Research & Innovation Actions

5G PPP Research and Validation of critical technologies and systems:
Enabling Smart Energy as a Service via 5G Mobile Network advances.

Project: H2020-ICT-07-2017

Enabling Smart Energy as a Service via 5G Mobile Network advances

Deliverable 5.2

Intermediate NRG-5 proof of concept

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Abstract: This deliverable represents a road map for carry out the preliminary deployment of the NRG-5 system and provide a detailed approach towards operational results of the NRG-5 field trials in U.K. and Italy sites. The objectives of the trials is to validate the NRG-5 concepts in a number of specific use cases, that are relevant for the future requirements of the vertical energy sector that will be enhanced by means of the new 5G communication infrastructure. Moreover will be illustrated the methodology from TRIANGLE test bed to assess the performance of smart energy grid use cases over mobile networks.

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1 Introduction

1.1 Purpose of the Document

The objectives of this deliverable are to provide a clear roadmap for each pilot, so that by the end of the NRG-5 we can deliver a complete, integrated demonstration of the different UCs. Another important aspect of this process is testing and with this aim the owner of the pilots site provides a first overview of the current implementations.

This document presents the activities performed within Task T5.2 “AMI as a Service validation” Task T5.3 “ PM as a service validation”, and Task T5.4 “DDR as a service validation” which cover the initial round of validation, testing evaluation of NRG-5 trials.

These activities come right after the integrated laboratory testing of NRG-5 framework during which the project, following the procedures presented in D4.3 “Intermediate NRG-5 laboratory validation” [1], has integrated the various VNFs .

A first round of results is now provided and offer a positive basis for the remaining elements of the trials and for the NRG-5 project itself.

The objectives and architecture of the two trials along with the demonstration scenarios are reviewed and presented. Minor changes to the approach, resulting from an improved understanding of the framework designed and implemented during the project, are reflected in the current design. The deployment status of each of the trials is reviewed; all trials are currently on track for deployment according to the plan set out in the first Deliverable D5.1 [2]. The focus of the trials is on the specific use cases proposed in Deliverable 5.1 [2], as a demonstration of the applicability of the NRG-5S concept in a range of different applications and scenarios.

The NRG-5 trials in U.K. and Italy are currently on track to test the NRG-5 approach in a range of different applications and scenarios and are reado to evaluate the benefit of 5G in the context of energy utility requirements.

In addition, this deliverable introduces the laboratory setup use for the validation of the project Use Cases, (UCs). The validation will be done in TRIANGLE testbed [3], located at the University of Malaga.

Thanks to TRIANGLE, the UCs would be validated in a controlled environment that can simulate a wide range of scenarios which allow to characterize the traffic profile of smart energy grid UCs over mobile network, as described in section 4.

1.2 Structure of the Document

The document structure is first trials sites and, next, use cases-oriented. Indeed, after Section 1 that introduces the document scope, Section 2 provides information related to the use cases implemented in the Italian trial site (that is Advanced Metering Infrastructure as a Service and Dispatchable Demand Response as a Service). Hints over the updated use cases design and architecture are provided, followed by a reference to the evaluation scenarios that will be used to assess the performance of the NRG-5 NFV framework and applications. The action plan related to the use cases deployment on the trials is documented and some first evaluation results are presented.

This exact same structure is followed in Section 3, with a focus on the UK trial and the Predictive Maintenance as a Service use case. Section 4 offers information related to the Triangle testbed that will be used to better evaluate the integrated NRG-5 context.

Finally, Section 5 concludes the document.

2 Italian trials Intermediate results

2.1 AMI as a Service

The scope of the AMI as a Service (AMIaaS) use case is to showcase that 5G can increase the monitoring capacity of smart grids under the presence of dense and smart metering infrastructures comprising real-time smart meters and multiple phasor measurement units (PMUs). Indeed, state-of-the-art smart meters are able to only provide updated smart grid measures every fifteen (15) minutes, next-generation ones able to provide such information every minute. NRG-5 considers the employment of i) sub-minute updates for smart meters (at the level of second) and ii) the mass deployment of low-cost PMUs reporting at least 20 samples per second – without calculating the phasors locally but on the edge assisted by vPMU. Such fine-grained monitoring under the presence of large shares of renewable energy sources is necessary due to the intermittent nature of the latter that may cause severe problems to the operation of the smart grid. Under these circumstances and considering dense deployments (e.g. in urban environments), 4G infrastructures simply cannot serve the requested bandwidth, particularly when considering the criticality requirement for the data delivery for the PMU case. As such, 5G has the capability of revolutionizing the way modern smart grids are monitored; this is the demonstration target of the AMIaaS UC.

2.1.1 Trial design and architecture update

Deliverable 5.1 [2] describes the set-up for the evaluation scenarios in a real life of NRG-5 solution. In that respect, the architecture and the trial design have been generally adapted to the trial site; moreover, specific details about the equipment and the needs have been provided. This section is providing an updated version of the trial design as for the AMI as a service, compliant with the project architecture and the pilot constraints. Figure 1 depicts the architecture for the UC and hints over the general control flow of interest to the use case. Note that the dependence of sets of marketplace instances has been stripped off the evaluation due to being considered as out of scope of the project; several marketplace implementations are available that, if the AMIaaS case is positively assessed, can be integrated without affecting the evaluation scope and outcome.

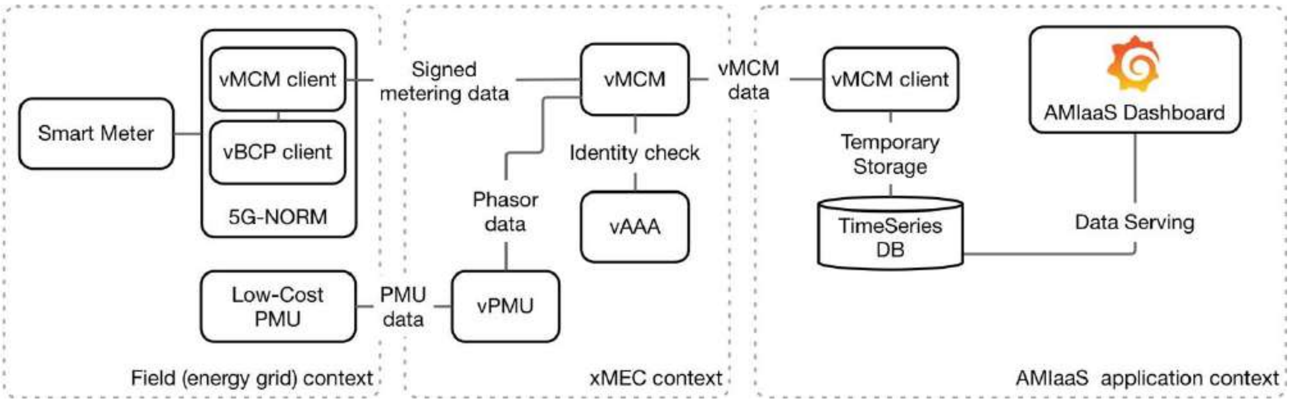


Figure 1: AMIaaS local grid monitoring dashboard technical overview.

As already described in [2], the key component for the demonstration activity is the 5G-NORM, that is an advanced Smart Metering device that enables real-time monitoring and allows to be remotely controlled. In addition to the NORM, this UC will leverage on the following VNFs:

- vBPC handling the storage of the monitoring data in the blockchain.
- vAAA handling the signing of the data packets at the client side, the signature and sender identity verification at the xMEC level, hence implementing authentication and authorization.
- vMCM acting as a device-specific cache at the edge and allowing for remote control of the devices (NORMs).
- vPMU handling the calculation and orchestration of PMU data and forwarding the resulting phasors to the vMCM.

2.1.2 Evaluation scenarios

2.1.2.1 *S1: Real time awareness of the DSO*

In the context of a high penetration percentage of Distributed Generations in the urban and suburban areas, the DSO is putting attention on technologies enabling real time observability of electrical parameters to quickly discover abnormal conditions, outages and to perform a prompt big data analysis.

In this respect, the main operational issue is:

- Voltage over limits because of distributed generation. It is well known that active power injection at LV level produces voltage increases, especially in case of long lines. This phenomena arise quite frequently when the share of distributed generation (DG) is high, otherwise, in the present status, the DSO can only leverage the existing Smart Meters to download the voltage profiles over the day. This operation is carried out only in case some problems arise (i.e., an interruption because of an overvoltage occurs). The AMIaaS, enabled by 5G technologies, allows the prompt alarms about critical situations, when the voltage is quite near to the limits

Finally, this scenario aims at evaluating real-time data availability, improving DSO as smart grid actor, namely it can be enabled as data responsible and manager, intermediating between third parties and final customers (e.g., peer to peer energy exchange and interaction with an aggregator). Granted the above, this scenario will provide valuable input as to the operational and financial impact that 5G could have in the way energy networks are monitored and their state is perceived.

2.1.2.2 *S2: Real time vizualization of trusted information by means of BCP*

A distributed sensing infrastructure allows for the establishment of increasing awareness of the DSO over the network status; on the contrary, the risk of cyber-attack on the smart metering infrastructure increases dramatically. In this respect, the AMIaaS is going to leverage on the vBCP in order to guarantee trustiness and incorruptibility of the data; having said that, the main operational issue is the trustiness of the information sent by local consumer and/or prosumer.

Granted the above context, this scenario aims to evaluate:

1. the efficiency of the NRG-5 framework to exploit the NRG-5 services to support near real-time metering data provision featuring blockchains-based identity and trust management as well as safe, indisputable storage;

2.1.2.3 *S3: Real time grid monitoring and enhanced phasor metrics calculation*

In order to optimally control a power grid, a proper knowledge of the current power flow is needed. The grid state estimation is based on measurements acquired by Phasor Measurement Units (PMUs), which provide amplitude and phase of voltages or currents as well as frequency and ROCOF (rate of change of frequency). Today's PMUs are expensive and therefore only used at key points of interest, to supervise the grid. In order to estimate the whole grid state much more PMUs are needed. To increase the number of PMUs the price per unit needs to be decreased. This is already done by using general purpose hardware, such as low cost single board computers. To further decrease the hardware price, the computation can be moved to the cloud, thus reducing the locally needed hardware resources.

Due to the sensitive nature of the phasor calculation, the benefits of URLLC and edge computing can be exploited. In fact, the data acquisition, transmission and elaboration have to be carried out in the most reliable and fast way possible, in order to be compliant with the reference IEEE c37.118.1-2011 standard for accuracy. This is done by extending the software stack of the Low Cost PMU, developed in SUCCESS project, and running an enhanced phasor calculation in the edge cloud. The new concept is based on transmitting the raw samples through the 5G communication channel and move the more demanding computation algorithms to the edge cloud.

To evaluate the new architecture the 5G-NORM will be used to acquire samples and the vPMU will calculate enhanced phasors. The impact of the communication channel quality will be evaluated with respect to upcoming 5G capabilities.

2.1.2.4 *S4: Real time distributed grid control based on the vESR function*

A centralized SCADA system as it is used in nowadays electrical infrastructure is a single point of failure, either by means of a cyber attack or due to technical failures or environmental disaster. To increase the resilience of the system a distributed control with failover capabilities can be a solution. In the case of an attack or other reasons of failure, then only a small portion of the grid is affected. Following a distributed approach that increases the overall scalability, the optimization of the electrical grid can be divided into small portions by deploying multiple instances of the control software in xMEC systems. To leverage these advantages the xMEC solution will be used to connect the vESR to the local energy resources through the vDES, vRES and vPMU components.

This scenario will be evaluated by means of real-time electrical simulations representing the local energy grid and instances of the vDES, vRES, vPMU and vESR. The vDES, vRES and vPMU interact with the simulated grid, control electrical sources and manage metering infrastructure. This becomes a hardware-in-the-loop simulation which will evaluate the functions and performance of energy-related VNFs, based on different simulated grid states.

2.1.2.5 *Functional and not functional evaluations*

In the context of AMIaaS, the evaluation of the following topics will be carried out:

- validation of the AMIaaS application ability to offer real-time energy grid monitoring;
- validation of the roll-out of the application;
- implementation and deployment of 10 new 5G-NORM prototypes in the pilot site to get real time awareness;
- evaluation of the decentralized, trusted lock-in free plug'n'play capability, provided by the new 5G-NORMs;

- comparison to actual smart meters (Lennt and ZMD405 of Landys + Gyr) installed in the grid, with respect to both communication channel (PLC, GPRS) and data size and frequency; notably, the monthly data flow could increase up to 1 GB/user (instead of some MB in Business as Usual, (BaU)) as well as time period of data sending could be decrease up to 1/5 s (instead of 15 min in BaU);
- validation of mMTC communications, including operations such as self-discovery and self-organization of the 5G network in large-scale testbed with configuration from real conditions. Specifically, the validation test will be done based on a wireless mesh network in the FITIOT-LAB [4] of which Sorbonne Université is a member of the FIT consortium. In the validation test, network traffic will be generated according to the network traffic pattern captured from real devices in ASM's premises.
- evaluation of the delay incurred in the monitoring process by the employment of blockchains to achieve effective trust management and safe storage.
- Evaluate the performance of AMIaaS over realistic scenarios, e.g., emulated 4G/5G base station, different radio propagation conditions, available radio resources, received signal power, interference, etc. Different network scenarios and impairments will be considered to identify what impact 4G/5G will have on the E2E performance and to predict possible weak points, e.g., throughput, delay, packet loss, etc. Several experiments will be executed using the TRIANGLE testbed located at the University of Malaga.
- Performance testing of smart meter from ASM. The smart meter will be connected to the emulated 4G/5G base station and some KPIs, e.g., latency, throughput, maximum coupling loss, will be measured.

2.1.2.6 *5G KPIs operational measurements*

As for the 5G KPIs, in Figure 2 reports the KPI that should be provided by the communication infrastructure; notably, it is worth pointing out that the required performances are the highest with respect to device density, user data rate and reliability.

N°	Description	Requirement	Notes
1	**Device density**	≥ 1000 (high)	N/A
2	**Mobility**	< 3km/h (low/pedestrian)	N/A
3	**Infrastructure**	big number of small cells (>10)	N/A
4	**Traffic type**	burst/periodic	N/A
5	**User data rate**	50 ÷ 100 Mbps (medium)	N/A
6	**Latency**	1 ÷ 10 ms (low)	N/A
7	**Reliability**	> 99 % (high)	N/A
8	**Availability**	> 99 % (high)	N/A

Table 1 : 5G KPIs for AMIaaS validation

The use of cellular (LTE) gateways is already well adopted for the purposes of monitoring and control of field devices in SCADA systems (IEC 60870 standard). The present trend in the smart grid industry is to complement this with the adoption of IEC 61850 standard, aimed at enabling interoperability among different devices within a substation. Recently, the scope of IEC 61850 has been extended to cover also elements like distributed energy resources, electric vehicles, protection relays, and metering devices. Effectively, this means pushing the protocol deep into the distribution grid, where wired communication is not cost effective to install and maintain. Benefiting in this respect from the 5G a comparable performance to wired infrastructure, would allow to discretize and network individual grid elements, which can then implement intelligent sensors and switching decisions to isolate faults, reroute power and self-heal the grid. Example applications include steady state situational awareness, on-line security assessment, dynamic protection for transient events, predictive maintenance, etc.

The demo setup will combine experimental setups at the University of Ljubljana and University of Malaga as depicted in Figure 2. The two setups will be connected using OpenVPN and possibly GEANT dedicated connection. The purpose of the demo is to measure the latency when connecting the PMU locally and when remotely through the cloud. The Keysight base station emulator will be used for latency comparison between local cloud and mobile communication for the PMU device. The PMU is based on IEEE C37.118-2014 standard, which requires low latency communication link.

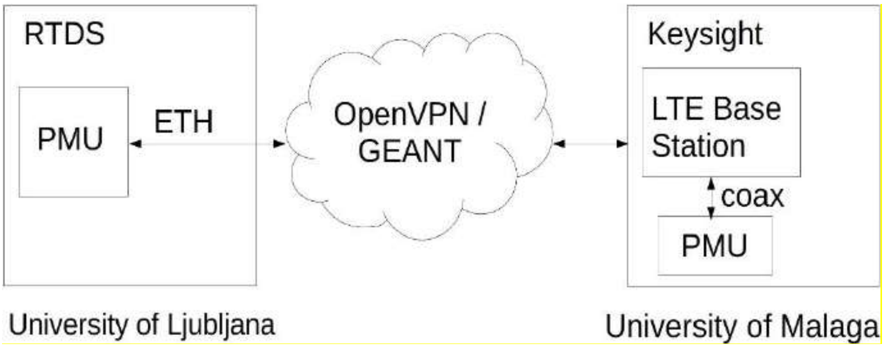


Figure 2 : Demo set up

Experiment tests

Urban-Pedestrian network scenario

- Throughput measurement
- One way delay measurement

Use case 1: IEEE C37.118-2014 protocol

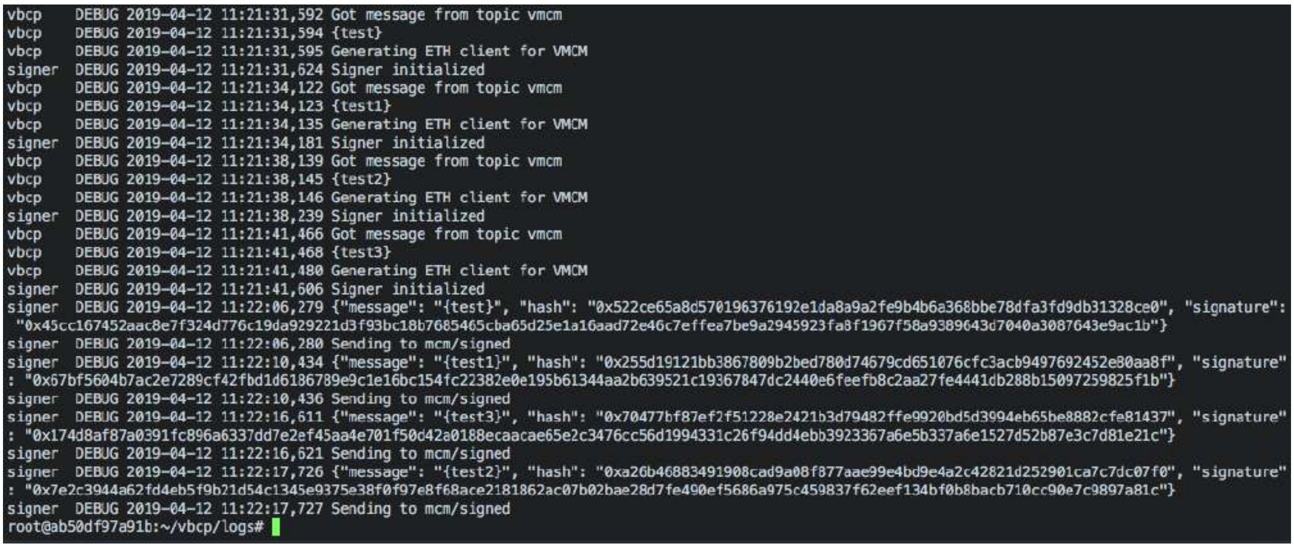
- TCP/UDP traffic type

Use case 2: IEC 61850-9-2 Sampled Values protocol

- TCP/UDP traffic type

2.1.3 Trial deployment action plan

The 5G-NORMs, locally installed in ASM living lab, have been already integrated with vBCP (e.g., Figure 3 showcases the operation of the vBCP 5G-NORM client signing test data). In addition, as reported in [2], the 5G-NORMs are currently in operation in ASM headquarters for measuring the consumptions and electric parameters of some loads and some generators.



```
vbcp    DEBUG 2019-04-12 11:21:31,592 Got message from topic vmcm
vbcp    DEBUG 2019-04-12 11:21:31,594 {test}
vbcp    DEBUG 2019-04-12 11:21:31,595 Generating ETH client for VMCM
signer  DEBUG 2019-04-12 11:21:31,624 Signer initialized
vbcp    DEBUG 2019-04-12 11:21:34,122 Got message from topic vmcm
vbcp    DEBUG 2019-04-12 11:21:34,123 {test1}
vbcp    DEBUG 2019-04-12 11:21:34,135 Generating ETH client for VMCM
signer  DEBUG 2019-04-12 11:21:34,181 Signer initialized
vbcp    DEBUG 2019-04-12 11:21:38,139 Got message from topic vmcm
vbcp    DEBUG 2019-04-12 11:21:38,145 {test2}
vbcp    DEBUG 2019-04-12 11:21:38,146 Generating ETH client for VMCM
signer  DEBUG 2019-04-12 11:21:38,239 Signer initialized
vbcp    DEBUG 2019-04-12 11:21:41,466 Got message from topic vmcm
vbcp    DEBUG 2019-04-12 11:21:41,468 {test3}
vbcp    DEBUG 2019-04-12 11:21:41,480 Generating ETH client for VMCM
signer  DEBUG 2019-04-12 11:21:41,606 Signer initialized
signer  DEBUG 2019-04-12 11:22:06,279 {"message": "{test}", "hash": "0x522ce65a8d570196376192e1da8a9a2fe9b4b6a368bbe78dfa3fd9db31328ce0", "signature":
 "0x45cc167452aac8e7f324d776c19da929221d3f93bc18b7685465cba65d25e1a16aad72e46c7effea7be9a2945923fa8f1967f58a9389643d7040a3087643e9ac1b"}
signer  DEBUG 2019-04-12 11:22:06,280 Sending to mcm/signed
signer  DEBUG 2019-04-12 11:22:10,434 {"message": "{test1}", "hash": "0x255d19121bb3867809b2bed780d74679cd651076cfc3acb9497692452e80aa8f", "signature"
: "0x67bf5604b7ac2e7289cf42fbd1d6186789e9c1e16bc154fc22382e0e195b61344aa2b639521c19367847dc2440e6feefb8c2aa27fe4441db288b15097259825f1b"}
signer  DEBUG 2019-04-12 11:22:10,436 Sending to mcm/signed
signer  DEBUG 2019-04-12 11:22:16,611 {"message": "{test3}", "hash": "0x70477bf87ef2f51228e2421b3d79482ffe9920bd5d3994eb65be8882cfe81437", "signature"
: "0x174d8af87a0391fc896a6337dd7e2ef45aa4e701f50d42a0188ecaacae65e2c3476cc56d1994331c26f94dd4ebb3923367a6e5b337a6e1527d52b87e3c7d81e21c"}
signer  DEBUG 2019-04-12 11:22:16,621 Sending to mcm/signed
signer  DEBUG 2019-04-12 11:22:17,726 {"message": "{test2}", "hash": "0xa26b46883491908cad9a08f877aae99e4bd9e4a2c42821d252901ca7c7dc07f0", "signature"
: "0x7e2c3944a62fd4eb5f9b21d54c1345e9375e38f0f97e8f68ace2181862ac07b02bae28d7fe490ef5686a975c459837f62eef134bf0b8bacb710cc90e7c9897a81c"}
signer  DEBUG 2019-04-12 11:22:17,727 Sending to mcm/signed
root@ab50df97a91b:~/vbcp/logs# 
```

Figure 3. NORM signature on BCP.

With respect to the infrastructure, the following activities have been planned:

- xMEC deployment in ASM local server farm, which has the following requirements
    - Local server featuring at least 8 CPU cores with virtualization capabilities and hyper-threading technology (or similar), 16GB of RAM, 80GB of hard disk.
    - Operational OpenStack deployment
    - Snapshot images of the VNFs implementing the VDU images.
- A local Virtual Machine for the implementation of the AMIaaS application, holding the connector of AMIaaS to the vMCM instance and the dashboard service allowing the grid status overviewing by the Utility.

The deployment plan consists of the elementary evaluation scenarios that build up the AMIaaS availability in the trial site.

Test id	Use case elements	Protocol	Evaluation criteria	Result
TA-1	5G- NORM image deployed in Trial equipment	N/A	NORM successfully installed and operational (different NORMs behind storage and photovoltaic installations)	Success
TA-2	NORM is a vBCP client	N/A	The vBCP client has been installed in the 5G-NORMs and vBCP is available as an instance	Success
TA-3	vMCM deployment and availability	N/A	The vMCM client has been installed in the 5G-NORMs and vMCM is available as an instance	Pending
TA-4	Connection between devices and vMCM through vBCP	MQTT	The vMCM gets signed information from the vBCP	Pending
TA-5	vMCM availability and connection between the devices	HTTP	The local vMCM instance is accessible from all 5G-NORMs	Pending
TA-6	Dashboard deployment	N/A	The AMIaaS service is integrated with vMCM and available for experimentation by the Utility	Pending
TA-7	Data visualization of the Smart Meter	N/A	The Utility is able to overview the grid state from a dashboard in real time	Pending
TA-8	Real time data acquisition and phasor calculation with	N/A	A function generator is used to generate known waveforms. The results calculated	Pending

	the 5G-NORM and the vPMU		in the vPMU are evaluated with respect to the correctness and vPMU performance.	
TA-9	Communication channel impact on the vPMU calculation results	N/A	The communication channel between 5G-NORM is varied in quality, in order to evaluate the consequences on the vPMU results	Pending

Table 2 : Deployment Test

This atomic validation steps are useful for the description of a procedure that allow the end-to-end evaluation to be judged successful

Evaluation S1 : S4	
Scenario narrative steps description	
	1. The vBCP allows data transfer of the Smart Meters 2. Smart Meter data are shown in the dashboard 3. The vESR requests profiles from vDES, vRES and vPMU 4. Information are transferred to other VNF to perform DDRaaS
Success scenario	
	• Dashboard shows data from the SM • Data are validated by BCP

Table 3 : AMIaaS Scenario steps

The realization of the different validation activities related to deployment in the real infrastructure will span the following time duration.

Activities																					
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
5G- NORM image deployed in Trial equipment										🟩	🟩	🟩	🟩								
NORM is a vBCP client										🟩	🟩	🟩	🟩								
vMCM deployment and availability													🟩	🟩	🟩	🟩					
Connection between devices and vMCM through vBCP														🟩	🟩	🟩					
vMCM availability and connection between the devices													🟩	🟩	🟩	🟩	🟩				
Dashboard deployment																🟩	🟩	🟩	🟩		
Data visualization of the Smart Meter																🟩	🟩	🟩	🟩	🟩	
Collection and analysis of the results																🟩	🟩	🟩	🟩		

Table 4 : Action Plan time line

2.2 Dispatchable Demand Response (DDR) as a Service

As stated in D3.2 [5] and D5.1 [2] the scope of this energy service demonstration in the ASM Terni premises is to show how the 5G paradigm can help on keep the grid stable when many renewables are injected in the distribution grid. The work in this scenario reveals that the application of smart grid technologies such as demand side management and the distributed energy storage (DES) have the potential of mitigating voltage variation problems with the coordinated optimization set point of PV installations and EV charging stations.

2.2.1 Trial Design and architecture update

D5.1 [2] reported on the initial design of the ASM trial site as regard the Dispatchable Demand Response. In short, the concept is to test the capability to alleviate the effects of the intermittent renewable power generation with the use of shaped load consumption and DES composed of 2nd life batteries and through the control of electric vehicle charging stations. The 5G infrastructure will support the utility on delivery in time the required information and actions that can minimize the voltage rise generation, when generation is more than consumption and there is a risk to overcame the voltage limits of the ASM micro-grid.

This is made via control of the MV feeder to avoid voltage rise (with high RES penetration) with the control running in the vESR that will send to LV side the power set-points. The mapping of the VNFs and the pilot infrastructure is described in Figure 4 where it is demonstrated that the vESR collects data from vRES and vDES that aggregate energy values from PV installation and DES and operate the optimization in case of voltage rise detection. In the Figure 3 is it possible to see the MV feeder that have storages, renewables and load field devices and how the correspondent VNFs manage and collect information from the point of view of vESR, vDES and vRES. The final result in case of voltage rise is then to produce a list of set points to be communicated via vDES and vRES to the real devices for actuation of active demand policies.

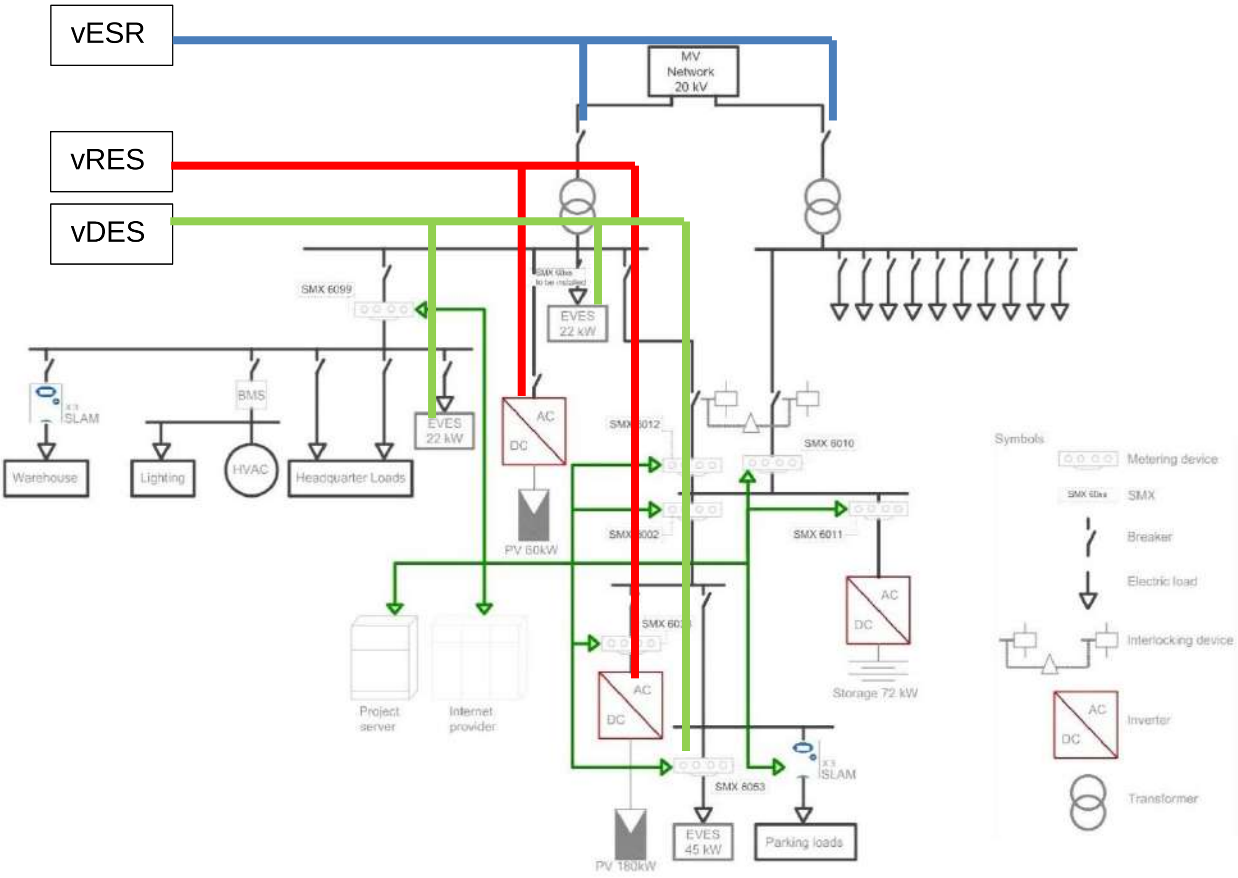


Figure 4: VNFs placement in the ASM smart grid

From the point of view of the infrastructure in the DDR as a service we have the following assets.

Field devices	Description

Storage System	72 kWh 2nd life Li-ion battery energy storage is the Block of Energy Unit (BoEU) providing the electric power storage and supply services. It is the BoEU that plays an important role in providing the district with the flexibility necessary to implement different services, especially ancillary services like Primary reserve, Dynamic reactive Power control and Reactive Power Compensation.
PV plant	The PV plant cover the Parking Surface (2000 m²) producing about 230 MWh yearly.
Charging Stations	The SpotLink EVO installed in ASM Terni, whose maximum power output is 22 kW, are intelligent charging stations equipped with a single-board computer that allows real-time monitoring and management of them remotely allowing the station manager to remotely modify the charge power output and start/stop the charging sessions.
Building	ASM Terni buildings comprising a 4,050 m² three stories office building, a 2,790 m² single-floor building consisting of technical offices, a computer centre and an operation control centre and a 1,350 m² warehouse; usually the base load varies between 50 kW and 90 kW and peak load is between 120 kW and 170 kW, depending on seasonal factors.
Primary Substation	It is the primary substation at which these facilities are normally connected. The energy drawn yearly is about 27 GWh, whilst Reverse Power Flow (RPF) produced by local Distributed Generators has a total amount equal to 5 GWh. The peak power is about 20 MW when it is absorbing energy from the TSO, while it is equal to 11.1 MW, in case of RPF.

Table 5 : Operational infrastructure

2.2.2 Evaluation scenarios

2.2.2.1 *Evaluation S1 Use of flexibility to avoid voltage limit violations in a network with high penetration of distributed generation from renewable energy sources*

The intense concern about the global warming effects has modified the national planning strategies for the energy sector. The decarbonisation of the energy sector by exploiting renewable energy resources can reduce environmental impact of the energy consumption. A large deployment of Distributed Energy Resources (DER) is planned ((the term DER expresses a cluster that includes storage, renewables generation and movable load/storage as EV);).and these technologies will significantly modify the demand profile of power systems and will affect the way distribution grids are managed and operated. A high penetration of DER however, can significantly affect the network operation in a number of ways. The main operational issues are:

- **Violation of thermal limits**: The integration of DER modifies the current power flows in the electricity network, which could lead to the violation of the thermal limits of network elements.

- **Voltage Regulation**: High DER production combined with low consumption may lead to overvoltage problems at remote nodes of the line.

- **Fault level:** DER contribution to fault currents may result in exceeding the capacity of the network.

- **Power Quality**: Power electronics included in DER elements provide harmonic distortions of the current waveforms.

- **Reverse Power Flow**: Distribution networks are designed based on the assumption of unidirectional power flows, under minimum demand and maximum DER generation conditions, reversal of power flows can have negative effects on certain types of electrical switches and on the operation of voltage control and protection schemes.

The scope of this evaluation test is to assess the performances of the NRG-5 exploiting the synergy between the energy VNFs that can model the real devices and to address the new requirements capacity of the distribution network without the need of a grid expansion plan.

The objectives of this evaluation scenario are:

- To evaluate the efficiency of the NRG-5 framework to exploit the demand flexibility offered by the active end-users represented by VDES, VRES and EVs
- To evaluate the efficiency of the NRG-5 demand response mechanism to offer voltage support services to system operator under high RES deployment scenarios.

2.2.2.2 *5G KPIs operational measurements*

N^o	Description	Requirement	Notes
1	**Device density**	1000÷10.000 (medium)	N/A
2	**Mobility**	> 50 (fast moving vehicles)	N/A
3	**Infrastructure**	Small amount of small cells (<10)	N/A
5	**User data rate**	50 ÷ 100 Mbps (medium)	N/A
6	**Latency**	50 ms (medium)	N/A
7	**Reliability**	> 99 % (high)	N/A
8	**Availability**	> 99 % (high)	N/A

Table : 5G KPIs for DDRaaS validation

2.2.3 Trial deployment action plan

The deployment plan is constituted of single tests and the final evaluation scenario that regard the NS.

Test id	Use case elements	Protocol communication	Evaluation criteria	Results
TA-1	5G- NORM image deployed in Trial equipment		NORM successfully installed and operational (different NORMs behind storage and photovoltaic installations)	Success
TA-2	Establishment of a connection from DES to vDES (via Vmcm)	MQTT Ditto/RESTful API	DES successfully sends/receives simulated data to/from vDES	Ongoing
TA-3	Establishment of a xx connection from RES to vRES (via vMCM)	MQTT Ditto/RESTful API	RES successfully sends/receives simulated data to/from vRES	Ongoing
TA-4	Connection between the vDES,vRES,vESR	RESTful API	vDES successfully responses to the GET/PUT data request from vESR	Pending

TA-5	Connection between vESR and dashboard application logic	MQTT Ditto/RESTful API	Dashboard obtain successfully responses to the GET/PUT data request from vESR	Ongoing
TA-6	VESR calculation of set point and communication to vDES and vRES	RESTful API	vESR sends the aggregated power consumption group data to vRES and vRES receives data successfully.	Pending
TA-7	Application of set point on DES, RES and EV charging station	Protocol between RES and PV station: TCP	1. vDES computes the solution to decide what devices should to perform what actions based on the LV group data received from vESR; 2. vDES sends action commands to DES instances of selected devices; 3. DES receives action commands from vDES, then, it translates the commands and sends the translated commands to EV charging station. 4. vRES computes the solution to decide what PV stations should to perform what actions based on the power group data received from vESR. 5. vRES sends action commands to RES instances of selected PV stations. RES receives action commands from vRES, then, it translates the commands and propagates them to the PV station..	Pending
TA-8	Posteriori verification of smart grid solved issue	RESTful API	Dashboard shows normal situation on the visualization dashboard	Ongoing

Table 6 : Deployment Test

Based on this scenario divided in time step we can describe the following table

Evaluation S1 Use of flexibility to avoid voltage limit violations in a network with high penetration of distributed generation

Scenario narrative steps description

1. The vESR shows monitor information about grid (real time information related to profiles nodes of micro-grid
2. Voltage limit violations are showed in the dashboard
3. The vESR requests profiles from vDES, and vRES
4. vESR calculates the new set point to be set on the real devices
5. vESR broadcasts new set point to the VNFS
6. Application of set point in the real devices or in simulated way
7. Dashboard show the result of application of new setpoint: overall voltages limit curves are below the safety threshold

Success scenario

- The proper set point are showed by different devices: storages, PV and EV charging station
- Voltage limit are keep below the threshold

- KPI satisfy the threshold
- Dashboard shows the smoothed curves

Table 7 : DDRaaS Scenario S1 steps

The realization of the different validation activities related to deployment in the real infrastructure will span the following time duration.

Activities																					
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
5G- NORM image deployed in Trial equipment																					
Establishment of a xx connection from DES to vDES (via Vmcm)										🟩	🟩	🟩	🟩	🟩	🟩						
Establishment of a xx connection from RES to vRES (via vMCM)										🟩	🟩	🟩	🟩								
Connection between the vDES,vRES,vESR													🟩	🟩	🟩	🟩	🟩				
Connection between vESR and dashboard application logic													🟩	🟩	🟩	🟩	🟩				
VESR calculation of set point and communication to vDES and vRES													🟩	🟩	🟩	🟩	🟩				
Application of set point on DES, RES and EV charging station																🟩	🟩	🟩	🟩	🟩	🟩
Posteriori verification of smart grid solved issue																🟩	🟩	🟩	🟩	🟩	🟩

Table 8 : Action Plan time line

3 UK trial intermediate results

3.1 Predictive Maintenance as a Service

The D5.1 [2] reported on the initial design of the ENGIE - STORENGY site trials as regard the Predictive Maintenance as a Service. In brief, the concept is to test the capability to stream video images from a drone and process them as well as having the ability to control the drone (automatically or manually) to perform usual maintenance activities on an energy facility. Maintenance activities on energy facility are seen through three different scenarios that are the subject of this UC2 trial that will be run on Storengy UK gas storage plant.(Storengy is a French Public Limited Company, 100% owned by ENGIE)

The 5G architecture will help on the different scenarios to reduced maintenance costs by having a more efficient operation which will help on reducing deployment timing, operational costs and avoiding accidents on site. This optimization of maintenance activities on storage facility profit to all citizen in the way that fast response on incident occurred will be fixed faster and safer than before.

3.1.1 Trial design and architecture update

Regarding the proof of concept design, field location is far from a town (or houses concentration) and mobile coverage is very limited or non-existing in some areas. Also, the field distances on the trial site are quite long compared to the laboratory testing. Under these circumstances, it was decided to set up in place a Wi-Fi link in the ground station and it will be required to use an external antenna on the drone to extend drone communication range.

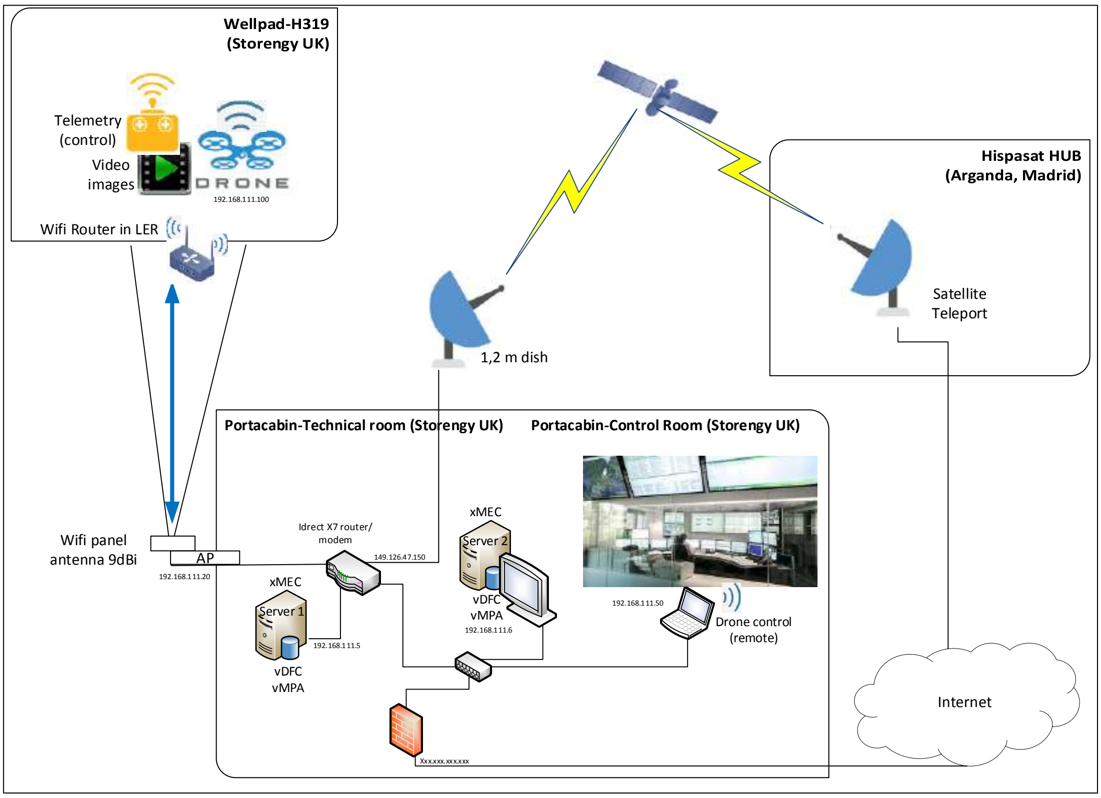


Figure 5 : PMaaS trial deployment overview

3.1.2 Evaluation scenarios

3.1.2.1 *S1: Automatic flight following a pre-defined path*

The first scenario involves automatic flight of the drone to detect real-time changes in the field. The detected changes will be showed accordingly to the operator, so it can be checked and take a decision.

At first this task was made by two operators walking more than 5 Kms in the field. Helped by a car, but restricted to the few dirt roads available, total distances growth up to 10 Kms and several hours of checking. For this reason, Storengy UK (the company that operates the gas plant) bought a drone to do a faster and less resources consuming checking. Although the bought of the drone save some time, there are still some problems, reason of only doing this routine checking every other month. No real-time images as they must be seen after the flight, taken from the memory card of the drone. No automatic flight as drone must be manually operated and the flight has to be conveniently planned.

The Predictive Maintenance as a Service (PMaaS), enabled by 5G technologies, allows the automatic predefined flying paths and the real-time video processing so no pilot is needed, and the operator can be placed in the control room to see real-time video and real-time alerts over the streamed video. Taking all this into consideration, this scenario aims at evaluating real-time data availability, deployment of a drone flight time and alert time in case any problem is detected.

This scenario will provide valuable input as to the operational and financial impact that 5G could have in routine surveillance reducing the costs and increasing the surveillance frequency.

3.1.2.2 *S2: Manual drone control triggered by an alarm*

The second scenario involve alarm detection (fire and gas detector triggered on site, access control system detecting intrusion on fence, etc..). This will always requires sending an operator to check what happened and verify the alarm.

This scenario involves manual control of the drone to visualize the incidence so effective maintenance or decision taking could be taken faster. The PMaaS allows the fast deployment of the drone and manual controlling to the check point by an operator that do not have to be a pilot or have knowledge of drone piloting as it’s going to be commanded from the control room computer. Once the drone arrived at the pointed destination, the operator can see real-time images and check if any automatic detection alarm from the vMPA has been raised allowed by edge computing to reduce the latency of response.

Reducing costs both economical and human by reducing risks as an operator is only sent if an event is detected and the operator knows in advance what type of event is so measures can be taken.

3.1.2.3 *S3: Remote control of the done*

The third scenario test the possibility to react as likely the second scenario but without having support from the maintenance team from the site due to unavailability (in case of catastrophe for example). A remote control is then launched from a remote location to fight the drone and be aware of the current status and condition of the gas plant and plan an intervention if necessary.

5G technologies enable the possibility of remote control in real-time the drone as low latency can be achieved no matter the distance of the connection. For the fastest response, the vDFC, responsible of controlling the drone, is run on the edge, but the control of the drone can be drone from worldwide.

3.1.2.4 *Functional and not functional evaluations*

In the context of PMaaS, the evaluation may validate the following requirements:

- Deployment and delay of deployment of a real drone for critical infrastructures inspection.
- Validation of the PMaaS application ability to offer real-time critical infrastructure monitoring.
- Validation of the vDFC within all trial scenarios. It shall be able to drive the drone among common maintenance paths for multiple and autonomous failure detection.
- Validation of the vMPA for real-time video processing running in the edge.
- Evaluation of the improvement from a maintenance perspective of the automatic flying mode and detection alerts.

Reaction time compare to traditional operating procedure in case of an event

3.1.2.5 *5G KPIs operational measurements*

N°	Description	Requirement	Notes
1	Device density	< 1000 (Low)	This KPI is not targeted in the present use case. Drones will be tested one by one, mainly for safety reasons.
2	Mobility	> 50 Km/h (fast moving vehicles)	Drone can reach 70 Km/h. This maximum speed under operation will be measured on site.
3	Infrastructure	Macro cell coverage	One cell can cover gas plant extension (500m radius). The maximum range reached will be measured on site.
4	Traffic type	Continuous / Burst	Continuous flow for video streaming (download) and bursts for telemetry (up/down). This is standard operation.
5	User data rate	50 ÷ 100 Mbps (medium)	High data rates are present when downloading video streaming from Full-HD to 4K resolution cameras embedded on the drone. The maximum data rate reached will be measured on site. In the future, intensive and simultaneous use of several drones (e.g. in case of alarms checks) shall lead to very high data rates close to the ones announced to be supported by 5G.
6	Latency	• 1 ÷ 10 ms (low) for alarms • > 50 ms (high) for video	No 5G infrastructure will be available on site by mid-2019. On site, the latency will be specific to the WIFI, VSAT and Internet media. The latency parameter cannot be measured on site, but thanks to specific tools it will be measured in the lab. The lab environment grants a pre-operational environment under wired and simulated 4G cell conditions. This is the near conditions for 5G parameters testing.
7	Reliability	> 99 % (high)	Redundancy of video data sent to the operator via a minimum of two different media, i.e. WIFI/ VSAT/ Internet, enables achieving high reliability rate of the datalinks.
8	Availability	> 99 % (high)	Redundancy of servers enables high availability rate of the application.

Table 9 : 5G KPIs for PMaaS validation

3.1.3 Trial deployment action plan

The deployment plan consists of the elementary evaluation scenarios that build up the PMaaS availability in the trial site.

Test id	Use case elements	Protocol	Evaluation criteria	Result
TA-1	vMPA image deployed in trial equipment	N/A	vMPA successfully installed and operational	Success
TA-2	vDFC image deployed in trial equipment	N/A	vDFC successfully installed and operational	Success
TA-3	Connection between the vDFC and the drone simulator	MAVLink	The drone simulator instance can connect to the vDFC	Success
TA-4	Connection between the vMPA and the vDFC	TCP	vMPA and vDFC can interact and change flight path	Pending
TA-5	Video stream availability from the vMPA	HTTP	Users from outside can see real-time video	Pending
TA-6	Drone control connection from the vDFC	MAVLink	vDFC can control a real drone	Pending
TA-7	Data collection from drone surveys	N/A	The utility company can view and review the collected data	Pending

Table 10 : Deployment test

The realization of the different validation activities related to deployment in the real infrastructure will span the following time duration.

Activities																					
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
vMPA image deployed in trial equipment							🟩	🟩	🟩	🟩	🟩	🟩	🟩								
vDFC image deployed in trial equipment							🟩	🟩	🟩	🟩	🟩	🟩	🟩								
Connection between the vDFC and the drone simulator										🟩	🟩	🟩	🟩								
Connection between the vMPA and the vDFC													🟩	🟩	🟩	🟩					
Video stream availability from the vMPA													🟩	🟩	🟩	🟩	🟩				
Drone control connection from the vDFC																🟩	🟩	🟩	🟩		
Data collection from drone surveys																🟩	🟩	🟩	🟩		
Collection and analysis of the results																	🟩	🟩	🟩	🟩	🟩

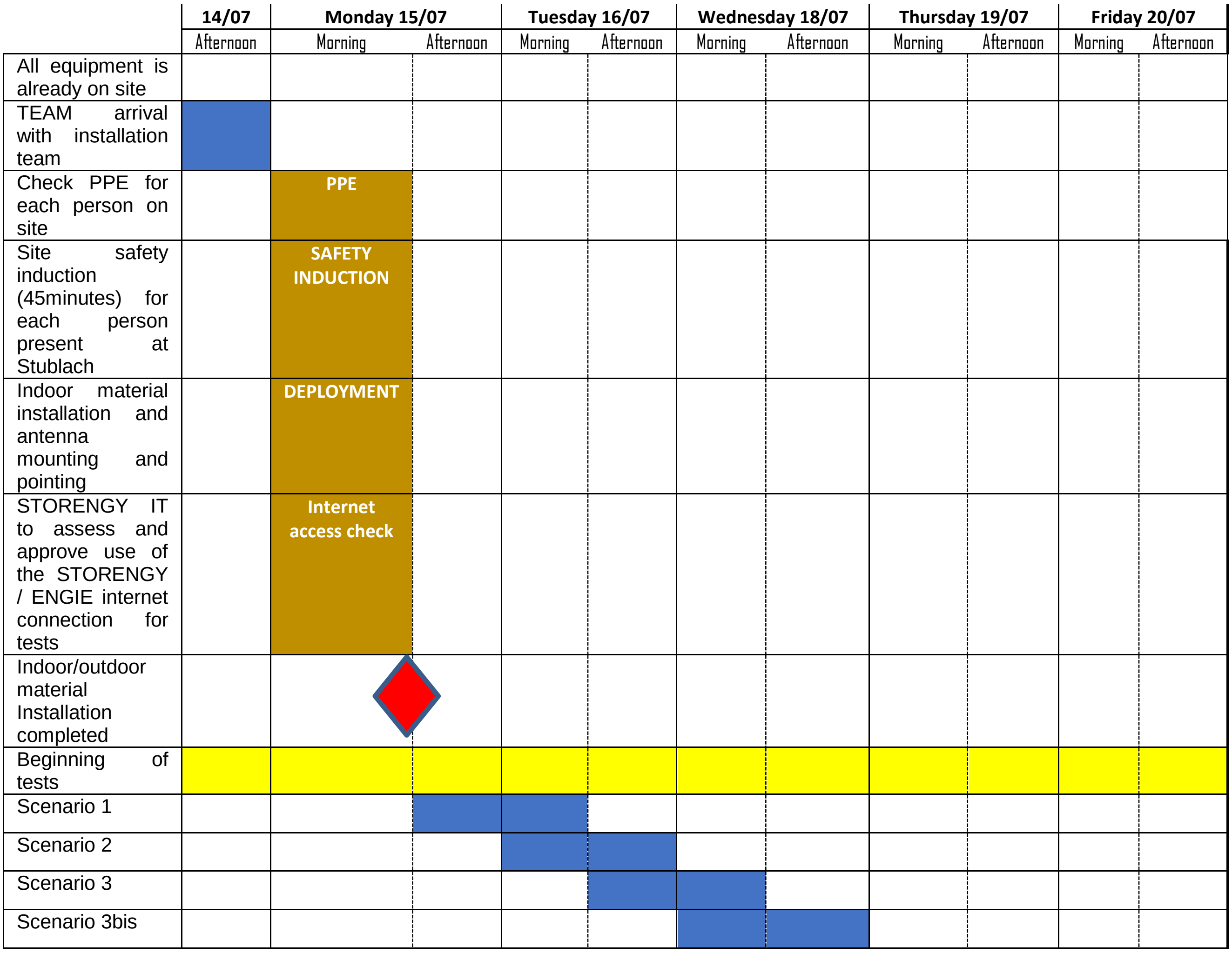
Table 11 : Action plan time line

The on-site trial deployment action plan includes the following milestones:

Date start	Date end	Location	Subject	Status
25/03/2019	28/03/2019	Madrid	Integration VIS-HIS	done
09/04/2019	10/04/2019	Stublach	Site survey et coordination with STORENGY	done
15/05/2019	16/05/2019	Malaga	Measurements and tests in lab in a simulated environment close to 5G	done
27/05/2019	-	Mail	Send other video recordings to VISIONA	done
TBD	TBD	Madrid	WIFI effective coverage measurement with new box	TBD
TBD	TBD	Stublach	Tests for live IR video streaming	TBD
10/06/2019	-	Mail	Site safety induction file	planned

06/06/2019	-	Tasks + scenario	Tasks details and scenario + tasks inserted in the overall timeline	planned
11/06/2019	-	Mail	RAMS document for installation and Drone flight for approval and creation of the work order	planned
26/06/2019	-	Mail	Send to STORENGY for approval: packing note and final packing list will be sent by e-mail prior to any shipment	planned
03/07/2019	-	Mail	Approval of the NRG-5 “packing note and final packing list”	planned
04/07/2019	-	Stublach logistics	Shipping the equipment for tests on site	planned
11/07/2019	-	Stublach logistics	All equipment shall be already received and confirmed by STORENGY at the Stublach site	planned
15/07/2019	19/07/2019	Stublach	UC2 trials	planned

Table 12 : Action plan before trials



	14/07	**Monday 15/07**		**Tuesday 16/07**		**Wednesday 18/07**		**Thursday 19/07**		**Friday 20/07**	
	Afternoon	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
All equipment is already on site											
TEAM arrival with installation team	🟦										
Check PPE for each person on site		PPE									
Site safety induction (45minutes) for each person present at Stublach		SAFETY INDUCTION									
Indoor material installation and antenna mounting and pointing		DEPLOYMENT									
STORENGY IT to assess and approve use of the STORENGY / ENGIE internet connection for tests		Internet access check									
Indoor/outdoor material Installation completed		◆									
Beginning of tests	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Scenario 1			🟦	🟦							
Scenario 2				🟦	🟦						
Scenario 3					🟦	🟦					
Scenario 3bis						🟦	🟦				

Back-up for extra tests								🟦	🟦		
Extra back-up										🟦	
Packing, shipping											🟨

Table 13 : Action plan during trials

Trials require installation of the equipment to run the different scenarios, this involves:

Drone equipped with normal camera

- Installation of satellite dish and modems for remote access.
- WIFI antenna and WIFI router for drone connectivity and servers for VNF services deployment.
- Laptop for images and control of the drone locally and remotely according to the scenarios.

Figure 6 : Material location on Stublach site

A container for material installation is made available for the trials. The container called Portacabin is divided into two rooms. The first room will be the technical room which will housed the satellite modem, the firewall and the local server. The second room, the control room will be used to house the remote server and the laptop for remote control of the drone.

The site survey shows some risk regarding the WIFI coverage, the nominal WIFI router range is about 500 m radius and may not be enough to ensure communications with the drone for all the tests we are planning. We have decided to install a directive panel antenna with a gain of 9dBi to extend the WIFI from the portacabin to the well pad H319.

Inside the wellpad, a Local Equipment Room (LER) is available for equipment installation. We will install on the roof of the LER, the WIFI Router and configure it on the bridge mode in order to repeat the WIFI and amplify the signal. The “H319 well pad” is located approximatively in the middle of the east flowline flight path.

Figure 7 : VSAT and planed installation

Figure 8: Portacabin prepared for trials indoor set up with two rooms

Once the installation is completed, tests can be run.

Evaluation S1 Automatic flight following a pre-defined path	
Scenario narrative steps description	
	1. Maintenance path (**East flowlines** is the usual maintenance path for Storengy operator) 2. Periodic surveillance for maintenance purpose
Success scenario	
	• As a result, the first scenario tests shall deliver the operators live images analysis and alarms detection. Today the operator needs to go on site on different spot to make the drone flight and capture video images on a SD storage card inside the drone for analysis when he is back to the office. Fast drone deployment for maintenance through the vDFC VNF and Edge computing for image processing through the vMPA VNF will be

	used to demonstrate the success of this scenario.

Table 14: PMaaS Scenario S1 steps

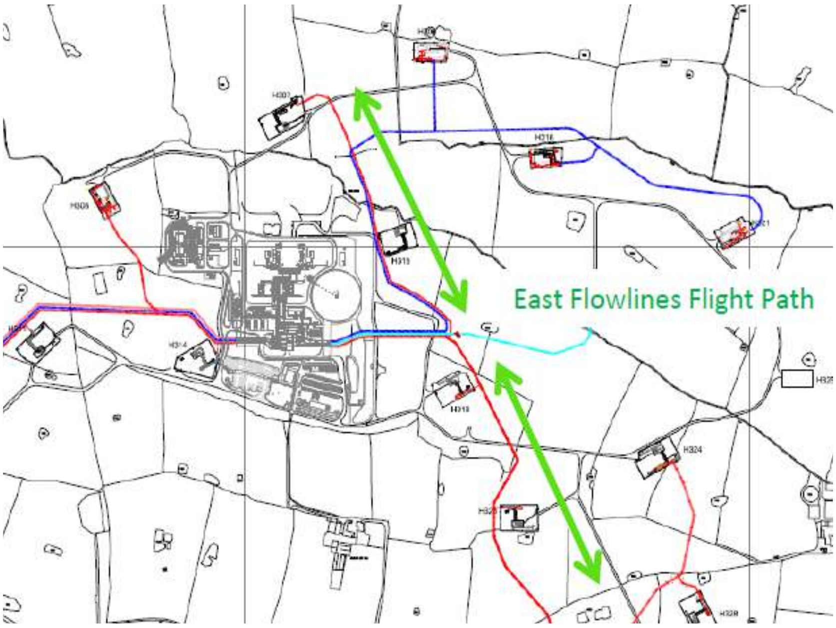


Figure 9 : East flowlines flight paths

Evaluation S2 Manual drone control triggered by an alarm	
Scenario narrative steps description	
	1. Alert received by sensors (flame detection) on the process area 2. Needs of videos images to schedule appropriate response
Success scenario	
	• As a result, the second scenario tests shall provide the operators with the possibility to analyse specific emergency incidents occurring on site, by deploying drones faster than before and make use of edge computing for image processing through the vMPA VNF.

Table 15 : PMaaS Scenario S2 step

Figure 10 : Flame detector

Evaluation S3 Remote control of the drone	
Scenario narrative steps description	
	1. Alert received by sensors (Fence/security detection on H319 well pad as in) 2. No communication available on site 3. Coordinator/expert not available on site 4. Needs of Drone remote control through external link (satellite coms, internet)
Success scenario	
	• The third scenario gives the possibility for the maintenance team to perform maintenance emergency activity via a remote control of drone. Approach of the third scenario considers that usual communication to site is not possible, that the maintenance team is not available during an emergency that occurs. The 5G scalability will then be tested by taking remote control of the drone and by having the video images available from a remote location. For this purpose, the drone will be directed via manual control to the incident location by an operator via a satellite link and internet connectivity. • MultiRAT access to the network to reach 99% availability. Edge computing for image processing through the vMPA VNF.

Table 16 : PMaaS Scenario S3 steps

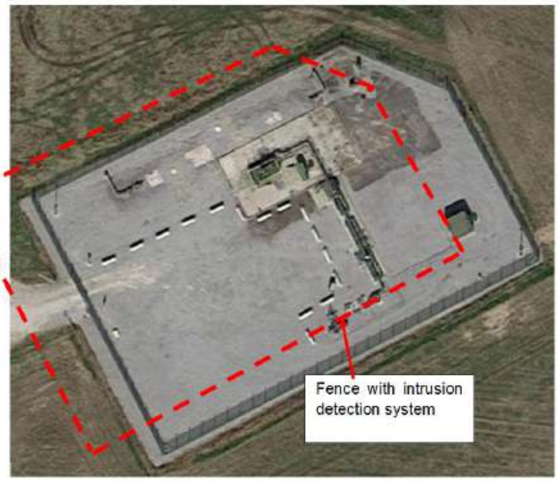


Figure 11 : Well pad aerial photography

4 Triangle test bed

One of the targets of the project is to characterize the performance of smart energy grid use cases over mobile networks. With this purpose, several experiments will be executed in the TRIANGLE [6] testbed located at the University of Malaga. One of the main features offered by the testbed is the simulation of realistic scenarios and the execution of repeatable test cases to obtain valid performance results.

The experiments seek to characterize the improvements provided by 5G in the context of smart energy grid. The TRIANGLE testbed supports LTE Advance PRO, a 4.9G technology. The results obtained will be extrapolated to 5G to obtain a preliminary baseline of the performance of the uses cases under test in 5G networks. Moreover, the TRIANGLE testbed provides the possibility to introduce impairments and fading profiles to reproduce realistic radio conditions (mobility, interferences, etc.).

The setup used in the testbed for the testing of smart energy grid uses cases is the following:

- **UXM RAN emulator**: The main component of the Testbed, it enables to emulate several cells of a cellular network in a controlled manner. The UXM features include intra-RAT and inter-RAT handovers, protocol debugging, IP end-to-end delay and throughput measurements, and RF conformance tests. Finally, it should be noted that the UXM also features an advanced fading engine with the main channel models defined by 3GPP.
- **LTE router, NETGEAR 4G LTE LB2120**. This modem provides LTE connectivity to the NORMs nodes. NORM nodes will connect via Ethernet to the LTE router.
- **The VNFs** corresponding to the vPMU vESR, vDES and vRES will be deployed at the virtualization infrastructure connected to the mobile access network.

Figure 12 depicts the setup.

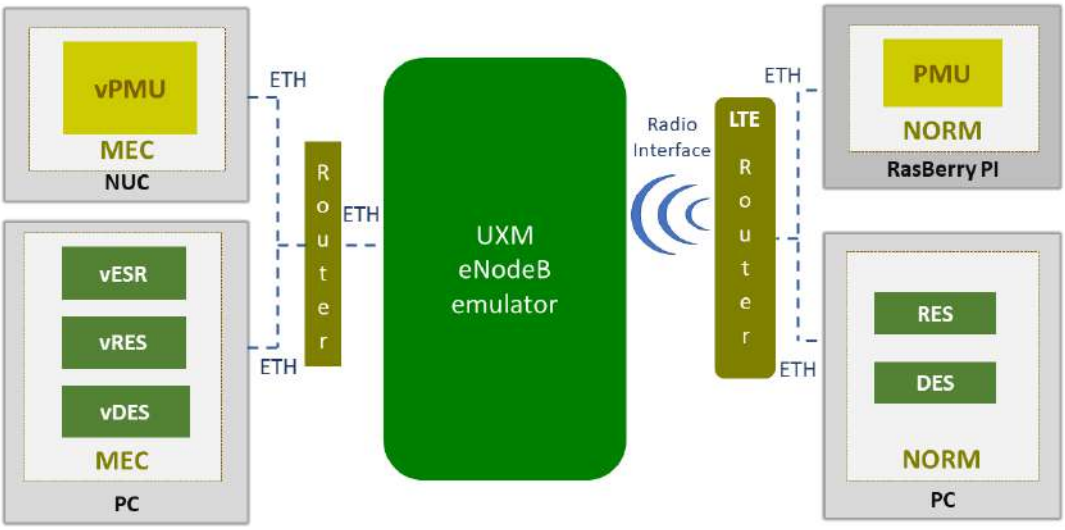


Figure 12 : Smart grid meter Use Cases

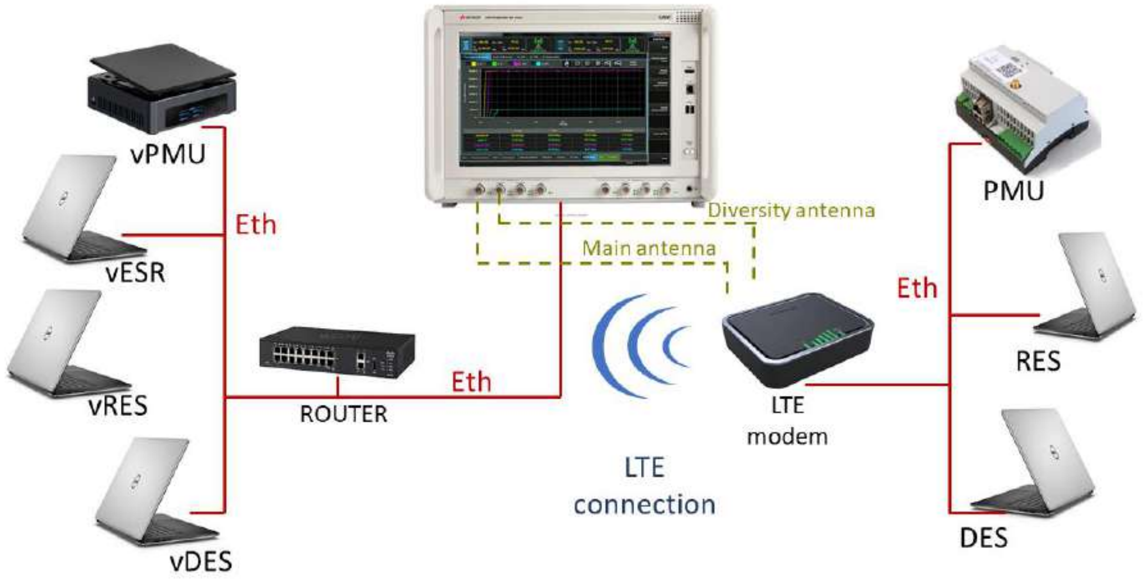


Figure 13 : Test bed setup

4.1 Test bed Scenarios

As part of the experimentation process we will define scenarios for reproducing network conditions relevant for smart energy grid use cases. The will be based on the configuration of the parameters shown in Table 17.

Parameter	Description
Received Power	This parameter fixes the perceived signal power at the device side assuming ideal conditions. High values are used to establish good signal coverage, while low values are necessary to emulate bad signal conditions. For example, extremely low values could be used for the home sensors scenario enabling test under very harsh conditions for the IoT device.
Duplex Mode	This parameter determines the mode of operation in LTE cells: FDD or TDD. TDD enables dynamic adaptation to the load on the cell; while FDD uplink and downlink resources are symmetric. Slight variations between both modes could be observed depending on the TDD configuration.
Transmission Mode	This parameter configures the way the downlink radio channel operates. There are nine different modes, each one has associated a downlink antenna configuration.
Downlink/Uplink Bands	These parameters fix the downlink and uplink frequencies. IoT devices are expected to reside in the lower part of the spectrum allocated to mobile operators as the penetration properties are better the lower the frequency is.
Downlink/Uplink Bandwidth	These parameters fix the downlink and uplink frequencies. IoT devices are expected to reside in the lower part of the spectrum allocated to mobile operators as the penetration properties are better the lower the frequency is.

Cyclic Prefix	Depending on cyclic prefix the information is more resistant to fading, which ultimately will determine the performance of the system.
CFI	The Control Format Indicator (CFI) defines how many OFDM symbols are used for the PDCCHs in a subframe.
Specific TDD configuration	This parameter fixes the amount of resources devoted to uplink or downlink. When in use is expected to have significant impact in the difference between downlink and uplink system throughput.
NB-IoT Mode	NB-IoT defines three main of operations: in-band, guard-band and standalone. Each operation mode faces different challenges and need to be studied in detail
Number of Tones	NB-IoT maximum throughput will depend on the number of tones supported by the IoT devices. We expect most of the first generation NB-IoT devices to be single tone.
Carrier Assignment	These parameters determine the type and number of active cells, i.e., primary cell, secondary cell or NB-IoT cell.
Carrier Setup	These parameters determine the type and number of active cells, i.e., primary cell, secondary cell or NB-IoT cell.
Downlink Scheduling	The following parameters will have significant impact on the system performance. These are: • Downlink Antenna Configuration • Resource Allocation • Modulation used • Support for 256-QAM
Downlink RB Allocation	This parameter determines the amount of resources, i.e., resource blocks, allocated to the device. Thus, the maximum throughput allocated to the UE. For example, scenarios with high load can be emulated by providing limited resources to the device.
Uplink Scheduling	The following parameters will have significant impact on the system performance. These are: • Modulation used • Support for 64-QAM
Power control	This parameter allows to configure the power level used by the UE for PUSCH and PUCCH channels.
HARQ	The number of maximum retransmissions will have a considerable impact on the reliability of the system. If the number is too low, a device experiencing bad radio conditions will be challenged to deliver its data in a reliable manner. On the other hand, if the number is too high the efficiency of the system might be affected.
Connected DRX	The DRX-configuration is expected to have significant impact on device's battery life.
Measurement reporting	The DRX-configuration is expected to have significant impact on device's battery life.
Impairments	The impairment described in Section 13 are expected to have significant impact on the system and device performance. Here we highlight the following: • Orthogonal Channel Noise Generation, which is used to model

	virtual devices in the network. • Channel emulator, which is used to determine the channel experienced by the devices, e.g., pedestrian, vehicular, high speed train, etc. • AWGN Noise

Table 17 : Main parameters used in the definition of the testing scenarios

In addition, the scenario will emulate realistic channel conditions in terms of signal levels, fading profiles, and noise and interference levels. Channel conditions will be based on fading profiles defined in 3GPP TR 37.901 and shown in Table 18

Propagation Condition	SNR	Justification
Static	No interference	To check that upper-layers do not constrain data throughput
EPA5	20 dB	To exhibits large TBS variations (see clause 5.5.4.3) and very common scenarios for high-data rate requiring processing capability
EVA5	10 dB	EVA occurs frequently in deployments
EVA70	20 dB	Adds EVA70, high SNR coverage which is common in low frequency(<1GHz) band networks
EVA200	20 dB	Covers high Doppler, high SNR scenario which is common in high frequency (≥1GHz) band networks
ETU70	0 dB	Fast variations and most common high-dispersion case
ETU300	0 dB	A high BLER scenario may trigger higher layer retransmissions, and also addresses the high speed scenario in the work item objective

Table 18 : Fading profiles characterization

The KPIs computed during the characterization experiments will be based on the measurements collected at the network, transport and application layer and will depend on the specific use case under test.

5 Conclusions

This deliverable has presented the current view on the 5G system concept from the NRG-5 project together with some system-level results aimed at providing a clear view on the impact of some of the most promising technology components in NRG-5. Simulation results have proven the potential of some of the techniques discussed along the NRG-5 project.

The objectives and architecture of the two trials and will also pass through The validation by TRIANGLE testbed intends to assess the performance of the services and technologies involved in NRG 5 project to ensure a good service quality on 5G.

The use of the trials as a vehicle to assess the NRG-5 concept in the context of utility operational requirements that will be supported by a future 5G infrastructure are directed towards positive results that will be demonstrated in D5.3.

Tests of key parameters defining the performance of the overall system has been designed and put in place. Furthermore the trial showed that large quantities of data can be handled and transmitted with performance fully aligned with 5GPPP KPIs.

More detailed data about the results of the tests that are at this stage ongoing will be provided in the next D5.3

6 Abbreviations

Acronym	**Explanation**
3GPP	3rd Generation Partnership Project (standardisation body)
4G	4th Generation of Mobile Communications
5G	5th Generation of Mobile Communications
5G-PPP	5th Generation-Public Private Partnership
AAA	Authentication, Authorisation and Accounting
ADN	Active Distribution Network
AMI	Advanced Metering Infrastructure
AMIaaS	Advanced Metering Infrastructure as a Service
AN	Access network
API	Application Programming Interface
CA	Consortium Agreement
CAP	Common Alerting Protocol
CAPEX	Capital Expenditure
CC	Cloud Computing
CI-SLA	Critical Infrastructures Service Level Agreements
CKAN	Comprehensive Knowledge Archive Network
CN	Core Network
COTS	Commercial off the shelf
CP	Control Plane
C-RAN	Cloud Radio Access Network
D2D	Device to Device

DA-RAN	Disaggregated-Radio Access Network
DC	Data Centre
DDRaaS	Dispatchable Demand Response as a Service
DER	Distributed Energy Resources
DoW	Description of Work
DSO	Distribution System Operator
E2E	End-to-End
EC	European Commission
EEML	Extended Environments Markup Language
EMS	Element Management System
ENI	Experiential Networked INTELligence
EuCNC	European Conference on Networks and Communications
EV	Electric Vehicle
EVE	Evolution and Ecosystem
FB	*Facebook*
FG	Forwarding Graph
FI	Future Internet
GA	Grant Agreement
GS	Group Specification
H2020	Horizon 2020
HSS	Home Subscriber Service
HV	High Voltage
HW	Hardware
ICC	International Conference on Communications
ICT	Information and Communications Technology

IETF	Internet Engineering Task Force
IMT	International Mobile Communications
IoT	Internet of Things
IP	Internet Protocol
IPR	Intellectual Property Right
IPSec	Internet Protocol Security
ISG	Industry Standardization Group
ISP	Internet Service Provider
IT	Information Technology
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LTE	Long Term Evolution
LV	Low Voltage
M2M	Machine to Machine
MANO	Management and Orchestration
MCM	Machine Cloud Machine
MCPTT	Mission Critical Push To Talk
MEC	Mobile Edge Computing/ Multi-access Edge Computing
mMTC	Massive MTC
MTC	Machine Type Communications
MV	Medium Voltage
MVNO	Mobile Virtual Network Operator
N/A	not applicable
NAT	Name Address Translation
NB-IOT	Narrow-Band Internet-of-Things

NFV	Network Function Virtualization
NGIN	Next Generation Intelligent Networks
NGMN	Next Generation Mobile Networks
NORM	New-generation Open Real-time Smart Meter
NS	Network service
NSO	Network Service Orchestrator
OBD	On Board Device
ONF	Open Networking Foundation
OPEX	Operational Expenditure
PaaS	Platform-as-a-Service
PCF	Policy Control Function
PKI	Public Key Infrastructure
PLMN	Public Land Mobile Network
PMaaS	Predictive Maintenance as a Service
PMR	Private Mobile Radio
PMU	PhasorMeasurement Unit
PUF	Physically Unclonable Function
PV	Photo Voltaic
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RES	Renewable Energy Sources
RIA	Research and Innovation Action
RO	Resource Orchestrator
RQL	Resource Query Language

RRM	Radio Resources Management
SCPC	Single Channel Per Carrier
SD	Software-Defined
SDN	Software-Defined Networking
SD-RAN	Software-Defined Radio Access Network
SM	Smart Meter
SMF	Security Monitoring Framework
SON	Self-Organising Network
SOSP	Symposium on Operating Systems Principles
SW	Software
TBD, tbd	to be defined
TSG	Technical Specification Group
UE	User Equipment
UP	User Plan
UPF	User Plane Function
UUID	Universally Unique Identifier
vAMI	Virtual Advance Metering Infrastructure
vBCP	virtual Blockchains Processing
vDER	virtual Distributed Energy Resource
vDES	virtual Distributed Energy Storage
vDFC	virtual Drones Flight Control
vESR	virtual Electricity Substation & Rerouting
VIM	Virtual Infrastructure Manager
VM	Virtual Machine
vMCM	virtual Machine-Cloud-Machine

vMME	virtual Mobility Management Entity
vMPA	virtual Media Processing & Analysis
VNF	Virtualized Network Function
VNFD	VNF Descriptors
VNO	Virtual Network Operator
VoIP	Voice over Internet Protocol
vPMU	virtual Phasor Measurement Unit
vRES	virtual Renewable Energy Sources
vSON	virtual Self-Organizing Networks
VTC	Vehicular Technology Conference
vTSD	virtual Terminals Self-Discovery
VTU	Video Transcoding Unit
XaaS	Platform or Infrastructure as-a-Service
xMBB	Massive broadband
xMEC	extended Mobile Edge Computing

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