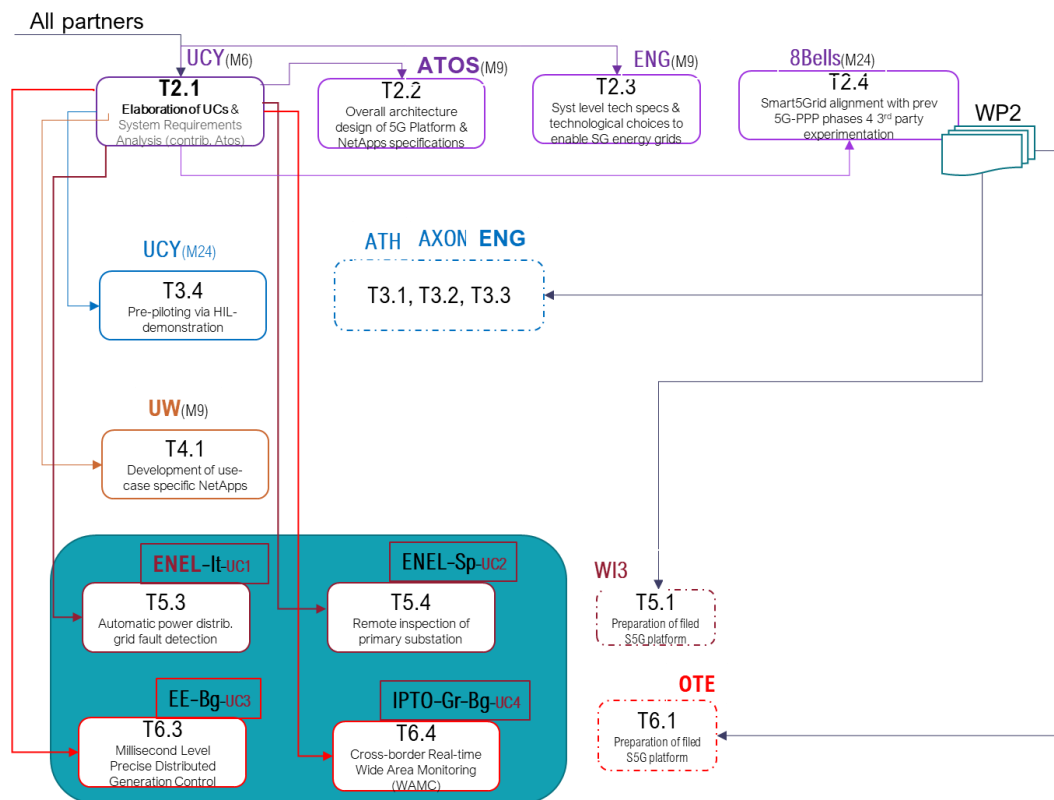
Figure 1: Relationship of D2.1. with the rest of the technical tasks and WPs in the Smart5Grid Project

As mentioned, the scope of this deliverable is to elicit and elaborate on the UCs requirements and to extract high-level network and architecture requirements. To do this, an iterative process divided in three major stages was adopted: (i) focusing on (a) the detailed description of the UCs, identifying the stakeholders and the actors involved, their roles, and their interactions and special relationship, and (b) the description and functionality of the UC-specific NetApps and their structure; (ii) collecting and analysing the 5G network requirements for each UC in relation to their specific NetApps, their deployment and operation environment, as well as the grid specific constraints (e.g., security, regulatory, interoperability with existing infrastructure, etc.); and (iii) deriving high-level functional requirements for the Smart5Grid platform which will facilitate the development, validation, and verification of the project and other 3rd party NetApps.

The outputs of this deliverable are the associated requirements of each UC to be targeted and technically assessed in each one of the WP5 and WP6 real-world field demonstrations. These requirements are also the main input for the definition of the Smart5Grid architecture as well as for the development of the UC-specific NetApps.

1.2. Smart5Grid objectives in the 5G-PPP perspective

The underlying technology developed in the context of the 5G-PPP Initiative was a "key enabler" for many success stories, among which several also partially address one or more UCs for the energy sector. Examples of past 5G-PPP projects addressing the energy vertical are: (i) 5G-VICTORI [8], where one of the UC addressed smart energy metering at hight voltage (HL) and low voltage (LV) within a smart city; (ii) 5GROWTH [9], where two UCs addressed monitoring solutions for medium voltage (MV)/LV (MV/LV) power substations, and controlling solutions for LV loads, respectively; and, (iii) MonB5G [10], which adopts a hierarchical approach for flexible and efficient management of network tasks in a fault-tolerant and automated data-driven manner.

Smart5Grid's goals are in line with the 5G-PPP programme vision. More specifically, the project has been structured in a way to address the challenges and meet the objectives of the H2020 ICT-41 2020 Call "5G innovations for verticals with third party services". Key contributions of Smart5Grid are aligned with the stated aim to put forth the evolution of 5G networks with innovative strategies to enable real-time applications on the distribution level of smart grids promoting the creation of new opportunities.

Towards this direction, one of the main objectives of the Smart5Grid project is to specify and make use of the architectural and technological enhancements that were achieved by other 5G-PPP projects, as well as to bridge the gaps that were revealed by them. The Smart5Grid aims to address the following challenge: the creation of an open experimental platform for the energy industry that will enable the development and the verification and validation of both the internal and the 3rd party NetApps. The project's NetApps will be then deployed via the specific use cases in controlled, but operational environments over 5G. More specifically, the identification of the 5G technological components that are relevant to the project will be defined by taking into consideration the nature of the use cases as well as the associated performance requirements that will emerge during the evolution of the project.

Based on the alignment of Smart5Grid alongside the previous 5G-PPP projects' results, one of the goals of the project is to identify the gaps and elaborate on the fields of 5G-RAN, MEC, network slicing, resource orchestration, as well as on the communication needs of the emerging smart 5G grids. This way, we will address one of the main 5G-PPP challenges which is the delivery of solutions, architectures, technologies, and standards for the ubiquitous next generation communication infrastructure.

Moreover, the fact that Smart5Grid will provide an integrated end-to-end solution for the energy vertical will reinforce the 5G-PPP vision for the opening of new innovation opportunities.

Finally, the project's consortium consists of both 5G telecommunication and energy distribution industries. As a result, this will accelerate synergies, knowledge transfer, and feedback from other 5G-PPP projects which is in line with the objective of 5G-PPP to ensure the access to a wider panel of services and applications for everyone and everywhere at lower cost.

1.3. Deliverable context on the overall WP2 objectives

The overall umbrella of WP2 addresses the first two major objectives of the Smart5Grid Project. Specifically, WP2 aims to address:

<u>Objective #1:</u> To specify the critical architectural and technological enhancements from previous 5G-PPP Phases needed to fully enable an open experimental platform for the Energy vertical **(WP2).**

As part of this objective two specific milestones are to be achieved:

- the set of technical requirements of Smart5Grid, including vertical oriented and generic requirements, which is the scope of this deliverable (D2.1.);
- the novel Smart5Grid Reference Architecture which is the scope of the next technical deliverable of WP2 (D2.2);

<u>Objective #2:</u> To design, deploy, operate, and evaluate in real-world conditions the baseline system architecture and interfaces for the provisioning of an integrated, open, cooperative, and fully featured 5G network platform, customised for smart energy distribution grids (which integrates the work of two interdependent work packages, WP2 and WP3, respectively).
As part of this second objective, the specific milestone to be achieved within this Deliverable is related to the collection of functional and non-functional requirements for the Smart5Grid architecture. These requirements will serve as design guidelines for the Smart5Grid platform, on top of the previous experiences gained from past 5G-PPP phases.

1.4. Document structure

The structure adopted in this document is as follows:

- Section 1 (the present section) introduces the full scope of the context of the document.
- Section 2 serves as a guide displaying and explaining the methodology followed and the necessary templates that are created for the requirement gathering.
- Section 3 is organized per use case. For each of the use cases, it begins with a detailed analysis of the respective UC, following by a high-level approach of the UC-specific NetApps and concluding with the identified requirements.
- Section 4 is dedicated to the high-level requirement for the Smart5Grid platform and it is organized by major architectural layers. For each one of the layers, we present a general description, the functional- and the non-functional requirements. Where relevant, sub-components of the architectural layer are also detailed by following the same structure, that is: general description, functional- and non-functional requirements.
- Section 5 concludes the deliverable
- Section 6 summarises the list of References. The last section is dedicated to Annexes, where empty templates used for collecting requirements are presented.

2. Methodology for UC elaboration and gathering of architecture requirements

As part of this deliverable three major objectives need to be reached:

- definition and description of the Smart5Grid UCs by identifying the relevant stakeholders´ interests and actors' roles in each of the four UCs;
- map actors' interactions and their special relationships in a structured manner, such as UC diagrams;
- collect and analyse high-level requirements for the Smart5Grid Architecture coming from the UCs such as vertical oriented requirements and generic requirements.

For the requirements elicitation, we have adopted an iterative process for collecting, understanding and continuously agreeing on the needed level of detail for each type of requirements which will be summarized below. The framework for UC elaboration and gathering of requirements consists of three paths of actions:

- Tailor the IEC 62559-2:1015[6] smart grids standardized template for requirements collection based on the scope of the Smart5Grid project. The aim of this template is to detail the use cases from the collaborative point of view of the actors involved in each UC, such as energy vertical experts, network operators or 5G network facilitators, NetApps developers, and integrators.
- Design a simplified template for collecting the 5G network requirements, specific for each UC.
- The approach used for gathering high-level requirements for the Smart5Grid platform involved two stages: (a) identification of general platform requirements from the DoW by the partners involved in the design of the Smart5Grid Architecture; (b) holding several webinars and dedicated meetings where the partners in charge of the development and/or definition of the specific components of the Smart5Grid architecture were requested to present their vision and to provide high-level functional and non-functional requirements, with a focus on the three major architectural blocks: (i) Open Service Repository; (ii) Validation and Verification Framework for the NetApps; and (iii) Management and Orchestration.

The iterative process consisted of collecting intermediate drafts of the first template based on IEC standard and arranging dedicated meetings with each of the teams in charge of the specific UC description to clarify ambiguities, terminology and definitions, as well as to understand in depth their needs as users of the Smart5Grid platform. These meetings also facilitated the next action steps of the UCs elicitation framework, such as the design of the second template specifically dedicated to the UC-specific 5G network requirements and for guiding the workshops for collecting the functional and non-functional requirements of the architecture.

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[6] IEC: 62559-2:2015: "Use case methodology – Part 2: Definition of the templates for use cases, actor list and requirements list". For further details see: https://webstore.iec.ch/publication/22349

The IEC 62559-2:2015 document defines the structure of a use case template, template lists for actors and Requirements, as well as their relation to each other. In this document, a standardized template for the description of use cases is defined for various purposes like the use in standardization organizations for standards development or within development projects for system development.

2.1. Templates for collecting UC requirements

2.1.1. Template for the UC description

This template is intended for the collection, in a structured and standardized form, of the relevant information for the elaboration of the UCs as reflected by the demonstration pilot sites to be implemented as part of work packages WP5 and WP6 of the Smart5Grid Project. Its focus is on the business and functional layers, as described by the Smart Grid Architecture Model (SGAM) [11]. Thus, the outcome of this template serves for the elaboration of the business use cases (BUCs) and the high-level description of the system use cases (SUCs). The latter describes the relevant functions for supporting the corresponding BUC of the demonstration sites.

The template is compliant with the IEC 62559-2:1015 Standard, which defines the structure for collecting requirements for smart grid projects, including the roles and types of possible actors involved in the UCs, as well as their relation to each other. The IEC 62559-2:1015 Standard also provides guidelines on what to point out in the storyline of the UC in order to get consistent information from which one could elaborate on specific UC requirements. The template is also in line with the guidelines set up by the European Smart Grids Task Force in 'Standards and Interoperability for Smart Grids Deployment' (2019) [12].

Within this template, in order to fully cover the Smart5Grid needs for UC specification, the following key sections needed to be detailed: location, the scope and the objectives of the UC both at the business and service levels, description of the actors and stakeholders involved in the UC and their roles, expected services to be demonstrated, their scenarios, and their sequence diagrams. The sequence diagrams aim to be an illustrative demonstration of the UC.

The empty form of this template is provided in the Annex.

2.1.2. Template for 5G network requirements

In the procedure of identifying the requirements for the 5G network infrastructure a large number of use cases have been described and analysed in the context of standards bodies, such as 3GPP[7] and ITU-T[8], industry forums such as NGMN[9] and last but not least the projects of phase 1 of the 5G-PPP. 5G service types, which have been consolidated and agreed in the context of 5G-PPP and different SDOs are as follows[10]:

- enhanced Mobile Broadband (eMBB) [13];
- Ultra-Reliable and Low Latency Communications (URLLC); and

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[7] The 3rd Generation Partnership Project (3GPP) unites [Seven] telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as "Organizational Partners" and provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies. The project covers cellular telecommunications technologies, including radio access, core network and service capabilities, which provide a complete system description for mobile telecommunications. The 3GPP specifications also provide hooks for non-radio access to the core network, and for interworking with non-3GPP networks. For further details see: https://www.3gpp.org/

[8] ITU's Telecommunication Standardization Sector (ITU-T) assemble experts from around the world to develop international standards known as ITU-T Recommendations which act as defining elements in the global infrastructure of information and communication technologies (ICTs). Standards are critical to the interoperability of ICTs and whether we exchange voice, video or data messages, standards enable global communications by ensuring that countries' ICT networks and devices are speaking the same language. For further details see: https://www.itu.int/en/ITU-T/about/Pages/default.aspx

[9] The vision of the NGMN Alliance is to provide impactful guidance to achieve innovative and affordable mobile telecommunication services for the end-user with a particular focus on supporting 5G's full implementation, mastering the route to disaggregation, sustainability and green networks, as well as starting work on 6G. For further details also see: https://www.ngmn.org/

[10] Also see, among others: International Telecommunication Union – Radiocommunications Sector (ITU-R): Recommendation ITU-R M.2083-0 (09-2015): "IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond".

- massive Machine Type Communications (mMTC).

eMBB is the natural evolution of the mobile-broadband services of 4G, enabling even larger data volumes and further enhanced user experience, for example, by supporting even higher end-user data rates.

URLLC has two parameters, namely low-latency and high reliability. URLLC provides ultra-high network reliability of more than 99.999% and very low latency (of 1 millisecond) for packet transmission. These two features make URLLC a primary use case scenario for 5G as it ensures data transmission within a few milliseconds, with high reliability.

mMTC use case category is characterized by a very large number of connected devices transmitting a relatively low volume of non-delay-sensitive data. Devices are required to be low cost and have a very long battery life.

Network slicing facilitates meeting the requirements of diverse UCs by dividing a physical network into multiple dedicated logical networks. In particular, 5G network slicing will allow the power grid to flexibly customize specific slices with different network functions and different service level agreement (SLA) assurances according to the different requirements of the various services on a power grid [14]. Therefore, the Smart5Grid architecture will empower its use [15].

The following template was designed in order to collect 5G requirements from the UCs.

Table 2: Template for collecting 5G Network requirements

	Use case Requirements	Units	5G Use case category/Slice Type		
			URLLC	eMBB	mMTC
1	Communication service **Availability**	%			
2	Communication service **Reliability**	%			
3	End-to-end **latency**	ms			
4	RAN **latency**	ms			
5	Data rate	Mbps			
6	Device Density	Dev/km2			
7	Location Accuracy	m			
8	Security	Y/N			
9	Network slicing	Y/N			
	Additional Requirements				
10	Type of connection				
11	Type of device				

2.1.2.1. Definitions

Communication service Availability is defined as the percentage value of the amount of time the end-to-end communication service is delivered according to an agreed quality of service (QoS), divided by the amount of time the system is expected to deliver the end-to-end service according to the specification in a specific area [16].

Communication service Reliability is defined as the percentage value of the amount of sent network layer packets successfully delivered to a given node within the time constraint required by the targeted service, divided by the total number of sent network layer packets [16]. The reliability rate is evaluated only when the network is available.

End-to-end latency is defined as the time it takes to transfer a given piece of information from a source to a destination (from the moment it is transmitted by the source to the moment it is successfully received at the destination, measured at the communication interface) [17].

RAN latency is defined as the time it takes for a packet of data sent from a source (UE/mobile device) to be received at the Radio Access Network (RAN) Base Station (i.e., e/gNB[11]). RAN Latency is measured in milliseconds.

Data rate is defined as peak and average values of data rates to be provided (also useful or mandatory to provide is the user experienced data rate: the minimum data rate required to achieve a sufficient quality experience (QoE)), with the exception of scenarios for broadcast type services, where the given value is the maximum that is needed). The data rate is a time-variable function. It might be important to define some parameters (e.g., peak, burst, average) in order to better describe the data rate.

Device Density refers to the number of devices in a specific area.

Location Accuracy involves the process of determining where a device is located.

While the following definitions are not part of the template for gathering 5G network requirements, they are useful because during the following sections they are mentioned several times as part of the UC elaboration.

Security refers to the level of importance for attack prevention. This is an attribute required in all the UCs and set up with high level of importance.

Network slice is defined as a logical network that provides specific network capabilities and network characteristics [18]. All UCs require slicing services. Besides the three categories of slicing services enumerated in the template for the collection of 5G network requirements from the UCs (e.g., eMBB, URLLC, and mMTC), network slicing is also needed in the context of the Smart5Grid platform as a Service-Based Architecture (SBA).

In the following, we provide a comparison of capabilities between the 4G and the 5G technologies based on the proposed set of requirements. For visualization purposes, the network requirements for each of the UCs will be also plotted on radar charts. A radar chart is a typical graphical method for showing multivariate data in the form of two-dimensional plot of three or more quantitative variables and where all axes are starting from the same point. In the literature they may be also known as spider charts, polar charts, star plots or web charts. It is to be mentioned that at least one attribute and one metric shall be shown on each of the axes.

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[11] Node B is the radio base station for 3G UMTS (Universal Mobile Telecommunications System), while eNodeB is the radio base station for 4G LTE (Long Term Evolution). The gNB is the logical 5G radio node, the equivalent of what was called NodeB in 3G-UMTS and eNodeB or eNB (i.e., evolved Node B) in 4G-LTE, is now called as the "next generation NodeB".

Table 3: Capability comparison between 4G and 5G technologies

	General 5G/4G capabilities	Units	4G Values	5G Values
1	Communication service **Availability**	%	99.9%	99.999%
2	Communication service **Reliability**	%	99.9%	99.999%
3	End-to-end **latency**	ms	25	15
4	RAN latency	ms	<10	1-2
5	Data rate	Mbps	400	1000
6	Device Density	Dev/km^2	100K	1000K
7	Location Accuracy	m	<5	<1
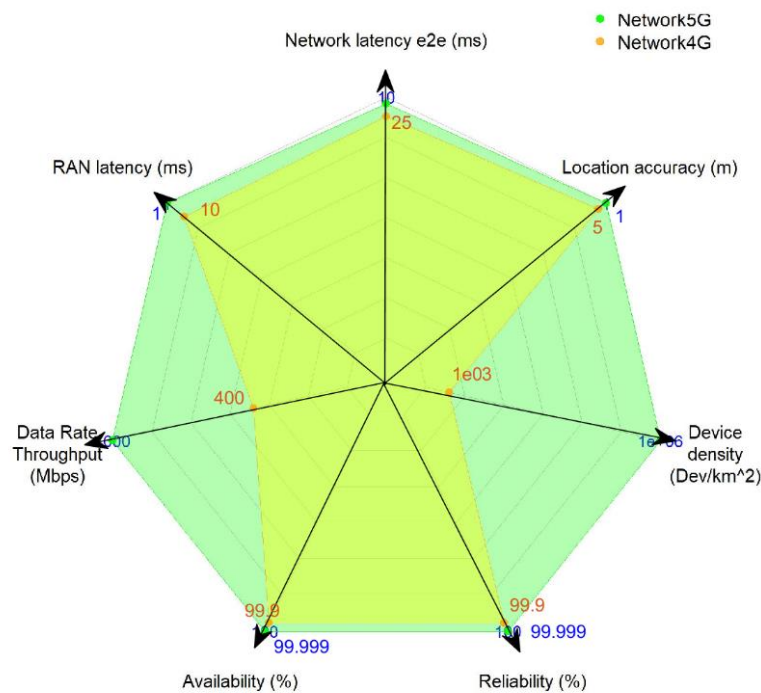
Figure 2: Radar chart showing the capability of 4G and 5G technologies

2.2. Methodology for derivation of high-level architectural requirements

The first step for the collection of architectural requirements was to extract the general Smart5Grid platform´s requirements from the DoW. This, together with the requirements collected from the definition of the UCs, allowed us to provide an initial update of the architecture. Several architectural layers were identified, so the next natural step was to delve deeper in the requirements of each of these architectural blocks. The partners involved in the definition and development of the specific components of the Smart5Grid architecture, led by the corresponding task leader, were requested to present their vision and

to provide high-level functional and non-functional requirements based on the identified UC´s needs and the purpose of the platform as an open 5G experimental facility.
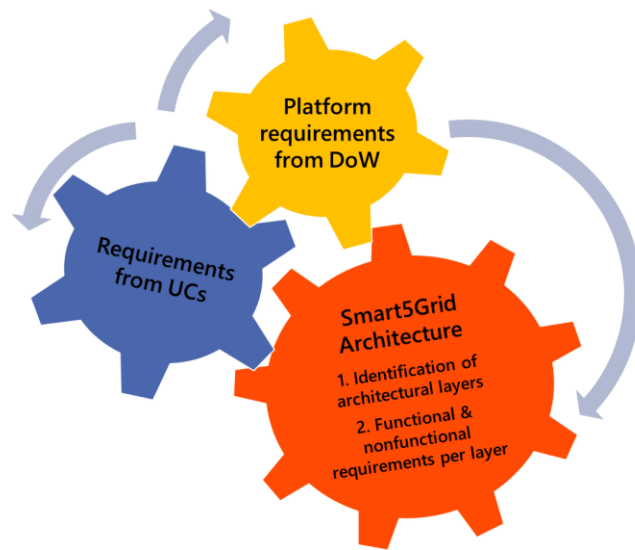
Figure 3: Methodology for gathering architectural requirements for the Smart5Grid platform

3.   Analysis of the use-cases

3.1. Overview of the UCs in the context of Smart5Grid

The UCs addressed by the Smart5Grid Project are focused on the upstream part of the grid, after the electricity meter. Specifically, they target operations of distribution and transmission system operators, as well as distributed renewable-based power generation. They cover a very diverse set of applications such as advanced self-healing automation systems, enhanced worker safety for high voltage power substations, wide area monitoring of cross-border regional power flow at transmission power level, and monitoring at millisecond level of multiple distributed renewable energy source (RES) generating units. The location of the four UCs of the Smart5Grid is shown in Figure 4. A brief overview of the four UCs to be demonstrated as part of the Smart5Grid project is given below.

Figure 4: Location of the demonstration sites of the Smart5Grid

(UC#1) Automatic Power Distribution Grid Fault Detection, in which a portion of the MV grid will be equipped with the most advanced grid automation system, called Smart Fault Selection (SFS). This system is able to identify the faults along the MV feeders, insulate them without opening the switchgear in the primary substation and re-supplying the rest of the customers in the healthy part of the grid in less than one second. Such grid automation system requires high responsiveness of the digital communication layer, with a total end-to-end latency among all the field devices along the feeder up to 40 ms, as well as stable performance in all conditions. For this purpose, a virtual communication monitoring tool will be developed and integrated in this grid automation system to continuously monitor the RAN segment of the 5G infrastructure. Important to be noted that this particular grid automation framework has been already implemented with dedicated Optical Fiber (OF) and 4G/LTE connectivity. While OF guarantees the needed communication requirements for this automation solution, it also comes with significant investments for the implementation and lacks in terms of flexibility for re-deployment of the system in a different location.

The automation solution implementing 4G/LTE on the communication layer gives the needed flexibility with acceptable connectivity features in normal conditions. However, this later solution gives no guarantee on the quality of the communication service (maintaining the required communication KPIs) and it can be exposed to congestion issues in densely populated areas. Indeed, the experience shows that, when latency degradation occurs in 4G/LTE connections, it is difficult to recognize what might have caused an abnormal operation in the SFS automation system. As a consequence, the current practice requires a series of actions for the verification of each segment of the grid automation infrastructure, either for the DSO's technical back-office, for the Telco operator, or both. In particular, the first step for the DSO is to send a field operator to locally check the status of the field devices, antennas and so on. The proposed communication monitoring tool can provide a flexible approach for the troubleshooting of the RAN segment of the communication infrastructure and ensure:

- Reliability of the communication infrastructure within the given Service Levels (very crucial for ensuring the correct working conditions for the SFS).
- Operative costs reductions, since field operators will perform local checks only if the problem is clearly identified to be in the field equipment.

(UC#2) Remote Inspection of Automatically Delimited Working Areas at Distribution Level, to be demonstrated in a remote area, Garraf Natural Park, outside Barcelona, Spain. The business scope of this UC is to introduce an automated process that enables the detection of workers and their working tools that are accessing a primary substation and crossing the borders of a delimited (forbidden) area. The detection, made via the use of cameras and other ultra-wide bandwidth (UWB) sensors has to be reliable and very fast, which is why a 5G network is chosen as the underlying technology to provide low-latency and fast processing capabilities to this UC. Activities in a primary substation are considered of high-risk, due to high voltage energized equipment involved. Therefore, safety of the workers to perform such activities is a top priority for E-Distribución Spain. A standardized safety procedure requires that the workers will be able to work only in safety areas where all the elements are deenergized. So, whenever any worker goes out of one of the volumetric delimited safety areas, the system needs to detect it and to automatically send a warning signal. The delimitation must be in real-time so the data processing and warning signal must be sent as fast as possible. That will be possible thanks to the use of a 5G NR private network with edge computing capabilities, providing low latency and high data transmission capacity.

(UC#3) Millisecond Level Precise Distributed Generation Monitoring, to be demonstrated at a wind farm located in the Silven region of South-East Bulgaria. The scope of this UC is to demonstrate a millisecond level precise distributed generation monitoring. Specifically, in the context of this use case, the real-time monitoring of a wind farm is going to be performed, by using the emerging capabilities of 5G telecommunication networks. From the wind farm owner perspective, real-time monitoring is vital for the proper operation of the wind farms mainly for two reasons: on the one side, being aware of the real-time condition of the farm, the owner can predict and prevent on time potential future malfunctions that will cause significant financial losses; on the other side, the wind farm owners, acting both as a Balancing Responsible Party (BRP) and Balancing Service Provider (BSP), are accountable for the potential imbalances and for the provision of the committed services in the real-time electricity market, respectively. From the grid operator perspective, increasing grid observability, particularly at and below MV level, is of critical importance, especially in the context of increased penetration of small and distributed energy resources (DER) such as wind farms, photovoltaics, or small hydro power plants. While the majority of small wind

farms possess a local Supervisory Control And Data Acquisition (SCADA) system provided by the manufacturer of the wind turbines, this system is not directly connected or integrated with the central SCADA of the DSO. As such, their visibility at DSO level in terms of real-time injected power production is missing. In the context of this UC, the real-time monitoring of active and reactive power output of the wind farm will be also made available to other third parties such as DSO/TSO or an aggregator.

To summarize, high granularity precise monitoring of the real-time power production will offer wind farm owners the capability to minimize their cost and, at the same time, being eligible for the provision of ancillary and innovative flexibility services through flexible plant management. At the same time, accurate monitoring of DER offers precious information to the DSOs for enhancing the grid observability and to better (optimally and securely) operate the grid. This UC will demonstrate a working solution of a distributed RES generator/producer, which could be adopted and implemented on a bigger scale for other RES producers during the post project market exploitation stage. The strict requirements set by power system operators for the service provision by RES requires highly reliable and secure telecommunication connection between the physical asset (wind farm) and the dispatch centre of the grid operator.

(UC#4) Real-time Wide Area Monitoring, to be demonstrated at the cross border between Greece and Bulgaria. The scope of this UC is the real-time monitoring of a geographical wide area where cross-border power exchanges take place. Specifically, in the context of this UC, the interconnection power and energy flow between Greece and Bulgaria will be monitored by leveraging the advantages that the 5G telecommunication infrastructure provides. This function will be executed from the newly established Regional Security Coordinator (RSC) in Thessaloniki, Greece. The role of RSC is to promote regional cooperation and to support the strengthening of the system and market operations in the region. To achieve the enhancement of the system operation, live monitoring of the power flows between the countries under its area of interest is of vital importance. Hence, through this UC, an additional element will be developed that increases the live monitoring capability of RSC. Phasor Measurement Units (PMUs) located at the High Voltage (HV) network of the Northern Greece, monitoring the interconnection area with Bulgaria, can be used as an input in the monitoring process of the RSC. By incorporating time-stamped synchronized PMU measurements, high data and fine granularity can be achieved (transmitting the required data 50 to 60 times per second) including positive, negative and zero sequence phasors of voltage and currents. A Virtual Phasor Data Concentrator (vPDC) will be developed for the data gathering process. The utilization of the 5G in this UC contributes to the connectivity between the PMUs and the vPDC, offering its low latency and high reliability needed, due to the criticality of the UC.

A summary of the identification based on title and location of these four UCs of the Smart5Grid Project is provided in Table 4.

Table 4: Identification of the UCs

UC# - Location	Full title	Use-case ID
UC#1 - Italy	Automatic Power Distribution Grid Fault Detection	IT-FD
UC#2 - Spain	Remote Inspection of Automatically Delimited Working Areas at Distribution Level	ES-RI
UC#3 - Bulgaria	Millisecond Level Precise Distribution Generation Control	BG-DG
UC#4 - Border of Bulgaria and Greece	Real-time Wide Area Monitoring	GR-WA

3.2. UC#1: Automatic power distribution grid fault detection

The Smart Fault Selection (SFS) with automatic self-healing is a grid automation framework developed by E-Distribuzione (EDI) in two stages. The first functionality, called FSL (Italian acronym for "Funzionalità di Selettività Logica", Logic Fault Selection) has been developed as part of the Puglia Active Network project[12], funded within NER300 framework[13], in which the Italian region of Apulia has been converted into the first smart region in Europe. By leveraging on the digital layer, this functionality is capable to identify any fault in the MV grid without opening the switchgear in the primary substation. Besides, developing this enhanced automation framework, more than 200 primary substations and over 8000 secondary substations have been fully digitalized to support the FSL functionality. On a later stage, the H2020 Replicate project (GA 691735)[14] extended the outcomes of Puglia Active Network adding the automatic self-healing feature. This new automation framework, called Smart Fault Selection (SFS), allows to identify maximum current and directional earth faults along a MV feeder, insulating the affected grid's trunk without opening the circuit breaker in the primary substation. Subsequently, the automatic self-healing function provides the energy for the residual portion of the grid after the affected trunk.

It is also worth mentioning that nowadays the SFS is the benchmark for all other grid automation systems worldwide, in terms of grid resilience and responsivity.

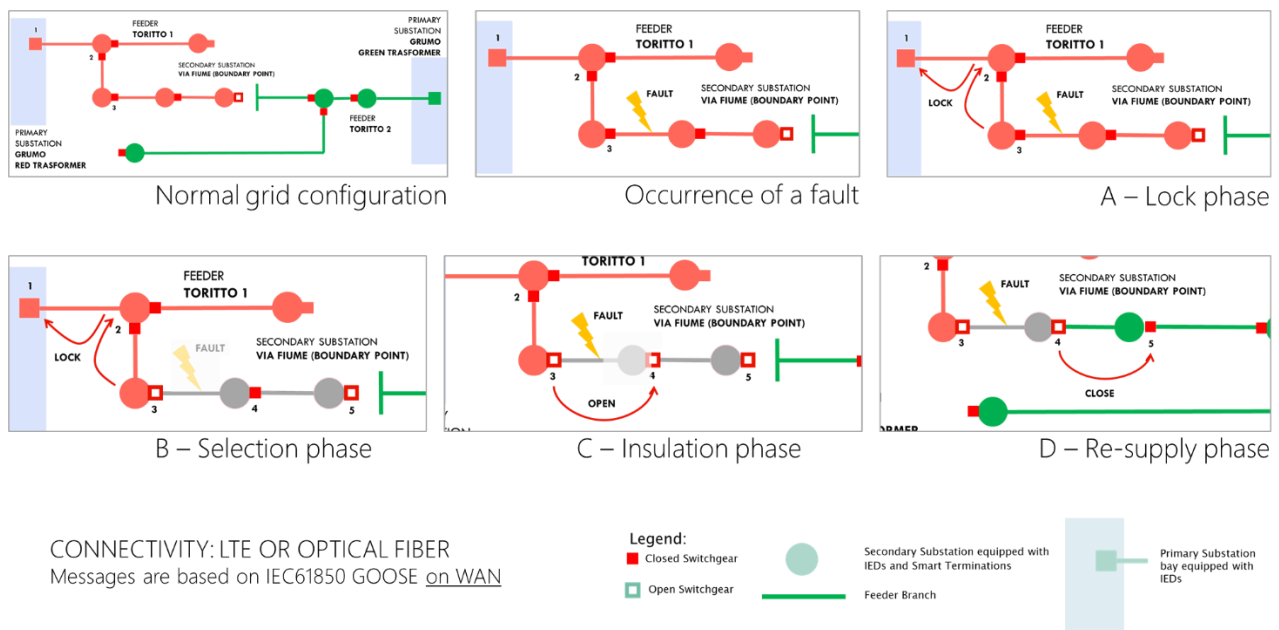Figure 5: Smart Fault Selection phases

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[12] https://www.e-distribuzione.it/progetti-e-innovazioni/PAN.html. In Italian only.

[13] https://ec.europa.eu/clima/eu-action/funding-climate-action/ner-300-programme_en

[14] https://replicate-project.eu

Figure 5 shows in a simplified grid diagram with the four steps needed for the FSL to perform the automatic self-healing function of the MV grid.

A) The fault is digitally localized through an exchange of GOOSE[15] messages among the field devices along the feeder. Those devices understand which one is the closest to the fault point and all the others (1 and 2) set themselves in a temporary lock status.
B) The faulty trunk is selected by opening the switchgear (3) closest to the fault before the automatic opening of primary substation.
C) The next switchgear after the fault point (4) opens automatically, insulating the faulty trunk.
D) The border switchgear (5) is automatically closed, re-supplying energy from a different feeder, and thus performing the automatic self-healing function.

Those four steps are executed in less than one second, such that the majority of the customers along the feeder will not be affected from the fault, while they barely recognize a transitory variation of the voltage, similar to a glitch on the power supply. After this automatic phase is concluded, the SCADA system alerts the operators in the regional control room, who can perform the fine reconfiguration of the grid via remote control and send the field operators to fix the issue. The most critical action is to execute the step B (opening the switchgear number 3) within 80ms. Otherwise, in case of delays in the selection phase (B) higher than 100ms from the occurrence of the fault due to delays in the message exchange, the primary substation opens the feeder and the automation fails.

The following example is used to make a better understanding on the assumptions made when we are calculating the SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) indices. Specifically, in terms of quality of service, we may assume to have 4 groups of customers along the feeder. Let's assume some indicative realistic quantities to better understand what happens:

1. A certain number of customers in the trunk automatically selected and insulated by the SFS (let's suppose 500 final customers) will be re-supplied via remote control in less than 3 minutes. For those clients, the duration is considered "short".
2. A certain number of customers in the portion of trunk selected by field operators will have a longer duration of the outage, for example 200 customers for 30 minutes. This is considered long term duration.
3. A certain number of customers, for example 50, in the faulty grid trunk will experience a longer duration of the fault, until the problem is fixed. Let's assume 2 hours (even in case of complex works, a generator is installed to minimize the impacts).
4. The majority of customers will either not suffer of the outage (before the node 3) or experience a so called "transitory" event, when the outage is shorter than one second, after node 4. For example, 4.500 customers for who there will be no outage.

The advantage of this automation framework is visible on both of the grid's technical indicators, SAIDI and SAIFI , which, in different proportion, are significantly reduced, as it was exemplified above.

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[15] IEC61850, Communication networks and systems in substations, International standard [available online: https://webstore.iec.ch/publication/6028] defines the GOOSE (Generic Object Oriented Substation Event) messages communication protocol for information exchange between IEDs (IED – Intelligent Electronic Device) in a power substation.

Such grid automation framework is a consequence of the digitalization of the grid devices. In the past, each component was only able to rely on the measurement of the electric parameters, such as 3-phase voltages, currents, phases and their variation, and then trigger the fault event based on set conditions. Today, the digital layer allows field devices to directly interact among them and quickly understand which grid element has to be opened to insulate the faulty trunk. This implies that a variety of field devices, either in the primary substation or in the secondary substations, must communicate within a very strict timeframe, with low latency in any environmental conditions. This communication is realized through an exchange of GOOSE messages among all the filed devices along the feeder and in the primary substation.

In the context of Smart5Grid, the focus of this UC will be on the monitoring of the communication layer of this complex automation framework. As it was mentioned in the previous section of this document, the current deployed solutions of the FSL used either dedicated OF or 4G/LTE connectivity. While OF guarantees the needed communication requirements, it also adds a significant investment cost for large scale deployment of the system, and it also lacks in terms of flexibility for re-deployment of the system in a different location. 4G/LTE offers acceptable connectivity features in normal conditions. However, in periods and locations with congested mobile traffic (e.g., in densely populated areas) the 4G/LTE solution gives no guarantee on the quality of the communication service, and thus endangering the proper operation of the FSL automation system. One of the challenges in case of abnormal operation of the FSL automation framework is to discriminate where the abnormality comes from (e.g., from the digital communication layer or from the grid side equipment involved in the automation system). Because of this complex interaction between a wide range of field devices along the feeder, it was impossible to shift this complex automation framework to a fully virtualized edge paradigm envisioned by the Smart5Grid. At the same time, as we operate this automation system in a real 5G public infrastructure and a real grid, we need to face with the constrains of Enel cybersecurity rules, that impose the use of an end-to-end VPN tunnel for any connection between field devices and the regional control room, that can't be opened along the chain. For this reason, the option of a monitoring tool has been considered as the proper trade-off to allow testing 5G connectivity for the SFS framework, together with a useful support for the teams responsible to identify and solve any connectivity issue between the regional control room and the field devices.

This automation framework requires very specific transmission parameters to be monitored, as better detailed later on: when a fault occurs in the grid, each component must be ready to act within the given strict timeframe. EDI's technical back-office has a reduced set of information to check the performance of the communication layer. For example, the SCADA system only provides information about reachable or unreachable field devices. However, the information about the communication quality is out of the scope of this system. In day-by-day operations, there are two levels of dedicated teams that supervise the availability of the communication layer and its reliability. The problem nowadays is that there is nothing that performs a constant monitoring of the communication layer, that is composed of different elements. In case of mobile network, this layer is seen by the DSO as a black-box, in which the only way to check the connection quality is to perform end-to-end tests. Besides this, we need to consider that all the field devices are in "competition" with all the users of the public telco infrastructure, exposing the grid automation system to congestion issues. Most of the times, only when the automation functionality fails, a series of ex-post analysis are performed to identify the problem and fix it, often with several time-consuming activities.

In the majority of cases, the failures are related to underperformances of the communication layer, that could also be aleatory (like in case of traffic congestions or severe weather conditions).

In this scenario, the proposed monitoring tool aims to perform a constant monitoring of the RAN segment of the 5G network, performing statistics and analysis of the connection. This will speed up the troubleshooting of the communication layer: if the last segment is working properly, there is no need to send an operator on field to perform local checks. Since the main tasks of field operators are focused on grid operation (realizing new connections, fixing the grid and so on), this kind of local communication connection checks could last up to few days to be concluded. Furthermore, excluding this last communication segment, the troubleshooting process could imply a consistent contraction of the time needed to identify which segment of the telco infrastructure is affecting the communication performance. The advantage is relevant also for the Telco operator technicians, since they will receive a more accurate description of the fault, reducing the perimeter of their investigation.

Business Goals: The aim of this monitoring tool is, on the one hand, to reduce the time and effort needed to troubleshoot the communication issues between the regional control room and the field devices; and, on the other hand, to recognize in the early stages the degradation of the communication performance, anticipating the event of compromising the performance of the grid automation framework. This monitoring tool will be implemented in the for of a NetApp which will ensure:

- Reliability of the communication infrastructure, within the given Service Levels (very crucial for ensuring the correct working conditions for the SFS grid automation system).

- Operative costs reductions, since field operators will perform in-site? local checks only if the problem is clearly identified to be in the field equipment.

Service Level Objectives: At present, the real-time self-healing is implemented in several EDI substations and mainly rely on Optical Fiber connectivity. While the communication performances are good and constant, this solution is costly and less flexible if compared to mobile technology that allows more and more devices to be quickly connected. The 5G technology is seen as an appealing trade-off between performance, cost, and flexibility for expanding the EDI's advanced self-healing solution at a larger scale within the distribution grid. The **service level in terms of latency** is expected to be between the performance of **4G and Optical Fiber (from 5 to 80 milliseconds)**, with a **better guaranteed performance** than 4G.

Expected benefits:

- **Business:** The aim of this implementation is to ensure that the connection parameters are continuously within the expected range, so that the automation framework will be ready to perform as expected. Besides this, troubleshooting activities will be simplified, reducing the need for sending field operators to perform connectivity checks in the substation and providing the technical back-office with more information about the connection performances and statistics. Moreover, in case the statistics will demonstrate that the latency is significantly dropped to a few milliseconds, more secondary substations along the feeder could be enabled to perform the SFS, increasing the number of trunks and reducing the number of residual customers affected by

unexpected grid faults. In areas where the SFS has been implemented, the reduction of SAIDI[16] has been of 18,2%[17], from 75,15 to 61,61 minutes per customer. Furthermore, SAIFI[18] index has also dropped 5,07%, from 5,95 to 5,65. Instead of SAIFI, for Italian regulation, the reference indicator is the NILB (Italian acronym for Number of long and short interruption per customer): since both FSL and SFS have impacts on the short ones, the benefits on this indicator is even more consistent[19]. Such quality indicators could have a positive impact only in case of wide implementation of the automation system. This test aims to verify that 5G can provide the adequate communication parameters in a constant and stable manner, giving the needed flexibility for a broader implementation of such automation framework.

- **Economic:** Operational cost reduction is expected. Having a clear picture of the performance of the RAN network segment allows to send EDI technicians on field only if strictly needed, not as a normal part of the troubleshooting process. Moreover, using 5G connectivity will allow more flexibility compared to optical fibre, accelerating the implementation of such an advanced automation system with lower costs for activating the connectivity. This flexibility will allow equipping more and more Secondary Substations, extending the granularity of the system, without the need of significant capital investment that is required for implementing optical fibre connectivity. In areas where only FSL and full SFS framework have been implemented, the reduction of SAIDI and SAIFI implied an economic benefit. The Italian regulatory frameworks, indeed, set the yearly quality target per region. Furthermore, they award those DSOs that perform under the target with monetary incentives and they penalize those DSOs that perform above the target. In case the underperformance of the digital layer causes a failure in the automation system, all the economic benefits are lost.

- **Social:** In case of broader implementation of such advanced automation framework, the local community (citizens and companies) will benefit by a more reliable power supply, increasing the trust on the electric system. If the target is to achieve the full energy transition towards electrification of polluting applications (like industry), the grids must be reliable and affordable, otherwise the final customers will not change their behaviour.

Table 5 summarizes several relevant business-related KPIs for the Italian demonstrator. Although during the deployment and implementation tests of the demonstrator, these KPIs will not be tested, they serve as indicative starting points for market analysis and potential business models for the outcome of the

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[16] System Average Interruption Duration Index (SAIDI) is commonly used as a reliability indicator by electric power utilities. SAIDI is the average outage duration for each customer served, and is calculated as $SAIDI = \frac{\sum U_i N_i}{N_T}$ where N_i is the number of customers and U_i is the annual outage time for location i, and N_T is the total number of customers served.

[17] The calculation of the benefits comes from PAN project, calculated by comparing the average yearly SAIDI and SAIFI in the period 2017-2019 with the period 2020. The maximum benefit has been in an area with low customers' concentration, where the reduction reached over 44% for SAIDI and over 27% for SAIFI.

[18] System Average Interruption Frequency Index (SAIFI) is commonly used as a reliability indicator by electric power utilities. SAIFI is the average number of interruptions that a customer would experience, and is calculated as $SAIFI = \frac{\sum \lambda_i N_i}{\sum N_i}$ where λ_i is the failure rate and N_i is the number of customers for location i.

[19] NILB, calculated as SAIDI, considering also the short failures in the λ_i. The reduction calculated with the same data has been of 12,92%, from 11,14 to 9,70 overall faults per customer in the reference area.

Smart5Grid project. Such type of analysis will follow in the last technical deliverable of WP2, D2.3, and in D7.2 of WP7.

Table 5: Summary of business KPIs for the UC#1

Business KPIs	Additional explanation	Means of verification	Indicative quantitative values
Reduced CapEx	No need for Optical Fiber	Comparison of pilot actual cost with similar implementations with Optical Fiber.	Estimated to be reduced by 3.000€ per connection in urban areas. Outside of urban areas (even if close to the city boundaries), Optical Fiber is not even an option.
Reduced OpEx	Less interventions of field technicians for 1st level connectivity troubleshooting	Annual maintenance statistics for "communication" activities	Estimated to be reduced by 5%
Reduced time for fault detection, isolation & self-healing of the grid	Reduced time for the 1st level of dichotomic selection	Annual maintenance statistics	From more than 3 minutes to less than 1 second.
Increased grid reliability	Expansion of SFS solution to more substations	Annual communication statistics	If the latency constantly stays below 4 ms, there will be room for further analysis

3.2.1.   Actors, conditions, and technologies involved

3.2.1.1.   Actors and stakeholders

As part of this section, we aim to identify all the stakeholders and actors involved in the UC and to describe their role(s) and their interests in the use cases, as well as their interaction.

Main Actors:

- **TLC-Team** (TLC, Italian acronym for Tele-Control) is a dedicated team within EDI responsible for operating the Remote-Control devices. To guarantee the highest standards of electric grid, all industrial control systems on field are constantly monitored, to ensure the availability and reliability of the connection during outages.
- **GDS** (Global Digital Services) **Control Room** personnel: Enel's Group business unit responsible to supervise the IP connectivity of all business lines, including offices and power plants.

Other actors:

- Within Enel Group:
  - **Contracted Service Providers** (e.g., WI3): Provide support in case of connectivity troubleshooting, for example in tunnelling analysis or router complex configurations.
  - **Regional Control Room (CO)** remotely operates the grid. All devices on field are connected to the CO.
  - **Field Devices** allow CO to operate the grid and are connected peer-to-peer to the CO systems.

- o **Field Work-Force,** asked to go on field in case of field devices malfunctioning, makes the on-site troubleshooting and fixes the issue (if any).
- **TELCO:** Provides the connectivity between the Remote Control-Room and the Field Devices.
- **Net-App providers** will perform the connectivity tests and will make available the information to TLC-Team, GDS and TELCO personnel.

Stakeholders:

- **EDI** (E-Distribuzione Italy, the DSO): ensures the quality of the power supply to its customers. The company as a whole is the main stakeholder of the end-to-end communication infrastructure.
- **Grid final customers and prosumers,** who need a reliable and affordable power grid.
- **National TSO,** who is responsible for the national and pan-European infrastructure.

Table 6: Summary of Actors involved in UC#1 and their description

Actor	Type	Actor Description
TLC-Team	Person (team)	Dedicated team of EDI, responsible for operating the Remote-Control devices.
EDI	Company	Ensures the quality of power supply to its customers. For this specific UC, it provides the field facilities and devices.
GDS	Person (team)	In the scope of the UC, GDS operates the Enel's group IP network in 24/7 shifts, providing the overlay connectivity between the Supervisory Control and Data Acquisition (SCADA) and the field router.
Contracted Service Providers	Company	Provide support in case of connectivity troubleshooting, for example in tunnelling analysis or router complex configurations.
Regional Control Room (CO)	Person (team)	It is a pool of Distribution Management System Operators, working in 24/7 shifts, who operate the grid
MARETC	System	System used to engage the field workflow. This is an internal system used by EDI to engage operative people that need to operate on field to solve a problem on the grid.
SCADA	System	Supervisory Control and Data Acquisition Systems, which are used for grid operation
HUB	System	Central device deputized to collapse all end-to-end tunnels towards the field router. It manages the traffic exchange between SCADA systems and field devices and the traffic sent by a field device and directed to another. To avoid a single point of failure, all field routers have always a session with two different remote HUBs.
Grid	Infrastructure	For clarity purposes, whenever a "grid" is mentioned in this document, it always refers to the electric distribution infrastructure.
Field devices	Devices	All field devices installed in a power plant, used for remote operation of the grid. All the devices are connected to a field router.
Field router	Device	It is the router installed in a power plant that allows the connection between field devices and the SCADA system.
Field work-force	Person (team)	Field technicians responsible for the grid operation. When needed, they are requested to perform local checks and replace the field devices.
TELCO	Company	Provides the underlying connectivity between CO and the Field Router and operates the TELCO infrastructure.

Net-App providers	Company	They will perform the connectivity tests and will make available the information to TLC-Team, GDS and TELCO
Grid final customers and prosumers	Stakeholders	They need a reliable and affordable power grid
National TSO	Stakeholder	Responsible for the national and pan-European infrastructure

3.2.1.2. Conditions and technologies involved

Real-time self-healing is one most advanced grid automation system available nowadays in the world. EDI has a fully in-house developed solution for this scope. While 4G and OF have been used in some areas of the distribution network of EDI, 5G connectivity will be used as part of the UC#1 demonstrator aiming to provide low latency and reliable communication between all the elements of the grid's protection system. Moreover, network slicing will be also implemented to guarantee high performance and security policies also in geographical area with a high-density population without the need to build a dedicated OF communication network. Wireless communication networks, like 5G, ensure more flexibility in grid management. However, not all Primary and Secondary Substations are equipped with a communication infrastructure to ensure real-time self-healing. If, for some reason, it is required to activate services like remote control and automation in some of the substations, wireless communication networks enable this, with lower time and cost than communications network based on OF. If compared with 4G, 5G offers a viable solution in case of congestion (network slicing), and a more reliable connection.

In order to ensure the safe and optimal management of power distribution grids, more and more monitoring devices are installed in many power substations to collect and exchange information with the central SCADA systems. It should be noted that typical power grids are supervised by a central SCADA system that interacts with all field devices through a dedicated communication infrastructure. A part of this system is represented by the field routers. Operators in the Regional Control Room constantly monitor the status of Primary Substations (fed in High Voltage), Medium Voltage (MV) feeders and Secondary Substations, ensuring the correct and safe operation of the distribution network in the Region.

In normal remote-control systems' operation, there is a dedicated TLC-Team that supervises the TLC infrastructures which provide connectivity between the Regional Control Room and all the field devices. In collaboration with the GDS control room, they perform connectivity checks with all power plants on a daily basis, thus ensuring the reliability of the system. In case any field device cannot be reached, GDS performs more accurate checks in the communication network, also with the support of contracted service providers in case where more detailed troubleshooting checks are needed.

In case of fault of the automation system, the TLC-Team and GDS control room need to understand which element in the complex chain has not performed correctly. Thus, they need to find solutions for correcting the problem and for preventing the situation to happen again in the future. Actually, in case of automation failure, it is very difficult to understand where the problem occurred. Thus, some inspections on the field devices, to perform connectivity checks, are needed.

Thus, besides providing the 5G connectivity for operating the grid, the aim of the demo is to provide the TLC-Team and GDS control room a flexible tool in order to understand how the 5G infrastructure is performing. In this way, any deviation from the expected performance is detected and, in case of outage, it can be more quickly understood which element of the chain did not perform properly. To do this, a

NetApp will be developed, to perform low-level connectivity checks from inside the TELCO infrastructure. Indeed, having a MEC server between the RAN and the IP network will allow both the TLC-Team and GDS to have a better understanding of the end-to-end connection performance, to better allocate resources while performing troubleshooting.

Other non-functional requirements of this UC may include:

Cybersecurity: To be compliant with all Enel's Group cybersecurity constrains while connecting field devices with SCADA system, a detailed communication flow has to be planned and agreed in the implementation phase.

Organization: It is of high importance for the EDI's Operation and Maintenance (O&M) department to review the assurance flow and interactions with other internal units involved in the monitoring of the telecommunication infrastructure. Thus, a verification process is required to ensure that new features of the real-time self-healing are not affecting the current working procedures.

3.2.2. UC-specific NetApp(s)

3.2.2.1. NetApp(s) scope

The scope of the UC#1 specific NetApp is to continuously monitor the communication service level. Specifically, the NetApp should provide statistics of the service levels of the RAN network in terms of latency and bandwidth and make them available to the DSO so as to help it in the monitoring and troubleshooting phases of its communication network dedicated to remote control and real-time self-healing of its electric distribution grid.

3.2.2.2. Scenarios and sequence diagram

The diagrams below refer to (1) the normal communication flow, and (2) what happens when a communication fault occurs. Both have four different associated scenarios, that are:

  i.   Reactive communication fault management flow with issue in TELCO domain;
  ii.   Reactive communication fault management flow with issue in DSO domain;
  iii. Pro- active communication fault management flow with issue in TELCO domain;
        Pro-active communication fault management flow with issue in DSO domain.

The scenario described in Figure 7 presents the situation when the regional control room identifies a problem in the communication data flow between the central SCADA system and one or more field devices and triggers the GDS control room to investigate the situation. In this scenario, it is assumed that the issue originated within the TELCO infrastructure.

The scenario described in Figure 8 presents the situation when the regional control room identifies a problem in the communication between the central SCADA and one or more field devices, and triggers the GDS control room to investigate. In this scenario the issue is about an issue that originated in the DSO infrastructure.
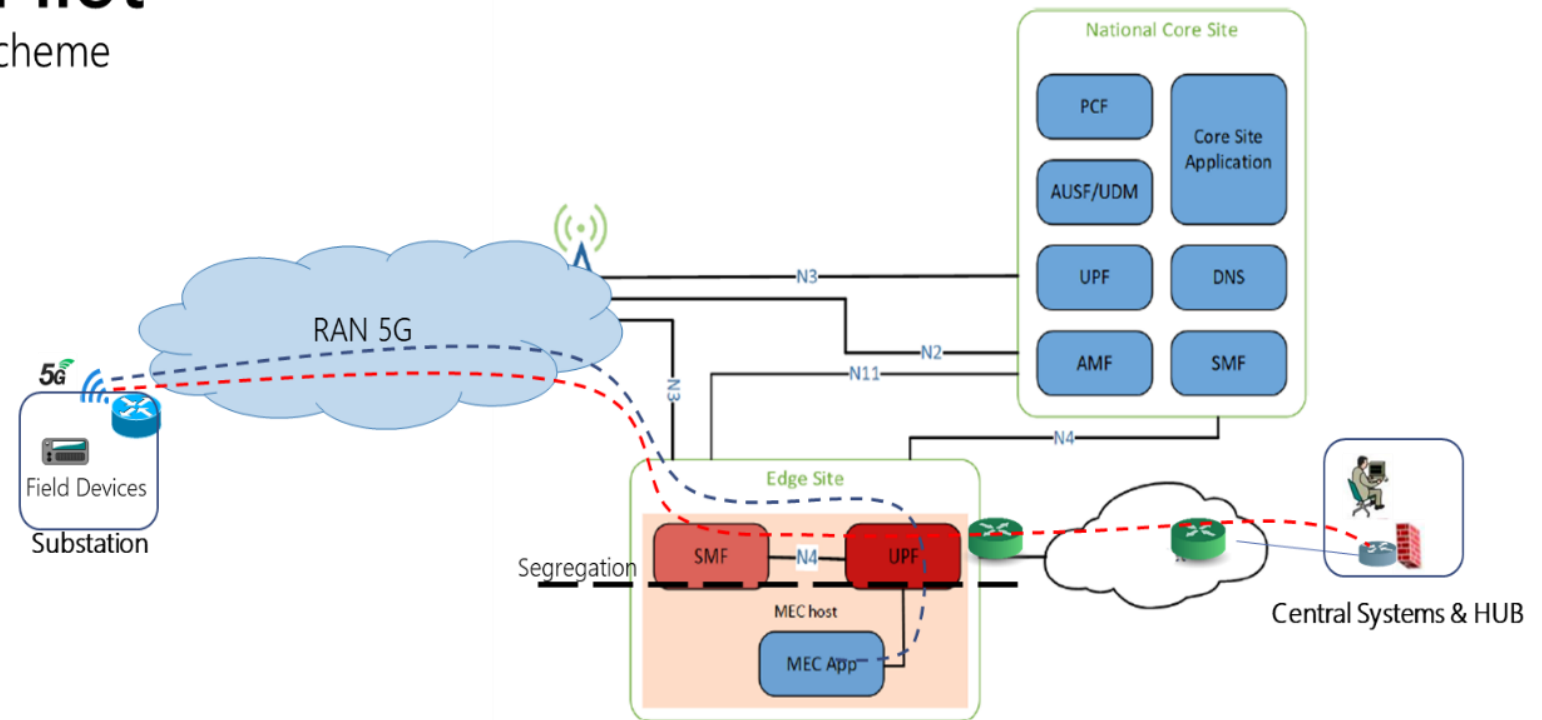
Figure 6: Use-case diagram of the Italian Demo

In the scenario described in Figure 9, the GDS control room investigates a situation signalized by the regional control room and identifies that the issue is out of its domain. Thus, it engages the TELCO team because there is an issue related to the TELCO domain.

In the scenario described in Figure 10, a communication problem between the central SCADA and one or more field devices was seen by the GDS control room that investigates it and engages TELCO because there is an issue in the TELCO domain.

Normal Communication Flow
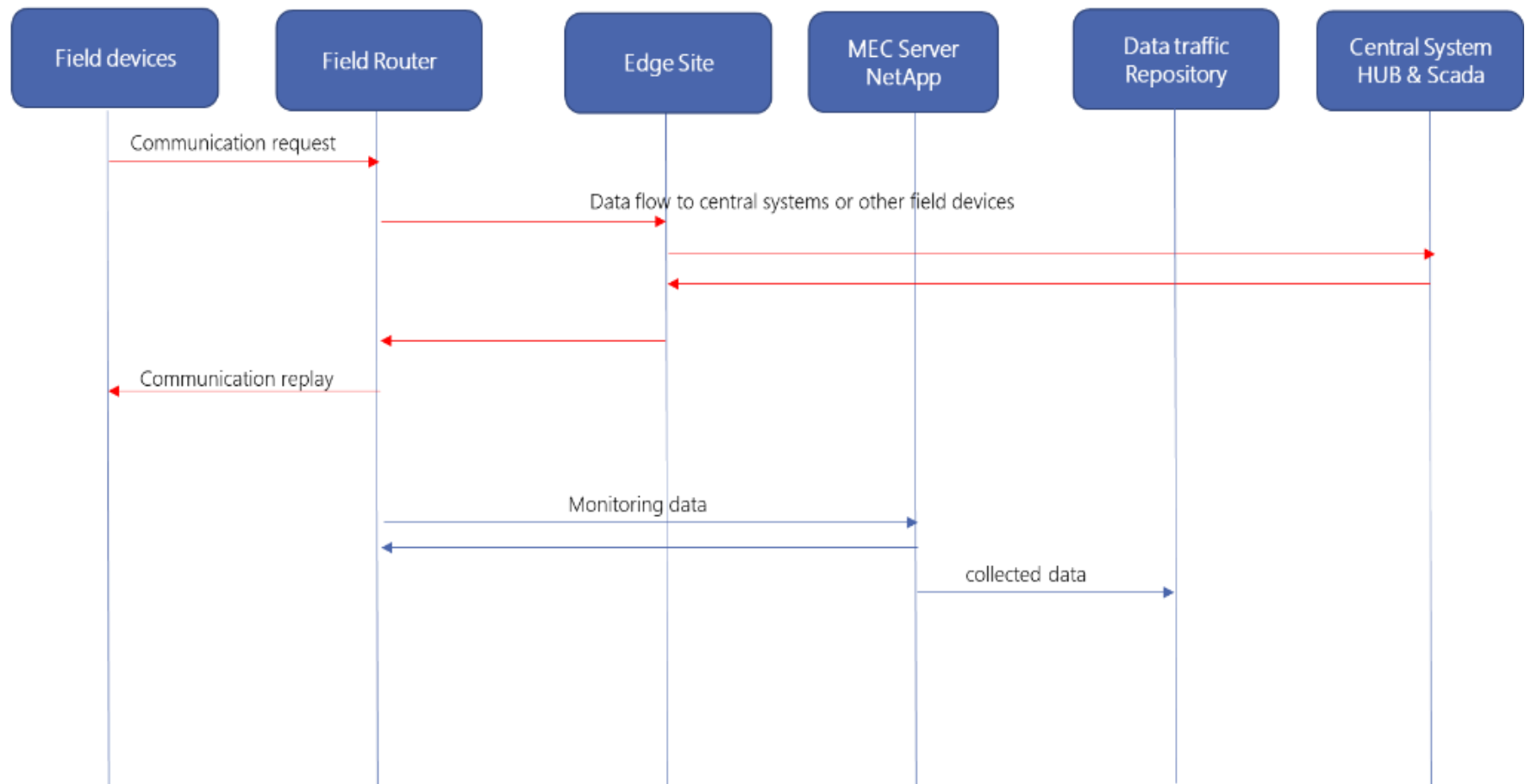
Figure 7: Sequence diagram of a normal communication flow (UC#1)
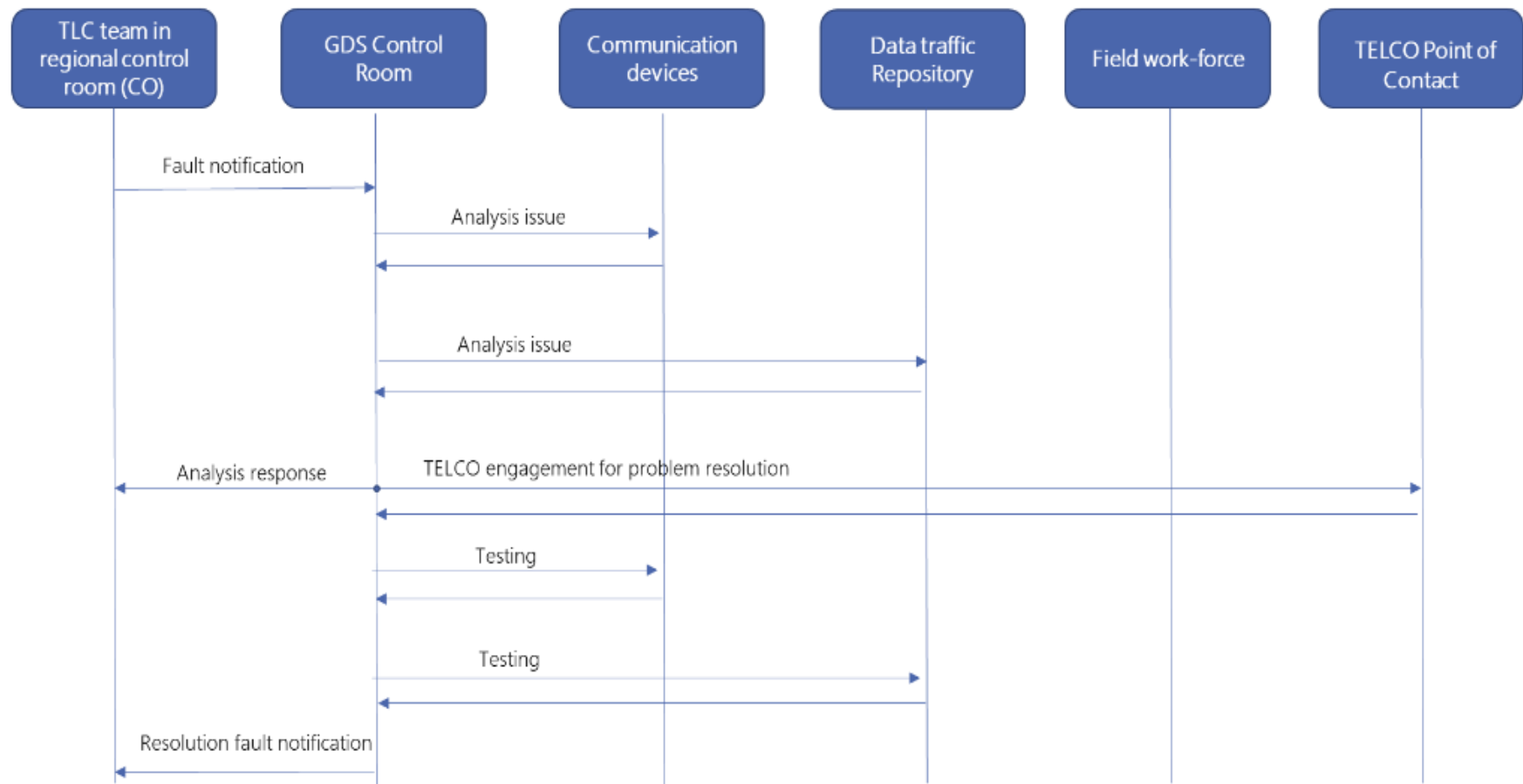
Figure 8: Sequence diagram of reactive communication fault management flow with an issue in the TELCO domain (UC#1)
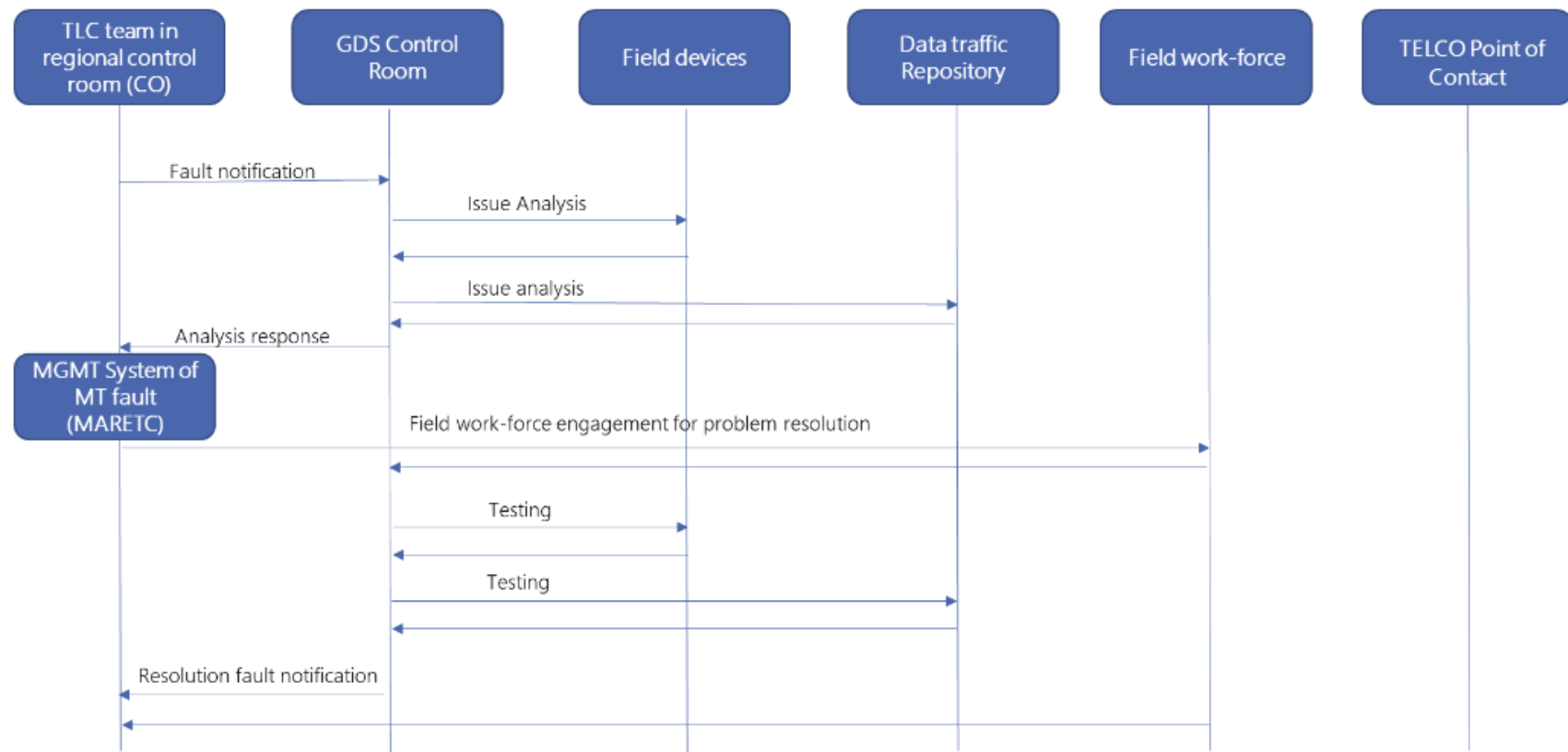
Figure 9: Sequence diagram of reactive communication fault management flow with an issue in the DSO domain (UC#1)
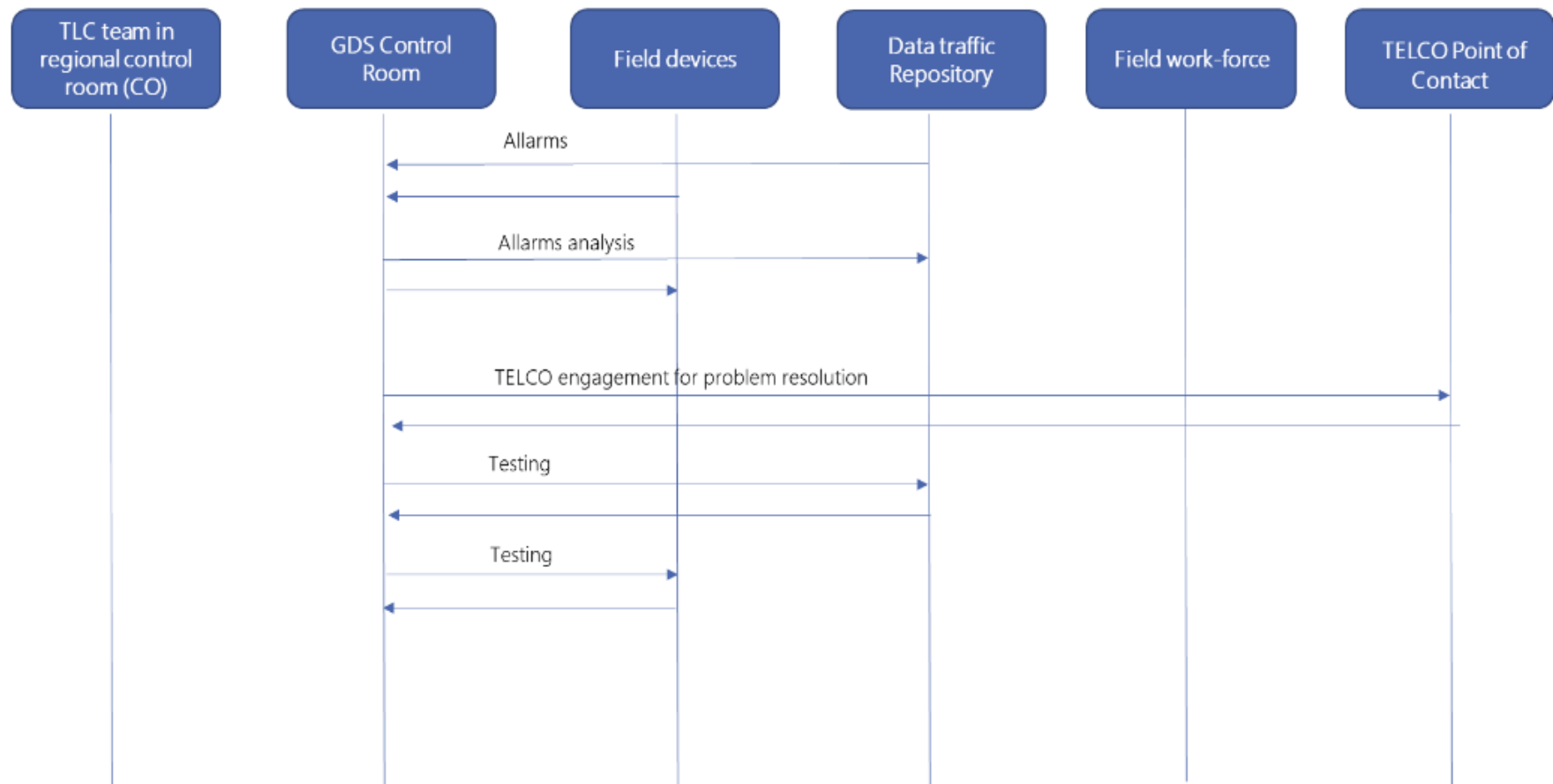
Figure 10: Sequence diagram of pro-active communication fault-management flow with an issue in the DSO domain (UC#1)

3.2.3. 5G-Network requirements

For operating a smart grid with SFS, the URLLC service is of utmost importance. As better described in the narrative part, the first switchgear must open within 80ms, otherwise the automation cycle fails. The 5G key requirements are listed below in the Table 7 and graphically represented in Figure 11.

Table 7: Summary of network requirements for the UC#1

	Use case Requirements	Units	Use Case #1		
			Automatic Power Distribution Grid Fault Detection		
			5G Use case category/Slice Type		
			URLLC	eMBB	mMTC
1	Communication service **Availability**	%	99.99	-	-
2	Communication service **Reliability**	%	99.99	-	-
3	End-to-end **latency**	msec	< 40	-	-
4	RAN latency	msec	-	-	-
5	Data rate	Gbps	>0.005	-	-
6	Device Density	Dev/km2	< 20	-	-
7	Location Accuracy	m	-	-	-
	Use case specific additional requirements				
10	Type of connection	5G - NR			
11	Type of device	CPE			
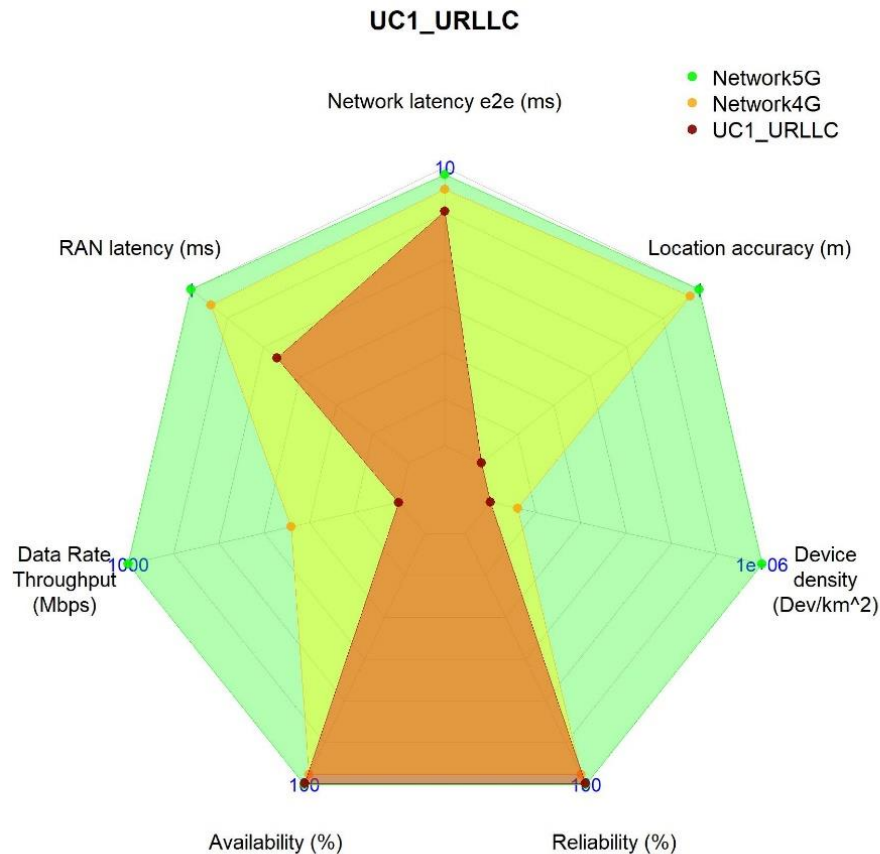
Figure 11: Radar chart for network requirements for UC#1 - slice URLLC

3.2.4. Summary of the UC

To ensure the regular operation of SFS automation framework, the underlying digital communication layer's performance should be guaranteed. Minimizing the efforts for troubleshooting will reduce the unavailability time of the automation framework. More in general, if we consider that this automation framework has been implemented with dedicated OF (costly, longer to implement, not flexible) and 4G/LTE (more economic, flexible, but with lower performance and no dedicated bandwidth), we are convinced that 5G could bridge the need for flexibility, cost-effectiveness and business continuity.

Table 8: Summary of the UC#1

UC-ID	UC Title
IT-FD	5G connectivity for advanced grid automation
Service(s)	Real-Time Self-Healing
New mechanism in the demo even if service already exists (new functional processes)	Improvement of performance and availability of the current real-time self-healing system of EDI, introducing an advanced monitoring function on communication layer of this system.
Assets used (infrastructure, resources)	Wind Tre (W3)'s 5G network (RAN, Core), MEC server provided by ATHONET 5G-enabled communication devices by EDI
NetApp role	Tracking and monitoring the performance of the 5G network and its elements
Scenarios	• DSO's TLC-Team is enabled to continuously monitor and supervise the communication status with the field devices. • The need to physically deploy the maintenance crew on field to perform tests is limited to hardware problems only, while communication issues might be solved remotely by the DSO's TLC-Team and the mobile provider.
5G-services in the Demo	List the 5G-services to be tested • 5G Core with a User Plane Function at the edge to enable local breakout. • 5G network with latency and bandwidth dedicated to the UC services. • Network slicing
5G KPIs of the Demo	List the relevant 5G KPIs targeted • Jitter: 1ms • Latency between Substations and HUB < 20ms • Throughput on each substations > 5 Mbit/s • network availability and network reliability, both > 99,99%

3.3. UC2: remote inspection of automatically delimited working areas at distribution level

The scope of UC#2 is to introduce an automated process that enables the detection of workers and their tools when they are accessing a primary power substation and crossing the borders of a delimited (forbidden) area. The detection via the use of cameras/sensors has to be reliable and very fast, which is why 5G is chosen as the underlying technology to provide low-latency and fast processing capabilities to this UC.

This UC is led by E-Distribucion, which belongs to Enel group, with strong Health and Safety Policies. Worker safety is a priority and must be guaranteed. The loss of life has a high business impact, not only economic but also on the reputation of the company, which indirectly affects the business value.

To prevent a fatal accident in a primary substation, the workers must follow different safety rules that will be explained in the storytelling of the use case later. If a fatal accident happens in a substation, there will be civil and criminal responsibilities for the workers and the company that can be translated into penalties and even criminal charges like prison.

The economic impact is both related to the different kind of penalties (criminal and civil risks) and to the repercussion on the investments made on the companies of the ENEL Group, at large.

The life of a person has an incalculable value for Enel group. This is the reason why the reinforcement of worker safety is so important and, thus, this use case. Enel's safety target in Enel group is **'0' accidents**.

This use case will be developed in the EcoGarraf primary substation that is located near the Garraf Natural Park, Barcelona, Spain. This substation has an outdoor park where the voltage is 66kV. Currently, whenever workers must perform any maintenance activity in an electrical primary substation, they must follow a strict safety procedure. Before executing any tasks, a safety work area must be delimited, and any electrical elements must be des-energized. The safety procedure includes several steps such as wearing electric risk protective clothes, checking des-energized electrical elements and the safety area delimitation, which is mostly made with physical barriers or perimeter fences in 2D.

It is necessary to complement the current safety procedure so that the responsibility for the activities does not fall only on the worker, thus reinforcing it through a real-time location system. The Real-Time Location System (RTLS) to be developed as part of the Smart5Grid project will be a customised safety solution comprised of a combination of 3D cameras and sensors developed as a custom safety solution in order to monitor the maintenance activity and create a 3D volumetric safety area. The system will activate audio-visual, electronic, and physical (vibration) warnings.

The substation will be covered by a network of reading devices e.g., UWB sensors and 3D cameras with AI functionalities, which will be connected to a gateway communicating with the server using 5G modems (CPEs). A 3D layout of the entire space will be provided, which will show the location of workers with accuracy of 30 cm using UWB sensors and cameras.

The backend application will run on a server, in which a 3D dangerous zone can be set through the frontend application. The manager of workers or the Head of the Substation will set through a dashboard the areas that will be dangerous for the technicians. As soon as a virtual 3D danger zone is entered, the system will detect it. The worker will wear a tag so the system will send to the worker a warning signal, whenever any change occurs in the 3D danger area monitored by cameras (e.g., when a person, tool or equipment goes out the safety zone the audio-visual alarm will be triggered).

A 5G NR network will be deployed, providing connectivity to a series of sensors and cameras. The configuration of the 5G NR network and its management will be enabled by a dedicated management system. The cameras, that are connected over 5G NR, will feed the NetApp with the necessary information to be able to detect when someone accesses the restricted areas. A NetApp is a set of virtual network

functions that will be developed in the UC#2 to provide the warning signal in case that any worker exists the safety area.

By using the 5G NR network, this transmission will be fast and reliable and, since the edge computer hosting the NetApp will be deployed right next to the 5G radio access network, the end-to-end delay between the camera and the equipment processing the information will be minimal.

The NetApp deployed in this UC#2 will continuously process the inputs from the different sensors deployed in the substation and will use the information to be able to detect whether a worker has accessed a forbidden area. If such a situation is detected, a notification or alarm will be triggered that will immediately notify the worker of the breach, making him aware of the potential risk.

Business goals

Because maintenance in Primary Substations is a high-risk activity due to high-voltage energized equipment, worker safety must be assured at the best level possible to avoid any casualties. EDistribución - Spain main focus is to offer workers the best protection possible by allowing them to work only in safety areas where all the elements are deenergized. Because of the Smart5Grid project, an additional automated system will complement the current safety practices, and it may also allow multiple maintenance actions within the same substation as all the technicians will be automatically monitored. The new system must also be integrated with EDistribución's Control Centre and Workforce management systems. The basic functionality of this UC#2 is that, whenever any worker goes out of one of the volumetric delimited safety areas, the system will detect it and send a warning signal automatically to several responsible actors (e.g., supervisor of the work, the operator of the primary substation where the work takes place, the central SCADA).

Service level objectives

The delimitation must be performed in real-time so that the data processing and warning signal must be sent as fast as possible. This will be possible due to the use of a 5G NR private network with edge computing capabilities, providing low latency and high data transmission capacity.

Expected benefits:

As explained before, the main safety target in Enel is '0' accidents. Currently, Enel Health and Safety Policies consider that accidents and near misses (as almost accidents are called) are low probability events.

As mentioned before, a person's life has countless value, so the '0' accident target for the reinforcement of the safety in all electric facilities is a priority for Enel Group.

- **Business:** As part of UC#2, a new customized digital system to reinforce safety of primary substation's workers will be integrated in the company's workforce management systems. This is expected to improve the current network operation procedures.

- **Economic:** To reduce cost by reinforcing the safety of the workers. If there is an accident at the primary substation, there may be a network failure and many customers may be affected. EDistribución would have to pay for the compensations and Government's penalties.

- **Social:** To reduce work accidents and improve the security at work. The new system will also help to improve the company's social image as the company will be seen as one that values greatly the welfare of its employees. Further, if an accident occurs at the primary substation, there may be a network failure and many customers may be affected by a lack of power supply, thus significantly worsening the image of the company as one that provides reliable and uninterruptible service to its customers.

Table 9: Summary of business KPIs for the UC#2

Business KPIs	Additional explanation	Means of verification	Indicative quantitative values
Improved worker safety/reduced number of accidents	It is of high priority for ENEL to ensure "0" accidents related to working conditions in HV substations	Annual statistics of working related accidents in HV substations	The target is "0" accidents (either light, serious or even fatal)
Better monitoring of near misses	Near miss (accident) are monitored on volunteer basis. Such automatic system will support a better monitoring, increasing the workers´ awareness.	Annual statistics of working related near misses	Even if the target is 0, the goal is to better monitor such events in an objective manner
Improved company's social image	Reinforcing the safety in substations will improve the society trust (investors, customers, etc.)	It is an indirect consequence of the reinforcement of safety in power substations	Brand analysis could be addressed to understand how the perception on safety for the stakeholder community is
Reduced cost of compensations/penalties	If there is an accident, some penalties must be paid (to the Government, to the ones that have suffered an injury, others)	Statistical analysis reflecting the reduction in the amount paid as penalties due to work related accidents	The target is to have "0" to be paid as penalties for work related accidents in a territorial area (e.g., Barcelona). However, the value of the potential loss of a human life is higher than any money to be paid
Increased worker compliance to procedures	Workers knowing that they are monitored will be less likely to 'bend the rules'	Annual statistics of working related adherence to processes	Target should be 100%

3.3.1. Actors, conditions and technologies involved

3.3.1.1. Actors and stakeholders

Main Actor:

- On-field workers: They work for the DSO and perform electrical activities in the primary substation.

Other actors:

- **Head of Substation:** The responsible person of the facility. To avoid be at the substation when the activity is performed, he can also upload the 3D safety area and monitor the work progress remotely. It is the first safety area that will be uploaded in the substation before performing any activity to guarantee that any technician that gets into the substation is safe and does not approach any energized electrical elements. The distance to any energized element must always be higher than three meters. He must be notified if any alarm triggers in the substation.
- **Foreman (Manager worker):** Responsible of the activities that must be performed in the station and of ensuring that any of the on-field workers knows what to do. He will also receive a warning signal if any alarm triggers.
- **Worker Responsible for Risk Prevention:** One of the workers on the field will have this role. He will survey the fulfilment of the safety rules in the primary substation. He will receive a warning signal as well if any alarm triggers.
- **DSO Control Room:** Constantly monitoring the substation especially when any activity is performed there. The on-field workers always call the Control Room when executing any task. Control Room must receive any warning signal from the RTL system.
- **5G Infrastructure Owner:** Responsible for configuring the 5G network (one-time configuration before operation of the network/UC starts) and the UC-specific services.
- **RLTS:** the system that will automatically track the worker position and will process all the information to generate the warning signal if needed.
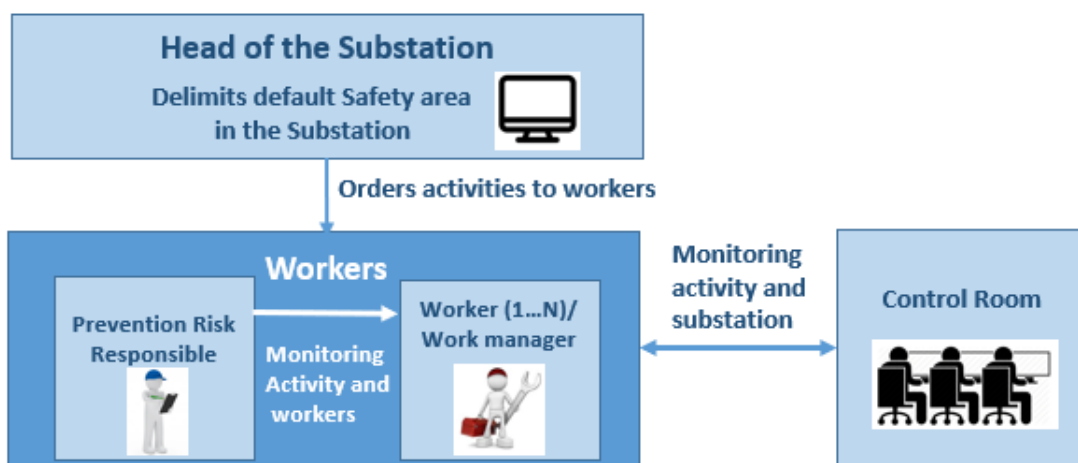
Figure 12: Actors and their interaction within UC#2

Stakeholders:

- **EDistribución** Spain is the DSO that will provide the site (EcoGarraf primary substation, Barcelona) to develop the UC#2. On-field workers also work for EDistribución Spain.
- **Nosia** will provide the hardware devices, sensors and cameras and develop the vertical software applications, tracking system module and artificial intelligence computer vision module.
- **I2CAT** will provide the private 5G network in the primary substation.

Table 10 indicates the actors that will be involved in the use case, that can be people, hardware, etc., as it is indicated in the second column. The third column describes these actors and their roles.

Table 10: List of actors and their roles in the UC#2

Actor	Type	Actor Description
On-field worker	Person (Company)	Worker that performs activities for the Electrical energy Distribution company that will allow testing the RLTS system in the primary substation EcoGarraf, Barcelona.
Head of Substation	Person (Company)	Responsible person of the facility who will upload in the system the 3D safety area by default. He must be notified if any alarm triggers in the substation.
Foreman (Manager worker)	Person (Company)	He is the person responsible of the activities that must be performed and will explain it to the workers and will assure that everyone knows what to do. He will receive a warning signal if it triggers.
Prevention Risk Responsible	Person (Company)	One of the workers will have this role. He will survey the fulfilment of the safety rules in the primary substation. He will receive a warning signal if it triggers.
DSO Control Room	Person/Team (Company)	The Control Room is always monitoring the substation and any activity that is performed there. The workers always call the Control Room when executing any task. Control Room must receive any warning signal from the RTL system.
RLTS	Hardware and software system	RTLS solution including devices (sensors, cameras) and software development to generate the warning signals.
5G Infrastructure	Hardware and software	The 5G infrastructure owner is responsible for configuring the network (one-time configuration before operation of the network/UC starts). A dashboard will be provided by the radio management system to facilitate these configuration tasks. It also includes the infrastructure devices.

3.3.1.2. Conditions and technologies involved

Some possible restrictions must be considered:

Functional:

- The primary substation is outdoors so meteorological as well as other environmental conditions like dust must be considered as they may affect the operation of the devices. Devices' maintenance must be defined to guarantee that the system works properly. It is mandatory to consider safety procedures during RTLS and 5G NR network maintenance.
- The RTL system must consider that the minimum number of workers that may be in the safety area will be two; one of them will be the preventative risk responsible. There may be more than one safety areas in the primary substation at the same time, as different activities can be carried out simultaneously.
- Tools or equipment carried out by workers must be monitored as well to guarantee they are inside the safety areas.

Technical:

- Devices must be installed considering the facility restrictions. EDistribución's Health & Safety department establishes strict rules that must be accomplished. Limited number of cables can be installed on dedicated areas within the perimeter of the substation. Being a critical facility within the operation and distribution of the electrical network, any new element must not affect in any way the normal operation of this facility. As such,
  - o Any new device must be installed at distance of more than 3 meters from any electric element of the primary substation.
  - o Other technical constraints must be considered, like the low voltage power supply that is not available at any place of the substation.
  - o Any device that is installed in the grid HV substations must comply several electromagnetic compatibility (EMC) criteria which are based on a set of technical standards, to be enumerated and exemplified later on. Otherwise, due to the high voltage operating environment of the substation, those devices might not operate properly or even break. The accomplishment of these EMC criteria must be verified through the device technical specifications provided by the manufacturer. In the case of pilot demonstrations, some of the devices could be developed as prototypes. In such a case, the EMC requirements will be tested by an Enel's ICT expert in the dedicated testing lab of Enel.
  - o The following tables are related to the technical requirements of the devices that can be installed in the primary substation.

Electromagnetic compatibility, or EMC, means that a device is compatible with (i.e., no interference is caused by) its electromagnetic (EM) environment and it does not emit levels of EM energy that cause electromagnetic interference (EMI) to other devices in its vicinity.

When the devices are tested in a dedicated EMC testing lab, they are exposed to several EM fields with intensities similar to those present in the HV primary substation. The severity levels refer to the intensity scale of the electromagnetic filed within which the installed devices need to operate normally. There is usually a range of allowed severity levels which allows for several choices in terms of device technology and price ranges. As such, those tables could serve for the technological choices of the devices to be installed as part of the UC#2 demo.

Table 11 summarizes the relevant set of standards related to EMC that the devices, to be installed as part of the UC#2 demo, need to comply with. Specifically, additional tests and acceptance criteria relevant to the special environmental conditions encountered in power substations need to be performed. The first column refers to the relevant standards, the second column provides the brief description of the key components of the devices that will undergo the relevant EMC tests before they are deployed on the pilot site. The third column refers to the standardized test levels, as they are described in the relevant standard, while the last column refers to the corresponding EMC severity levels. Test levels and severity levels are defined in IEC 61000-2 series.

Table 11: Technical requirements for UC#2's devices in line with Electromagnetic Compatibility

EMC	Description	Test levels	Severity levels
IEC 61000-4-2 [20] compliant about Electrostatic discharge immunity	Enclosure contact	6 kV	3
	Enclosure air	8 kV	
IEC 61000-4-3 [21] compliant about electromagnetic fields radiated immunity.	Enclosure port	10 V/m	3
IEC 61000-4-4 [22] compliant about bursts of rapid transit immunity	Signal ports	1 kV @ 2.5 kHz	3
	D.C. power ports	2 kV	3
	A.C. power ports	2 kV	3
	Earth ground ports	2 kV	3
IEC 61000-4-5[23] Surge	Signal ports	1 kV line-to-earth, 0.5 kV line-to-line	2, 1
	D.C. power ports	2 kV line-to-earth, 1 kV line-to-line	3, 2
	A.C. power ports	2 kV line-to-earth, 1 kV line-to-line	3, 2
IEC 61000-4-6 [24] compliant about immunity conducted disturbances	Signal ports	10 V	3
	D.C. power ports	10 V	
	A.C. power ports	10 V	
	Earth ground ports	10 V	
IEC 61000-4-8 [25] Power frequency magnetic field	Enclosure ports	3 A/m continuous	2

[20] IEC 61000-4-2: "Electromagnetic Compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test". The IEC 61000-4-2 is the International Electrotechnical Commission's immunity standard on Electrostatic Discharge (ESD). The publication is one of the basic EMC standards of the IEC 61000–4 series. The European equivalent of the standard is called EN 61000-4-2. For further details also see: https://webstore.iec.ch/publication/4189.

[21] IEC 61000-4-3: "Electromagnetic Compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency electromagnetic field immunity test". It is applicable to the immunity requirements of electrical and electronic equipment to radiated electromagnetic energy. It establishes test levels and the required test procedures. The object of this document is to establish a common reference for evaluating the immunity of electrical and electronic equipment when subjected to radiated, radio-frequency electromagnetic fields. For more details also see: https://webstore.iec.ch/publication/59849.

[22] IEC 61000-4-4: "Electromagnetic Compatibility (EMC) – Part 4-4: Testing and measurement techniques – Emission and immunity testing in transverse electromagnetic (TEM) waveguides". It relates to emission and immunity test methods for electrical and electronic equipment using various types of transverse electromagnetic (TEM) waveguides. These types include open structures (for example, striplines and electromagnetic pulse simulators) and closed structures (for example, TEM cells). These structures can be further classified as one-, two-, or multi-port TEM waveguides.. For more details also see: https://webstore.iec.ch/publication/4190.

[23] IEC 61000-4-5: "Electromagnetic Compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test". It relates to the immunity requirements, test methods, and range of recommended test levels for equipment with regard to unidirectional surges caused by over-voltages from switching and lightning transients. Several test levels are defined which relate to different environment and installation conditions. These requirements are developed for and are applicable to electrical and electronic equipment. The object of this standard is to establish a common reference for evaluating the immunity of electrical and electronic equipment when subjected to surges. For more details also see: https://webstore.iec.ch/publication/61166.

[24] IEC 61000-4-6: "Electromagnetic Compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducting disturbances, induced by radio-frequency fields". It relates to the conducted immunity requirements of electrical and electronic equipment to electromagnetic disturbances coming from intended radio-frequency (RF) transmitters in the frequency range 150 kHz up to 80 MHz. Equipment not having at least one conducting wire and/or cable (such as mains supply, signal line or earth connection) which can couple the equipment to the disturbing RF fields is excluded from the scope of this publication. The object of this standard is to establish a common reference for evaluating the functional immunity of electrical and electronic equipment when subjected to conducted disturbances. For more details also see: https://webstore.iec.ch/publication/4224.

[25] IEC 61000-4-8: "Electromagnetic Compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test". It relates to the immunity requirements of equipment, only under operational conditions, to magnetic disturbances at power frequencies 50 Hz and 60 Hz. For more details also see: https://webstore.iec.ch/publication/22272.

EMC	Description	Test levels	Severity levels
IEC 61000-4-29 [26] compliant about voltage ripple	D.C. power ports	30% for 0.1s, 60% for 0.1s, 100% for 0.05s	-
	A.C. power ports	30% for 1 period, 60% for 50 periods	-
IEC 61000-4-11 [27] compliant about voltage ripple		100% for 5 periods, 100% for 50 periods	-
IEC 61000-4-12 [28] compliant about Oscillatory waves immunity	Signal ports	-	-
	D.C. power ports	1 kV common, 0.5 kV diff. Mode	2
	A.C. power ports	1 kV common, 0.5 kV diff. Mode	2
IEC 61000-4-16[29] Mains freq. Voltage	Signal ports	-	-
	D.C. power ports	10 V continuous, 100 V for 1 s	3
IEC 61000-4-17[30] Ripple on DC power supply	D.C. power ports	10 %	3
EN 55022[31]	Class A	Pass	

Table 12 summarises the functional requirements in relation to the EMC immunity that each new installed device need to comply with. The first column refers to the type of EMC phenomena, the second column provides its brief description, while the last column provide additional information on how the evaluation of the functional requirement will be done.

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[26] IEC 61000-4-29: "Electromagnetic Compatibility (EMC) – Part 4-29: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests". It establishes a common and reproducible basis for testing electrical and electronic equipment when subjected to voltage dips, short interruptions or voltage variations on d.c. power ports. This standard defines: the range of test levels; the test generator; the test set-up, and; the test procedure. For more details also see: https://webstore.iec.ch/publication/4206.

[27] IEC 61000-4-11: "Electromagnetic Compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase". It defines the immunity test methods and range of preferred test levels for electrical and electronic equipment connected to low-voltage power supply networks for voltage dips, short interruptions, and voltage variations. For more details also see: https://webstore.iec.ch/publication/66487.

[28] IEC 61000-4-12: "Electromagnetic Compatibility (EMC) – Part 4-12: Testing and measurement techniques – Ring wave immunity test". It relates to the immunity requirements and test methods for electrical and electronic equipment, under operational conditions, to ring waves occurring in low-voltage power, control and signal lines supplied by public and non-public networks. For more details also see: https://webstore.iec.ch/publication/61074.

[29] IEC 61000-4-16: "Electromagnetic Compatibility (EMC) – Part 4-16: Testing and measurement techniques – Damped oscillatory wave immunity test". It focuses on the immunity requirements and test methods for electrical and electronic equipment, under operational conditions, with regard to: (i) repetitive slow damped oscillatory waves occurring mainly in power, control and signal cables installed in high voltage and medium voltage (HV/MV) substations; (ii) repetitive fast damped oscillatory waves occurring mainly in power, control and signal cables installed in gas insulated substations (GIS) and in some cases also air insulated substations (AIS) or in any installation due to high-altitude electromagnetic pulse (HEMP) phenomena. For more details also see: https://webstore.iec.ch/publication/60676.

[30] IEC 61000-4-17: "Electromagnetic Compatibility (EMC) – Part 4-17: Testing and measurement techniques – Ripple on d.c. input power port immunity test". It defines test methods for immunity to ripple at the d.c. power port of electrical or electronic equipment. It applies to low voltage d.c. power ports of equipment supplied by external rectifier systems, or batteries which are being charged. This standard defines: the test voltage waveform; the range of test levels, the test generator; test set-up; test procedure. For more details also see: https://webstore.iec.ch/publication/4184.

[31] EN 55022: "Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement". For more details about the context of this document also see, among others: https://www.cenelec.eu/dyn/www/f?p=104:110:870973412534701::::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1258289,42105,25.

Table 12: Technical requirements of UC#2's devices versus electromagnetic phenomena

Functional requirements vs. Electromagnetic phenomena	Description	Comments
Continuous phenomena	Normal performance within the specification limits	
Transient phenomena with high occurrence	No loss, possible bit error rate degradation	Temporary bit error rate degradation can affect the communication efficiency; automatic restoration of any stoppage of the communication is mandatory
Transient phenomena with low occurrence	Temporary loss	

Table 13 provides the necessary standards that the devices need to comply with in terms of environmental requirements. Among the most important environmental parameters, we can consider the resistance to vibration and to shocks. The third column shows the test levels which the devices should pass, i.e., devices should work properly under a sine wave of magnitude two times gravity acceleration and of a frequency from 10 to 150 Hz. While for the shock or impact test, a sine pulse of amplitude 20 times gravity acceleration and pulse width of 11 milliseconds is applied.

Table 13: Tests to account for environmental requirements of UC#2's devices

Environmental Type Tests	Description	Test levels
IEC 60068-21-1[32]	Vibration	2g @ (10 - 150) Hz
IEC 60068-21-2[33]	Shock	20g @ 11mS

Table 14 provides the necessary standards that the devices need to comply with in terms of electrical isolation requirements. The first column provides the relevant standard that the device needs to comply with in terms of electrical isolation requirements, the second column indicates the device component that will need to fulfil the respective requirement, the third column indicates the type of tests, while the last column indicates the severity level.

Table 14: Technical requirements of UC#2's devices with regards to isolation

Isolation	Description	Test levels	Severity level
IEC 60255-5[34]	Power supply	between independent circuits between independent circuits and ground	2.5 kV
IEC 60255-5	Serial port, Ethernet port	between independent circuits between independent circuits and ground	1.5 kV

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[32] IEC 60068-21-1: "Environmental testing - Part 1: General and guidance". This standard is part of the IEC 60068 series, which is applicable to all electrical and electronic components whose terminations or integral mounting devices are liable to be submitted to stresses during normal assembly or handling operations. For more details also see: https://webstore.iec.ch/preview/info_iec60068-1..

[33] IEC 60068-21-2: "Environmental testing –Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices". This standard is part of the IEC 60068 series, which is applicable to all electrical and electronic components whose terminations or integral mounting devices are liable to be submitted to stresses during normal assembly or handling operations. For more details also see: https://webstore.iec.ch/preview/info_iec60068-2-21.

[34] IEC 60255-5: "Electrical Relays – Part 5: Insulation coordination for measuring relays and protection equipment – Requirements and tests". (Text withdrawn) For more details also see: https://webstore.iec.ch/publication/14328.

Table 15 refers to the Conformité Européenne (CE) marking which is a regulatory standard that verifies certain products are safe for sale and use in the European Economic Area (EEA). In this table level of compliance does not apply. All the devices installed in a substation must have CE marking that means they have been assessed to meet high safety, health, and environmental protection requirements.

Table 16 indicates other relevant standards that the cameras need to comply with in terms of technical specifications for their communication ports. In this table level of compliance does not apply.

Table 15: Technical requirements of UC#2's devices with regards to marking compliance

CE Marking	Level of compliance	Comments
CE Marking compliance[35]		

Table 16: Technical requirements of UC#2's devices with respect to other standards

Other Standards	Level of compliance	Comments
RFC 6864: Updated Specification of the IPv4 ID Field[36]		

Other types of constraints:

- Constraint due to 5G bandwidth 20MHz from the mobile operator (Orange). A national reallocation of frequencies will occur in Spain that may affect the demo (the exact date is not known as of yet).
- The external connection to the substation's fibre network is critical because the DSO's infrastructure needs to guarantee the power supply for all its customers. The available speed would be of 100Mbps but not all the time.
- It may be also possible to set up a new 4G external communication (to be analysed). It will allow any external connection to collect information from the Smart5grid platform.
- **Cybersecurity:** To check all cyber security constrains of the network devices due to Enel's group policy. We will have to specify what kind of software we are going to integrate with the existing system.
- **Security:** EDistribución already has its own video surveillance circuit in the primary substation. The new elements cannot interfere with any of the existing ones. The two video systems will run independently from one another.
- **Legal:** To analyse the legal requirements stemming from recording the workers (they may be also external from EDistribución's contractors). Images are stored. To take into account Spanish Law Protection Data and register the data file with the Spanish Protection Data Agency.
- **Health & Safety:** To check the possible constraints to deploy the overall system in the primary substation from Enel Group Health & Safety Department.

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[35] CE Marking: "A Conformité Européenne (CE) marking is a regulatory standard that verifies certain products are safe for sale and use in the European Economic Area (EEA)". For more details also see: https://ec.europa.eu/growth/single-market/ce-marking_en.

[36] For further details also see: https://datatracker.ietf.org/doc/html/rfc6864.

- **Organisation**: To check interactions with other EDistribución's Departments and how the new technical solution may affect current work procedures.
  Telecommunications:
- i2CAT will ask the mobile operator (Orange) for permission to use the same spectrum (20-40 MHz) for the Spanish Pilot in Garraf ("EcoGarraf" substation) in the 3.5 GHz Spectrum. If the permission is not obtained by Orange, a request will be made to the Spanish Ministry of Economic Affairs and Digital Transformation for it (Band n77, 3.8-4.2 GHz). This could be a risk due to the long time it may take for permissions to be granted.

Proposed Technical Solution:

A diagram showing the communication flow and the equipment involved in UC#2 is shown in Figure 13 and in Figure 14 for two complementary sensing units (intelligent cameras and portable sensing tags). These sensing units will be integrated for the development of the UC#2 specific NetApp in charge of tracking and sending warning signals in case a worker is in danger while performing maintenance work in Primary Substations.
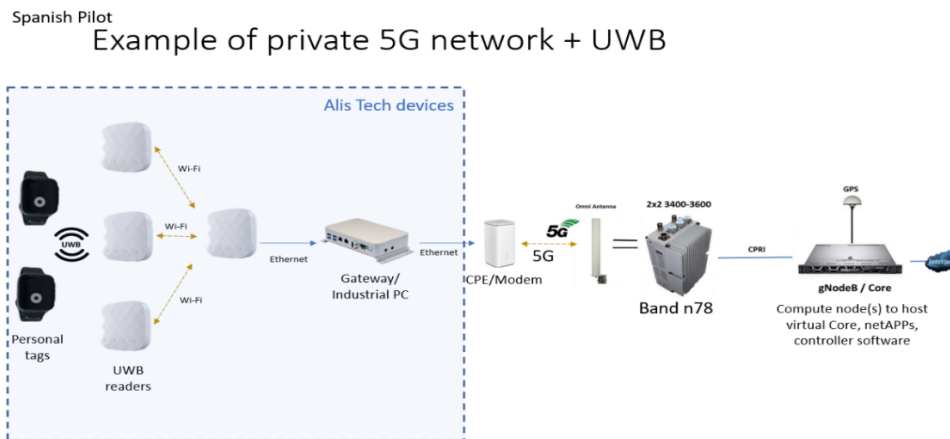
Figure 13: Communication flow and equipment involved in UC#2. Portable sensors for the workers
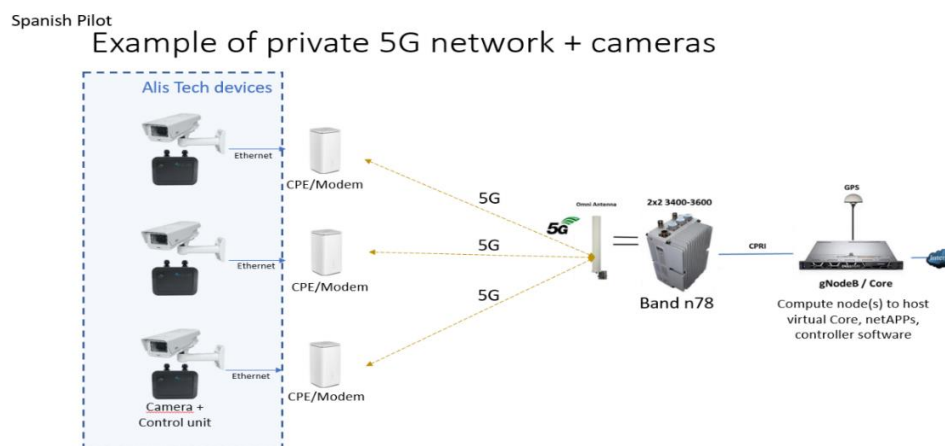
Figure 14: Communication flow and equipment involved in UC#2. Fixed smart cameras to track and sense any potential danger in the activity of the workers

3.3.2. UC-specific NetApp(s)

3.3.2.1. NetApp(s) scope

One NetApp will be developed, including different functions:

1. Front- end software: to delimit 3D safety areas (this is the first software function);
2. Software function related to the tracking function that will monitor all information originating from sensors (fixed cameras and mobile tags);
3. Software function related to AI computer vision that will process data originating from cameras;
4. The synchronization application (Synchro NetApp) that will verify and evaluate the data coming from the software functions (sensors and cameras). The outcome of the Synchro NetApp will be the generation of a danger warning signal in case of either worker(s) or their working tools enter the danger zone.
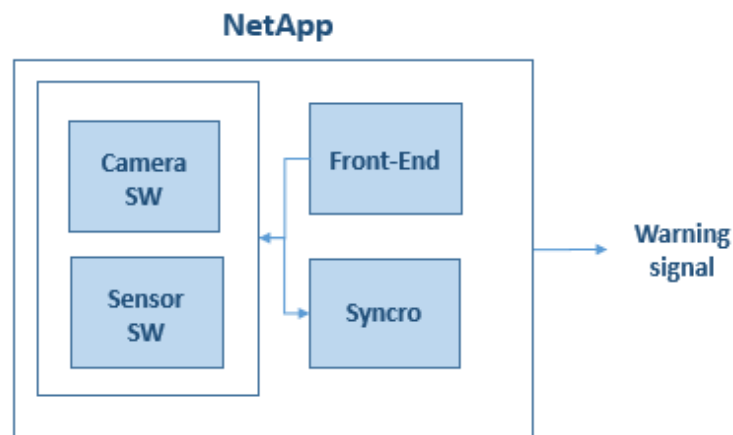
Figure 15: High-level logic of the UC#2 NetApp

Table 17 summarizes the different software that will be running and will provide information to develop the Netapp. The first column indicates the software typology, the second column indicates its functionality, the third one is the input to the software, the fourth one is the expected output after running the software, while the last one is the source from where the software can be accessed.

Table 17: NetApp chart for UC#2

Software	Functionality	Input	Output	Accessible from
Front end (Volumetric safety area)	To configure volumetric safety area	Safety area	Information to sensors and camera apps	Smartphone/PC dashboards
Cameras Software	Image matching and initialization (on a server)	An inertial system, .json, mask, bounding box (received from camera control units)	Information, that someone is in a danger zone (ID, absolute x,y,z, bounding box)	Industrial PC (not by users)

Software	Functionality	Input	Output	Accessible from
	Translation of 3D camera data (from relative coordinates into absolute coordinates)	Polygons (front-end NetApp – 3rd site)	Preview cam screen – image stream	
	Creation of reference image (view) -> detection of any change in the scanned 3D picture -> relative x,y,z (bounding box)	Camera positioning - x,y,z, camera ID	The video stream can be seen in the front-end application.	
	Plastic fences will be in the safety area, but they will not be used to create the 3D safety area automatically. The worker will introduce the data of deenergized elements to be uploaded to the cameras (to change the safety area that was defined by default). The worker should receive a notification if safety area is not right. It is not possible to recognize the identity of people.	Front-end NetApp – administrator section. It indicates the border of the safety area, where the plastic fences are placed.		
UWB Sensor Software	Detect, if someone left a safety zone (is in the danger zone)	X, Y, Z, ID, battery, SOS signal (it can be used but not obligation), no motion signal (received from industrial PC)	Information of unallowed ID (ID, x,y,z, event name)	Industrial PC (not by users)
	Detect ID, which is not allowed in the pre-set safety area	Polygons, List of allowed IDs in each polygon (front-end NetApp – 3rd site)	Information, someone is in a danger zone (ID, x,y,z, event name)	
			Information, someone pressed an SOS button – (ID, x,y,z, event name)	
			Information of ID with no movement – (ID, x,y,z, event name)	
			Information on battery status – (ID, battery percentage)	
			Time stamp	
			Date stamp	

Software	Functionality	Input	Output	Accessible from
Synchro	Verifies the inputs of both Software (Cameras and sensors) and evaluates its credibility.	Information of unallowed ID (ID, x,y,z, event name)	Verified and reliable input data	Industrial PC (not by users)
		Information, someone is in a danger zone (ID, x,y,z, event name)	Info or warning alarm (to be defined audio-visual and tag vibration)	
		Information, that someone pressed an SOS button – (ID, x,y,z, event name)		
		Information of ID with no movement – (ID, x,y,z, event name)		
		Information on battery status – (ID, battery percentage)		
		Information, someone is in a danger zone (ID, absolute x,y,z, bounding box)		
		Preview cam screen – image stream		

The story telling of the UC#2 specific NetApp is given by the steps below:

1. A group of workers must perform a maintenance task in the EcoGarraf primary substation.
2. The 5G NR network is configured, and the service set up. For the deployment and activation of a NetApp, a network slice instance must be previously activated. The network slice activation involves the execution of different processes conducted by the M&O system: (i) reservation of physical resources both in the radio devices and in the computing nodes, (ii) deployment of the virtualized 5GCN in the computing node, (iii) and finally the radio devices configuration to enable communications with the 5GCN.
3. As a very first step, the Head of the Substation will configure a 3D volume safety area by default to avoid that any worker might go too close to any high-risk element of the primary substation. This action will be done by the front-end application able to run on either a PC or any android device.
4. Once the contractor receives the maintenance order from the DSO (this is not included in the use case), they will go to the substation to perform the activities.

5. They will get into the substation and will wear personal tags. Their smartphones will be connected to the 5G network. There is a passive lock on the door of the substation, and they will have a smart key to open the lock. They will use their smartphones to scan a QR code that it is on the door or to enter a number code related to the substation. The smartphone will send the authorization to the smart key to open the door.

6. At that moment, the NetApp is already working and will warn any worker if he/she goes out of the default 3D safety area.

7. The workers will wear tag sensors that will be used to warn them if they go out of the safety area because, in that situation, they can be too close to other high-risk elements of the substation. According to Spanish Law RD 614/2001, the distance cannot be less than 3 meters in a 66 kV substation. The tags will send vibration or audio-visual warning signals (to be defined).

8. Before executing any tasks, the work manager will inform the workers about the safety area they are allowed to perform the maintenance task in the substation. Before the worker starts the activities, he/she must follow a safety procedure that is ordered by the DSO. They are obliged by the DSO to know the 3D safety areas which must be delimited before executing any task in a primary substation.

9. As a part of the procedure, there are strict rules that establish different roles for the workers in the primary substation before performing the activities.

   o At least two workers must work together when they perform an activity inside the safety area.

   o One of the workers is the **work manager**, that must check that all workers know the activity to be performed.

   o Another worker is the **preventive risk responsible**. He only must supervise that the prevention risk rules are being complied and that everyone is inside the safety area.

   o More than two users can be in the 3D safety area, depending on the task they must perform.

   o The workers must wear the safety clothes and must comply with the 5 golden rules (DSO's safety and health procedure) before executing any task. They must be sure that all the elements of the area they are going to work on have been deenergized.

   o The five golden rules consist of the following steps:

      1. Opening with effective cut-off of all voltage sources.
      2. Locking and signalling of the circuit-breaking devices in the open position.
      3. Checking for absence of voltage (immediately before earthing and short circuiting).
      4. Short-circuit and earthing (immediately after verifying the absence of voltage).
      5. Marking and delimitation of the working area (physically). Plastic fences and signaling will be installed for the scope. The fifth step is implemented only if the previous four are completed and verified by the work manager, who verifies the correct application of the steps and authorizes the access to the area for installing the fences.

10. Before executing any task, the work manager will configure and upload the safety areas to the software front-end through a dashboard. The dashboard will be accessed on the main PC of the primary substation, on the smartphone or on a tablet (Android devices). The system will have some predefined areas depending on the activities that will be carried out to suggest the worker the safety areas (a guide for the workers).

11. At that moment, the real-time system will monitor the worker and his tools (like poles, screw drivers, etc.), and guarantee that none of them trespass the safety area.

12. It will also be possible that more than one group of workers are working at another site of the substation, so more than one safety areas will be delimited. None of the workers can change from one safety area to another one.

13. If any worker exits the safety area while the work is being executed, the system will emit the warning signal.

14. The warning signal will be sent to different people/entities, as it can be seen in Table 18.

15. The worker may go out of the safety area to get some tools and will do it through safe corridors that will also be indicated to the workers.

16. There should be a tool/tag so that the preventive risk responsible can deactivate the warning signal if it is a false alarm.

17. Once the activities are finished, the 3D work safety area is removed by the manager worker in the dashboard. The RLTS will always have uploaded a default safety area to avoid that any worker approaches any high voltage element.

18. When the workers finalize their maintenance activity, they will leave the substation.

The people whom the warning signal will arrive after an intrusion are listed in Table 18. The first column indicates the role of the person that receives the warning signal. The second column indicates the type of warning signal; tag refers to vibration of the devices that workers wear on the wrist, audio visual refers to an alarm that will emit sound and lights. The column comments may clarify the position of the receiver.

Table 18: Destinations for the warning signal in #UC2

Receiver	Warning signals	Comments
Worker	Tag	
	Audio-visual	
Manager of workers	Tag	
	Audio-visual	
Preventive risk responsible	Tag	
	Audio-visual	
Control room	Call	Monitoring the substation
	email	
	Other-SCADA control room signalling	
Head of Substation	call	He will be at the Substation
	email	

3.3.2.2. Scenarios and sequence diagram

Scenario 1 (one or more safety areas) – stay in the safety area. The worker gets into the primary substation and stays in the predefined, safety area and no warning is triggered.
- Step 0: 5G network configuration
- Step 1: Safety and delimitation process
- Step 2: Removal of safety area

Scenario 2 (one or more safety areas) – cross passing the safety area and trigger of alarm. Worker gets into the primary substation enters delimited area and a warning is generated.
- Step 0: 5G network configuration
- Step 1: Safety and delimitation process
- Step 2: Warning signal
- Step 3: Removal of safety area

0) "Day 0" configuration, necessary before the actual demo that involves workers going to the substation.
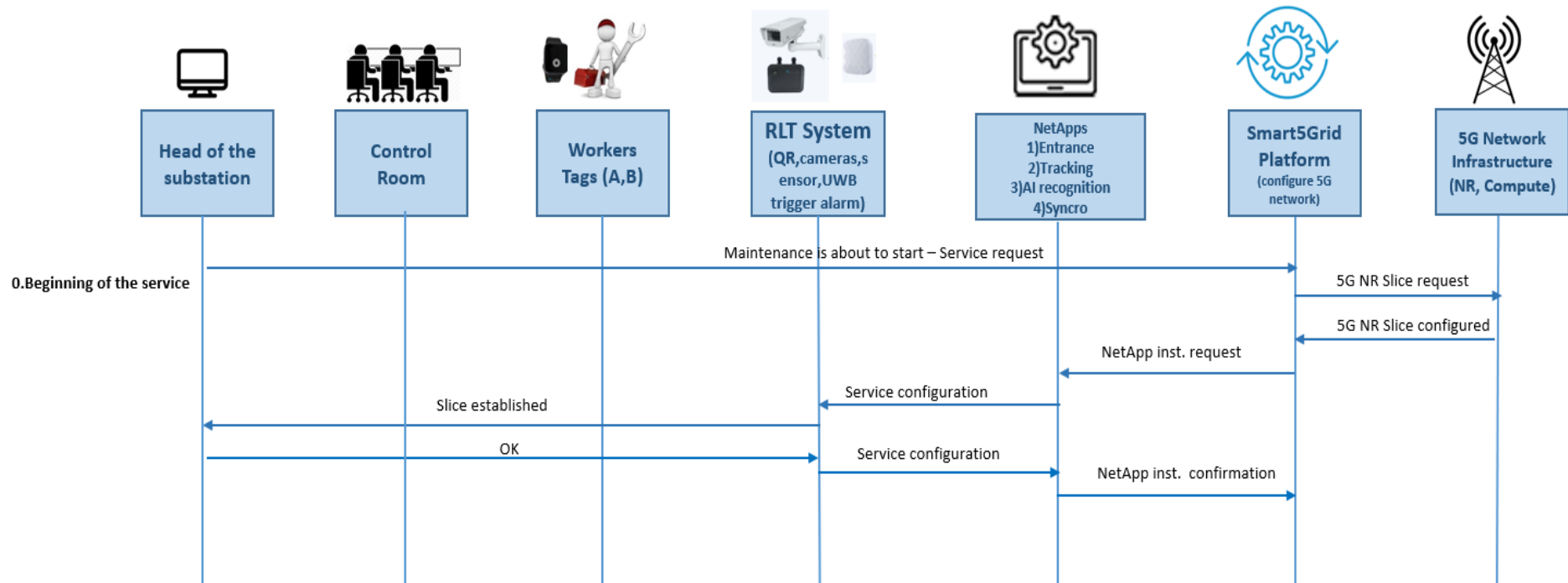
Figure 16: UC#2: Sequence diagram for the network service configuration stage
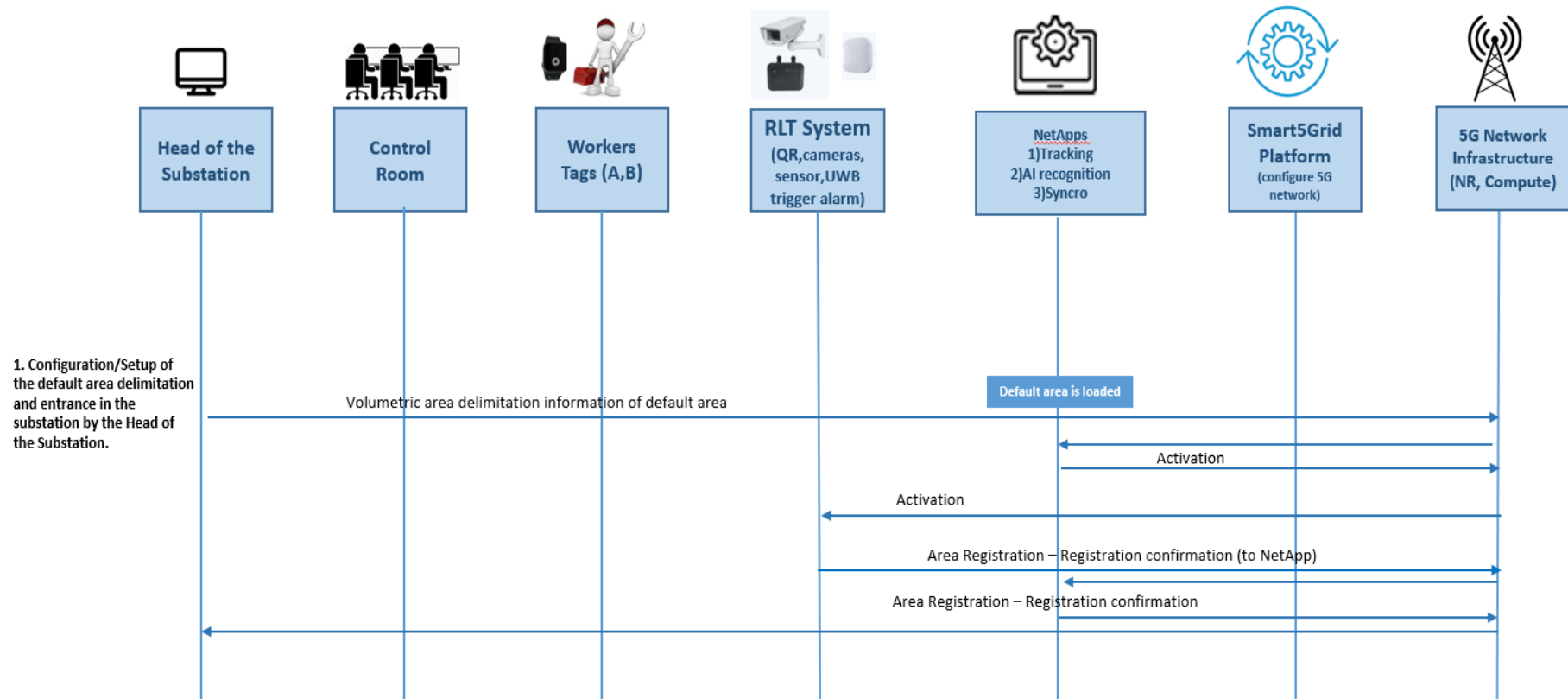
Figure 17: UC#2 Sequence diagram for the safety area delimitation process
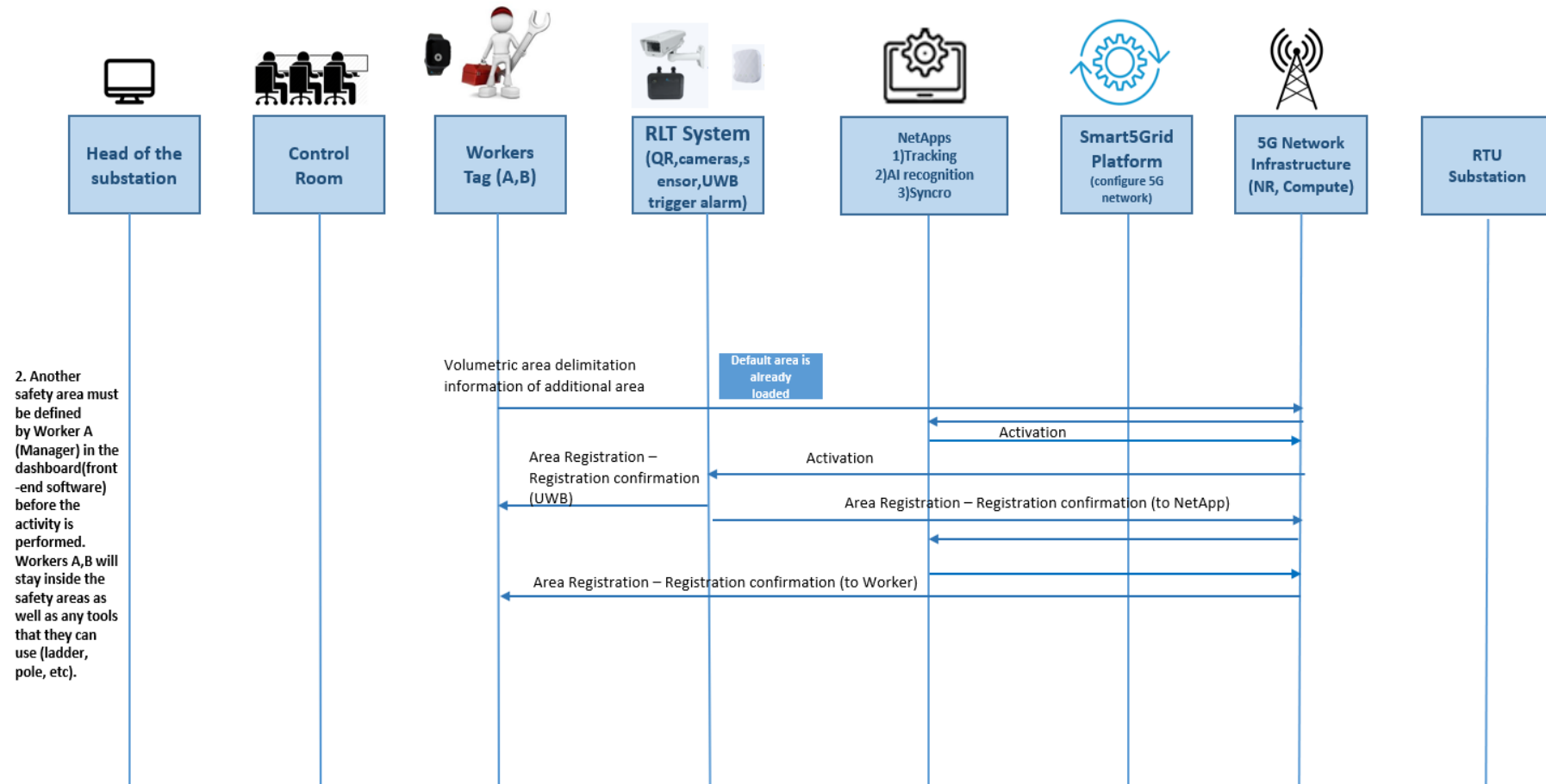
Figure 18: UC#2 Sequence diagram for the safety area delimitation process
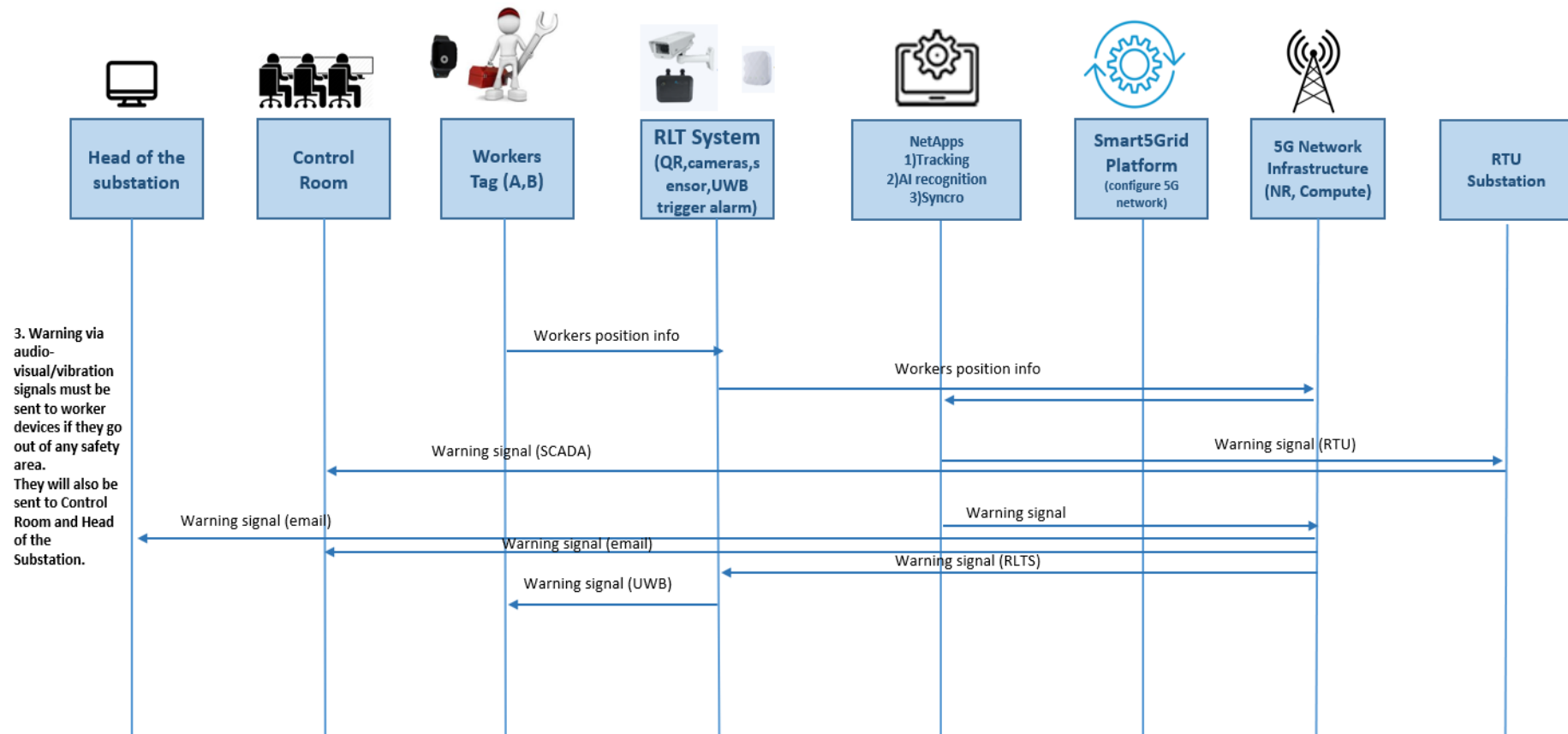
Figure 19: UC#2: Sequence diagram for warning signal trigger in the case when the workers are performing maintenance activities in the primary substation
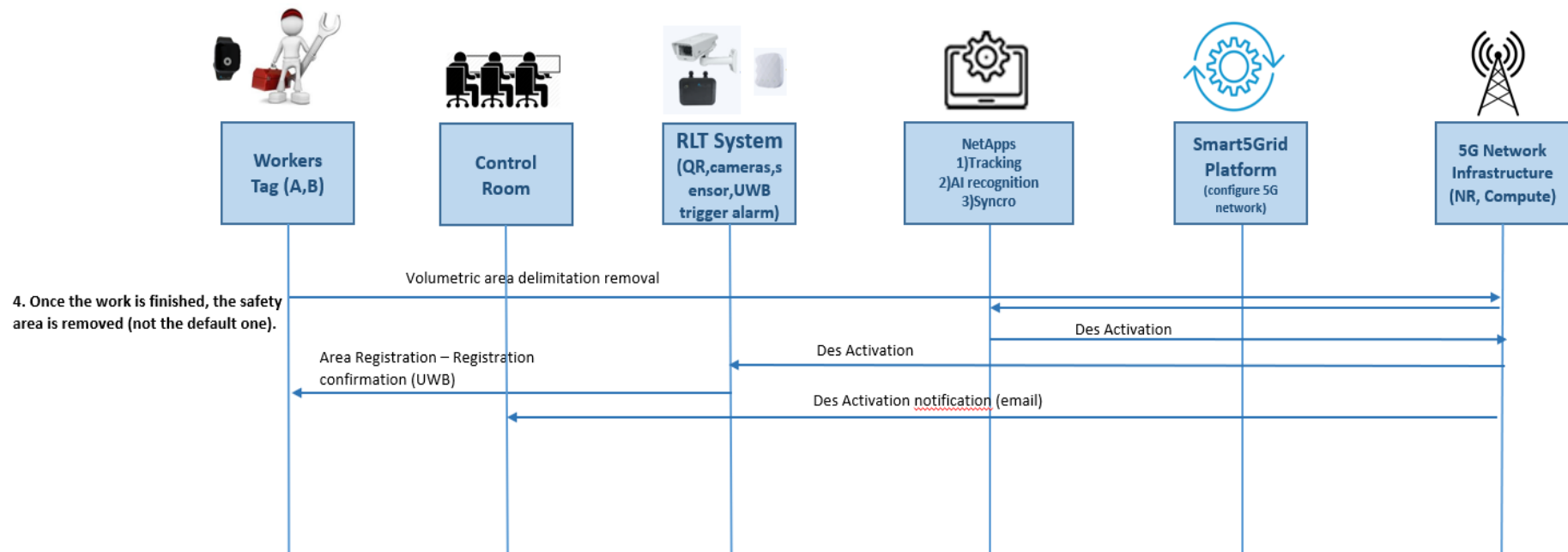
Figure 20: UC#2: Sequence diagram for the removal of the safety area.
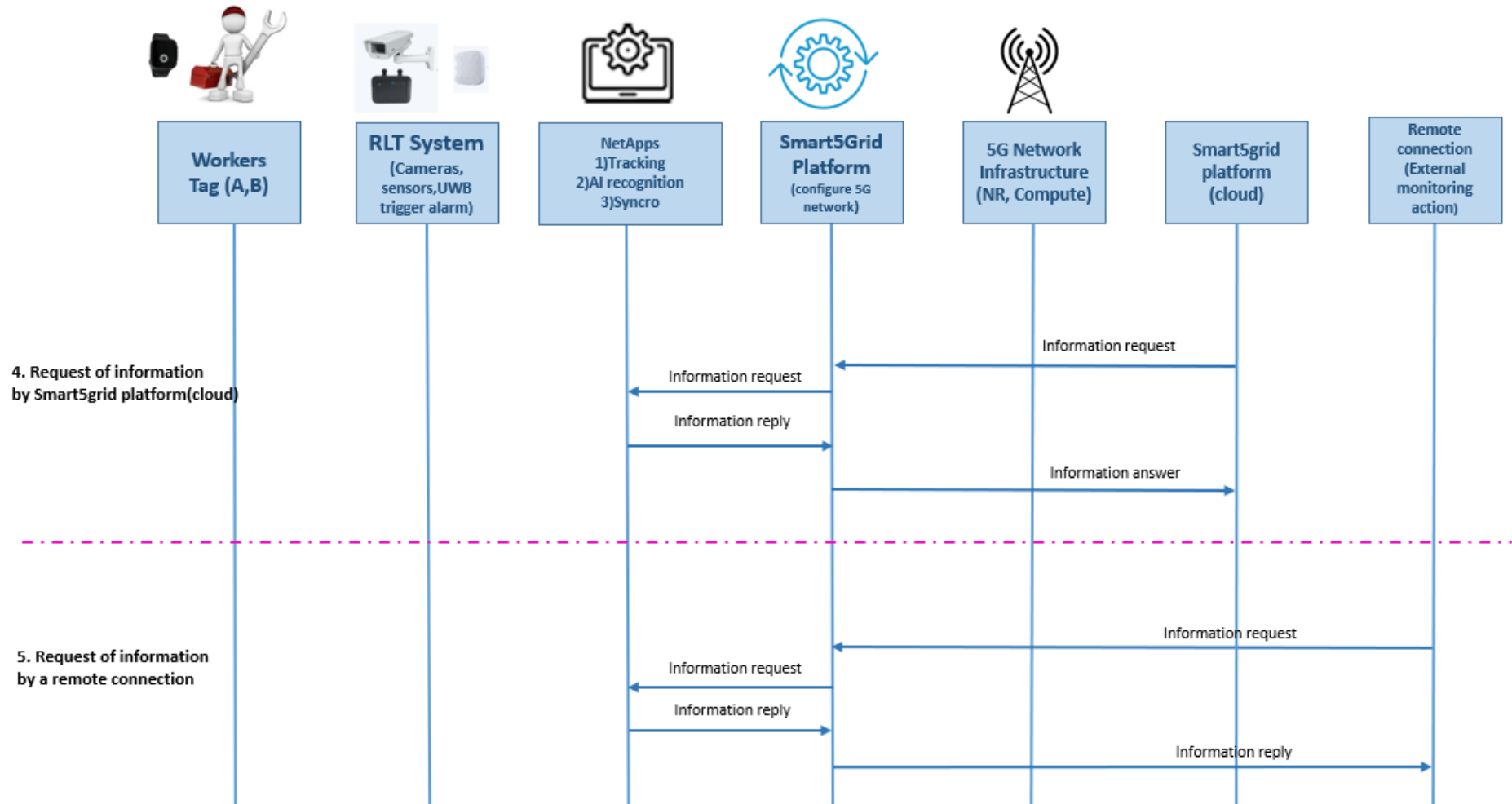
Figure 21 UC#2: Sequence diagram for the interaction between workers and the Smart5Grid Platform

3.3.3. 5G-Network requirements

As it concerns UC#2, two types of network services are considered of importance, the URLLC and the eMBB. The initial use case requirements gathered in Table 19 are intended to be as representative as possible taking into account the radio hardware for private 5G networks expected to be deployed and using the knowledge about the performance of other software and hardware elements used in the use case.

Table 19: Summary of network requirements for the UC#2

| Use case Requirements		Units	UC #2		
			Remote Inspection of Automatically Delimited Working Areas at Distribution Level		
			5G Use case category/Slice Type		
			URLLC	eMBB	mMTC
1	Communication service **Availability**	%	99.99%	99.99%	-
2	Communication service **Reliability**	%	99.99%	> 90%	-
3	End-to-end **latency**	ms	< 100	< 200	-
4	RAN latency	ms	< 50	< 50	-
5	Data rate	Gbps	< 0.01	< 0.15	-
6	Device Density	Dev/km2	< 30	< 20	-
7	Location Accuracy	m	0.5	< 2	-
8	Security	Y/N	Y	Y	-
9	Network slicing	Y/N	Y	Y	-
Use case specific additional requirements					
10	Type of connection		UWB, 5G NR	5G NR	
11	Type of device		CPEs, UWB-tags	CPEs	

Please note, that the set of requirements shown here could potentially also be served by other, non-5G radio technologies (e.g., the RAN latency below 50 ms could also be provided by 4G radio). However, it is important to note that the pilot deployed in this use case

- will be of small dimensions, i.e., presenting only small coverage and a limited number of use equipment, which limits the required bandwidth as with only a single radio unit the entire pilot can be covered;
- combines 5G-NR technologies with non-5G technologies, which reduces reliability and expected data throughput and packet loss rate;
- the commercially available 5G NR equipment and software solutions is not yet delivering the features of ultra-reliable and low-latency communications (e.g., delays of several tens of milliseconds;
- includes image processing, which has a significant impact on the end-to-end delay.

Considering the above, the radar charts of the network requirements per each type of services to be exploited as part of UC#2 are presented below.
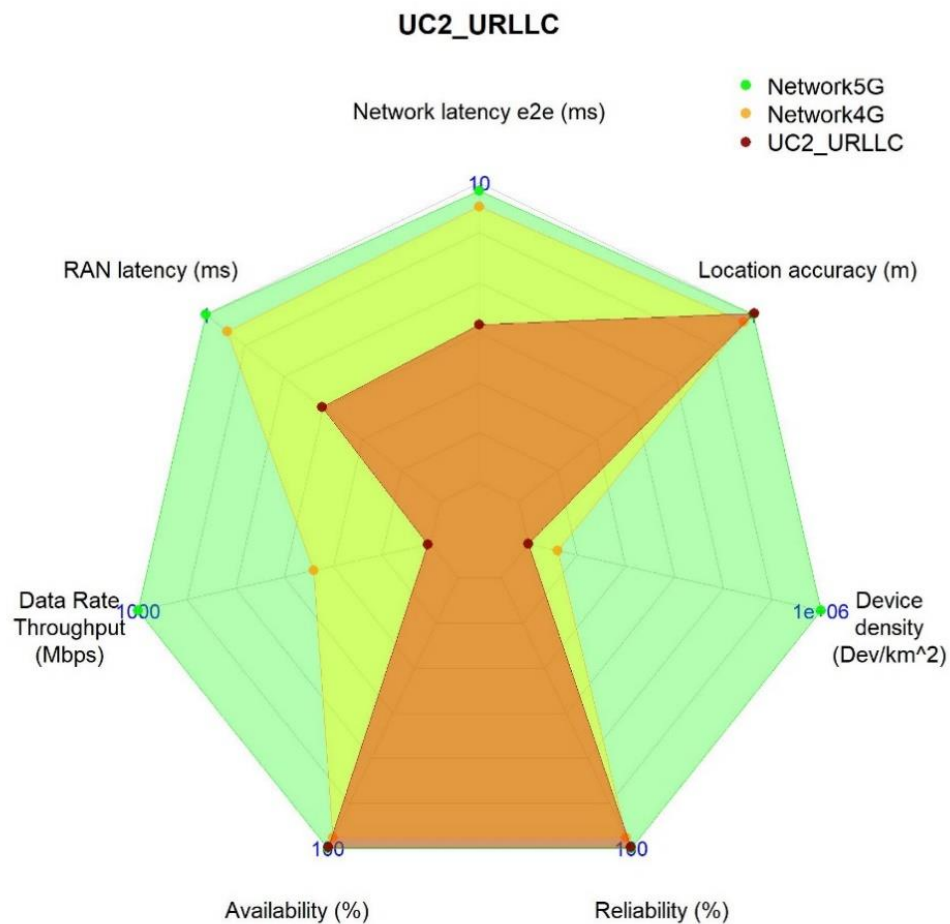
Figure 22: Radar chart for network requirements for UC#2 - slice URLLC

It is important to highlight that those certain features, such as edge computing, which reduces latencies considerably, as well as the network slicing to differentiate types of traffic and assigning different QoS is not possible without 5G. Further, as the commercial availability of 5G will increase and the performance of the radio elements will be better in terms of latencies, the requirements imposed upon such a network for this use case can be much lower, which will lead to even higher security levels for the early detection of risk for the workers in substations. Also, with more spectrum available than the expected 20 MHz in the pilot, many more devices in different slices will be able to be served, potentially also supporting additional, non-critical slices used for regular communications.
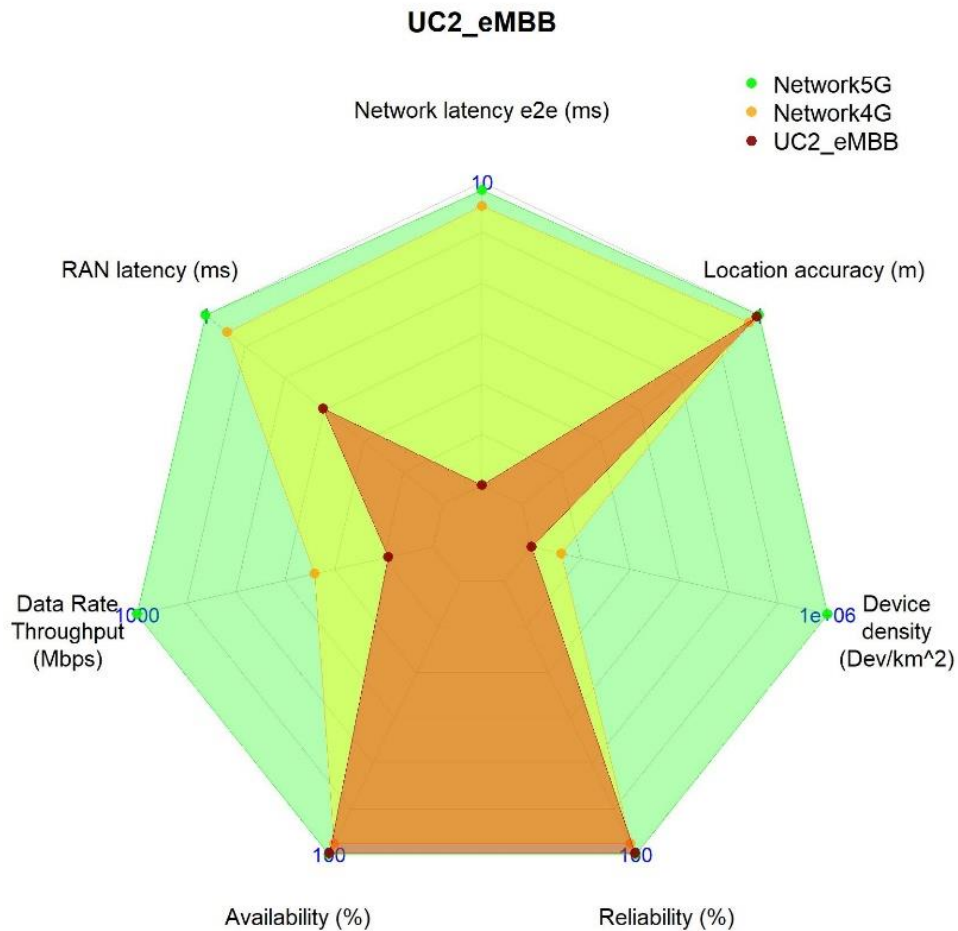
Figure 23: Radar chart for network requirements for UC#2 - slice eMBB

3.3.4. Summary of the UC

Below we provide a summary of the most important aspects of the UC#2 in what concerns the use-case specific service to be developed in the form of NetApp, as well as specific network services to be exploited.

Table 20: Summary of UC#2

UC-ID	UC Title
ES-RI	Remote Inspection of Automatically Delimited Working Areas at Distribution Level
Service(s)	Real Time Location System
New mechanism in the demo even if service already exists (new functional processes)	Improvement of working safety conditions

UC-ID	UC Title
Assets used (infrastructure, resources)	UWB zone readers, gateways, personal tags, stereo cameras. 5G network (Radio elements, Core), Edge Compute, RAN Controller and Slicing and Orchestration Engine.
NetApp role	Tracking function and AI recognition system.
Scenarios	• Workers enter the primary substation and stay in the predefined, safety area and no warning is triggered. • Workers enter the primary substation, enter a delimited area, and a warning is generated. • Note: both scenarios support multiple workers and several safety areas.
5G-services in the Demo	List the 5G-services to be tested • 5G Core with a User Plain Function at the edge to enable local breakout. • 5G Stand Alone network with bandwidth dedicated to the UC services.
5G KPIs of the Demo	List the relevant 5G KPIs targeted • Reducing average service deployment time cycle to 90 minutes • End-to-End Delay: 50-100ms • High network availability/reliability: 99%

Due to the usage of 5G communication, the transmission of images and data in real time (only with 50-100 ms delay) can be done. The safety of a l worker must be monitored in real time because, as mentioned before, the person's life is at a stake. The great advantage of using this private 5G network is also that other sensor devices can be deployed in the substation. The 5G networks offers this flexibility and, as t more services can be provided, other kind of different Netapps could be developed for the Distribution System Operator.

3.4. UC#3: millisecond level precise distributed generation monitoring

Due to the decarbonization mandates, the rate of penetration of DERs at the different voltage levels of the European interconnected power system is steadily increasing. However, the high stochasticity of DER provokes significant problems in the operation of both transmission and distribution grids, where issues regarding voltage stability, congestion management, and frequency regulation are augmented. In addition, the steadily decreasing power system physical inertia (due to the reduction of synchronous generators), necessitates the operation of very fast frequency regulation services (such as the Fast Frequency Response service in Nordics with full activation time of 700 ms for 0.5 Hz deviation[37] and the dynamic containment in United Kingdom with full activation time of less than 1s[38]). The participation of DERs, such as battery storage assets, wind farms, IoT-enabled devices for demand response activation,

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[37] https://www.statnett.no/globalassets/for-aktorer-i-kraftsystemet/utvikling-av-kraftsystemet/nordisk-frekvensstabilitet/ffr-stakeholder-report_13122019.pdf.

[38] https://www.nationalgrideso.com/balancing-services/frequency-response-services/dynamic-containment?technical-requirements.

etc. in those innovative services through electricity market frameworks, requires both orchestration (optimization of assets setpoint) and assets full activation in sub-second latency, in order to meet the strict temporal requirements for service provision. In addition, DER aggregators, and Balancing Responsible Parties (BRPs) shall be able to balance their portfolio in hard-real time conditions, eliminating any imbalances introduced in the high-RES penetrated power system, and thus saving money from heavy balancing costs (avoidance of imbalance penalties). Therefore, the introduction of 5G can reduce significantly the time needed for both the monitoring and activation of signals to arrive from and to the field assets, while ensuring reliability and last mile connection in remote areas (e.g., wind farms are usually located outside residential areas). This will provide an adequate time for complex computational activities to be conducted in hard real-time, leading to an efficiency increase in DERs orchestration and enhanced economic benefits of the owners/aggregators/BRPs.

Towards that direction, UC#3 aims at demonstrating the utilization of 5G for the fast monitoring of DERs. Specifically, in the context of this use case, the real-time monitoring with millisecond latency of a wind farm connected to the Medium Voltage (MV) level will be performed by using the emerging capabilities of 5G telecommunication networks. Furthermore, on top of that functionality, UC#3 deals with the operational availability of the Wind Farm. It is important for the Wind Farm owner, or aggregator or DSO to be confident whether the power plant is currently in operation. Thus, besides lack of real-time observability of those grid connection points, sometimes, due to maintenance, inspection, or unforeseen circumstances (such as a wind turbine failure or a grid fault close to the connection point of the wind turbine), the DER power plant may not be in operation. In such a case, the power plant manager/ owner may forget to notify the aggregator/DSO which can result in heavy balancing costs (unbalance penalties occur). In case of fast monitoring of a wind farm in such unforeseen cases, the DSO or an aggregator may be able to regulate fast upward service by other flexible resources to compensate the abrupt power change that can disturb the operation of the grid.

Specifically, in the context of UC#3, a NetApp will be developed for real-time monitoring of the operational characteristics of the wind farm. It is to be noted that the utilization of massive machine type communications (mMTC) core service of 5G can be leveraged to collect data stemming from IoT-enabled sensors and other sources (e.g., vibration sensors, data from SCADA, etc.) when similar NetApps are available for all small DER spread across the entire grid and which currently are not observable by the relevant DSOs or TSOs. As such, the NetApp to be demonstrated in UC#3 is aimed to provide proof of concept for scalable solutions for connectivity to a huge number of devices that measure the operational characteristics of wind parks, or other type of small DER. Besides observability, the real time monitoring of those assets will also enable scalable predictive maintenance applications for DER owners through the utilization of 5G networks. It is intended that the developed solution will be complementing the existing developed in-house solutions, and thus leveraging the data stemming also from different vendors, improving the quality of predictive maintenance processes.

The wind farm involved in the UC#3 is a small generating unit which has a stand-alone, vendor closed-SCADA system which is not integrated with the SCADA of the DSO where the farm is connected within the power grid. Note that this is not a particular case, but it is rather a very common situation that at DSO level there is no or little real-time power system observability (both for RES production and for the load consumption). This situation is a real challenge when it comes to proper operation of the distribution grid or coordinated operation of transmission and distribution grids. Thus, as part of this UC#3, the direct connection of DER assets connected to the distribution grid with the SCADA system of the operators (both DSO and TSO) will be demonstrated and thus enhancing the real-time power system observability.

To this end, two services are targeted as a part of the UC#3, which are related to two distinct and UC-specific NetApps:

• **Real-time production monitoring**: the wind farm owner, and the power system operator (i.e., DSO or TSO) monitor in real-time with a millisecond latency the production of the wind farm (active and reactive power measurements). On the one side, wind farm owner can increase efficiency and response in production control. On the other side, the DSOs/TSOs can enhance power system stability through the participation of DER connected to the distribution grid in fast frequency response services in hard-real-time. Even though in the existing regulatory framework the DSOs/TSOs cannot observe the production of assets connected to the distribution grid, in UC#3 it is demonstrated that the monitoring signal of a wind farm is sent to both TSOs and DSOs. This will foster the development of innovative observability models for power system operation, where TSOs gain insight in lower voltage levels of the grid.

• **Predictive maintenance**: gathering measurements from sensors, such as rotational speed, vibration, wind speed, total energy production, moment power, temperature of the environment, etc. allows for capturing the performance of key components of the wind turbines, and thus offering the wind farm owner information regarding the asset performance, and the power system operator information about the operational availability of the asset.

Considering the above framework, an additional investigation will be performed to validate the applicability of 5G network to be used for enabling the coordination of DER portfolio to provide balancing services in a millisecond basis. This investigation will only be showcased during the pre-piloting phase, using the real-time hardware in the loop facilities of UCY. In this pre-piloting investigation, realistic operating conditions of a power system with intense penetration of RES will be emulated within a real time simulator, and the balancing services provided by flexible DER will be evaluated when 5G communication is used. It is noted that the exact field conditions of UC#3 will not be replicated due to confidentiality of the data related to the Bulgarian power system, and dynamic test systems will be used instead to formulate this investigation. The 5G communication will be integrated in the hardware in the loop framework through a network emulator to investigate how the performance of the communication network can affect the operation of the power system in such a use case. It should be clarified that this investigation cannot be demonstrated in the actual field due to the lack of a regulatory environment in Bulgaria about the existence of fast frequency services and products[39], and the participation of DERs in the ancillary services market. Furthermore, the invasive character of this investigation, which relies on a high-power disturbance imposed by a wind farm operation, needs first to be validated and demonstrated in a controllable but realistic environment (such as the real time hardware in the loop framework) in order to convince the stakeholder for the necessity to use 5G communication in such fast balancing services.

Business Goals:

From the vertical application point of view, there are three main business level objectives:

1. Provide real-time monitoring services of the energy generation of a wind farm in hard real-time conditions, i.e., milliseconds response time, for both owner and system operators.
2. Enable predictive maintenance services in the wind farm (located in a rural area), by receiving real-time measurements from multiple sensors.

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[39] Krstevski, Petar, Stefan Borozan, and Aleksandra Krkoleva Mateska. "Electricity balancing markets in South East Europe—Investigation of the level of development and regional integration." Energy Reports 7 (2021): 7955-7966.

3. Provide the wind farm owner live monitoring features through a web dashboard and/or application on a smartphone device.

Service Objectives:

In terms of services, in order to accomplish the previous defined business level objectives, the following technical objectives are defined:

1. Collecting real-time measurements from the sensors existing at different parts of the wind farm. The data that monitor the operation of the wind farm will be stemming both from the wind farm SCADA system and from other sensors. For the former, an OPC server client pair will be used for communication purposes using the relevant protocols of the SCADA system., In the later case, such as vibration sensors procured from Vestas (the provider of wind turbine SCADA) or by other 3rd party vendors the communication protocol is to be defined based on the sensor's technical specifications.
2. Visualization of the power production (both active and reactive power) of the wind farm.
3. Analysing data which enables predictive maintenance through 5G infrastructure of the wind farm to the wind farm owner and/or to the maintenance service supplier.

Benefits

The benefits that this use case has can be classified in the following four categories as:

- **Business:** Increased visibility in wind farm operation, not only from an energy production point of view but also from a multi-parameter wind turbine life cycle perspective, provides the owners fertile ground to better manage their assets and offer innovative flexibility services. From the DSO point of view, enhancing the observability of the grid by real-time visibility and monitoring of the DER power production allow for better operation of the grid; while from the aggregator point of view, real-time monitoring of portfolio assents such as DER allows for better planning of the service portfolios to be offered, especially in real-time balancing electricity market. Table 21 provides a summary of a set of comprehensive business related KPIs for this UC.

- **Economic:** Replacing parts of the wind turbines on time before the complete performance degradation of the wind farm, leads to continuous uninterruptible production, minimizing, at the same time, the maintenance cost. Having knowledge of the real-time production in a millisecond basis, the system operator can minimize the overall system cost and the owner can benefit financially by providing innovative services to the operator, such as voltage regulation. In addition to that, better portfolio management of the BRPs can lead to lower deviations from the committed program and thus to lower needs and cost for balancing services.

- **Social:** Secure and uninterruptible energy provision to the end-user.

- **Environmental:** High visibility in RES production leads to better management of the power system and thus reducing the need for RES curtailment in order to alleviate congestion issues and imbalances. Higher participation rate of RES in the energy mix leads to cleaner energy production and lower levels of CO_2 emissions.

- **Technological:** 5G is a relatively new technology and researching, testing and validating IoT devices to work over 5G in a real use case will pave the way for further adoption of IoT devices over 5G into energy sector and other industry verticals.

Table 21: Summary of business KPIs for the UC#3

Business KPIs	Additional explanation	Means of verification	Indicative quantitative values
Reduced wind farm down time	Due to a malfunction	Comparison between historical annual statistics and down time during the demonstration activities	Reduction >120%
Reduced maintenance cost	Predictive maintenance can prevent faults and therefore expensive repairs	Comparison between existing maintenance cost and costs due to the predictive maintenance NetApp	Reduction >10%
Reduced financial loss	Reduction of wind farm down time leads to reduction in financial losses	1) Number of down time events 2) MWh lost during downtime period Comparison between historical data, and actual data measured from the demonstration activities.	Reduction >10%
Decreased DER asset monitoring time	Due to low latency monitoring of power production	Measure the difference in time monitoring in the existing conditions (measurements though OPC server) and the time through the 5G infrastructure in the lab environment.	Reduction >80%
Potential for asset owner to generate additional revenues from providing ancillary services	Real time visibility on the asset generation will allow the asset owner to participate in the (future) flexibility market and provide/trade flexibility services	1) Number of the actual flexibility transactions 2) Volume (MWh) of the actual flexibility transactions	Minimum 1 transaction per month (this could be only demonstrated on a simulated lab environment, as the current legislation and market design don´t provide for ancillary services for RES)

3.4.1. Actors, conditions and technologies involved

3.4.1.1. Actors and stakeholders

Main Actors:

- **Transmission System Operator (TSO):** responsible for system balancing and for the procurement of ancillary services.
- **Wind Farm Owner:** owner of the wind farm plant.
- **Balancing Service Provider (BSP):** responsible for provision of balancing services to the grid system operator.
- **Balancing Responsible Party (BRP):** entity accountable for imbalances in the real-time electricity market.
- **Dispatch Center:** responsible for proper operation of the power system.
- **IoT devices:** sensors measuring the real-time operation of different components of the wind farm.
- **User Interface (UI) dashboard:** responsible for visualizing data based on end-user's needs.
- **Telecommunication Provider:** owner of the telecommunication network (i.e., gNBs, optical fibre, backhauling system), that is responsible for stable, secure and reliable 5G coverage. Besides the needed infrastructure, the Telco Provider also offers the 5G Core to ensure the low latency and high reliability needed for the UC.
- **Infrastructure Owner:** the provider of the server that is going to host the Smart5Grid Platform, and the developed NetApps, that will run at the edge. This infrastructure is crucial as most parts of the pilot will be executed on it.

Stakeholders:

- **ESO:** The transmission system operator directly engaged in the use case, due to the need to increase visibility in DERs state, thus enhancing system balancing capability.
- DSO: The distribution system operator indirectly engages in this use case, due to the need to increase its forecasting abilities in the connected DER assets to its network.
- **National Regulatory Authority (NRA):** The national regulatory entity of Bulgaria could leverage the outcome of this use case, in order to identify the applicability of the developed NetApps in the Business-as-Usual practices of the operators and aggregators.
- **Aggregators:** New business models could be created using the functionalities introduced by the NetApps developed as part of this use case.
- **End-consumers:** End-consumers of electricity could be considered as stakeholders, who are interested in lower prices and better quality of power, benefits that the functionality of this NetApp could offer.
- **VIVACOM:** The telco provider in this use case could leverage the knowledge gained through the engagement in this use case, in order to develop new business models in the energy sector leveraging the opportunity that 5G networks offer.

Table 22: Actors involved in the UC#3 and their roles

Actor	Type	Actor Description
TSO	Role	Responsible for system balancing and procurement of ancillary services.
Wind Farm owner	Person	The owner of the wind farm plant.
BSP	Role	Responsible for provision of balancing services.

Actor	Type	Actor Description
BRP	Role	Entity accountable for imbalances in real-time market.
Dispatch Centre	System	Responsible for proper operation of the grid.
IoT devices	System	Sensors measuring the real-time operation of different components of the wind farm.
UI dashboard	System	Responsible for visualizing data based on end-user's needs.
Telecommunication Provider	Role	Owner of the telecommunication network and responsible for stable, secure and reliable 5G coverage. Besides the needed infrastructure, the Telco Provider also offers the 5G Core to ensure the low latency and high reliability needed in the UC.
Infrastructure Owner	Role	The infrastructure owner is the provider of the server that is going to host the Smart5Grid Platform, and the developed NetApps, that will run at the edge. This infrastructure is crucial as most parts of the pilot will be executed on it.

3.4.1.2. Conditions and technologies involved

Due to climate change, the finite reservoirs of fossil fuels, and the constant reduction cost of RESs technologies, it is expected that by 2050 most of the worldwide electricity will be produced by renewable sources. This unprecedented high percentage creates new challenges for the power grid stability, as most of the RESs produce extremely volatile energy and have extreme power variations in short amounts of time. Additionally, the most widely used RESs, solar and wind energy, cannot reliably inject mechanical inertia into the local power grid, which creates reliability issues for keeping the frequency at the desirable nominal range. As the RES deployment is essential, and utility companies demand that the total amount of planned and unplanned downtime of the power grid is not more than 5,26 minutes per year (i.e., 99.999% reliability), DSOs/TSOs need to deploy new techniques for keeping the power grid performance at high levels. The control of voltage and frequency in both distribution and transmission grids isthe key challenge for the future 100% renewable smart grids. These new procedures are still under development, and require many economic, legal, and technological changes (apart from the modifications in the electric grid).

 In the context of this use case, in order to increase the visibility in the operation process of RES, 5G technology is leveraged by collecting measurements from IoT devices existing at a wind farm. The business goal of this process is both the predictive maintenance of the wind farm (by gathering measurements from sensors capturing the performance of key components of the wind turbines) and the real-time operation (by measuring the real-time production of the wind farm and identifying deviations from the committed power in previous time frames). This information can be visualized either on a UI dashboard or a mobile phone application offering the owners the opportunity to be aware of their assets´ performance in hard real-time, i.e., with milliseconds latency.

Regarding the wind turbine performance monitoring, key performance parameters (such as turbine rotation and vibration) are collected from the IoT devices. Moreover, environmental parameters (such as wind speed, humidity, and ambient temperature) along with electrical parameters (such as power output, grid frequency, and voltage) are measured in order to provide, through the 5G network, fast and reliable real-time operation of the wind farm and to increase the owner's role both as a BRP and BSP.

Location

In this UC, the specific location of the wind farm is South-East Bulgaria – Sliven region. The wind farm has an installed capacity of 2MW. The turbine and respectively the SCADA system are manufactured by VESTAS[40]. However, 5G rollout in Bulgaria is still in an initial phase. On September 21, 2020, VIVACOM announced the launch of its 5G network in all 27 district cities. This is the first stage of the introduction of the new technology which works simultaneously in the same frequency for both 4G and 5G - DSS in N3 (1800 MHz) frequency band. In 2021, VIVACOM have acquired N78 (3600 MHz) frequency resources and intensive rollout process was initiated in all settlements with population over 5000 inhabitants.

5G infrastructure rollout implies an intensive capital expenditure to introduce the technology. It is not financially viable to deploy in all geographic places at one time, e.g., in rural areas for residential, agricultural, or industrial use. The issue is related to the need of many base stations all over the place to deliver consistent coverage.

Since current 5G coverage does not reach the physical location of the wind farm, a real-time synchronized representation of the actual asset, i.e., wind farm, will be developed in the Vivacom's (Bulgarian telecommunication Operator) lab in Sofia, where 5G is already available for commercial use. Figure 24 illustrates the use case topology. In order to ensure that the simulated model replicates the data sent by the actual wind farm without any deficiencies and inaccuracies, tests will be conducted during the pre-piloting phase to compare those datasets with data stemming from the Hardware-in-the-loop (HIL) asset, which will emulate the Wind Farm operation.

Current Situation

Today, the vast majority of the communication technologies used for the communication between the RES assets and the power grid are still wire-bound, including a variety of dedicated Industrial Ethernet and power line solutions, as there was no need for wireless connectivity in the past, due to the relatively static and long-lasting installation of the power grid equipment. In addition, up to now, most of the existing wireless technologies could not achieve the demanding requirements of industrial applications, especially with respect to end-to-end latency, communication service availability, jitter, and reliability. The farm is interconnected to the Medium Voltage grid of the local DSO-EVN. There is a land line that connects the Turbine's systems to the internet. The supervision and the on-site support of the wind farm is provided by OEM (Vestas) and Entra Energy and both have access to the SCADA data (trough IP). Neither DSO nor TSO have access / is connected to the wind farms SCADA system (nor to the other sensors data). With the advent of future Smart Grids and 5G, however, this will change fundamentally, since wireless connectivity can increase the degree of flexibility, mobility, versatility, and ergonomics required for the energy networks of the future. It is evident that the modern smart grid era will depend on devices that can monitor the various assets and manage big data, through ultrafast communications and cloud-based apps for efficient processing and decision-making. To do that efficiently, there is a need for devices that could help monitor, collect, and store data based on which innovative solutions for improving the grid could be made. Next-generation hardware and software technology with ultra-fast communications can ensure the smooth integration of the high RESs penetration to the smart grids.

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[40] https://www.vestas.com/en

 Assumption and Prerequisites

The following prerequisites are considered for the demonstration of the use case:

- The wind farm is already connected and fully operational.

- Currently, there is no regulatory framework in place in Bulgaria to allow the real field experimentation regarding the control of the wind farm production for the provision of fast frequency response services.

- Therefore, as mentioned above, through the simulations that will be conducted during the pre-piloting phase, the impact of sub-second control of DERs will be demonstrated, and thus the contribution of 5G network in the operation of the new era smart grids validated.

In addition, the IoT devices capturing the different parameters of the operation will be installed as part of the use case execution.

The data measured from the sensors that exist in the wind farm are forwarded through an open platform communications (OPC) server, located in the laboratory of VIVACOM, where the actual processing takes place. The data generation process is repeated in a Raspberry Pi, which possesses a 5G-HAT type module, supporting 5G connectivity. OPC Unified Architecture (UA), which is a machine-to-machine (M2M) communication protocol for industrial automation developed by the OPC Foundation, will be used as the communication protocol in the context of this use case. Afterwards, this component collects the data and executes an internal process to assess the wind farm operation to conclude whether any predictive maintenance action must be taken. IoT devices can allow the long-range connectivity and use lower-cost infrastructure to connect sensors manufactured by different vendors. Hence, through the utilization of IoT devices, different paradigms of data transfer and integration in the existing SCADA systems of both operators and RES owners will be demonstrated.

5G technology need

The need for 5G technology for the development of this use case is based on the following reasons:
- Previous generations of wireless technology do not fulfil the criteria for low-latency and high reliability in millisecond basis imposed by the use case's specifications. The participation of DERs in fast frequency response requires orchestration (optimization of assets setpoints) and assets activation in sub-second latency in order to meet the strict temporal requirements for service provision. Therefore, the introduction of 5G can reduce significantly the latency needed for the activation signal to arrive in the field assets. This will provide adequate time for complex computational activities to be conducted in hard real-time, thus increasing the efficiency of DERs orchestration. The scope of this use-case is not to read measurements with a millisecond resolution, but to demonstrate the millisecond latency of the signal to travel from the field assets to the NetApp.
- Anticipating and foreseeing the massive deployment of DERs that will penetrate the power systems, there is a need for new technology that could assist the transformation that the grid will experience, as well as the issues that will arise from that. The envision that more and more IoT-enabled energy devices will be connected and controlled by aggregators or system operators, and thus rendering necessary the investigation of robust solutions that consider the scalability aspect.
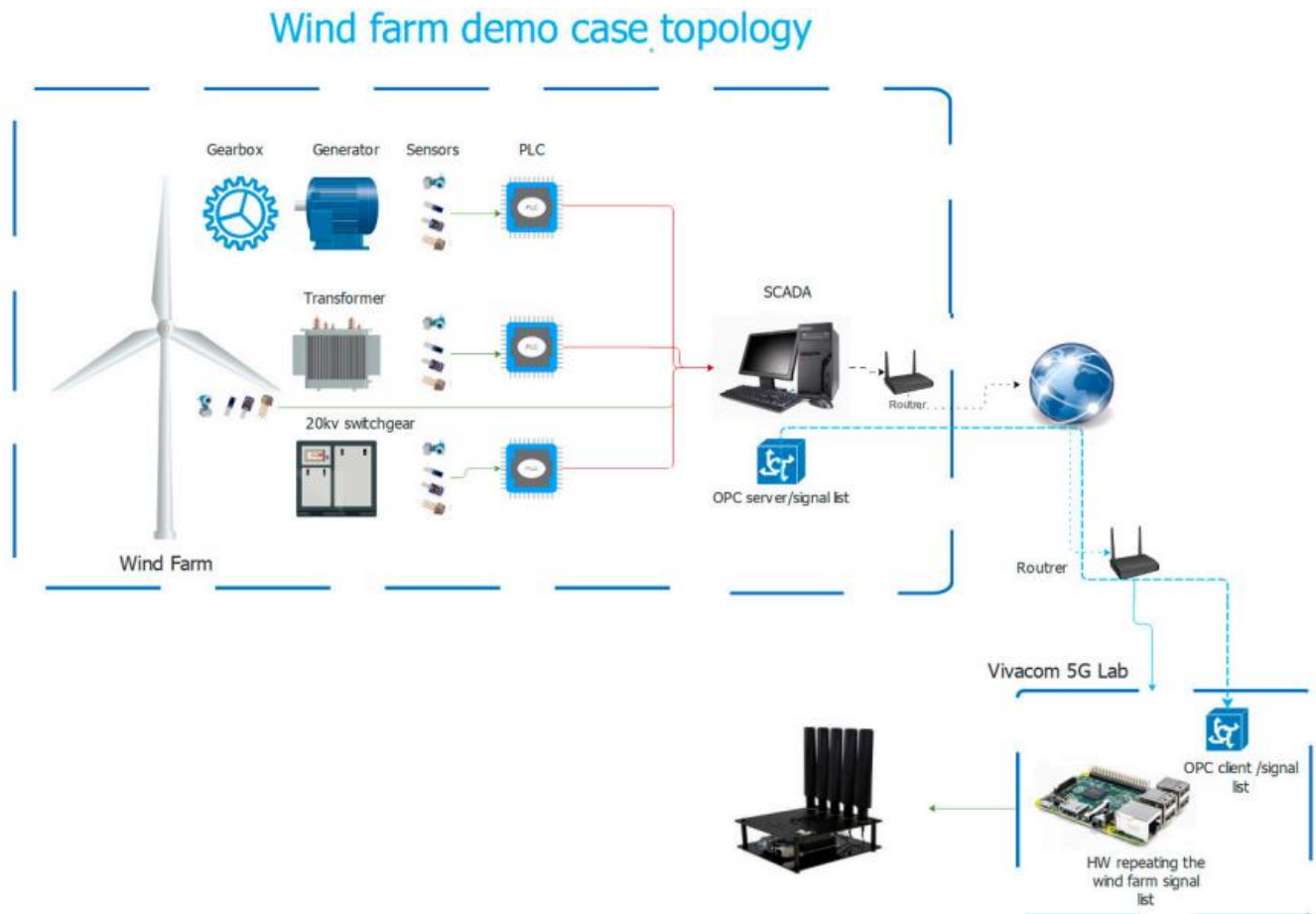
Figure 24: UC#3 Diagram of the demonstration setup

- In this case, we are talking about a widespread IoT ecosystem that includes millions or even billions of devices that operate on a range speed, have different bandwidth as well as a variety of quality of service (QoS) requirements. To achieve that, technologies before 5G cannot provide the needed coverage, latency, security, and cost optimization. Hence, scalability can be achieved through the utilization of 5G infrastructure and the mMTC core service of 5G, where data stemming from 5G-enabled IoT devices owned by different vendors can be sent to the NetApp without deteriorating the performance of the services. This solution provides scalability potential, where data stemming from sensors of thousands of different types of DERs, such as wind farms, solar parks etc., located at dispersed geographical areas and managed by a specific entity (e.g., aggregator) can be optimally used to increase efficiency in operation.

Compared to the optical fibre, 5G offers a more flexible and cost-efficient way of communication for the last mile connection, with similar values of the above-mentioned metrics. The rural location of the RES significantly increases the CAPEX in new projects, due to the high cost for dedicated investments in fibre infrastructure. Hence, the utilization of 5G can provide incentives to RES owners to further invest in new installations, by utilizing 5G networks even for the last mile network connection. In addition, the scalability potential of this UC can promote the deployment of 5G networks in remote rural areas across EU. In those particular areas, high wind potential may exist, enabling the construction of wind parks.

Preliminary requirements

The following requirements are identified in the initial phase of the NetApps development:

- **Cybersecurity:** Data security is of crucial importance for the power system. The wind farm operator should be ensured that an adequate level of data security must be achieved during the data transmission process through the 5G network, regardless of the data protocol used. In addition to that, information regarding grid variables must be ensured that is not linked to any party outside of the consortium, according to the data security protocols of the ESO.
- **Regulation:** According to the NetApp development phase, the regulatory framework defined by the National Regulatory Authority of Energy in Bulgaria should be respected.

3.4.2. UC-specific NetApp(s)

3.4.2.1. NetApp scope

Based on the above-mentioned desirable functionalities, the NetApp that will be developed in the context of UC#3 will implement two services:

Real-time production monitoring (URLLC): this service provides real-time data monitoring (i.e., with milliseconds latency) of the wind farm production to the owner and to the power system operator (i.e., DSO/TSO). Having knowledge of the real-time production with millisecond latency, the system operator can minimize the overall system cost, while the owner of the wind farm could increase the financial benefit from its asset by adding other services to be provided to the grid, such as fast frequency regulation services on top of regular power injection.

Predictive maintenance (mMTC): this service offers predictive maintenance capabilities to the wind farm owner, leveraging the data (from generator and switchgear) gathered from the sensors installed in the wind farm. In addition to that, real-time operational information about wind farm can be forwarded to the system operator, informing about the availability of the asset in real-time conditions.

3.4.2.2. Scenarios and sequence diagram

Below are given the sequence diagrams of the communication instantiation process and the NetApps evolution, together with their associated sequential steps.

The sequence diagram in Figure 25 provides the step followed during the instantiation phase, to be executed just one time, when the service goes live. Specifically, they are:
 Wind farm owner sends a service activation request to Smart5Grid platform.
2. Smart5Grid platform sends the sensors an activation request.
3. Sensors response to this activation signal.
4. Smart5Grid platform sends an activation signal to OPC server.
5. OPC server sends activation response to Smart5Grid platform.
6. Smart5Grid platform sends activation request to signal repeaters.
7. Signal repeaters send confirmation signal to Smart5Grid platform.
8. Slice request is sent from Smart5Grid platform to 5G Network Infrastructure.
9. Slice establishment response is sent to Smart5Grid platform.
10. Smart5Grid platform sends NetApp activation request to NetApps.
11. NetApps send activation response signals.
12. Service activation establishment signal is sent to wind farm owner.
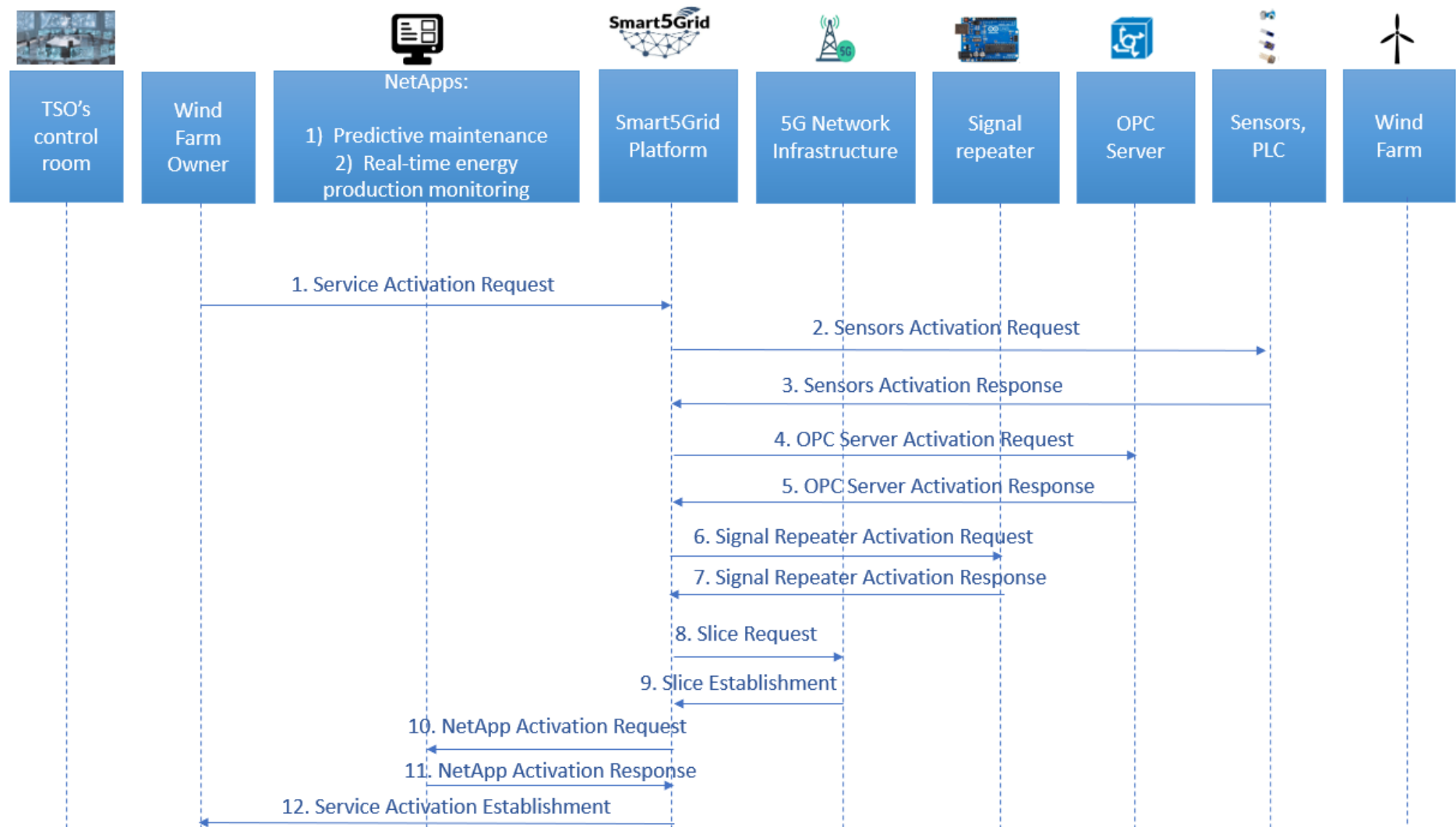
Day 0: Instantiation of Service

Figure 25: UC#3 Sequence diagram of Day-0, Instantiation of service

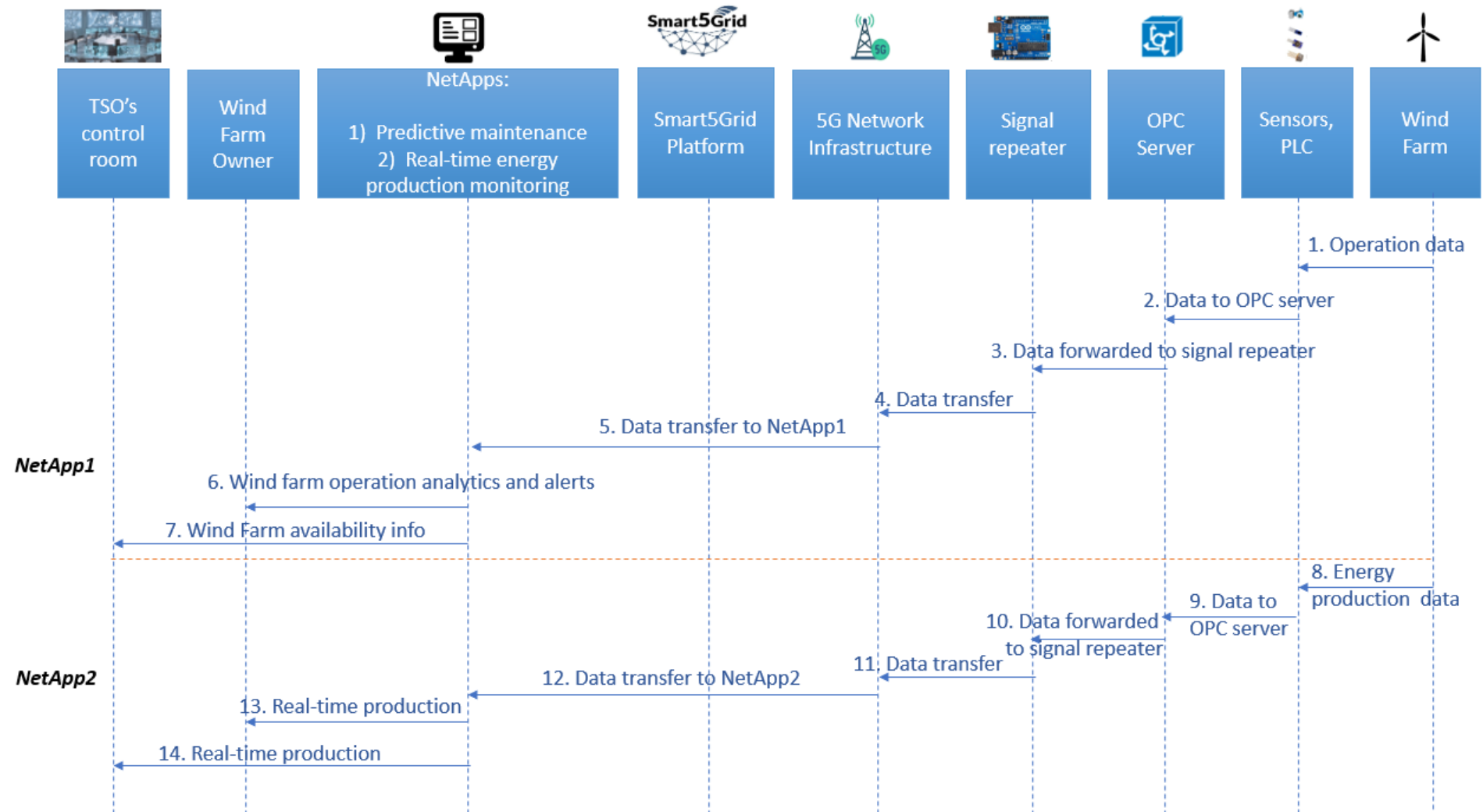Service operation to wind farm owner and TSO

Figure 26: UC#3 Sequence diagram of the NetApps' operation

The above sequence diagram provides the step followed during the service operation phase. Specifically:

1. Wind farm operation data, such as meteorological (humidity, temperature), electrical (power output, grid frequency, voltage) and mechanical (turbine rotation and vibration), are collected through sensors and PLC.
2. Data sent to OPC server.
3. Data forwarded to signal repeater located in Vivacom's lab.
4. Data collected by the 5G Network Infrastructure.
5. Data transfer to NetApp1.
6. Extra fine-granularity data, metrics, and alerts regarding the performance of the wind farm are illustrated.
7. Wind farm availability info are given to TSO's control room, in case that normal operation interruption occurs.
8. Wind farm energy production data in high resolution, i.e., millisecond basis, are provided by sensors.
9. Data sent to OPC server.
10. Data forwarded to signal repeater located in Vivacom's lab.
11. Data collected by the 5G Network Infrastructure.
12. Data transfer to NetApp2.
13. Real-time production data are sent and visualized in the wind farm owner's dashboard, or mobile application.
14. Real-time energy production information to the TSO's control room.

Some demonstration scenarios regarding the vertical service provided by the NetApps are:

- There is no abnormality detection in the wind farm operation, thus no alerts are sent to the wind farm operator.
- There is an identification of potential operation failure in the wind farm in the near future, and predictive maintenance information is sent to the wind farm owner.
- There is an availability issue of the wind farm in real-time (stop operating), and information is sent to both system operator and wind farm owner.
- Real-time production does not introduce any burden to the power system operator.
- Real-time production of the wind farm provokes system stability issues, and thus the system operator shall curtail the operation of wind farm.

3.4.3. 5G-Network requirements

As part of the UC#3 demonstrator two network slicing services are foreseen as necessary: the URLLC, present in all the other UCs as well, and the mMTC slicing service. The use-case specific requirements are related to the types of devices to be used, such as IoT and Gateways. High reliability and high availability are of significant importance, on top of an ideal 20 ms end-to-end latency.

A summary of the specific network requirements for this UC, are provided in Table 23 below. Further, for each type of slicing services the corresponding radar charts are following.

Table 23: 5G Network requirements for UC#3

	Use case Requirements	Units	UC #3		
			Millisecond Level Precise Distribution Generation Control		
			5G Use case category/Slice Type		
			URLLC	eMBB	mMTC
1	Communication service **Availability**	%	99.999	-	99
2	Communication service **Reliability**	%	99.999	-	99.0
3	End-to-end **latency**	ms	20-200	-	Not critical
4	RAN latency	ms	-	-	-
5	Data rate	Gbps	-	-	
6	Device Density	Dev/km2	1	-	1000/km2
7	Location Accuracy	m	not critical (static and known location of sensors)	-	not critical (static and known location of sensors)
8	Security	Y/N	Y	-	Y
9	Network slicing	Y/N	Y	-	Y
10	Private slicing	Y/N	Y	-	Y
	Use case specific additional requirements				
10	Type of connection		5G/NB-IoT/Wi-Fi		5G/NB-IoT/Wi-Fi
11	Type of device		IoT devices/ Gateways		IoT devices/ Gateways
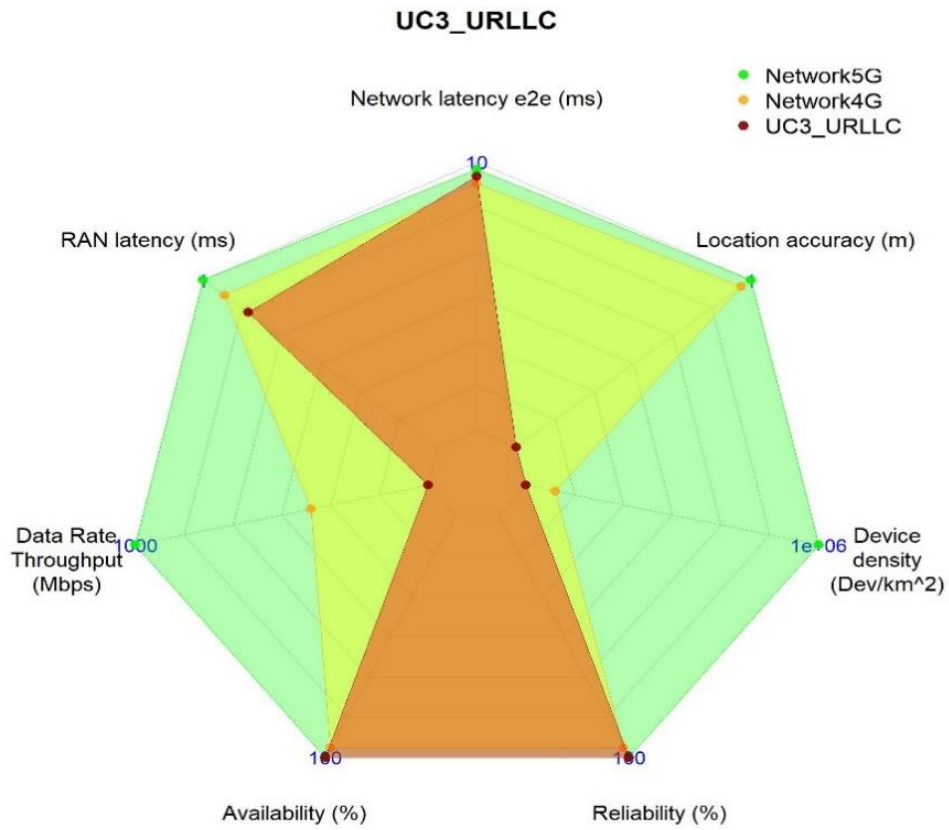
Figure 27: Radar chart for network requirements for UC#3 - slice URLLC
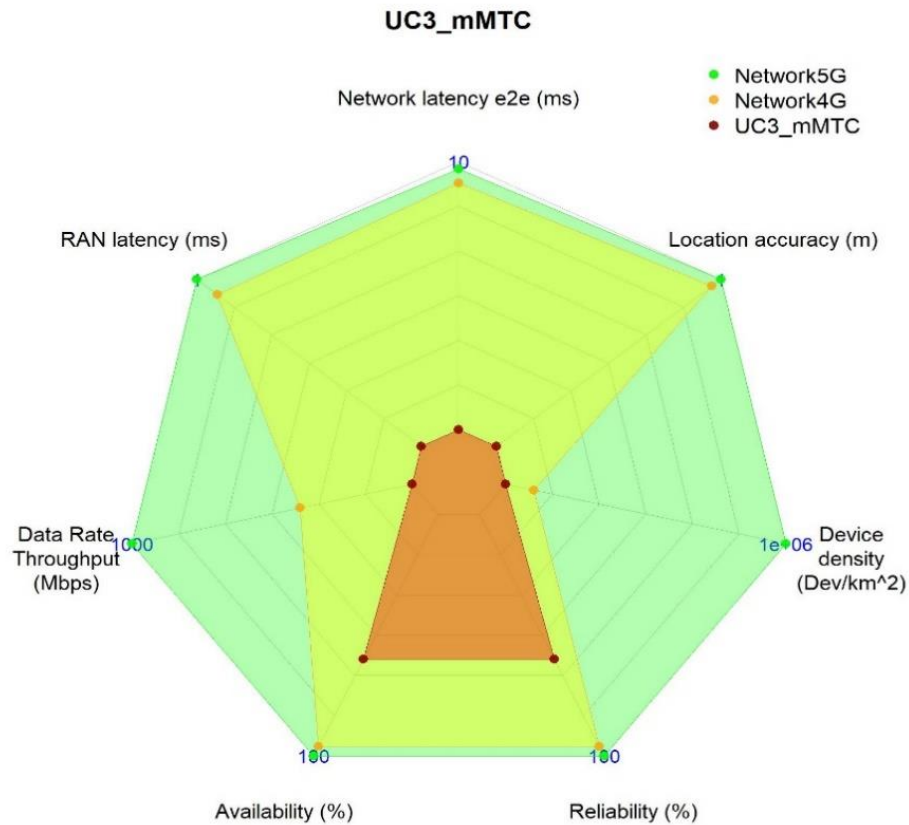
Figure 28: Radar chart for network requirements for UC#3 - slice mMTC

3.4.4. Summary of the UC

A summary of UC#3 is given in the table below. The use-case highlights the need for flexible and scalable communication solutions to be deployed in remote places, where wind farms are usually located. The trade-off between cost and performance of the communication service (especially availability, reliability, and low latency) is foreseen as necessary. The utilization of both URLLC and mMTC 5G services will enable the fast monitoring with a sub-second latency of a wind farm production and the utilization of data stemming from several sensors to enhance predictive maintenance services. In the new era of high-RES penetrated power systems, these services will increase the operational availability of RES and will increase power system stability through the provision of fast frequency services from RES assets connected to the distribution grid.

Table 24: Summary of the UC#3

UC-ID	UC Title
BG-DG	Millisecond Level Precise Distributed Generation Monitoring
Service(s)	S1: Predictive maintenance: gathering measurements from sensors capturing the performance of key components of the wind turbines, offering the wind farm owner information about the asset's performance. Offer the power system operator information about operational availability of the asset. S2: Real-time energy production monitoring: the wind farm owner, and the power system operator monitor in real-time the energy production with millisecond latency. Wind farm owner can increase efficiency and accuracy of both production monitoring and control. TSO can enhance power system stability through the supervision of RES production in hard-real-time and to enable the wind farm owner to offer fast frequency services
New mechanism in the demo	Achieve low latency end-to-end measurements of wind farm's key parameters using 5G connectivity.
Assets used (infrastructure, resources)	Wind farm IoT devices (sensors, inverters) 5G public network provided by VIVACOM/ NIS
NetApp role	Enable massive data processing for advanced analytics and real-time monitoring
Scenarios	• There is no abnormality detection in the wind farm operation, thus any alerts are sent to the wind farm operator. • There is an identification of potential operation failure in the wind farm in the near future, and predictive maintenance information is sent to the wind farm owner. • There is an availability issue of the wind farm in real-time (stop operating), and information are sent to both system operator and wind farm owner. • Real-time production does not introduce any burden to the power system operator. • Real-time production of the wind farm provokes system stability issues, and thus system operator shall curtail the operation of wind farm.
5G-services	mMTC and URLLC services
5G KPIs of the Demo	• E2E Latency 20-200 msec (minimum between user service and endpoints) • Reliability 99.999 (%) • Reducing average service creation time cycle to 90 minutes

3.5. UC#4: real-time wide area monitoring

The scope of UC#4 is the real-time monitoring of a geographical wide area where cross-border power exchanges take place. UC#4 addresses the energy reliability and security domain of the broad energy vertical. Specifically, in the context of this UC, the interconnection flow between Greece and Bulgaria is monitored leveraging the advantages that the 5G telecommunication infrastructure provides. This function will be executed from the newly established Regional Security Coordinator (RSC) in Thessaloniki, Greece. The role of the RSC is to promote regional cooperation and to support the strengthening of the

neighbouring power systems and market operations in the region. To achieve the enhancement of the interconnected power system operation, live monitoring of the power flows between the countries under its area of interest is of vital importance. Hence, this UC can be considered as the development of an additional element that increases the live monitoring capability of RSC. Phasor Measurement Units (PMUs) located at the High Voltage network of Northern Greece, monitoring the interconnection area with Bulgaria, will be used as the input in the monitoring process of the RSC. By incorporating time-stamped synchronized PMU measurements high data granularity can be achieved (receiving the requested data 50 to 60 times per second, including positive, negative and zero sequence phasors of voltage and currents). A virtual Phasor Data Concentrator (vPDC) will be developed for the data gathering process. The utilization of 5G in UC#4 contributes to the connectivity between the PMUs and the vPDC, offering its low latency and high reliability needed, due to the criticality of the UC.

To give a broader perspective, it is worth mentioning that the continuous expansion of the European High penetration rate of the distributed energy resources (DERs) significantly increases the complexity of the power system making its real-time operation and control functions demanding, and difficult to handle. As the DER penetration rate increases, inverter-connected devices dominate, leading to the lack of physical inertia. The lack of inertia results in significant variations in the Rate of change of Frequency (RoCoF), thus subsequently results in fundamental changes in the dynamic behaviour of the power system. Therefore, for the proper real-time operation of the power system, the existence of a Wide Area Monitoring (WAM) system is essential, that is capable of capturing and alleviating dynamic phenomena that create hazardous conditions for the stability of the entire interconnected European power system. Occurrences taking place at a specific location of the power system are able to create instability in the entire power system. WAM systems mainly leverage the high accuracy of PMUs and the low latency of the new era telecommunication networks. Multiple control areas exist in the European power system, where each Transmission System Operator (TSO) is responsible for the control of its system. For the proper coordination between neighbouring control areas, RSCs owned by adjacent TSOs were established. One of the five RSC's goals is the coordinated security analysis in multiple timeframes (Day-ahead, Intraday, and real-time). Regarding the real-time monitoring of their area (including areas controlled by multiple TSOs), the RSCs provide advice to the TSOs for the proper operation of the power system. In addition, RSC contributes by offering post-event feedback (in case of a major grid disturbance or frequency deviations) to the concerned TSOs in order to develop and improve guidelines for this kind of problematic situation. In the context of this UC, the real-time monitoring function of the RSC from PMU measurements from Northern Greece monitoring the interconnection area is demonstrated. Afterwards, TSOs leverage the information of their connected assets and the recommendations arriving from the RSC in order to perform better control actions and alleviate occurrences that threaten system stability.

Interconnected power systems often face frequency oscillations that tend to challenge their proper way of operation, even leading to instability of the system. A very effective way to monitor those events is the use of the synchronized measurements provided by the PMUs, which are placed near the borders of the connected power systems. These measurements are gathered by the PDCs in order to be sorted accordingly and get forwarded to the WAM service. However, due to the vast amount of data provided by the PMUs and their criticality, a highly reliable means of communications is needed to ensure the flawless monitoring of the power system. This is where the 5G infrastructure can be utilized, offering that

high reliability and low latency needed, as well as the flexibility to add more measurement units, without high cost and hard to move installations (e.g., optical fibre).

Location

For the demonstration of the WAM service, PMUs located in the Northern Greece (owned by IPTO) transmission system will be used. Specifically, the PMUs will be located at the substations from where the interconnecting transmission line of Greece and Bulgaria departs. Hence, a wide area monitoring system for two different (interconnected) control areas will be deployed.

Potential candidate PMUs are located at substations at the greater Thessaloniki region. Considering the demonstrator's implementation horizon and the infrastructure upgrades in the IPTO's network, the specific location of the PMUs that will be used is going to be assessed in depth in the upcoming months.

Business Goals

The Primary Actor of this use case can be considered the entity that monitors both concerned transmission grids. The RSC may be responsible for this task. Both TSOs, i.e., Greek, and Bulgarian, involved in the use case can be considered as facilitators providing access to the measurement infrastructure (PMUs). The business goal of the RSC is the real-time monitoring of the supervision area and the provision to the TSOs of the information and strategies for the proper coordinated security analysis and operation of the system in real-time conditions. By doing so, the power system in the greater region operates under secure conditions and is robust towards abnormal dynamic contingencies that threaten the overall system balance.

Service objectives

In terms of services, the goal is the monitoring of the PMUs' status and the visualisation of their features in such a way that efficient suggestions regarding power system control will be offered to the TSO. Such indicators may be the voltage and current values as well as the angle between them, and, of course, the Rate of Change of Frequency (RoCoF) value in both sides of the area to be monitored. The combination of different features and the comparison of each one with its symmetrical could also reveal hidden but useful results and deductions.

Expected benefits

- **Business:** Better monitoring of the power system for the RSC leads both the operators to have an enhanced monitoring ability and supervision of their area by being aware of the adjacent energy network condition. This benefit could be measured by the increase in the amount of the Identified Abnormalities (IA) detected in the energy grid. Table 25 summarizes several business related KPIs for this UC.
- **Economic:** By establishing an adequate level of coordination, faults leading to severe conditions in the transmission system such as outages can be captured and handled in time, saving TSOs from costs due to the energy not being provided to the customers. In addition to that, better network observability in the critical elements connecting Greece and Bulgaria can increase the energy transfer between the two countries, leading to stronger electricity market coupling between the countries and thus potential financial benefits for both. An increase in the economic

welfare caused by the reduction of the unexpected outages can be calculated by the difference in the amount of the "Expected Energy Not Served" (EENS) multiplied by its average cost.

- **Social:** Secure and uninterruptible energy provision to the end-user.
- **Environmental:** Higher share of renewable energy sources (RES) in the energy production mix significantly reduces the usage of fossil-dependent conventional power plants, thus leading to CO_2 emissions' reduction. However, the high penetration of RES increases security issues due to their intermittent stochastic nature and the inverter-based grid connection. This use case can be seen as a step to increase coordination security, an essential element for the further increase in the penetration rate of RES. Therefore, we can consider that this use case has indirect environmental benefits.

Table 25: Summary of business KPIs for the UC#4

Business KPIs	Additional explanation	Means of verification	Indicative quantitative values
Decreased WAM application deployment time	Due to virtualization of the PDC	Difference between deployment duration of the actual hardware and the vPDC	30% reduction
Decreased WAM application cost	Due to virtualization of the PDC	Difference between the cost of actual hardware and vPDC deployment	20% reduction
Increased system awareness	Due to high granularity of PMU measurements (in contrast with legacy metering devices) and low latency communication network	Detection of transient events / faster detection of non-transient events	10% reduction

3.5.1. Actors, conditions and technologies involved

3.5.1.1. Actors and stakeholders

Main Actors:

- **RSC**: Both TSOs participating in this UC (i.e., ESO and IPTO), are owners of the South-East Europe RSC. In the context of Smart5Grid, we consider that the primary actor is the RSC. RSC is not participating in the project as a different partner of the aforementioned operators. We emulate its participation by considering that the developed system is utilized by the RSC to further increase its capability. Hence, RSC is considered as the owner of the WAM.
- **TSO**: Owner of the assets existing at the transmission grid (i.e., lines, substations, measurement units), and responsible for maintenance, planning, and safe and reliable operation of its system. Main priority of the TSO is to ensure the grid stability, guaranteeing consumers' security of supply.

- **Telecommunication Provider**: Owner of the telecommunication network (i.e., gNBs, optical fibre, backhaul network), and is responsible for stable, secure, and reliable 5G coverage. Besides the needed infrastructure, the telco provider also offers the 5G Core to ensure the low latency and high reliability needed for this UC.
- **Infrastructure Owner**: Provider of the server that will host the Smart5Grid Platform, and the developed NetApps, and that will run at the edge. This infrastructure is crucial as most parts of the pilot will be executed on it.
- **PMU**: PMUs measure grid current and voltage by amplitude and phase at selected substations (nodes) of the transmission system. The high-precision time synchronization allows comparing measured values (synchro-phasors) from different substations far apart and drawing conclusions as to the system state and dynamic events such as power swing conditions.

Stakeholders:

- **IPTO:** Provider of the measurement units and subsequently of the measurements. As the owner of the grid, IPTO will leverage the suggestions made by the WAM system in order to operate it in an optimized way.
- **ESO:** Grid owner from the Bulgarian side of the transmission line interconnection. ESO will also leverage the suggestions made by the WAM system.
- **OTE:** Provider of 5G coverage in the area of the measurement units. Apart from their direct engagement in the project, OTE will also benefit, as the infrastructure offered could be also used for commercial purposes.
- **VIVACOM:** VIVACOM will provide the connection to ESO's control centre in order to close the information loop of the UC. Apart from that, VIVACOM could gain valuable knowledge regarding the next generation networks deployed in Bulgaria.
- **South-East Europe RSC:** This entity is the main owner of this use case, leveraging its functionalities to increase observability capabilities in the grid.
- **National Regulatory Authorities (NRAs):** The national regulatory entities of the countries under interest in this use case, namely Greece and Bulgaria, could be considered as stakeholders due to the indirect engagement in this use case. These entities could investigate the outcome of these demonstration activities,and propose additional functions and systems to be included as Business-as-Usual processes in the power systems for security enhancement.
- **European Union Agency for the Cooperation of Energy Regulators (ACER)**[41]**:** ACER could take as an input the outcome of the demonstration activities of this use case, initiating consultations with the national regulatory entities, and potentially at the end proposing and drafting network codes considering the solution in the grid security methodology proposed by this use case.
- **European Network of Transmission System Operators for Electricity (ENTSO-e)**[42]**:** ENTSO-e could be considered as a potential stakeholder by observing the results of this use case, in close collaboration with the national TSOs, and at the end proposing and drafting network codes

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[41] For further details also see: https://www.acer.europa.eu/en/The_agency/Pages/default.aspx

[42] ENTSO-E, the European Network of Transmission System Operators for Electricity, is the association for the cooperation of the European transmission system operators (TSOs). The 42 member TSOs representing 35 countries are responsible for the secure and coordinated operation of Europe's electricity system, the largest interconnected electrical grid in the world. In addition to its core, historical role in technical cooperation, ENTSO-E is also the common voice of TSOs. Also see: https://www.entsoe.eu/

including the proposed solution in grid security. In addition to that, the proposed use case could be considered as an additional element to increase the technology readiness level (TRL) of 5G telecommunication networks in power system's applications, addressed by ENTSO-e's technopedia [21].

Table 26: Actors involved in the UC#4 and their roles

Actor	Type	Actor Description
RSC	Role	Both TSOs participating in this UC, i.e., ESO and IPTO, are owners of the South-East Europe RSC. In the context of Smart5Grid, the primary actor is the RSC (not participating in the project). RSC is considered as the owner of the WAM.
TSO	Role	Owner of the assets existing at the transmission grid and responsible to ensure the grid stability, guaranteeing consumers' security of supply.
Telecommunication Provider	Role	Owner of the telecommunication network and responsible for stable, secure and reliable 5G coverage under the service agreement parameters.
Infrastructure Owner	Role	Owner and provider of the infrastructure needed to host the Smart5Grid Platform, and the NetApps, that will run at the edge.
PMU	Device	In charge of measuring grid parameters (i.e., current and voltage by amplitude and phase angle) with high-precision time synchronization.

3.5.1.2. Conditions and technologies involved

For the purposes of this UC the following assumptions and prerequisites are considered:

- Due to the fact that the control centres of both of the TSOs are closed systems and additional integration of PMUs is difficult to be implemented in the context of a project (primary for security reasons), the scope of this use case is to emulate and broaden the existing operation of the RSC.
- The RSC, that is considered as the owner of the vPDC and is described as the entity responsible for the collection and comparison of PMU measurements originating from the two TSOs, does not participate as an external entity in the project. However, because of the fact that it is owned by both of the participating TSOs (i.e., IPTO and ESO) and located in Thessaloniki, we can either emulate its function or consider that one of the two TSO performs this function.
- The PMUs are already installed at one of the TSOs from previous Horizon 2020 projects (such as the PMUs installed at IPTO in the context of the FARCROSS project [22]).
- The PMUs need to be inside the limits of the 5G coverage of the Telecommunication Provider, i.e., OTE, in order to make the experimentations feasible. This backbone connectivity is essential as the UC relies on it.
- The cloud infrastructure that will host the vPDC, both the NetApp and the platform developed by the early stages of the project, should pre-exist. It is to be noted that depending on the end-to-end latency of the system (PMUs, network from the PMUs to cloud, NetApp), the vPDC might also be located at the edge and in the local could (e.g., if the latency exceeds its upper allowed limit, then the vPDC might be needed to be placed at the edge; otherwise, it will be located in the cloud).

Current situation

In the current situation, each TSO is responsible for the control of its area. The newly established RSC mainly cooperates with other TSOs for the power system under its supervision (potentially controlled by multiple grid operators) in the day-ahead and intraday operation. For the real-time operation, the role of the RSC is bound to provide suggestions to the operators. This use case is foreseen to be an additional tool for the RSC in order to increase its visibility to the power system operation in hard real-time conditions, meeting the objectives for an adequate coordinated security analysis.

5G technology need

The need for 5G technology for the development of UC#4 is based on the following reasons:

- Previous generations of wireless networks do not fulfil the latency, bandwidth, and reliability requirements imposed by the criticality of the application.
- Compared to the optical fibre, 5G offers a more flexible and cost-efficient way of communication, with similar values for the aforementioned metrics.

Preliminary functional, technical and security requirements

It is important to define the maximum vPDC latency needed by the PDC to aggregate and process data. The worst case vPDC latency is the absolute waiting time, plus the vPDC processing completion time. That waiting time is the upper bound that the vPDC will wait for the data sent from the PMUs to arrive. It is a way to maintain the normal operation of the vPDC, if for example a data packet gets lost or takes too long to arrive. Any data that arrive later than their timestamp time plus the absolute waiting time, would not be included in the aggregated forwarded data. vPDC latency for data aggregation with time alignment to absolute time is shown in the following figure. Because of the fact that the vPDC will be used as an input from grid operators to control the area, the maximum absolute waiting time of vPDC is defined equal to 40ms [23]. After the course of this timespan, vPDC processes, and forwards data that are available by then.

As the 21st meeting of the Working Party 5A of International Telecommunication Union (ITU) reported, for the adequate functionality of wide area monitoring as a power system application, the following network requirements must be satisfied:

Table 27: Communication requirements for the vPDC in the context of UC#4

Requirements	Values
Reliability	99.999 %
E2E Latency	20ms-200ms
vPDC absolute wait time	40ms
Bandwidth	699-1500 kbps/node[43]
Multi-Domain Slicing	Yes
Private Slicing	Yes
Security	High

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[43] Node, in the context of the bandwidth requirement refers to the point of each PMU connection with the network.
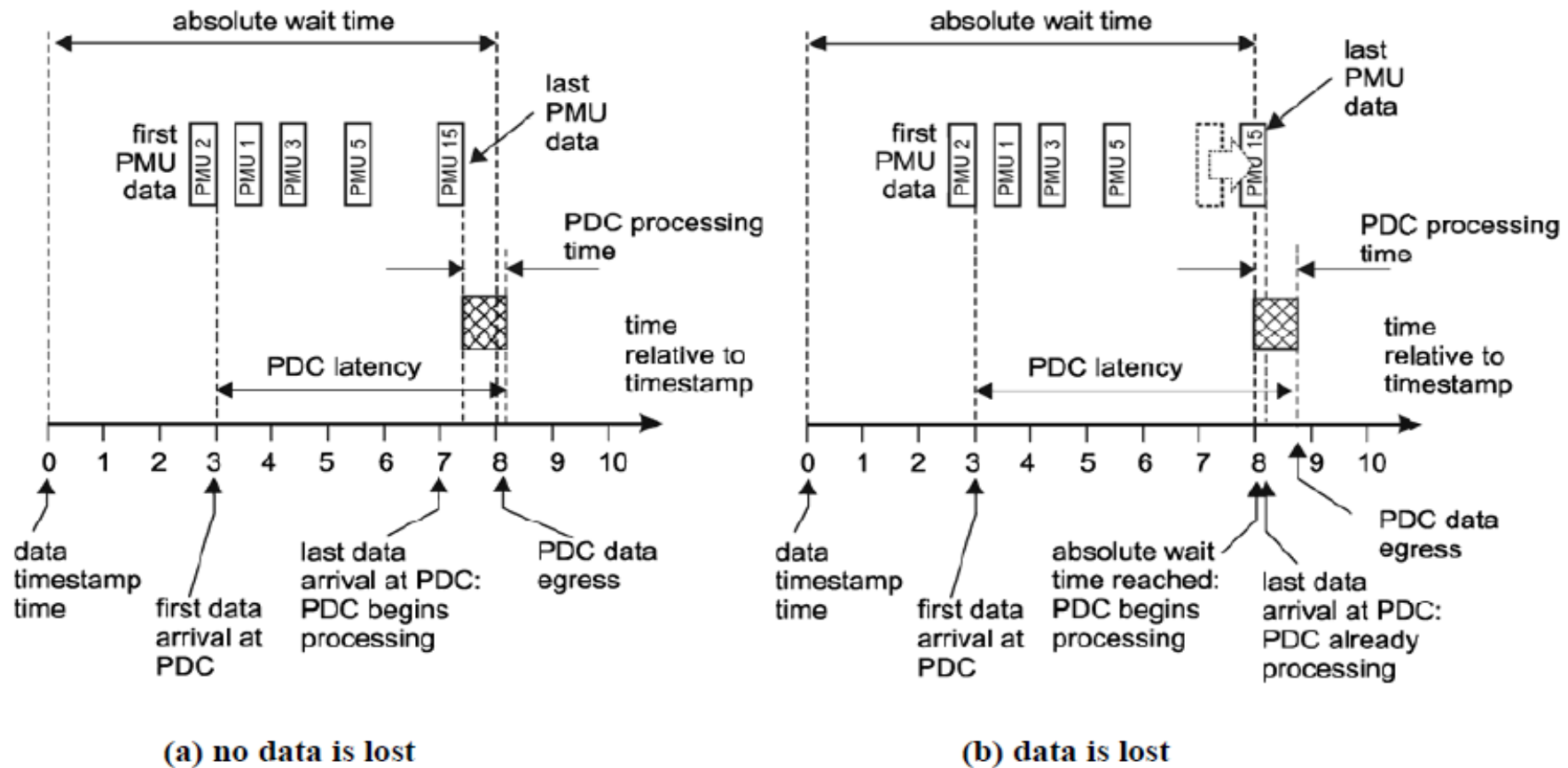
Figure 29: Indicative example of PDC latency for data aggregation with time alignment to absolute time [23]

3.5.2. UC-specific NetApp(s)

3.5.2.1. NetApp(s) scope

The UC#4 specific NetApps aim to cover three types of services:

1. **vPDC Service**

   The first service that this use case addresses is the vPDC that is responsible for data gathering from the PMUs placed in the broader interconnection area of Greece and Bulgaria. In that way, they are going to be comparable to each other. The vPDC receives and time-synchronizes phasor data from multiple PMUs to produce a real-time, time-aligned output data stream. Virtualization of the PDC significantly minimizes communication and transfer delays in the network as it is closer to the PMUs. It also minimizes the implementation cost.

2. **WAM Service**

   Afterwards, the WAM service will present several status indicators and visualization features of the PMUs. Some of those features may be:

   - A map indicating the device's current location.
   - The device's name, address, model, serial number and firmware version.
   - The nominal grid frequency [Hz] and the current reporting speed [fps].
   - The phase diagram with voltage and current vectors displayed (updated in near real-time).
   - Voltage magnitude and angle difference monitoring, derived from historical data of both sites.

3. **Advisory Service**

The third service will provide advisory indications for real-time operation to both TSOs, and ex-post analysis provision in case of severe event occurrence in the grid.

Based on the desirable functionalities envisioned in the context of this UC, three NetApps for development are defined:

UC4-NetApp1: vPDC

The UC4-NetApp1 is the vPDC that is responsible for data gathering from the PMUs placed in the broader interconnection area of Greece and Bulgaria. That vPDC is also going to synchronize the measurements according to their timestamp. In that way, they are going to be comparable to each other. The C37.118 protocol[44] will be used to collect data from the PMUs.

UC4-NetApp2: WAM

The UC4-NetApp2 is the WAM service that will present several status indicators and visualization features of the PMUs. Some of those features may be:

   - A map indicating the device's current location.

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[44] The C37.118 standard defines a method for exchange of synchronized phasor measurement data between power system equipment. It specifies messaging including types, use, contents, and data formats for real-time communication between Phasor Measurement Units (PMU), Phasor Data Concentrators (PDC) and other applications. For further informative details also see, *among others*: https://standards.ieee.org/standard/C37_118_1-2011.html.

- The device's name, address, model, serial number and firmware version.
- The nominal grid frequency [Hz] and the current reporting speed [fps].
- The phase diagram with voltage and current vectors displayed (updated in near real-time).
- Voltage magnitude and angle difference monitoring, derived from historical data of both sites.

UC4-NetApp3: Advisory Provisioning to TSO

The UC#4-NetApp3 is the Advisory service that will propose the remedial actions for real-time operation to both TSOs and ex-post analysis provision in case of severe event occurrences in the grid.
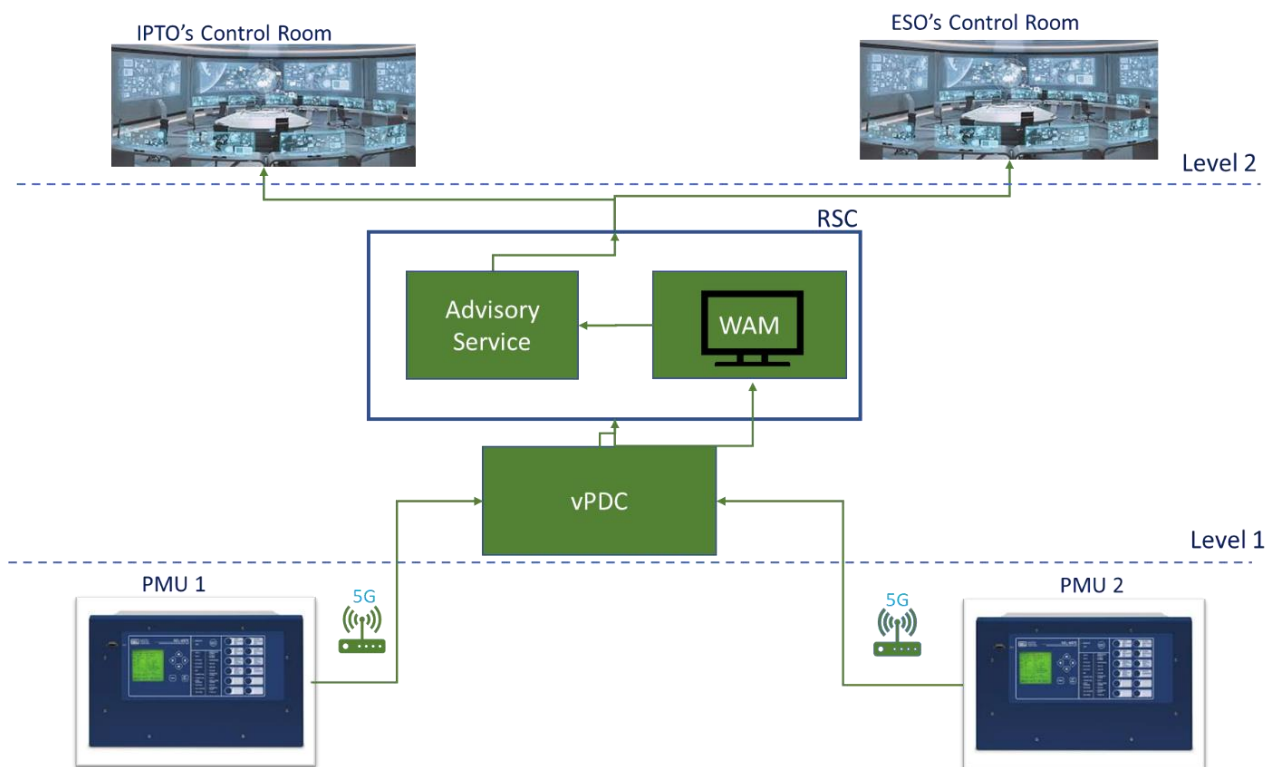
Figure 30: UC#4 High-level diagram

3.5.2.2. Scenarios and sequence diagram

Scenarios

The scenarios to be implemented by the UC are the ones visualized and explained in the next sequence diagrams. They concern the initialization of the services and the network connections between the entities, as well as their operation any moment after the completion of the initialization.

The first sequence diagram provides a view of the instantiation (Day-0) of the UC as a service. The steps followed for this action are the ones below:

1. The RSC informs the TSOs that it is going to start the service.
2. IPTO requests the PMUs activation.
3. After their activation, PMUs respond to IPTO.
4. IPTO confirms the activation of the PMUs to RSC.

5. Then, RSC requests the Service activation from the Smart5Grid Platform.
6. The Platform requests the 5G Network Slice from the Telecommunication Provider.
7. The Network Slice is provided.
8. The Platform informs the PMUs about the Slice for them to be connected to.
9. The PMUs confirm the connection.
10. The Platform requests the instantiation of the NetApps.
11. When ready, the NetApps confirm the activation.
12. The Platform informs that the services have been established.

The second sequence diagram providing an overview of the use case is presented in the following figure. The particular steps that are followed during the wide area monitoring function are:

1. The PMUs carry the necessary measurements and forward them to the 5G infrastructure.
2. The data packages that are sent via the 5G infrastructure reach the vPDC.
3. The data also reach the TSO for its own use.
4. The unified data from the vPDC reach the RSC to be visualised.
5. Suggestions are provisioned to the TSO according to the abnormality detected.
6. Same as Step 5, for the second TSO
   All six (6) steps occur in hard real-time in order to give the opportunity to the TSOs to counteract the rapidly evolving dynamic events in the power grid.

Some demonstration scenarios regarding the vertical service, provided by the NetApps, could be:

- No abnormality detected in the grid operation, so no suggestion provision occurs.
- Detection of RoCoF abnormality, suggestion to both TSOs provisioned.
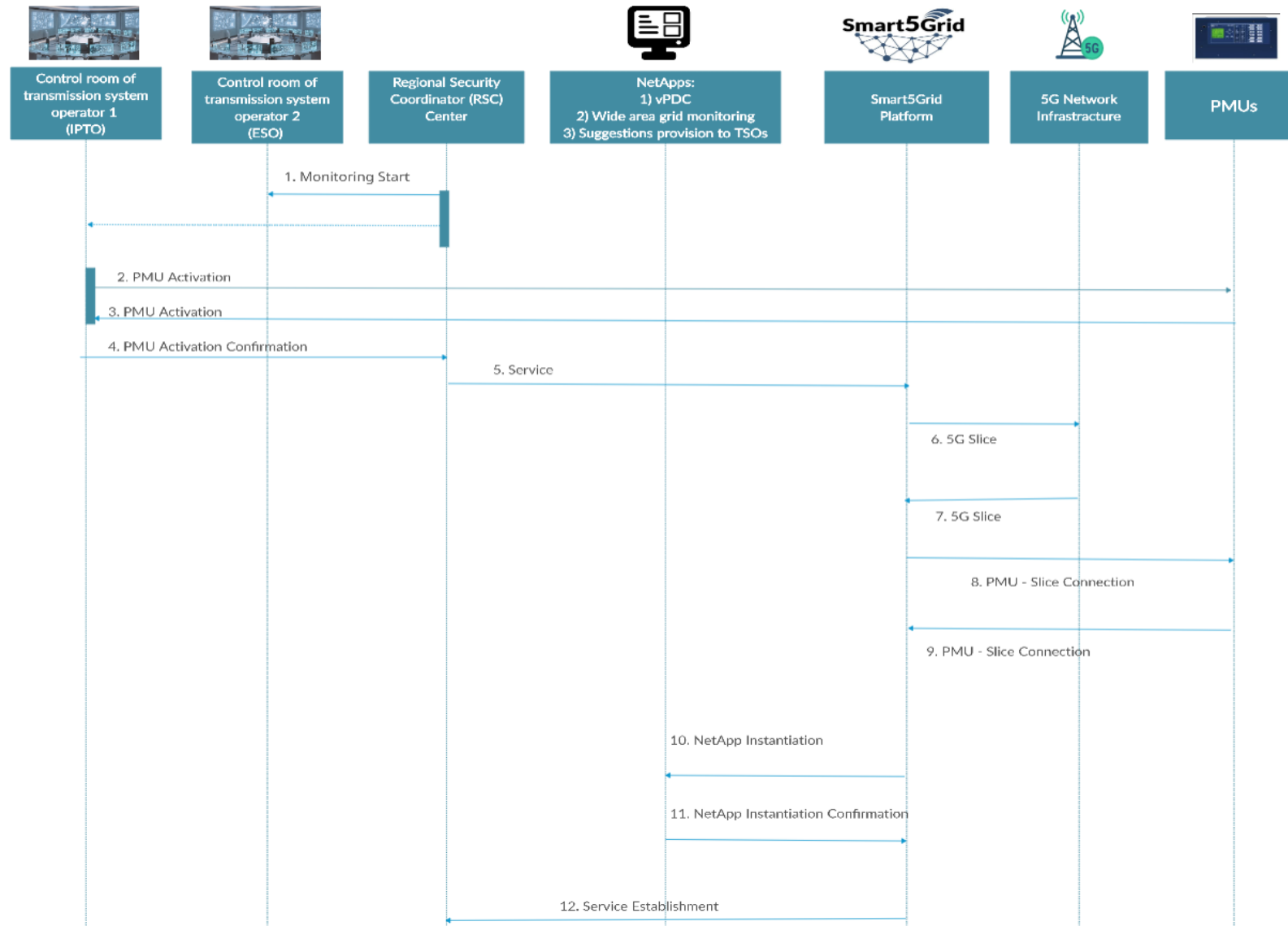- Detection of abnormalities in voltage and current phasors, suggestion to the related TSO is provisioned.

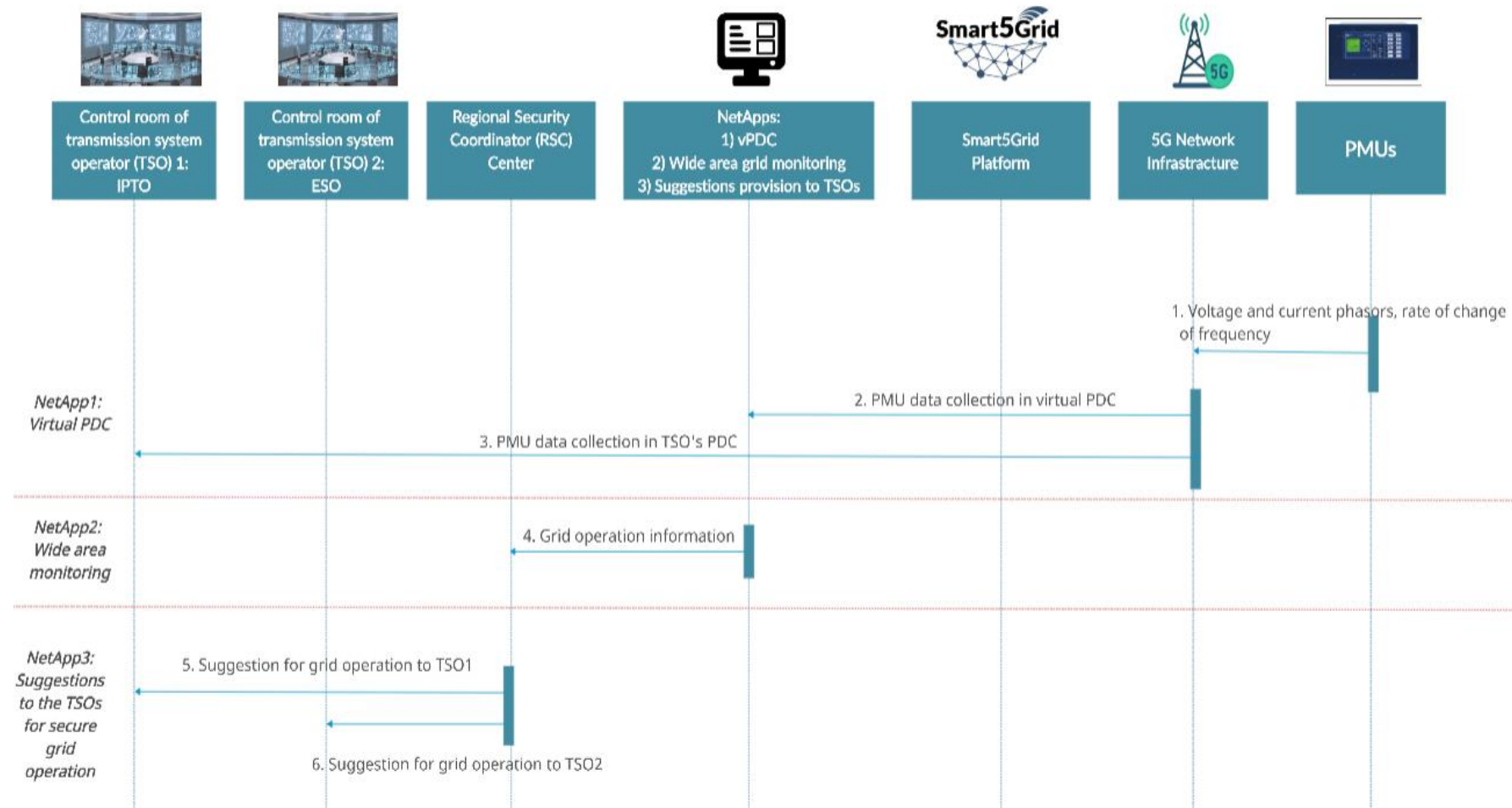Figure 31: UC#4 Sequence diagram of the Day-0

Figure 32: UC#4 Sequence diagram of an operational day

3.5.3. 5G-Network requirements

As a summary, the particular network requirements relevant for UC#4 are: (i) the absolute waiting time for the vPDC, which was defined in the previous section and, (ii) the need for private slicing. Data security, high availability and high reliability on top of the demand for end-to-end latency are foreseen with high importance for UC#4, where the URLLC type of slicing service is foreseen as necessary.

All the 5G Network requirements as per the guide template for their gathering are shown in Table 28.

Following is the radar chart reflecting the comparison in performance requirements of the UC#4 against the capability of both 5G and 4G technologies. As it can be observed, at least three requested attributes (latency, availability and reliability) are calling for 5G technology. These requirements are on top of high levels of security.

Table 28: UC#4 Requirements for the 5G network

|	Use case Requirements	Units	UC #4		
			Real-time Wide Area Monitoring		
			5G Use case category/Slice Type		
			URLLC	eMBB	mMTC
1	Communication service **Availability**	%	99.999	-	-
2	Communication service **Reliability**	%	99.999	-	-
3	End-to-end **latency**	msec	20-200	-	-
4	vPDC absolute waiting time	msec	40	-	-
7	Device Density	Dev/km2	1	-	-
8	Location Accuracy	m	-	-	-
9	Security	Y/N	Y	-	-
10	Network slicing	Y/N	Y	-	-
11	Private slicing	Y/N	Y	-	-
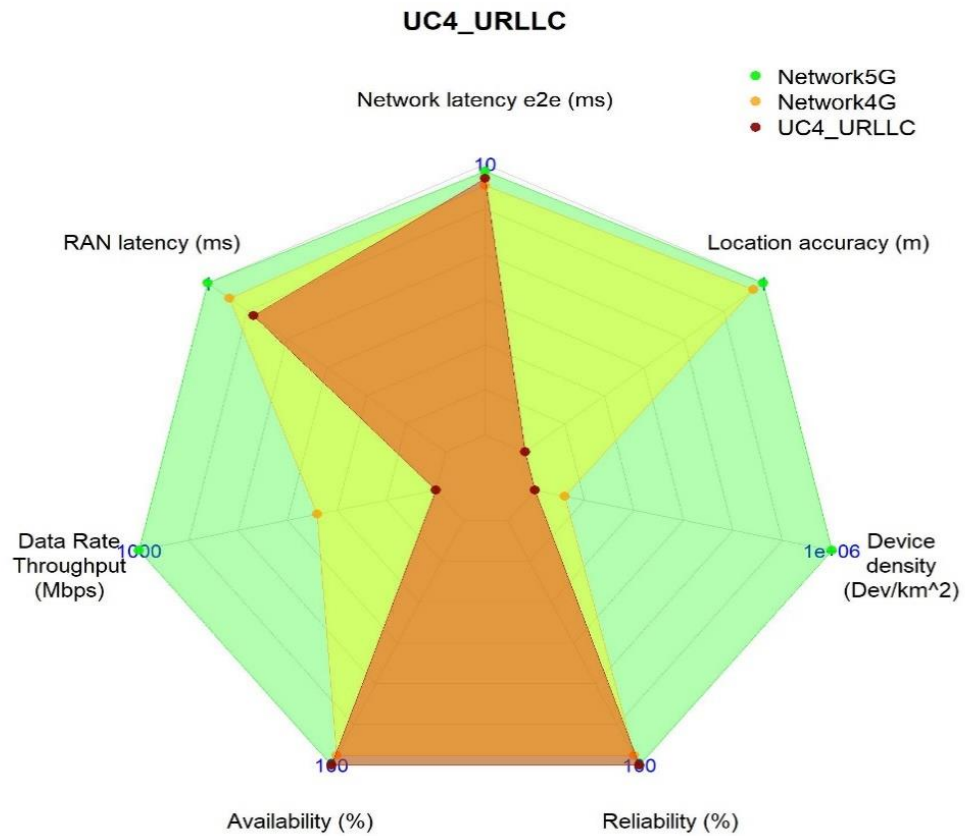
Figure 33: Radar chart for the network requirements in UC#4 - slice URLLC

3.5.4. Summary of the UC

The goal of this UC is to facilitate the provision of a Wide Area Monitoring tool that could be used as a decision support system for advanced control actions over two neighbouring smart grids. 5G in this UC supports a cost efficient and agile way of communication, in comparison with the optical fiber, while fulfilling the needs for increased reliability and availability in comparison with the previous generations of the communication networks. The relevant information summarizing UC#4 and its associated requirements and components is provided in the table below.

Table 29: Summary of UC#4

BUC-ID	BUC Name
GR-WA	Real-time Wide Area Monitoring
Service(s)	vPDC, WAM & Suggestions
New mechanism in the demo even if service already exists (new functional processes)	• vPDC will gather the data sent by the PDUs according to PDC standards. • WAM of the power system encapsulating two different neighboring control areas, namely Greece and Bulgaria. • Suggestions provision to two different power grid control areas.
Assets used (infrastructure, resources)	PMUs 5G Backbone Infrastructure Edge-Cloud Infrastructure
NetApps role	Collect the measurements based on PDC standards from the installed PMUs and provide live monitoring analytics in the concerned wide area of the power system and suggestions to the TSO for adequate control.
Scenarios	• No abnormality detected in the grid operation, so the no suggestion provision occurs. • Detection of RoCoF deviation, suggestion to both TSOs provisioned. • Detection of abnormalities in voltage and current phasors, suggestion to the related TSO is provisioned.
5G-services in the Demo	URLLC services
5G KPIs of the Demo	• E2E Latency (minimum between user service end-points) • Reliability • Bandwidth • Private Slicing • vPDC Absolute Waiting Time

4. High-level requirements of the Smart5Grid open platform

4.1. Introduction

In this section, we present the general requirements of the Smart5Grid platform. First, an initial collection of requirements extracted from the DoW are introduced. Then, we delve deeper by providing requirements per each of the main layers identified in the Smart5Grid high-level architecture.

Specifically, from those generic requirements extracted at platform level from the DoW, we then transition towards more specific functional and non-functional requirements for three major layers of the Smart5Grid Architecture, namely: (1) the Open Service Repository, which will serve as the entrance/exit gate of the NetApps; (2) the Validation and Verification (V&V) layer, which is in charge with auditing of the NetApps by performing automatic verification and validation of the service, and (3) the Management and Orchestration Layer, which is responsible for the management and orchestration of both the network and the NetApps.

4.1.1. Requirements elicitation from the DoW

Here, we briefly present generic requirements for the overall Smart5Grid platform, as they were detailed in the DoW. Specifically, at the business and functional levels, the Smart5Grid will:

1. Be an open, fully softwarised 5G experimental facility specifically addressed to the energy vertical;
2. support integration, testing and validation of UC-specific NetApps based on existing and new 5G services and NetApps for 3rd parties;
3. provide support for the high-bitrate, low-latency energy critical services as part of the Smart5Grid specific UCs and beyond ;
4. enable network slicing, multi-access edge computing, service orchestration, automation, etc., for improved services in the energy vertical;
5. offer an open access NetApp repository;
6. offer a monitoring mechanism able to cover the needs of network and energy operators;
7. integrate concepts such as DevOps, serverless and container-based principles for supporting the NetApps validation and verification, lifecycle o slice instances across several domains;
8. become available for experiments regardless of the size and complexity of the experiment;
9. allow experimenters to run their experiments and test and validate their NetApps by accessing Smart5Grid services, systems and tools on demand, under a controlled environment, with replicable conditions, and in accordance with specific requirements; this will be achieved by a Validation and Verification (V&V) framework for NetApp automatic testing, certification, and integration;
10. facilitate accelerated development, deployments and integration of the NetApps (both UCs specific for the project and for 3rd parties);
11. define a set of open APIs through which third parties, vertical industries, service providers and end-users will be able to interact with the network and the platform, according to DevOps practises;
12. be designed to be malware-free and provide a management system and tools intended to search, install, and manipulate NetApps inside the Open Service Repository;
13. be attached to already existing functional distribution power grids, in order to benefit from the new capabilities offered by the 5G features;

14. promote a virtualised infrastructure (i.e., cloud environment, right at the network's edge, which will permit multiple network services, applications VNFs and NetApps to be deployed at a much lower time scale);

15. allow rapid integration of multiple network services in the energy vertical (e.g., isolated and secure provision of vertical services for massive amount of connected devices) and offer support specifically for cloud infrastructures that consist of loosely-coupled microservices, and thus, enabling zero-touch orchestration and agile DevOps practices.

4.2. Smart5Grid architecture

4.2.1. High-level description

The Smart5Grid Open Experimental 5G Platform is currently being designed considering the requirements that have been extracted from the Dow as well as the energy use cases previously described. Figure 34 shows the first iteration of the design, highlighting the main functional blocks that can be divided into three high-level sections.

First, the platform will allow developers to upload vertical specific NetApps which will be hosted on the **Open Service Repository** for discovery and consumption by 3rd parties. Before these NetApps are available in the repository, they would have been extensively tested by the **Validation & Verification framework.**

This validation step is supported by the necessary infrastructure to execute a fully featured NetApp so that a comprehensive test suite can be performed.

The lowermost layer represents the **electrical "smart" grid** where "smartness" is to be read as enhanced automation for improving controllability and predictability in the operation of the power grid assets. Controllability, resilience, and predictability are prerequisites for safe, sustainable, and economic operation of the grid. They are also necessary for the scalable integration of renewables into the energy grid and the potential transition to new grid architectures (e.g., community grids, microgrids, hybrid AC and DC power grids).

The following section gathers the functional and non-functional requirements of the Smart5Grid Platform of each of the aforementioned architectural layers.
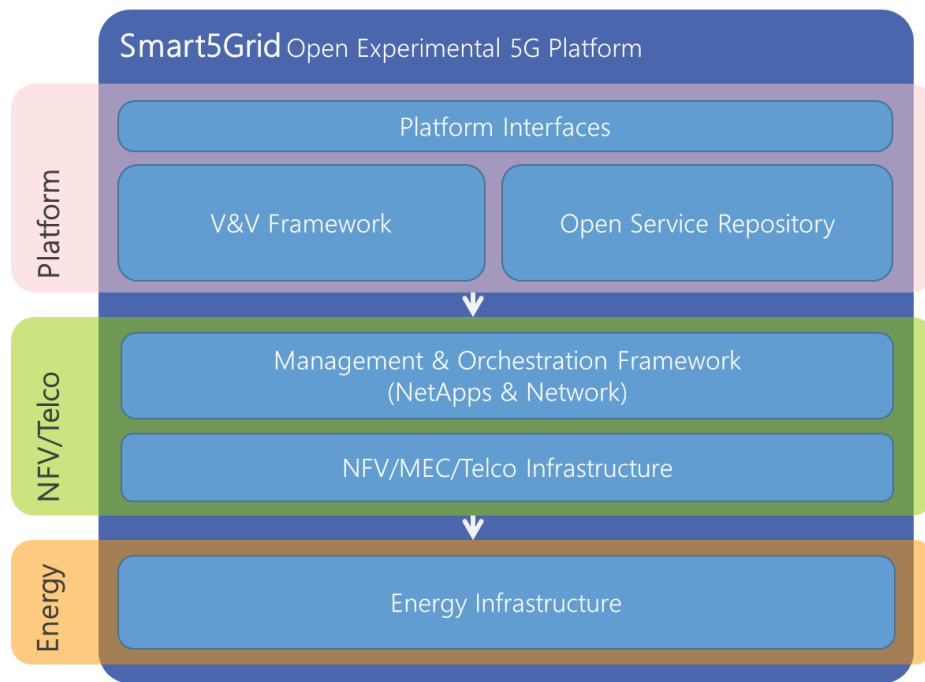
Figure 34: Smart5Grid High-level Architecture

4.2.2. Requirements

4.2.2.1. OSR layer

High-level description

The OSR is an integral component of the Smart5Grid Open Platform, taking a pivotal role in the development and testing of NetApps. The main function of the OSR will be to allow NetApp developers to upload (store) and modify their VNFs and NetApps. Furthermore, it will connect the NetApp developer with the V&V framework, enabling the verification and validation of NetApps to ensure they are Smart5Grid-compliant. This aims to facilitate DevOps practices by connecting NetApp development with NetApp operation. A working prototype for a NetApp can therefore be delivered quickly, and the developer will be able to continuously improve it based on its previous tested versions that are known to work within Smart5Grid's infrastructure.

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Figure 35: The lifecycle of a NetApp according to DevOps [24]

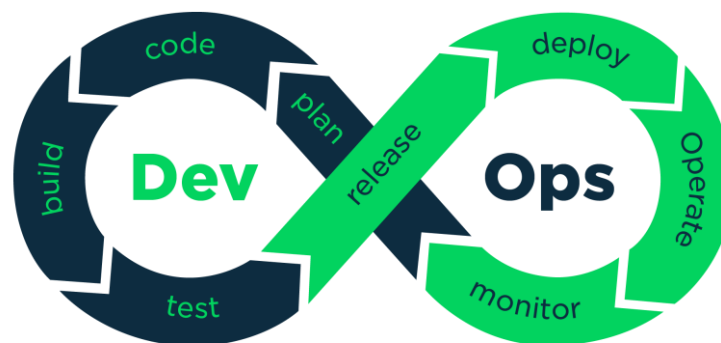The purpose of the OSR, however, is not only to facilitate the development and testing of NetApps, but also to make these processes well-understood and transparent to the Smart5Grid's consortium, the European Commission and, importantly, to external stakeholders and SMEs. This means that access, upload/modification information, and also information that results from testing and validating the NetApp must be recorded in and be made available through the OSR. Apart from the obvious security benefits within the Smart5Grid project, this transparency will hopefully stimulate further interest in NetApps pertinent to the energy vertical across stakeholders. Transparency is also key in helping external parties (users) become confident in downloading Smart5Grid's NetApps for further modification and usage within their own infrastructures.

Functional Requirements

Regarding the functions of the OSR, some requirements are a direct consequence of the discussion above. These are:

1. The OSR must allow developers to store, modify, download, and request the validation of their VNFs and NetApps, and also to view all relevant information.
2. The OSR must feature a catalogue of NetApps. This in turn consists of a catalogue of VNFs and the Information Models (e.g., blueprints & descriptors) used to combine VNFs into each NetApp.
3. All additions/modifications to OSR contents need to be kept in logs according to who made them and when, so that the development of NetApps can be tracked.
4. The execution outcomes and the performance of NetApps during verification and validation need to be recorded for each NetApp for greater transparency.
5. Third parties (users) must be able to view all relevant recorded information about a NetApp pertaining to its development, validation and testing, and must be able to download a NetApp and its VNFs if they wish to.
6. A web-based graphical user interface (UI) is necessary to allow developers and users uninterrupted access to the OSR from anywhere, in a user-friendly manner.

From here, there are a few further functional requirements that emerge. Firstly, the people who use the OSR and the platform need to be able to interact with it in a straightforward manner no matter of their physical location, and access to the functions of the OSR should be controlled. We have identified two categories of actors for the OSR; the NetApp developers, and the users. Developers should be able to perform all the functions the OSR is capable of, while users' access should be limited. Thus, two further functional requirements are:

7. The OSR must be connected to the UI and the V&V framework using appropriate communication techniques to be determined together with the consortium.

8. The UI must feature a login system to control access to the OSR's functions according to developer and user credentials in the manner set by requirements 1, 5 and 6.

Non-Functional Requirements

Apart from functional, there are other requirements that need to be discussed. First, in order to avoid malicious or erroneous applications being downloaded and deployed on third parties' systems, the

interaction of the OSR with the V&V framework needs to be defined in more detail. To guarantee the validity of NetApps, therefore, we consider the following mandatory requirement:

1. It is paramount that any version of a VNF/NetApp which is not both verified and validated will not be available for download by users, but it may be available for download by developers if they are granted access explicitly by the owner of the VNF/NetApp.

Last, there are two derived requirements for the effective integration of the OSR into the Smart5Grid's Open Platform:

2. Partners need to agree at a later stage on the appropriate data exchange technologies that will enable the OSR's integration with the V&V framework.

3. Remote deployment of the OSR in relation to the rest of the Open Platform, especially the V&V framework, may result in very large communication overhead. Therefore, it may not be practicable or desirable. Hence the consortium needs to determine whether the OSR will be deployed remotely in relation to the Open Platform or locally at a later stage, when the size of VNFs and NetApps can be assessed.

4.2.2.2. V&V layer

High-level description

The Verification and Validation (V&V) Platform will be responsible for the auditing of Smart5Grid NetApps by performing automatic verification and validation of the service to be provided, while monitoring and managing results to help in the service development process. The main objective of this platform is to accelerate the Development and Operations (DevOps) of the developer, enabling a continuous improvement of services and VNFs based on the results obtained in previous tests, thus achieving a continuous integration and development loop cycle.

The V&V Platform will interact with several entities, namely the NetApp Developers, the Open Service Repository (OSR), and the NVF MANO(s). The developers may be able to request the verification, or verification and validation of their NetApps in order to accelerate the development of the VNFs and service. The OSR must request the verification and validation of a NetApp before it is stored in its repository. Upon validation requests, the validation engine will request the onboarding and instantiation of services in a particular MANO, which will be terminated automatically once all the results are gathered and the service is properly validated.

Functional requirements

Based on the description above the following functional requirements have been identified:

1. The V&V Platform must provide an API, protected against unidentified and unauthorized users, to enable access to its functionalities.

2. Several users with different roles and authorizations must be specified, namely "admin", "developer", "OSR".

3. The verification and validation are independent processes, therefore a request to perform a verification can be done without the validation. On the other hand, to perform a validation, the verification must always be performed first successfully.

4. The developer user role should be able to request a NetApp verification alone, without having to pass to the validation phase, however other user roles are not provided with this ability.

5. The validation of NetApps must consider the KPIs specified in the descriptors. These are specified by the developers and serve as a benchmark to assess if the service is running properly.
6. The verification results of the NetApps must be persisted in a database indicating the evaluation of the syntax, integrity, topology of VNFs network and forwarding graphs.
7. The validation results of NetApps must be persisted in a database indicating which M&O framework was used for the execution test and the results of general KPIs and of KPIs specified by the developer.
8. Both verification and validation results must be always available and provided through the API.
9. Should multiple M&O frameworks be available to perform validation tests and the validation execution, then this should be done in the specified M&O framework selected (from a potential availability list) by the developer. If none has been specified, the V&V Platform will arbitrarily choose which one is going to use.

Non-functional requirements

The V&V Platform has also non-functional/external dependency requirements:

1. At least one M&O framework must be available for the validation of NetApps as well as its respective adapter module in order to be able to translate the NetApp descriptors and package the service in its format;
2. The bandwidth and goodput between the V&V Platform, OSR and MANO are critical metrics that should be considered to ensure a good performance and smooth execution of the V&V Platform. At this point the minimum/maximum values are still not possible to be assessed, and they will depend mainly on the size of the VNFs VMs/containers that compose the service; however, they must be taken into account at a later stage.

4.2.2.3. Management and Orchestration layer

The M&O framework plays a key role in both the validation and deployment of NetApps. The role of the M&O framework is to manage all aspects of the NetApp execution across its lifecycle over the virtualization and telecommunications infrastructure. This control is performed through different components that manage a particular infrastructure domain (i.e., Virtualization and Edge Computing, Core Network, Radio Access Network). The resources consumed on each domain are grouped into slices that provide segregation among deployments. Lastly, metrics from each execution are collected from each domain to evaluate the validation tests performed and monitor the performance of the NetApps. The following section describes the requirements from the elements foreseen within the Management & Orchestration framework.

4.2.2.3.1. SLICE MANAGER

High-level description

The Slice Manager (SM) is responsible for the lifecycle management of network slices covering the management and partitioning of infrastructure resources as well as the orchestration of vertical services. Whenever a slice is requested, SM is in charge of breaking down the slice creation request and delegating it to other components of the framework.

The SM solution will manage the available compute and radio resources of the nomadic node infrastructure, creating and grouping resource partitions or chunks to form end-to-end (E2E) slices. The

SM provides the required logic for the dynamic creation and management of slices, which are defined as a collection of compute, network and radio chunks combined together with the orchestration of NetApps deployed on top of them. Apart from managing the registration of infrastructure resources and the life-cycle of slices, the Slice Manager also performs several actions to seamlessly automate operational tasks related to slice provisioning and day-1 (i.e., configuration) and day-2 (i.e., optimization) operations over deployed virtual functions.

Functional requirements

1. SM exposes northbound (NB) API to allow creation of slices.
2. SM implements a southbound (SB) client for each of the sliceable underlying network technology including OpenStack[45] for computation and RAN controller for 5GNR.
3. SM implements a particular NFV orchestrator (NFVO)[46] SB client leveraging upon NFVO NB APIs to enable service instantiation in a particular slice.

Non-functional requirements

1. SM keeps the inventory for each created slice and its respective chunks.
2. SM uses a NFVO for service deployment.
3. SM maintains logical segmentation of each slice belonging to different tenant.

4.2.2.3.2. NETAPP CONTROLLER & MEC ORCHESTRATOR

High-level description

The NetApp Controller is the key unit that hosts the MEC offloading and Elastic VNF sizing and chaining functions. This component enables the placement and deployment of NetApps on MEC servers, deciding where the different NetApp parts will be deployed and how many resources (computational and network) need to be reserved to meet the Service Level Objective (SLOs) selected by the user for the particular instance of the NetApp. Furthermore, the MEC offloading component of the NetApp controller instructs the other network components (i.e., 5G Core and UPF) to set the correct traffic steering policy (e.g., route traffic directed to smart5grid.eu to the MEC node with IP 10.113.0.83).

The NetApp controller takes care of the entire NetApp lifecycle from deployment to termination, including also possible migrations and resizing of the resources. To provide a high-level of service availability, the NetApp controller must monitor each NetApp's SLO and the status of each node available to migrate and resize the VNF whenever needed. Furthermore, upon a NetApp deployment, the NetApp controller reserves the required computational resources and it forwards to the Slice Manager the NetApp requirements so to create a dedicate network slice.

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[45] For further information also see: https://www.openstack.org/

[46] The goal of ETSI OSM (Open Source MANO) is the development of a community-driven production-quality E2E Network Service Orchestrator (E2E NSO) for telco services, capable of modelling and automating real telco-grade services, with all the intrinsic complexity of production environments. OSM provides a way to accelerate maturation of NFV technologies and standards, enable a broad ecosystem of VNF vendors, and test and validate the joint interaction of the orchestrator with the other components it has to interact with: commercial NFV infrastructures (NFVI+VIM) and Network Functions (either VNFs, PNFs or Hybrid ones). For further information also see: https://osm.etsi.org/docs/user-guide/02-osm-architecture-and-functions.html

Functional requirements

1. The user interface of the NetApp controller must request an authentication through username and password. Furthermore, it must integrate functionalities to recover lost passwords and register new users.
2. The NetApp Controller must allow the registration of already deployed nodes as well as the registration of new nodes that shall be provisioned using near Zero Touch Provisioning[47] (nZTP).
3. The NetApp Controller must provide interfaces (both for human users and software) to deploy NetApps (chosen from the OSR) using the Information Models (e.g., blueprints & descriptors) of the VNFs that compose the specific NetApp.
4. Upon a NetApp deployment, the NetApp Controller must either find a good placement for every and each of the VNF composing the NetApp itself or fail. A good placement means that:
   o The NetApp starts its execution.
   o The NepApp SLOs are met.
   o The required resource (e.g., number of CPU cores, amount of DRAM, accelerators, etc) and network slicing requirements are guaranteed.
   o The required traffic steering rules are set in place.
5. Upon a failed NetApp deployment, the controller must gracefully mark the deployed service as failed and trigger alarms to notify the user associated with the failed NetApp.
6. The NetApp Controller must be reactive and act accordingly when the connection with a node is lost or when a failure occurs on a node. When such events occur, the NetApp deployed on the affected nodes need to be migrate as soon as possible to minimize any service disruptions. Furthermore, the NetApp Controller shall record such events and trigger alarms.
7. The NetApp Controller must be reactive and act accordingly when a NetApp SLO is close to being breached. When this occurs, the placement algorithm should be automatically executed to find a better placement. In case of no better placement available, the controller must trigger the alarms to notify the users that deployed this NetApp.

Non-functional requirements

In the following, we provide a list of performance, interface, and operational non-functional requirements:

1. The placement algorithm shall be executed and provide an outcome (i.e., either placement solution or failure) on the order of a few seconds.
2. Among the possible solutions for the placement algorithm, the option to migrate other NetApps shall be considered. This helps in minimizing resource fragmentation and in consolidating the VNFs of the same NetApp in as few nodes (even in the same node) as possible.
3. If multiple acceptable placement solutions are found, the controller should pick the solution that provide a better margin for the NetApp SLOs or the one that minimizes communication latency

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[47] Zero-touch provisioning (ZTP) is a method of setting up devices that automatically configures the device using a switch feature. ZTP helps IT teams quickly deploy network devices in a large-scale environment, eliminating most of the manual labor involved with adding them to a network. ZTP can be found in devices and tools such as network switches, routers, wireless access points and firewalls. The goal is to enable IT personnel and network operators to install networking devices without manual intervention. Manual configuration takes time and is prone to human error, especially if many devices must be configured at scale. ZTP is faster in this case, reduces the chance of error and ensures configuration consistency.

between the data sources and destinations involved (e.g., PMUs, other sensors, NVFs). The different criteria should be provided by the NetApp owner.

4. The interface shall allow administrators to group users into organisations (or "teams").
5. The interface of the NetApp controller shall offer distinct and separate views for each organisation. NetApps deployed by users of one organisation, shall not be editable nor visible by users from a different organisation. This isolation is also in line with the network slicing concept.

The list of non-functional requirements continues with requirements regarding reliability, portability, and maintainability:

6. The NetApp Controller shall be able to run in bare-metal nodes and in a virtual machine instance.
7. The NetApp Controller shall be portable - able to run in commodity hardware and without the need for specialised HW.
8. The NetApp Controller shall provide high-availability by running multiple – three or more – instances in parallel.
9. The re-deployment and updates of the NetApp Controller shall have low complexity in order to be carried out even by non-technical non-qualified users.

4.2.2.3.3.   5GCN CONTROLLER

High-level description

The 5G Core Network (5G CN) Controller is responsible for the configuration and management of the resources of the 5G CN. It acts upon request of the slice manager, which requests CN resources to be reserved and assigned to a specific slice. For this purpose, the 5G CN Controller exposes a northbound RESTful API towards the Slice Manager and a southbound API towards the CN's resources.

Functional requirements

1. The 5G CN Controller must have full visibility and control over the core network resources/VNFs allocated/deployed in each of the existing slice instances.
2. The 5G CN Controller must manage the lifecycle of all the existing core network slice-subnets, which can include both cloud and edge core VNFs.
3. The 5G CN Controller must be able to provide the Slice Manager with information about the availability of CN resources for the instantiation of new slice instances.
4. The 5G CN Controller must be interfaced with an NFVO and a Slice Manager. In particular, the 5G CN Controller must expose a northbound API that enables the Slice Manager to request the creation (or in more generic terms, the management) of core network slices and the reservation of core network resources.
5. The 5G CN Controller needs to support the protocols used for the configuration and management of the core VNFs and resources on the southbound API.
6. The 5G CN Controller needs to support workflows for slice creation, slice deletion, and (if necessary) slice modification, and needs to translate the calls issued by the Slice Manager for this purpose to a series of calls towards the core network resources.
7. The data exchange technologies supported by the 5G CN Controller must be compatible with those of the modules connected to it, to guarantee an appropriate interaction among them and a successful deployment and execution of the NetApps and the other networking services over the network.

8. Upon a NetApp deployment, the 5G CN Controller must find a good placement for every and each one of the core VNFs that are part of the NetApp itself or fail. A good placement means that:
    o The NetApp starts its execution.
    o The resources required by the core VNFs of the NetApp (e.g., number of CPU cores, amount of DRAM, accelerators, etc) are guaranteed.
    o The required traffic steering rules are set in place.
    o Upon a failed deployment, the 5G CN Controller should gracefully mark the deployed service as failed and trigger alarms to notify the Slice Manager (and/or the NetApp Controller via the Slice Manager) associated with the failed deployment.
9. The 5G CN Controller shall be reactive and act accordingly when the connection with a physical set of resources is lost or when a failure occurs on them. When such events occur, the core VNFs deployed on the affected nodes need to be migrated as soon as possible to minimize service disruptions. Furthermore, the 5G CN Controller shall record such events and trigger alarms.
10. In case the relocation of a core VNF is requested by the Slice Manager (or by the NetApp Controller via the Slice Manager), the 5G CN Controller must either execute this relocation or send back a request denial.

Non-functional requirements

1. The core VNF migration algorithm must be designed to act as fast as possible and to look for placement solutions that do not compromise the overall service performance.
2. The 5G CN Controller shall be virtualized and able to run in bare-metal nodes and in a virtual machine instance.
3. The 5G CN Controller shall provide high availability, possibly by running multiple instances in parallel.
4. The 5G CN Controller needs to have data integrity, e.g., the internal representation of the core network resources must match their actual state.
5. The 5G CN Controller should only allow access from within the same network, and no undesired external access is possible.
6. Given a well-defined deployment of core VNFs that serve a number of slices, radio devices, and an expected number of UEs, the 5G CN Controller needs to be stable.
7. The access to any of the internal dashboard and functionalities of the 5G CN Controller needs to be secured with an authentication method that requires credentials.

4.2.2.3.4. RAN CONTROLLER
High-level Description

The Radio Access Network (RAN) Controller is responsible for the configuration and management of the 5G RAN devices of the network. The RAN controller acts upon request of the slice manager, that requests radio resources to be reserved and assigned to a specific slice. For this purpose, the RAN controller exposes a northbound RESTful API, whereas any southbound API is directed towards the radio devices. Since there is no set of generic APIs used across different radio device vendors (except maybe for those being

developed by the O-RAN Alliance[48]), the RAN controller has to support the specific protocols and APIs implemented and accepted by the radio devices for configuration and management purposes. Protocols like NETCONF[49] are commonly used by the different vendors, but also RESTful APIs are common, especially if the radio devices rely on a proprietary management layer for talking to their devices. In the latter case, the RAN controller communicates with the management system instead of directly communicating with the radio devices.

Functional requirements

1. The RAN Controller has to expose a northbound API that enables the slice manager to request the creation (or in more generic terms, the management) of radio slices and the reservation of radio resources.
2. The RAN Controller needs to allow the registration of new 5G NR devices.
3. The RAN Controller needs to support the protocols used for the configuration and management protocols of the radio devices on the southbound API.
4. The RAN Controller needs to support workflows for RAN slice creation, slice deletion, and (if necessary) slice modification, and needs to translate the calls issued by the slice manager for this purpose to a series of calls towards the radio devices.
5. The RAN Controller needs to report any failed configuration or service instantiation on the radio devices to the slice manager.
6. The RAN Controller needs to be virtualized, so it can be deployed in the computational resources available to the use case without relying on specific hardware.

Non-functional requirements

1. The RAN controller needs to have data integrity, e.g., the internal representation of the radio resources must match the actual state of the radio devices.
2. The RAN Controller should only allow access from within the same network, so no undesired external access is possible.
3. Given a well-defined number of radio devices and expected numbers of UEs attached to the radio access network managed by the RAN controller, the system needs to be stable.
4. The access to any of the internal dashboard needs to be secured with an authentication method that requires credentials.

4.2.2.3.5.   NFVO

High-level description

The NetApp concept is built around the Network Function Virtualization (NFV) paradigm, which allows for the decoupling of hardware and the software that runs on it. This enables software applications that were traditionally tied to dedicated hardware to run on Commercial-Off-The-Shelf (COTS) equipment, providing flexibility and reduction in cost. Smart5Grid aims to apply this paradigm not only to Network Functions in

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[48] The O-RAN Alliance is transforming the Radio Access Networks industry towards open, intelligent, virtualized and fully interoperable RAN. Related standards enable a more competitive and vibrant RAN supplier ecosystem with faster innovation. More related information can be found at: https://www.o-ran.org/

[49] NETCONF is a protocol defined by the IETF to "install, manipulate, and delete the configuration of network devices". NETCONF operations are realized on top of a Remote Procedure Call (RPC) layer using an XML encoding and provide a basic set of operations to edit and query configuration on a network device. Also see, *among others*: https://en.wikipedia.org/wiki/NETCONF

the strictest sense, but also to the energy vertical specific applications that compose the novel Smart5Grid NetApps.

NFV standardization efforts are being led by ETSI ISG NFV [25], currently working on the Release 4 of the specification which, among other features, revolves around the enhancement of the NFV framework for cloud-native applications and services at the edge.
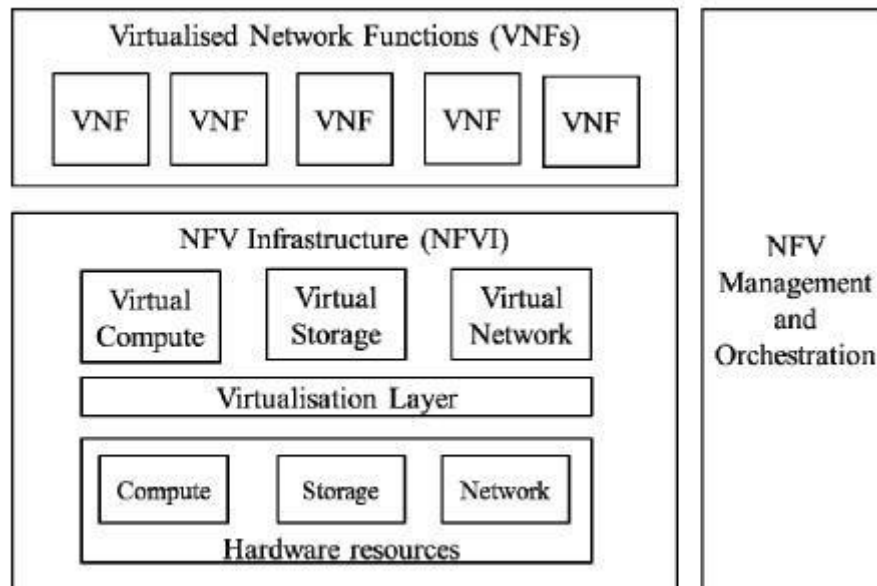

Figure 36: NFV Framework components [26]

Figure 36 represents the main components of the NFV Framework:

- NFV Management and Orchestration (NFVO): responsible for the management of virtualised resources and network services (NS). It is also responsible for managing the lifecycle of an NS together with its VNFs.
- NFV Infrastructure (NFVI) with the resources that are virtualised and over which VNFs run.
- Virtualised Network Function (VNFs): the software network functions that are deployed on the infrastructure.

Functional requirements

In NFV-IFA010 [27], ETSI specifies an exhaustive list of requirements for the NFV framework. In the following list we present a collection of requirements of the NFV framework from the Smart5Grid perspective:

1. The NFV system shall be able to orchestrate the NFV Infrastructure (NFVI) resources, in order to fulfil the requirements of VNFs.
2. The NFV system shall be able to support the orchestration of the virtualized components of the NetApps as cloud-native functions.
3. The NFV system shall support the ability to request multiple Virtual Infrastructure Managers (VIMs) for instantiation, scaling, and termination of VNFs.
4. The NFV system shall support the interconnection of VNFs that are executed on different parts of the infrastructure (cloud vs edge) or on different VIMs.

5. The NFV system shall be able to configure thresholds to set events and alarms to report on a virtualised resource in a VIM.
6. The NFV system shall support VNFs scaling out if a threshold is reached and scaling in when the load decreases.
7. The NFV system shall allow updates of the available VNFs.
8. The NFV system shall validate that the VNF and NS packets have the mandatory information and verify the integrity and authenticity of the VNFD/NSD.
9. The NFV system shall be able to query the images available in a VIM and distribute images to one or more VIMs in order to deploy the VNFs with the required image.

Non-functional requirements

1. The NFV system shall run on a bare metal or virtual machine with the supported OS and the necessary CPU, RAM and disk resources. The NFV system shall give a quick response to users when they perform an action.
2. The NFV system shall allow grouping of the deployed VNFs or NSs into projects running concurrently.
3. The NFV system shall be continuously operational and, in case of a fall down, shall recover as quickly as possible.
4. The NFV system shall support a widely adopted descriptor model.

4.2.2.3.6. TELEMETRY

High-level Description

A Reliable Critical Infrastructure (CI), such as the smart grid, has monitoring functionality that relies on direct and indirect monitoring components. The direct monitoring components refer to the direct observation of events and faults of the infrastructure itself while the indirect monitoring components refer to the monitoring of the network and processing infrastructure that, in a general way, supports the direct monitoring of the CI.

An example of this could be, for instance, monitoring the status of the smart gird, as well as the status of the edge processing's components. Thus, one may decide, at execution time, where to optimally place a set of VNFs.

This two-fold kind of monitoring functionalities can be mapped in the general telemetry component of Smart5Grid and can be intended and handled as a stack ensuring with the synergetic work in the platform that the smart energy applications' requirements are always met.

The telemetry's main scope is to support the network and the processing infrastructure that serves the different orchestrators and the different optimization engines with the purpose of placing VNFs NetApp and, in general, different functions closer to the device or to migrate them to a more powerful or tailored cloud environment.

Often the choice is unknown to the function/application developers ahead of time because the potential system configurations are numerous. In fact, what may be the right choice for a low-end device (such as a smart meter) with good connectivity may be a wrong choice for another device.

Regarding network and infrastructure monitoring, several components will be monitored in Smart5Grid. Among them we distinguish:

- (Mobile) device level metrics (e.g., CPU/GPU status, network status, battery level);
- application requirements (e.g., execution time, memory required);
- wireless network connectivity metrics (e.g., channel occupancy, delay, packet loss, etc.);
- energy related data (e.g., current, voltage in amplitude and phase, etc).

All these data can be ordered and processed in different way but at this stage we can describe a first list of high-level requirements that will prepare the telemetry functionalities to serve the Smart5Grid platform.

We remind, in fact, that telemetry is an enabler that thanks to the collection and storage of metrics from different "environments": (i) gives to the other components of the platform useful information on how process data for supporting the operation of the vertical, and; (ii) allows the flow of information to run in an optimized way, in the vertical infrastructure.

First we distinguish a monitoring phase in which the collected metrics reflect the status of resources in the integrated NFVIs, the network conditions, the performance and the behaviour of the instantiated network services. Then, an analysis functionality prepares and executes deterministic analysis and related algorithms to forecast resource demand, future network conditions and service performance. It can apply deterministic or ML-based analysis to predict future conditions in user demand and optimise utilisation of Network Functions Virtualisation Infrastructure (NFVI) resources. After that we have planning functions in which services' deployment, Virtual Network Function (VNF) placement, and network operation are executed after the forecast has been received by the analysis phase. Finally, we define an execution functionality that will be responsible for communicating concrete recommendations and configuration directives to the Service Orchestrators.

In the following subsection, the design stage of the telemetry is tackled and an initial list of high-level requirements per component is defined for each main block that composes the Smart5Grid architecture.

Functional requirements

Most of the components described above should expose the telemetry relative to node, resources, or the deployed NetApps, among others. A generic, non-exhaustive, list of functional requirements for telemetry is given below:

1. Both the 5G CN Controller and the RAN controller need to be able to extract telemetry data from the core network and from the radio devices, respectively, and to expose them.
2. The NFV system shall support the collection of infrastructure as well as VNF-specific metrics, such as CPU utilization, memory utilization, or network traffic.
3. The metrics collected by the NFV system shall be exposed for utilization by other components of the platform.
4. The NetApp Controller must allow other components to reach all the telemetry exposed by the NetApps. That is, the NetApp Controller should provide the proper traffic steering rules to reach each endpoint published. Whenever a VNF is migrated, for whatever reason, the NetApp Controller should ensure that the traffic rules are properly updated so that to avoid (or at least minimize) any service disruption.

5. The NetApp controller must expose basic telemetry regarding the nodes and hardware resources managed. Basic telemetry includes, but is not limited to, CPU core usage, memory usage, and network connectivity status.
6. The NFV M&O framework used by the V&V Platform to conduct validation tests must support the monitoring and extraction of KPIs; for instance, it must be possible to retrieve the bandwidth, and the latency between two VNFs of the NetApp.
    - o (optional) The NFV M&O framework used in validation tests should be able to execute arbitrary scripts inside the VMs/containers of the VNFs using its VNF management service. The output of those scripts should also be accessible.

4.3. Smart5Grid NetApps: high-level definition and initial general requirements

As per the DoW and in line with the call for proposals in the 5G-PPP Phase 3, "VNF's may be chained across several domains to create **Network Applications (NetApps)** tailored to the requirements of specific tenants, as demonstrated under previous 5G-PPP phases". This is the first and the broadest definition of NetApp that is adopted by the Smart5Grid project.

Complementary to this definition and in the context of this project, we can extend this definition with several properties of our proposal for Smart5Grid NetApps:

(1) **Provides a service** specific to the **energy vertical**;
(2) The service is implemented as a **cloud-native** application.
(3) **Interfaces** with the **5G network** and the **virtualization infrastructure.**
(4) Has a **modular structure** such that its components could be leveraged across different domains, on a cloud and/or edge deployment (e.g., one component running at the edge and another one running on the cloud);
(5) Includes the necessary **performance requirements** at component (container) and application levels for the service to function properly.
(6) Is **self-contained**, to promote **portability** and increase its **impact**. This is, to **encompass** the necessary **software components** to provide the end-to-end service.
(7) The service offered by the NetApp may be **standalone** or **consumed** by external or legacy applications through provided interfaces.

5. Conclusions

This document provided a detailed elaboration on the Smart5Grid UCs, with a strong focus on the main actors (users) and stakeholders involved, and their roles and relationships within the respective UCs illustrated through UC diagrams. The UC specific NetApps were also described and represented through the use of sequence diagrams.

After the identification process of the UCs requirements (functional and non-functional, as well as business, standardization, regulatory related), the next step involved the translation of these requirements into 5G network requirements. Service providers and 5G network vendors had a significant role in elaborating on these requirements based on their involvement and expertise in the corresponding UCs. The analysis was performed per UC, and quantitative parameters per type of slice were identified. Further, all these parameters were summed up in tables and using radar charts diagrams for each use case and per slice service category. The radar charts offer an easy to identify visual perspective of the use-cases performance requirements in comparison with the general capabilities of the 4G and 5G networks. Reliability and availability of the service were seen to provide an important value for the highly critical infrastructure such as the energy vertical.

For the elaboration of the use-cases and their associated network requirements, extensive collaboration was needed between the teams to be involved in the demonstrators and those responsible for the design and implementation of the Smart5Grid platform components. Thus, D2.1. provides an integration of inputs from all partners with expertise from the energy vertical domain, network operators or network providers, ICT integrators, and applications developers.

These requirements were then discussed and agreed with the experts involved in the Smart5Grid Architecture and the System Design, who, based on them, also provided initial functional and non-functional requirements for each of the main architectural blocks. This work will be extended in the following tasks of WP2 and WP3 in the next months.

It is worth mentioning that the requirements analysis shall follow an iterative process for further identification and validation of requirements, which may be refined in the development and deployment of the Smart5Grid Platform and the demonstrators. While D2.1. will remain the reference point in the analysis, several requirements may need further details or interpretations, depending on the technologies to be finally adopted. Thus, this first deliverable of WP2 also clarifies the need for maintaining the dialog with respect to UC-specific and Smart5Grid architecture requirements through the project agile implementation and towards completion of the demonstrators.

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7. Annex

Table 30: First template for collecting the UC requirements at generic level.

Scope and Objectives of the Use-Case	
Scope	The scope defines the boundaries of the use case, i.e., what is in and what is out of the scope of the use case. This section may refer to the domain being considered (e.g., **domain overview**).
Objectives	List of goals expected to be achieved within the UC demo (from the point of view of the **target customer** for the service/system). The target customer is also known as the **Primary Actor** (the person/entity which triggers the activation of the service or of the system). Actor is an entity that communicates and interacts with the system. Further explanations are provided at the Actors Section (see point 3 below). If possible, please separate them in two sections: A. The **business goals** to be summarized here shall give a first answer to the question: "Why is the primary actor doing this?"; conversely, the functional processes answer: "How is the system going to deliver the primary actor's goals?"[50]. Please provide only the expected **measurable objectives** of the UC. B. The **service level objectives** are the objectives to be demonstrated during the UC and which are expected to be covered by the system as **general functional requirements**.

1.   Narrative of the use-case
One paragraph which captures the essence of the UC (a general description, which could be understood by a general audience). **Storyline of the use-case (max 10 lines):** Please provide a narrative description of the **"storyline" of the use-case**. It should briefly cover: • What is the problem and its context? • What is the proposed solution and why is it innovative? • What are the benefits? **Services:** (provide a short description how the service(s) to be provided by the NepApp specific for your UC meets the needs described in the problem (short description, few sentences).

2.   List Actors and Roles
2.1. Identify all the actors and stakeholders involved in the UC and describe their role(s) within the UC Demo. 2.2. Create a short list of actors relevant for the Demo site (UC) (those that directly interact with the System to be defined as part of the UC Solution)

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[50] Alistair, C. (2001). Writing effective use cases. Addison-Wesley Professional.

Actors are entities that interact with the system.

Stakeholders are entities which care or are affected in some way by the project (e.g., who might be materially affected by the outcome of the project/UC). Actors are always stakeholders, but the reciprocal is not.

Role is played by an actor in interaction with the system (e.g., a legally defined market participant such as grid operator, customer; a generic role which could comprise of a bundle of possible roles, such as a flexibility operator).

Note: one actor may have multiple roles, while different actors could have the same role.

A first step would be to clearly identify the *Primary Actor (other names could be the consumer of the service or target customer),* who is the person, entity or thing that starts (triggers) the execution of the UC. Note that the primary goal of the UC would be to meet the goal(s) or expectations of the *Primary Actor*.

By type, Actor can be a:

- **Role** (a DSO, a Balance Responsible Party, an Aggregator…),
- **Person** (a Distribution Management System Operator),
- **System** (a SCADA, a Weather Forecast System, a Demand Response Management System, …),
- **Device (**a remote terminal unit, ….), or an application.

Mention in the rows below all the actors that are involved within your demonstrator and a short description for each one concerning their role (how it interacts & communicates with the system). It is recommended the that Actors are defined according to the ETSI-CENELEC list[51] (Annex A. Actors list pages 82- 93)

3. Actor Name	4. Actor type	5. Actor Description
e.g., DSO		e.g., The DSO in the demo #BUC-ID will procure services and monitor the congestion of the system
e.g., Aggregators and prosumers		e.g., The aggregators and prosumers will be responsible for providing the distributed flexibility services
e.g., Market operator		e.g., The market operator will award the services to the market participants.

6. Complete description of the Use-Case

Please provide the detailed description of the use-case (e.g., the details around the context, current situation, and how the demo will exactly address the problem).

This section shall include a complete narrative of the use case from a domain expert user's point of view, including a brief description of the **Location and Site Facility,** then describe **what** occurs **when, why, with what expectation** (metrics where appropriate), and **under what conditions**. This narrative should be written in plain text such that non-domain experts can understand it.

This section offers also **the reflexion of the domain expert about the requirements for the use case before getting into the details needed for Technical Specifications**.

The followings shall be also covered in this section:

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[51]See: https://ec.europa.eu/energy/sites/ener/files/documents//xpert_group1_sustainable_processes.pdf

4. Details of **the problem** to be solved
   - o Include details about the context of the problem.
   - o Assumptions and prerequisites.
   - o Describe **the need for 5G technology** (collaboration with the Telco involved in the UC).
   - o Briefly describe the **preliminary functional, technical and security requirements** (e.g., constraints which need to be captured by the solution of the problem which may include communication-connectivity, etc.).
5. Details on **the current situation**
   - o Is the service already available? If yes, why there is a need for change?
     How the current situation is linked with the problem identified above.
   - o Details on any possible technical, legal, organizational limitations (constraints) for the problem to be solved (you may link them with the assumptions and prerequisites presented above, add anything which might have an impact on the solution and specify the level of importance).
6. Detail **the Solution** to be implemented by the UC Demo
   - o Detail as much as possible the Solution.
   - o Describe **the relevant 5G services involved in the Solution as they are identified by the 5G-PPP** (vision of the Telco/Network partners involved in the UC Demo).
   - o Identify what is the **role of the UC specific NetApp** in the Solution.
   - o **limitations.**
     Ddescribe any possible site-specific *deployment implications* for the Solution
   - o **Innovations** (please highlight the possible innovations to come out of the UC demo)
7. **Benefits (**enumerate as many as possible in terms of business and economic implications, social and environmental benefits).

List and describe the **scenarios** to be tested within the UC Demo (e.g., **trial overview**). A sequence diagram would be highly desired here.

7. Summary of UC:

BUC-ID	BUC Name
Service(s)	name of the service
New mechanism in the demo even if service already exists (new functional processes)	what brings new as service feature compare to the status-quo
Assets used (infrastructure, resources)	
NetApp role	
Scenarios	list the scenarios to be tested
5G-services in the Demo	list the 5G-services to be tested
5G KPIs of the Demo	list the relevant 5G KPIs targeted