5G European Validation platform for Extensive trials

D2.6: Participating vertical industries planning

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Author(s):	R. Legouable, K.Trichias, Y. Kritikou, D. Meridou, V. Stavroulaki, V. Kosmatos, A. Skalidi, G. Loukas, N. Kostopoulos, K. Kravariotis, A. Tzoulis, E. Paraskevakis, G. Agapiou, V. Gezerlis, T. Doukoglou, P. Verrios, M. Yassin, L. Yala, S. Morant, M. Corriou, L. Roullet, A. Abouliatim, R. Knopp, M. Tognaccini, F. Sorvillo, A. Germanò, P. Serrano, I. Berberana, J.M. Rodera, J.J. García-Reinoso, A. Sessler, L.Stroppolo, L. Rossato, S. Canale, G. Ciucciarelli, V. Suraci, M. Agus, A. Orlando, G. Carrozzo, E. Kraja, F. Curci, G. Corsaletti, L. Agueci, P. Giaccone, C. Casetti, C. F. Chiasserini, U. Herzog
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List of Acronyms and Abbreviation

3GPP	Third Generation Partnership Project
5G	Fifth Generation
AGV	Automated Guided Vehicle
API	Application Programming Interface
AR	Augmented Reality
BBU	Base Band Unit
CEE	Cloud Execution (Ericsson) Environment
CP	Control Plane
CPRI	Common Public Radio Interface
C-RAN	Cloud Radio Access Network
CU	Cloud Unit
E2E	End-to-End
EC	Enterprise Core
EDA	Ericsson Dynamic Activation
eMBB	Enhanced Mobile Broad Band
eMTC	enhanced Machine Type Communication
EPC	Evolved Packet Core
E-UTRAN	Evolved Terrestrial Radio Access Network
FDD	Frequency Division Duplex
HDR	High Definition Resolution
HSS	Home Subscriber Server
HW	HardWare
IaaS	Interface as a Service
IoT	Internet of Thing
KPI	Key Performance Indicator
LAN	Local Access Network
LIDAR	LIght Detection And Ranging
LTE	Long-Term Evolution
MANO	Management and Orchestration
MEC	Mobile Edge Computing
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
mMTC	massive Mobile Type Communication
NB-IoT	Narrow Band – Internet of Things
NFV	Network Function Virtualization
NFVO	NFV Orchestrator
NFVI PoP	NFV Infrastructure Point of Presence
NR	New Radio
NSA	Non Stand-Alone
OAI	Open Air Interface
ODL	OpenDayLight
OSM	Orchestrator Service Manager
Paas	Platform as a Service
PLMN	Public Land Mobile Network
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RAN	Radio Access Network
RD	Radio Dot
RDS	RD System
RRH	Remote Radio Head
RRU	Remote Radio Unit
RTT	Round Trip Time
SA	StandAlone
SBA	Service Based Architecture
SDN	Software Defined Network
SDR	Software Defined Radio
SLA	Service Level Agreement
SW	SoftWare
TaaS	Testing as a Service
TDD	Time Division Duplexing
UC	Use case
UE	User Equipment
uRLLC	Ultra-Reliable Low-Latency Communications
USRP	Universal Software Radio Peripheral
vCPU	Virtual Central Processing Units
vEPC	virtual Evolved Packet Core
vEPG	virtual Evolved Packet Gateway
VIM	Virtualized Infrastructure Manager

VM	Virtual Machine	***VR***	Virtual Reality
VNF	Virtual Network Function		
VPN	Virtual Private Network		

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Executive Summary

The present deliverable aims at giving the planning of the integration, test and validation of the different verticals in the 5G EVE facility. First, an overview of the 5G EVE E2E facility is given through the status of the 4 sites facilities focusing on their main updates since their description carried out in [2]. Then, we mainly detail the planning of the **internal** 5G EVE verticals before introducing the **external** ones. The internal 5G EVE verticals have already been described, as well as their KPIs in [1]. A very short summary of each of them is proposed, sometimes giving also some preliminary performance results obtained during first experimentation (most often achieved in lab) and mostly providing the roadmap of their integration, test and validation in the 5G EVE facility. The external verticals are issued from the ICT-19 and ICT-22 projects that have expressed their interests to use the 5G EVE facility to experiment their use-cases. So, a short description of the ICT-19/22 projects is carried out by detailing their respective use-cases they want to integrate. For each use-case, the KPIs and main features requested are detailed. Then, a tentative planning is proposed for each external vertical.

1 Introduction

The objective of this document is to provide a planning of the 5G EVE verticals integration, test and validation. Two kinds of verticals have to be considered:

- The first ones are the **internal** 5G EVE verticals that have already been described [1] and sometimes already integrated in some site facilities. These verticals and respective use-cases are from now well known to 5G EVE project. So, a very short description is reported with the main KPIs to achieve. Some first preliminary performance results have already been obtained. Of course, the planning of each vertical is given to provision the operation execution time.
- The second class of verticals will be issued from the new ICT-19/22 projects, mainly addressing 5G verticals that have expressed their interests in using 5G EVE facility for experimentation. Experimentation means integration, test and validation. After a synthesis of ICT 19/22 project description, an overview of the main verticals that expects to use 5G EVE facility is described. The main KPIs that have been identified to be validated are listed, as well as the main technical features that must be implemented in the facility. Comparison with what is or will be available in the framework of 5G EVE is done, in order to identify the potential risks of the vertical hosting. A first tentative of planning for **each external** vertical is realized in the same way as what is done for internal vertical.

At the beginning of the document, we propose a status check of the 5G EVE E2E facility by introducing the main updates that have been or will be implemented in the four different site facilities. This introduction allows to mention the main improvements since the beginning of the project and to complement the information in the deliverables already provided [2] [3].

1.1 Structure of the document

The main structure of this deliverable is as follows:

- Chapter 2 contains the E2E 5G EVE facility description by giving the status of each of the 4 sites facilities;
- Chapter 3 summarizes the 5G EVE internal verticals by synthetizing the use-cases, the KPIs and by giving sometimes some performance results issued from preliminary integration. For each vertical a planning is proposed;
- Chapter 4 addresses the external verticals issued from ICT19/22 projects, with the expected KPIs and technical features. For each vertical a tentative planning is proposed;
- Chapter 5 concludes the deliverable and gives some potential risks and perspectives about the verticals operation.

For the edition of this deliverable, we have used some material that has been delivered during the first year of the project:

- Deliverable D1.1[1] that describes the internal 5G EVE use-cases and the main KPIs to achieve;
- Deliverables D2.1 [2] and D2.2 [3] describing the sites facilities functionalities and their planning of implementation in terms of main components;
- MS5 [4] and MS6 [5] videos supports available on the 5G EVE public website [11];
- Sites facilities services implementation on the 5G EVE facility discussed between 5G EVE partners;
- The first version of the D1.2 [6] document listing the ICT19/22 projects wishing to be hosted by 5G EVE, and their respective KPIs;
- The demonstrations and videos that have been shown during the EuCNC event in Valencia, Spain in June 2019. The poster that has been edited for this event is available in [13].
- The sites facilities planning that are periodically updated with their current implemented features and the new upcoming ones.

2 5G EVE E2E site facility description

2.1 Architecture overview

The main 5G EVE objective is to create a 5G E2E facility that will be useful for a number of vertical industries to implement, test and validate their 5G-ready use-cases in real on-air transmission. From the beginning of the project, the 5G EVE facility has evolved with new features issued from 3GPP R15 releases, complying at the end of the project with 3GPP-R16 specifications.

The 5G EVE E2E site facility is composed of four European operational and interconnected site facilities (France, Greece, Italia and Spain). Each site facility has its own 5G full-chain from physical infrastructure to orchestration. Then, all sites are interconnected and, on top of them, a homogeneous testing and validation framework for Verticals is developed, integrated and offered to verticals through a common portal allowing them for defining, planning, executing and validating test cases related to their 5G-based applications.

Figure 1 gives the general 5G EVE architecture overview, starting at the top from the web portal application that is developed by the WP4. This portal is a web interface where the verticals will be able to define their use-case (Design, run and validate experience by collecting the performance evaluation) for experimentation operation. The first version of the portal will be implemented at the end of this year (M18) whereas the main version with all services committed by the project will be available at M24 (June 2020). While the 4 sites facilities are implementing different orchestrator type, it has to be implemented an interworking layer (IWL) that manages multi-site services orchestrator, sites interconnection, multi-site catalogue …

The IWL is defined in the WP3. So, each site facility is connected via its north bound interface to the IWL south bound. As described in the following section (§2.3), each of the 4 sites facilities is based on different functional components, technologies and physical infrastructure where the verticals are locally deployed.

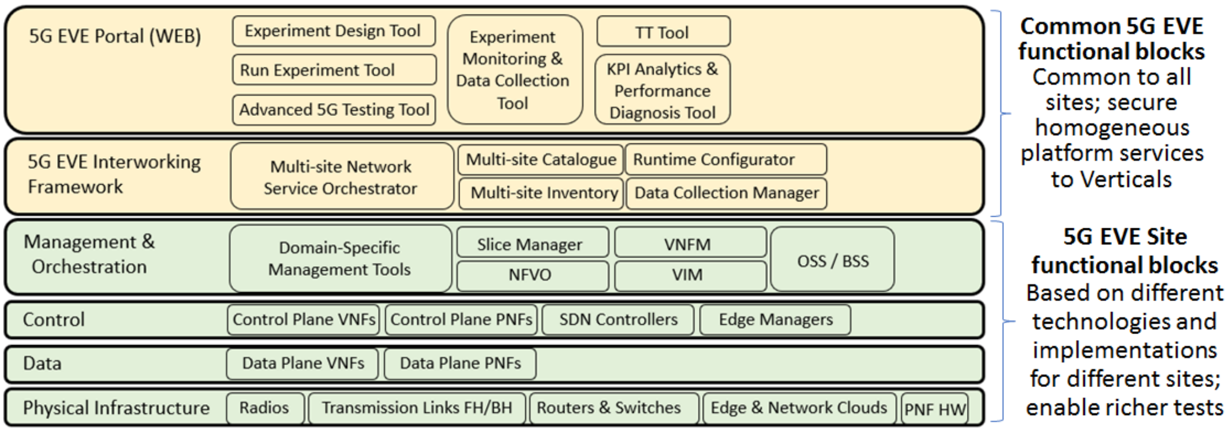

Figure 1: 5G EVE general architecture overview

The main objective until the end of the year 2019 is to interconnect the 4 sites facilities to the IWL to form the 5G E2E facility, leading to MS8 [7]. It has been agreed that the IWL is hosted in Turin in the TIM premises. The multi-orchestrator part will be on the other hand implemented during the first 2020 semester. At this time, it should be possible for the verticals to directly access to any distant sites facilities for starting the integration and use-case execution. This will lead to MS9 [8] and MS10 [9], integrating upgrades of the site facility that will be aligned with the different 3GPP releases. While waiting for this multi-orchestrator component, the verticals could be integrated from a specific site from its own orchestrator.

2.2 Services overview

The objective of the different sites facilities is to expose to the verticals services that serve to deploy the different use-cases. During the first project year, a first general planning in terms of 5G EVE E2E facility specifications has been concluded. The different phases, with some technical specifications, are reported in Table 1, with some features that are common to the project and not only especially from WP2, but part of the 5G EVE facility.

Table 1: 5G EVE capabilities roadmap

Capabilities	Features	2019/MAY	2020/JAN	2020/JUL	2021/JAN
5G Services	**Enhanced MBB (eMBB)**	**Y**	**Y**	**Y**	**Y**
	URLLC (URLLC)	(Pre-sched)	Y(Rel-15)	Y(Rel15)	Y(Rel-16)
	Massive IoT (mMTC)	Y (LTE-M+NB-IoT)	Y (LTE-M+NB-IoT)	Y (LTE-M+NB-IoT)	Y(Rel-16)
5G Architecture Options	**Option-1 (Legacy)**	**Y**	**Y**	**Y**	**Y**
	Rel15-GNR + EPC in NSA mode		Y	Y	Y
	Rel15-5GNR + Rel15-5GC in SA mode			Y	Y
	Rel16-5GNR + Rel16-5GCore (in NSA & SA modes)				Y
	Flexible Numerology		Y	Y	Y

5G Access Features	Massive MIMO	Y	Y	Y	Y
	Multi-User MIMO		Y	Y	Y
	RAN Virtualization			Y	Y
	Latency Reduction	Y (pre-scheduling)	Y(Rel-15)	Y(Rel15)	Y(Rel-16)
Core Network	**vEPC supporting 5G**	**Y**	**Y**	**Y**	**Y**
	5GC			Y	Y
	CUPS	Y	Y	Y	Y
	SBA			Y	Y
	Interworking with LTE			Y	Y
Slicing	Network Slicing (std 5G Services: eMBB, URLLC, mMTC)		Y	Y	Y
	Service Slicing (cloud orchestration level)			Y	Y
	Multi-site Slicing			Y	Y
Virtualization	NFVi support	Y	Y	Y	Y
	SDN control		TBD	Y	Y
	Vertical Virtualized Application deployment support	Y	Y	Y	Y
Edge Computing	3GPP Edge Computing		Y	Y	Y
	ETSI MEC		(optional)	(optional)	(optional)

The mapping of the capabilities, highlighted in Table 1, has been made in terms of services availability in the different sites. Table 2 gives the main services that are planned to be implemented in the different sites via access to VNF catalogue (local or multi-sites).

Table 2: Mapping between sites facilities capabilities and services offer

Site					French site				Italian site	Spanish site	Greek site	
Service class	Service type	Lowest place where is it provided	Other services dependency	Tools & APIs	Rennes	Paris	Sophia	Paris-Saclay			NOKIA	Ericsson
Wireless Connectivity-aaS	Network Slice lifecyle	Global/Site/Location	hosting/*	ONAP/OSM/Openstack/Cloudiy… RADCOM, DHCP, Alpha networks	x	x	x	x		x		
	UE beacons service lifecycle	Location	hosting/*	REST				-				
	Device-to-device connectivity lifecycle	Location	hosting/*	REST				-	x			
	UE control	Global/Site/Location	hosting/AAA-access	REST	x		x	x		x		
	Segment configuration (RAN, CORE, MEC)	Location	hosting/AAA-access	REST, Dashboard	x		x	x	x	x	x	
Test-aaS	Test edition	Global/Site/Location	hosting/AAA-access	Robot, TestLink, Netrounds	x			x	x	x	x	
	Test execution	Global/Site/Location	hosting/AAA-access	Robot, Jenkins, Cucumber, Netrounds…	x		x	x	x	x	x	
	UE emulation	Global/Site/Location	hosting/AAA-access	OAIsim, UDP_Replay, Prox, vPE	x		x	x	x	x		
Monitoring-aaS	Health Check Service	Global/Site/Location	hosting/AAA-access	ONAP/OSM/Openstack/Cloudiy…	x	x	x	x	x	x	x	
	Cloud Infrastructure metric	Location	hosting/AAA-access	Prometheus/elk/Gnocchi/ …	x	x	x	x	x	x		
	Wireless Connectivity-aaS monitoring	Location	hosting/AAA-access & WaaS/*	iPerf	x	x	x	x	x	x	x	
	Service monitoring	Global/Site/Location	hosting/AAA-access & relevant services	WP5, OpenNetMon, EvA (Empirix Virtual Agent)				x	x	x		x
	UE monitoring	Global/Site/Location	hosting/AAA-access	WP5			x	x	x			x
Hosting	Accounting/Authentication/Authorization	Global/Site/Location	-	Keycloak, AAA, vACL, Indra iAAA				x	x	x		
	Local access	Location	Hosting/AAA	-	x		x	x	x	x		
	Remote access	Location	Hosting/AAA	NAT, FW, vFW, CGNAPT, BIND9, FHOSS, Hillstone Cloud	x		x	x	x	x		
	VNF	Location	Hosting/Ticketing	ONAP/OSM/Openstack/Cloudiy… Open vSwitch, VyOS VNF, EPC Magma, srsLTE, OpenMME, ODL, HSS, MME, S/P GW	x	x	x	x	x	x	x	x
	PNF	Location	Hosting/Ticketing	SWITCH	x		x	x	x	x	x	
	service	Location	all other relevant services	REST				x	x		x	x
	Calendar	Location	Hosting/Ticketing	-	x	x		x	x	x		
Support	Ticketing	Global/Site/Location	Hosting/AAA	GLPI, Bugzilla, Jira, osTicket		x		-	x	x		
	Online documentation	Location	-	wiki tool (mediawiki)?			x	-	x			

As described in Table 2, the services have been categorized commonly for each site in 5 main different classes:

- Wireless Connectivity as a Service (WaaS): this is the 5G connectivity service. It shall be possible to set up/remove a specific slice (IoT, URLLC, eMBB...) on a given area for a fleet of terminals (Notion of "blueprint").
    - When WaaS is available, it is possible to consult the Calendaring and then reserve a timeslot for operation.
- Test as a Service (TaaS): This is the possibility to configure a specific test. A test implies a specific configuration of other services such as wireless transport, hosting, analysis...
- Measurement as a Service (MaaS): this is the possibility to configure a specific measurement including the set of probes, the logging itself and possibly some form of "simple" analysis on this logging (not machine learning of large data set but like ITTT "If This Then That", machine learning on large data sets is separated in the analysis service).
- Hosting: this is the service providing for hosting data (storage) and computing (VM, containers...)
- Support: this is the service for providing any kind of support for accessing the resources, troubleshooting... (contact, ticketing, wiki page ...)

2.3 5G EVE site facilities

As already described in [2] and illustrated in Figure 2, the 5G EVE facility is composed of a cluster of sites facilities located in several European countries (France, Greece, Italia and Spain). The particularity of the French site is that itself it is composed of federation of 4 French sites. We can already mention (and we will give more details in the site descriptions themselves in the following sub-sections §2.3.1to §2.3.4) that 5G vendor equipment such as Ericsson and Nokia are involved in the different sites deployment.

To constitute one single 5G EVE E2E facility, the sites will be interconnected via secured VPN tunnels.

Figure 2: Location of the 5G EVE sites facilities

The main functionalities, components and technologies that compose the different 5G site facilities are detailed in the following sub-sections, site per site. For each site, a review of the main features are given, especially for: RAN, CORE, Orchestration, slice management, HW/SW resources provisioning, Interfaces, technologies, frequency bands, tools …

2.3.1 Greek site

2.3.1.1 Architecture

The Greek site facility is located in the research labs of OTE at the OTE Academy premises. This architecture combines infrastructure of OTE along with equipment from Ericsson and Nokia of 4G type initially that will be upgraded to 5G in the future. An overview of the high-level architecture is shown in Figure 3 in which it is shown a general view of the Ericsson and NOKIA infrastructure along with a view of the testbed of Wings which is based on a limited scale of the Open Air Interface network. The Ericsson infrastructure will be used for the testing of the 5G-Heart project use-cases of Sensory data monitoring, camera remote monitoring and drone and the remote operated vehicle, while the NOKIA infrastructure will be used for implementing the 5G-Tours use-cases of smart airport parking management, video-enhanced ground based moving vehicles, emergency airport evacuation and excursion on an AR/VR enhanced bus both of which are ICT-19 projects.

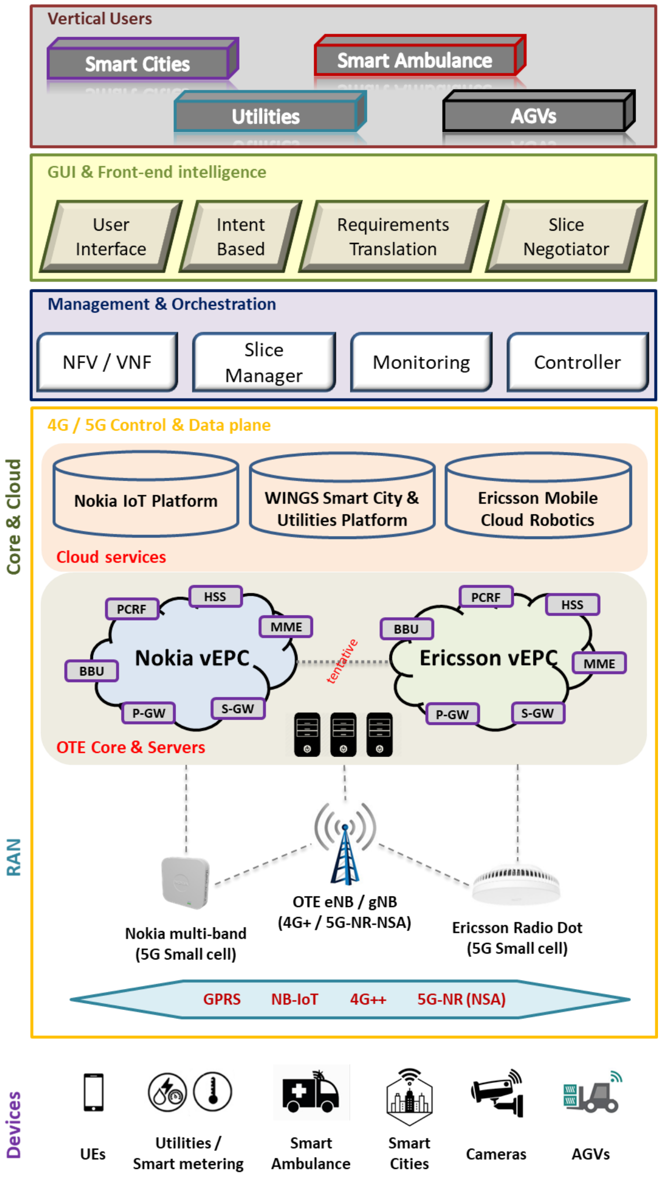

Figure 3: High level overview of the Greek architecture to be used for the implementation of the use cases

2.3.1.2 Main features

Ericsson Infrastructure

The current infrastructure of the 5G EVE Greek site consists of two testbeds that are provided from Ericsson and Nokia. The Ericsson infrastructure is shown underneath in the Figure 4.

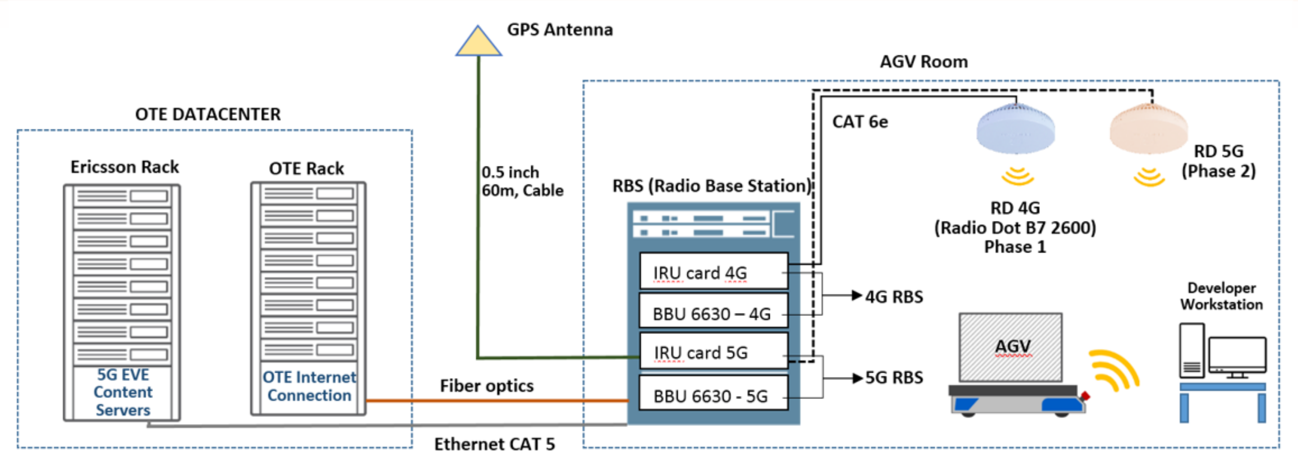

Figure 4: Ericsson architecture

- The *RAN network* of the Ericsson architecture consists of 4G Radio Dots (RD) which provide indoor coverage that communicate with the access anchors that are installed for the use case. The RDs have a capability of transmitting 2 Gbps of data. The signals of the RDs are transmitted in further distances through a front-end system based on CPRI interface which is transported to the BBU unit. The frequency band which is used is B7 which is, FDD 2600 MHz with 20 MHz spectrum deployment, based on the selection criterion to minimize interference and overlapping coverage with the commercial OTE/COSMOTE MBB network. The B42 band which is TDD at 3500 MHz is considered for deployment of the 5G-NR in order to provide 5G access at the second stage of the Greek site facility upgrades. This is planned at Q4 of 2019.
- The *core network* is based on a 5G virtual EPC, named Enterprise Core (EC). Enterprise Core is deployed on a dual server Dell Power Edge R640, with 2x18 Cores. All virtualized network functions and the hosting execution environment (Ericsson Cloud Execution Environment, CEE) are pre-configured and pre-integrated. The EC core network system fulfils the requirements for cost-effective systems with few subscribers and minimal footprint. The core network is shown in Figure 5.

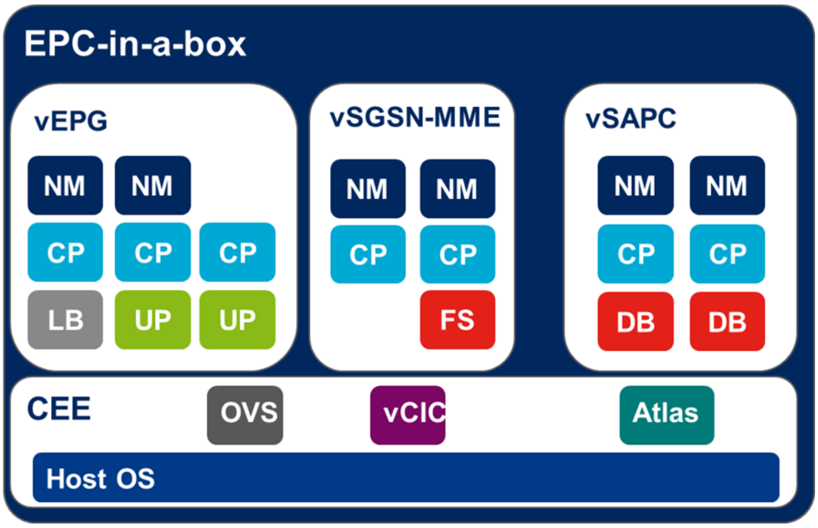

Figure 5: Ericsson core network

Nokia Infrastructure

The Nokia infrastructure is shown underneath in Figure 6.

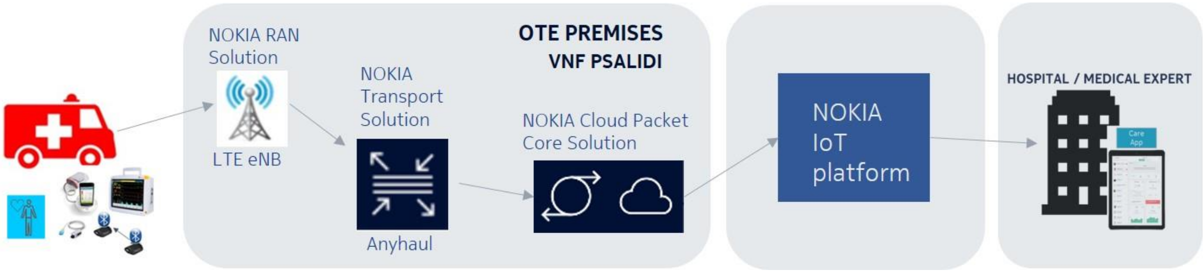

Figure 6: Nokia high level overview architecture

The *RAN network* currently consists of a small base station of type eNB which is going to be upgraded to 5G NR in the Q1 of 2020.

The *core network* is a 5G EPC-in-a-box that fulfils the requirements for cost-effective test systems with few subscribers and minimal footprint. It is a further evolution of the Virtual Network Function (VNF) single server deployment enabling multiple VNFs on a single server. The server contains vEPG, vSGSN-MME and vSAPC.

EPC-in-a-box, as depicted in the following Figure 7 below, which is designed to include vSGSN-MME, vSAPC and vEPG/EVR. By default, a set of different Neutron networks are used to separate different logical networks. External traffic to and from the vEPG is routed by the vEPG through its LBs as usual. Between EVR and vSGSN-MME static routing is used. This static routing is preconfigured. BFD is used to supervise the static routes. All the service IP addresses of the vSGSN-MME need to be configured as static routes in the EVR. Externally VLAN separation is used for logical network separation. The box is preconfigured with default set of networks which may be changed. In the future it will be possible to use BGP/MPLS for network separation as well.

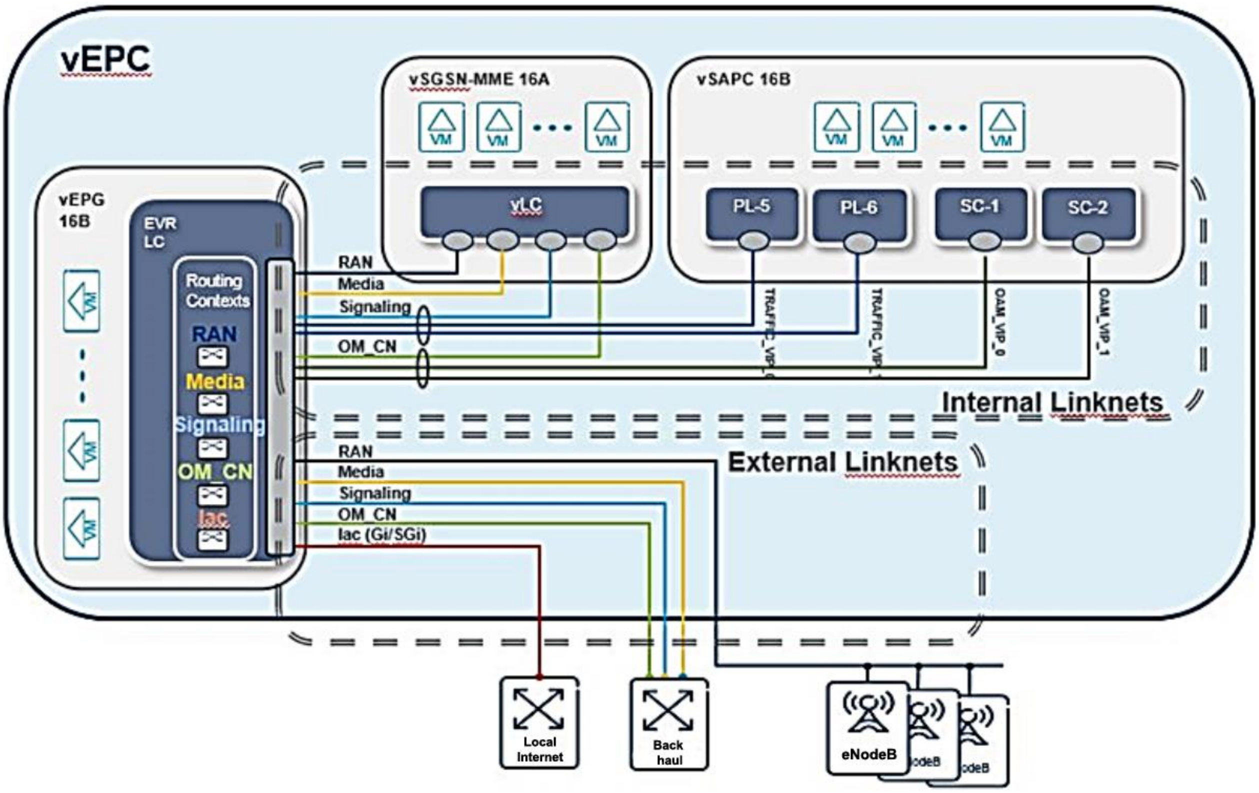

Figure 7: Nokia's EPC in a box

Services

The *services* which are provided by the Ericsson testbed are shown in Table 3, while the service type used for each service is shown in Table 4.

Table 3: Availability of the Greek site services classes for the Ericsson testbed

Common service \ Site	Greek site Ericsson's services			
Release		M16	M18	M24
WaaS				
TaaS				
MaaS		x	x	x
Hosting		x	x	x
Support				

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Table 4: Referencing of the service type, location, dependency and tools/API for the Ericsson and Nokia testbeds

Site					Greek site	
Service class	**Service type**	**Lowest place where is it provided**	**Other services dependency**	**Tools & APIs**	**NOKIA**	**Ericsson**
Wireless Connectivity-aaS	Network Slice lifecyle	Global/Site/Location	hosting/*	ONAP/OSM/Openstack/Cloudiy... RADCOM, DHCP, Alpha networks		
	UE beacons service lifecycle	Location	hosting/*	REST		
	Device-to-device connectivity lifecycle	Location	hosting/*	REST		
	UE control	Global/Site/Location	hosting/AAA-access	REST		
	Segment configuration (RAN, CORE, MEC)	Location	hosting/AAA-access	REST, Dashboard	x	
Test-aaS	Test edition	Global/Site/Location	hosting/AAA-access	Robot, TestLink, Netrounds	x	
	Test execution	Global/Site/Location	hosting/AAA-access	Robot, Jenkins, Cucumber, Netrounds...	x	
	UE emulation	Global/Site/Location	hosting/AAA-access	OAIsim, UDP_Replay, Prox, vPE		
Monitoring-aaS	Health Check Service	Global/Site/Location	hosting/AAA-access	ONAP/OSM/Openstack/Cloudiy...	x	
	Cloud Infrastructure metric	Location	hosting/AAA-access	Prometheus/elk/Gnocchi/ ...		
	Wireless Connectivity-aaS monitoring	Location	hosting/AAA-access & WaaS/*	iPerf	x	
	Service monitoring	Global/Site/Location	hosting/AAA-access & relevant services	WP5, OpenNetMon, EvA (Empirix Virtual Agent)		x
	UE monitoring	Global/Site/Location	hosting/AAA-access	WP5		x
Hosting	Accounting/Authentication/Authorization	Global/Site/Location	-	Keycloak, AAA, vACL, Indra iAAA		
	Local access	Location	Hosting/AAA	-		
	Remote access	Location	Hosting/AAA	NAT, FW, vFW, CGNAPT, BIND9, FHOSS, Hillstone CloudEdge, FortiGate-VM		
	VNF	Location	Hosting/Ticketing	ONAP/OSM/Openstack/Cloudiy... Open vSwitch, VyOS VNF, EPC Magma, srsLTE, OpenMME, ODL, HSS, MME, SIP GW	x	x
	PNF	Location	Hosting/Ticketing	SWITCH	x	
	service	Location	all other relevant services	REST	x	x
	Calendar	Location	Hosting/Ticketing	-		
Support	Ticketing	Global/Site/Location	Hosting/AAA	GLPI, Bugzilla, Jira, osTicket		
	Online documentation	Location	-	wiki tool (mediawiki)?		

Test environment

The Ericsson testbed is located in an indoor environment and operates in a room of 100m^2. The access network currently consists of Radio Dots, operating at the 2600 MHz band as explained in the architecture section, while the core network is based on a 5G virtual EPC which is used as a real but also as a test system. For the Nokia test environment, the radio access currently consists of a small base station which is located in an outdoor environment. The EPC is located in a lab which is used only for testing purposes.

2.3.2 Italian site

2.3.2.1 Architecture

The Italian site facility is based in Turin, mainly in TIM and Politecnico di Torino (CNIT) premises. The 5G outdoor coverage is guaranteed by TIM on their commercial network. 5G EVE traffic is properly segregated from the commercial traffic. The architecture of the Italian site facility is composed by different elements deployed in various geographical areas of the city of Turin as depicted in Figure 8:

- **TIM laboratories at via Borgaro building**: in this location a 5G end-to-end full chain aligned to 3GPP R15 release. This is based on a Non-Standalone (NSA) solution combining 4G with 5G radio technologies. The configuration and management of the 5G radio segment is supported by Ericsson

Radio System and Evolved Packet Core (EPC). Radio coverage in the lab is implemented via a PLMN ID dedicated to 5G EVE experiments.

- In addition, a network orchestrator will be placed in TIM lab by Ericsson. This lab infrastructure might host also an application server, to allow verticals to test the use-cases in a controlled environment.
- **Live network in the City of Turin**: currently more the three sites (3 sectors/site) implemented in the city centre which are ready to serve 5G use-cases in the 5G EVE framework. Following the commercial launch in the City of Turin (in July 2019), new 5G commercial sites will be progressively included in the EVE city-wide testing area based on the verticals' requirement and TIM strategy on integration. OneM2M platform instance is available for IoT data integration.
- **Politecnico di Torino Campus**: Politecnico hosts a private NFV cloud facility with NFV MANO and Experiment management components. In this virtualization infrastructure Vertical applications and network resources related to 5G EVE use-cases for Smart City and Smart Transport (urban mobility data analysis scenario) will be orchestrated and tested. The infrastructure consists of four servers, three of which dedicated to implement the NFVI layer managed by an OpenStack VIM (release Queens), the fourth used to host all the orchestration tools of the project (i.e. NFVO based on ETSI OSM software Rel.5, 5G EVE Experiment Execution and Validation Framework based on Jenkins and Robot Framework software, 5G App & Service Catalogue, Prometheus, etc.).

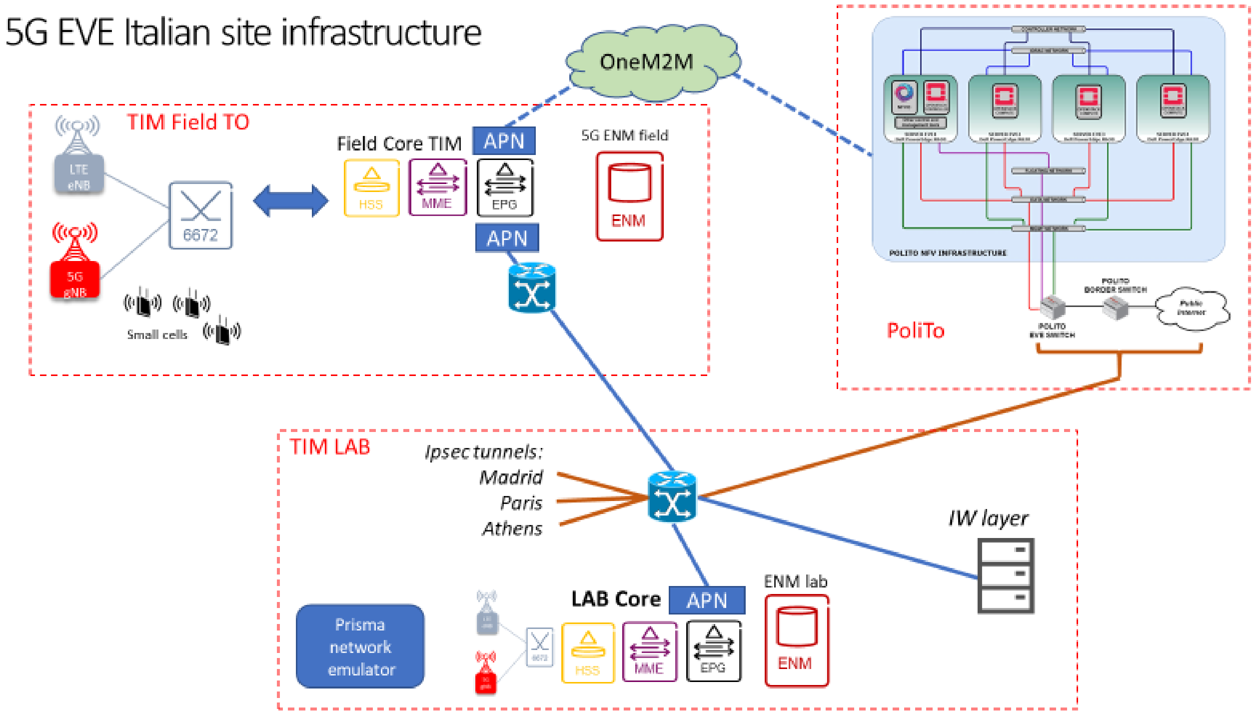

Figure 8: Logical high-level architecture of the 5G EVE Italian Site facility

All these 5G EVE distributed facility areas will be interconnected via IPsec VPN tunnels. Since the 5G EVE end-to-end 5G network will share radio and core parts with the TIM's 5G production network, a dedicated APN (part of TIM corporate APN set) will be configured to isolate 5G EVE traffic related to vertical use-cases from the commercial live traffic on the TIM mobile network.

2.3.2.2 Main features

Infrastructure

The 5G network solution implemented in 5G EVE is based on the 3GPP R15 Option 3x, where the connectivity is provided by a combination of LTE and 5G NR systems. LTE radio components in TIM network are configured to operate in the spectrum 2600 MHz (B7), whilst 5G NR is licensed for frequencies 3600-3800 MHz (B43). The following equipment has been installed in TIM lab by Ericsson as part of 5G end-to-end network chain dedicated to 5G EVE use-cases testing in a controlled environment:

- **<u>RAN Section (TIM Lab):</u>**

The following equipment is intended to provide the RAN access chain in TIM Lab (NR & LTE) of the NSA architecture:

  - Baseband 6630
  - Baseband 5216
  - Air 6488 B43
  - RBS 2217 B7

In addition, some hardware is required to set up the complete chain

  - RBS 6601 magazines
  - Firewall
  - Router 6672
  - Terminal server
  - GPS sync splitter
  - DUS41
  - Power Subrack

- **<u>Core Section (TIM Lab):</u>**
  Specific equipment is intended to provide the CORE network (5G EPC) section of the NSA architecture. More in details the following HW is required to set up the complete chain:
  - Blade PC hosting EPC-box: Dell OEM PowerEdge R640

Field network is also shared to provide outdoor coverage on 5G EVE users, it is structured as a NSA architecture with 5G NR coverage in TIM licensed spectrum.

- **<u>RAN section (Field)</u>**:
  Deployment of radio units on field as follows (the number of pieces is ongoing, according to the TIM development plan):
  - On field specific coverage with AIR6488 (43) BB6630
  - gNodeB co-located with LTE NodeB equipped with BB5216
  - CSR 6672 switch for the interworking between BB 6630 and BB5216
- **<u>CORE Section (Field):</u>**
  Commercial CORE based in Milan main site, actually serving TIM live network (4G/5G) including 5G EVE nodes in Turin.

The private NFV cloud facility installed at Politecnico (Figure 9) includes NFV MANO and Experiment management components together with the Italian site facility catalogue functions for VNFs and the 5G EVE Service Platforms for monitoring (Prometheus) and Experiment Execution Management (Robot Framework with Jenkins) as illustrated in Figure 10:

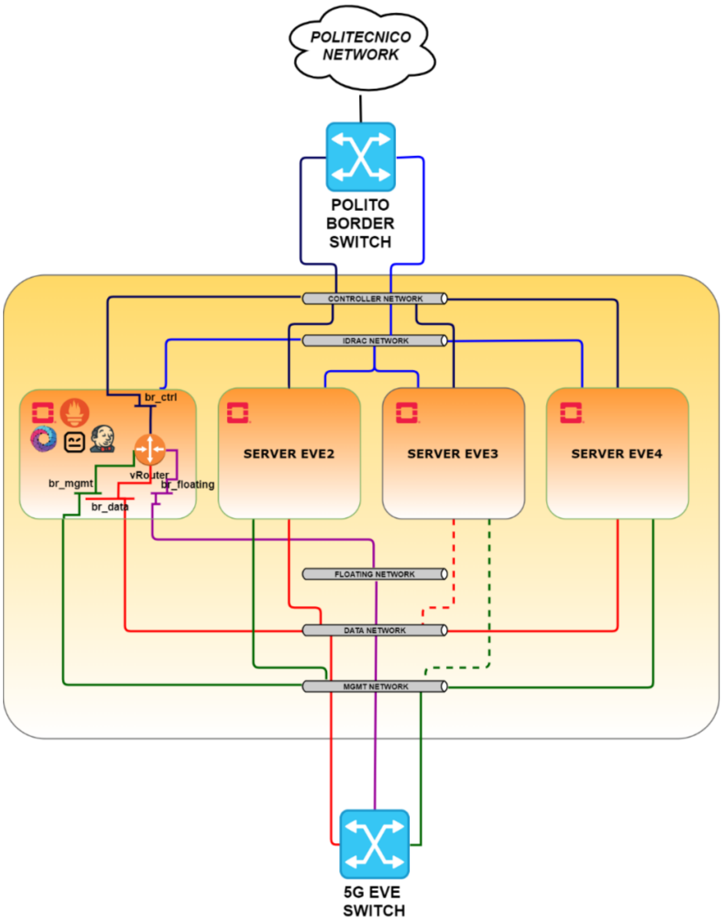

Figure 9: High level physical layout of the private NFV cloud facility at Politecnico di Torino (Turin, IT).

- **Politecnico area:**
  - 4x Dell PowerEdge R630 servers (160 vCores, 512 GB vRAM, 4TB internal storage) compose the private NFV cloud facility in Politecnico for 5G EVE and host:
    - OpenStack compute and controller services (release Queens, https://www.openstack.org/software/queens/) to implement the Virtual Infrastructure Management layer
    - The NFV Orchestrator for Vertical Network Services based on ETSI Open Source MANO - OSM Release 5 (https://osm.etsi.org/wikipub/index.php/OSM_Release_FIVE)
    - Jenkins (https://jenkins.io/) + RobotFramework (https://robotframework.org/) for managing the automation of experiment executions
    - Prometheus (https://prometheus.io/) to implement the monitoring platform for the NFV services
    - The 5G App & Service Catalogue (https://github.com/nextworks-it/5g-catalogue) to host NFV SOL005 compliant descriptors for Network Services and Virtual Network Functions
    - A Virtual Router to implement VPN termination and routing towards external networks of the overall private NFV Cloud environment

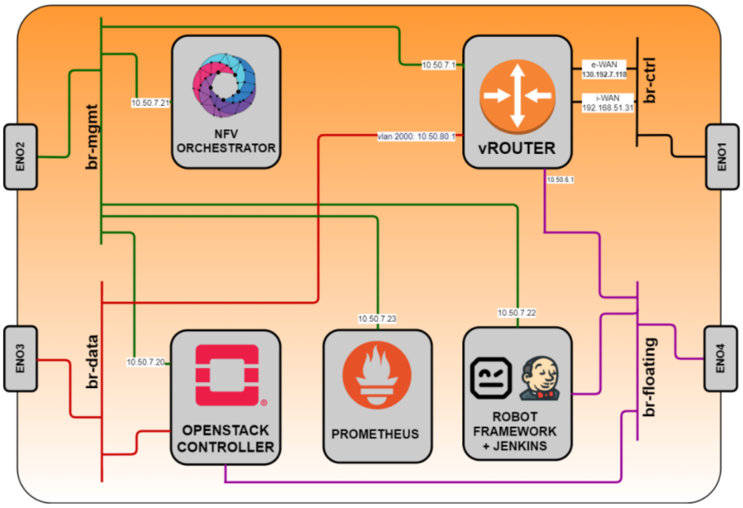

Figure 10: High level schematic of the NFV orchestration and Experiment Execution Framework at Politecnico di Torino (Turin, IT).

Services

During the first project year the available services have been identified as depicted in Table 2. Table 5 gives the availability of the different services classes in the Italian site facility.

Table 5: Availability of the Italian site services classes

Common service \ Site	Italian site			
Release	M10	M16	M18	M24
WaaS	x	x	x	x
TaaS		x	x	x
MaaS		x	x	x
Hosting	x	x	x	x
Support		x	x	x

Test environment

In the Italian sites facilities, the available frequencies bands are the LTE ones and the NR 3.720-3.8 GHz, both **indoor** and **outdoor** environment. For outdoor radio transmission, large coverage can be achieved thanks to field deployment (Turin centre area). The tests will generate "real traffic" from the use-cases terminals or dummy traffic from traffic generators (several protocols, like TPC, UDP, HTTPS…), specific to the vertical experiments. In addition, network environment can be emulated by Prisma emulator in Via Borgaro TIM labs.

The R15 only provides standard eMBB but pre-standard solutions will be tested in lab for other slices.
As an example, traffic on field network, generated via Iperf has been used for testing the performances. Table 6 illustrates the achieved values:

Table 6: Throughput performance field

Macrosite areas	DL Throughput (Mbps)	UL Throughput (Mbps)	Test mode
Porta Susa	527	21.9	Outdoor
Matteotti	511	24.6	Outdoor
Politecnico	419	6.6	Outdoor

2.3.3 Spanish site

The Spanish site, 5TONIC, has some special characteristics in the sense that it pre-existed the launch of the 5G EVE project and has among its members companies that are not part of the project consortium. In this sense, the laboratory supports the implementation of use-cases both from other EU projects, like 5G Vinni or 5Genesis, and also for companies that are not involved in EU funded projects.

2.3.3.1 Architecture

The 5TONIC site architecture can be described as composed by several layers that encompass a set of functionalities that allow the implementation of different use-cases for 5G. These layers are:

Infrastructure layer

This layer incorporates the network elements/functions that provide the connectivity required for the implementation the different use-cases in a self-contained way, i.e., not requiring the support of external elements.

There are several components of this layer that is continuously evolving in order to incorporate the latest developments of the 5G standard:

- Radio access, which provides 4G coverage and 5G NSA coverage and support, LTE, NR NSA and NB-IoT access in different frequency bands. 5G SA support is expected to be supported during the first quarter of 2020.
- Packet core network, which in the current implementation supports 4G virtualized EPC and 5G NSA virtualized core, ready to evolve to 5GC SA. The core also implements the elements required for the support of different policies and the management of the users' data.
- Transport network, that implements or emulates different transport alternatives for fronthaul and backhaul.

Service and application layer

This layer incorporates the network elements/functions that provide the capabilities to implement different use-cases on top of the infrastructure layer. For these purposes, the site provides processing capabilities that can be deployed either at the edge of the network or in the cloud. It also provides the mechanisms to measure and evaluate different indicators in order to characterize the services and applications performance in different operational conditions.

It should be noticed that in some cases elements from the infrastructure and service layers share the same hardware platform.

Control and management layer

The main function of this layer is to support the flexible configuration of the infrastructure and the service layers in order to support the requirements of different layers. In this sense, the layer is based on the use of cloud, software, and virtualization techniques, including the support of container-based deployment of VNFs. It also incorporates architectural elements from SDN in order to manage the 5TONIC transport network.

The orchestration platform, that constitutes the core of this layer, is currently based in ETSI OSM, with different options as VIM (OpenStack, SONA).

Interaction and security layer

This layer is in charge of facilitating the interaction with potential user, as well as other sites, in a secure way. This layer will evolve to incorporate the 5G EVE developed solutions.

The security layer is also in charge of guaranteeing the privacy requirements between the parties that may be involved in the support of different use cases, as well as preventing any intrusion or attack from outside.

2.3.3.2 Main features

Infrastructure

The infrastructure deployed at the 5TONIC site is represented in the following Figure 11:

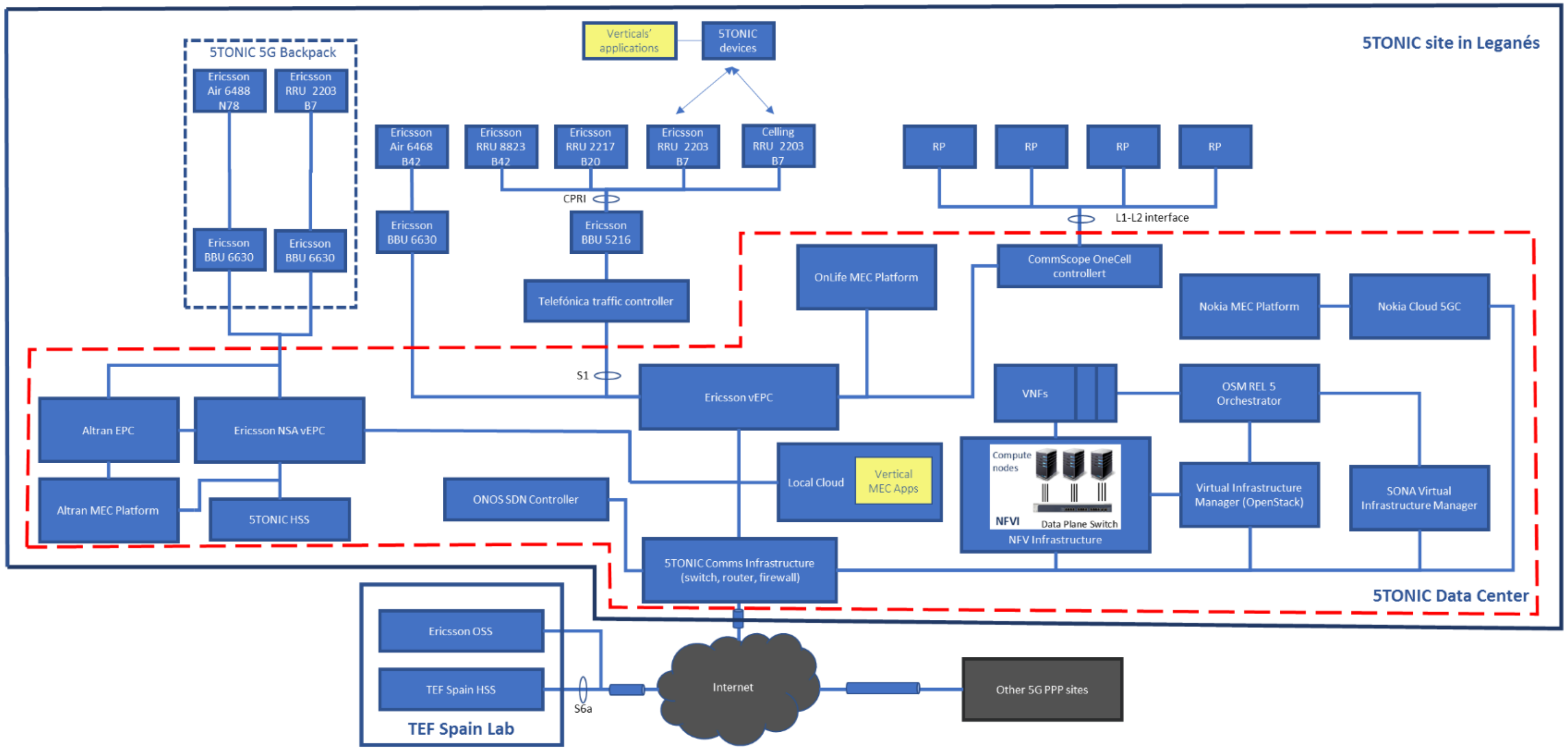

Figure 11: Spanish site facility deployed infrastructure

Current 5TONIC radio infrastructure incorporates the following elements:

- 4 baseband processing units (BBUs) from Ericsson, 3 of them 6630 (that support NR processing) and 1 5216 (that currently does not support NR processing).
- 3 Ericsson RRU 2203 that support LTE in band 7.
- 1 Ericsson RRU 2217 that supports LTE in band 20.
- 1 Ericsson RRU 8823 that supports TD-LTE in band 42.
- 2 active antenna systems, both with 64 TRX for supporting multiuser MIMO, 1 Air 6468 that supports TD-LTE in band 42 and 1 Air 6488 that supports 5G NR in band 43/n78.

Several of these elements are expected to be software upgraded (e.g., RRU 8823) to support NR radio interface. New 5G RAN elements are expected to be deployed in the laboratory during 2020.

To support the radio connectivity, the lab has acquired several devices that include:

- 4G smartphones, including 3 that support band 42 and also 256QAM
- 4G LTE routers, including one that supports 256QAM
- 5G NSA smartphones from different vendors (LG, Samsung, Xiaomi, Huawei)
- Raspberry Pi boards with LTE NB-IoT HATs.

In terms of core infrastructure, 5TONIC implements two virtual EPC from Ericsson, one of them just supporting 4G access and the second one supporting 5G NSA access. The first one is deployed on a Dell commercial server, while the second is based on Ericsson Hyperscale Datacenter System 8000.

5GC supporting SA connectivity is scheduled to be deployed by the end of Q1, 2020. The transport infrastructure of the site includes 4 Ericsson routers 6675, as well as several HP SDN enabled switches. For supporting the control and interaction layers a set of servers have been deployed at the site.

Services

Hitherto, the services provided by the site have been adapted to the specific requirements of the different use-cases that have been deployed at 5TONIC. In this sense, there are several options that have been supported (see Table 2)

- Provision of basic 4G and/or 5G connectivity, e.g., to test the impact of 5G connectivity on a UE application performance. Because of the development of a portable 5G backpack, connectivity
- Provision of performance parameters measurement capabilities, e.g., to evaluate KPIs like throughput, latency or reliability.
- Provision of network configuration capabilities in order to define the test's topology as well as other network parameters.
- Provision of service and applications support capabilities, so the user of the site services can rely of the lab processing infrastructure for supporting the implementation of the use cases.
- Provision of adequate space and facilities for deploying its own infrastructure by the site user.
- Maintenance services of the infrastructure deployed by the user.
- Provision of security services

Test environment

5TONIC premises have several environments to carry out different kinds of experiments, including both indoor (in two different rooms) and outdoor coverage at IMDEA Networks premises. Also there is an open area that allows the movement of small vehicle. 5TONIC also has carried out tests on other premises, like Telefónica headquarters in Distrito C, Madrid, and the campus of the UC3M in Leganés.

UC3M has also a location in Madrid city center where it is feasible to carry out tests in dense urban areas. Also, thanks to the implementation of the 5G backpack, it will be feasible to bring end-to-end 5G connectivity to other areas for testing purposes. The use of the spectrum required for these tests has been granted by Telefónica.

2.3.4 French site

2.3.4.1 Architecture

As already explained and described in [2], the French site facility is constituted by 4 interconnected nodes, located in Rennes, Sophia, Paris-Saclay and Paris Châtillon. The entry point of the network infrastructure of the French site is located in Orange Paris Châtillon where the ONAP orchestrator is implemented as well as the central point of the VPN tunnels interconnection between the sites (star network infrastructure); the others 5G EVE European sites will be, by the end of 2019, interconnected from the same entry Orange point to the interworking layer. Figure 12 illustrates this common architecture.

As detailed in sections 3.4 and 3.6, this infrastructure has been put in place, firstly, to deploy the 2 internal verticals that are:

1/ Smart Energy (mMTC scenario) provided by EDF: Fault management for distributed electricity generation in smart grids that aims at providing low latency and high sensors capacity. This use-case should be deployed independently to any French nodes that will have mainly deployed IoT systems (LTE-M, NB-IoT …);

2/ Video 360° virtual visit use-case (eMBB scenario) provided by Orange that aims at providing high user throughput and low latency. This use-case should be deployed independently to any French nodes.

A VNF/PNF catalogue (local or multi-site VNF/PNF catalogue) has been shared to expose some services from ONAP directly and/or from each local site. One objective is to evaluate the impact on some measurement in terms of data rates and latency, when deporting and mutualizing some functionalities (ePC, HSS, applications server …) between the different sites. Excepted one pillar of the Nokia site that is based on 5G NSA Core (option 3x) and RAN MIMO 64T64R equipment, each site implements Opensource solutions integrated in OpenAirInterface with various technologies (5G, 4G, NB-IoT, LTE-M, WiFi …). The first vertical integrations will be performed in 5G NSA Core solution. **The 5G SA Core solution should substitute the NSA one not before end of year 2020**.

To summarize, the French sites are interconnected together from Orange network infrastructure via secured VPN tunnels (some performance are detailed in 1.1.1.1.1). The infrastructure is also ready to be connected with the other sites facilities. ONAP orchestrator (Dublin version) is installed in Orange servers and is currently on-boarding VNFs/PNFs that will compose the catalogue of services (the first ONAP onboarding VNF is the b<>com Wireless Edge Factory [15] component that is Core Network allowing to support several radio interfaces (WiFi, LoRa, LTE and soon NB-IoT and 5G NR).

All the main current implemented features are specified, site per site, in the following sub-sections. The different sites facilities upgrades planned during the next months are sum-up in Table 36 in Annex A.

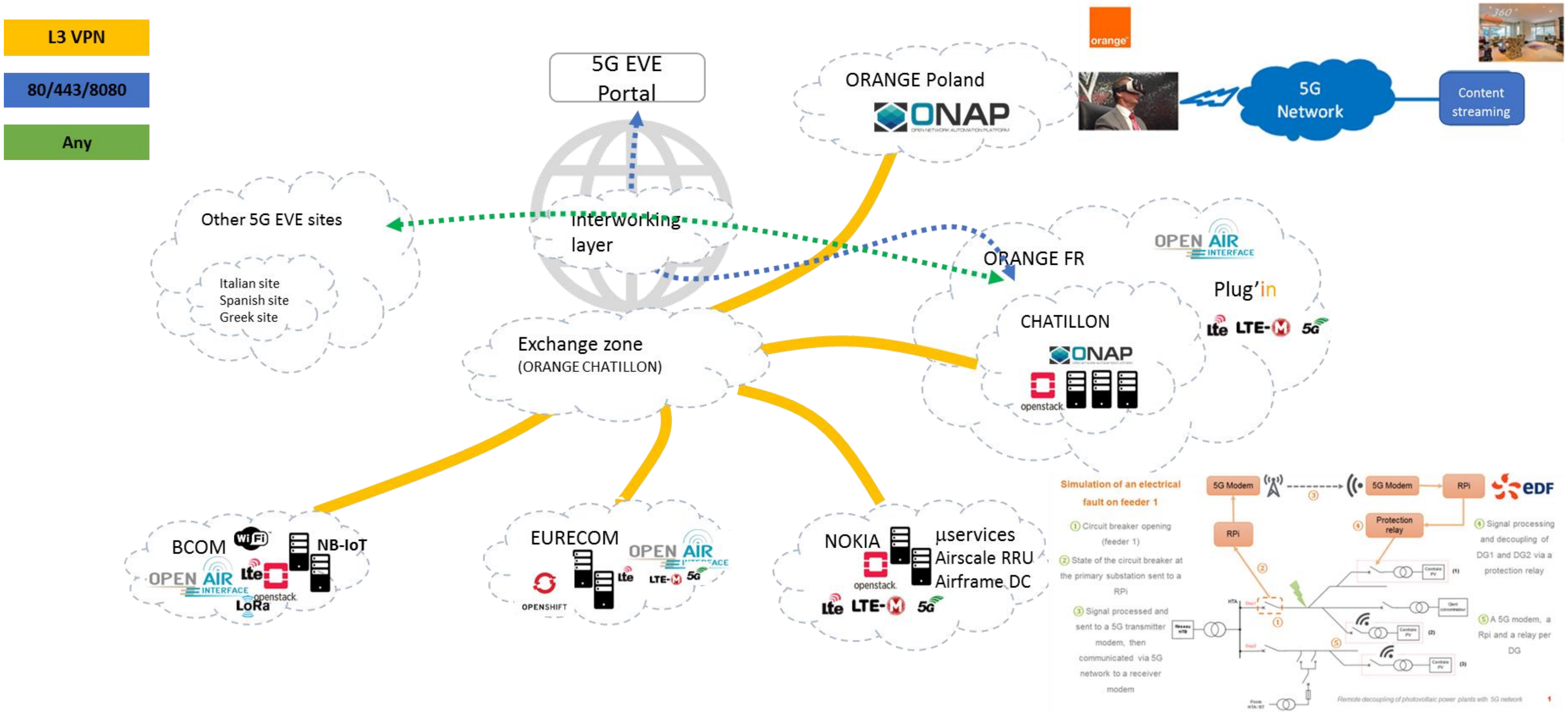

Figure 12: French site facility architecture

2.3.4.2 Main features

Orange Infrastructure

The main components already deployed in the Orange infrastructure are dedicated to the network implementation and management. Indeed, several DELL servers have been installed to host Openstack framework and ONAP orchestration, as well as the site interconnection done via secured VPN tunnels with switch and router. One other DELL server is dedicated to the open-source 5G RAN (gNB), and an HP workstation will host the open-source 5G UE. Two USRP N310 cards are also installed in the server room for gNB and UE testing. In parallel to the 4G integration, NR 5G is on progress and follows the OAI roadmap. The new N310 equipment has been purchased, installed, and tested with OAI 4G develop branch. This card will be employed to implement the 5G gNB using OAI 5G NR source code, which will permit to move the video 360° use-case in NR 5G framework.

According to what was planned initially and referred in [3], the Table 32 in Annex A states the components already implemented. However, two actions are delayed:

- The availability of the 5G devices. Indeed some vendors are still under validation of the UE specifications. We expect to provision some NR 5G mobile terminals in November 2019 no later.
- The outdoor RRH is not still deployed in Châtillon premises. This is mainly due to the fact that we were concentrated on the network infrastructure deployment that was the bottleneck for the French site facility implementation. However, this is not blocking because the other French sites have already their installation ready to conduct the on-air trial operations. The availability to have an NR 5G RRH at Châtillon is planned during the first semester of Q1-2020.

Nokia Paris/Saclay Infrastructure

As already described in [2][3], Nokia Paris/Saclay site facility relies on two pillars. The first one, is based and comprises pre-commercial Nokia 4G/5G E2E network facility composed of the pre-commercial 5G platform based on open-source and inner-source products developed by Nokia Mobile Networks Business Unit (so-called "NOKIA pre-commercial platform" or IFUN that stands for "Internal Friendly User Network"). The second pillar is based on the "Nokia research platform" that is a research platform based on open-source and inner-source developed in Nokia Bell Labs that relies, in terms of hardware, on specific and local resources (Edge and Central). In terms of software, it relies on NGPaaS [17] technology based on cloud-native and micro-services. RAN and CORE are deployed on different platforms operated by an end-to-end service orchestration.

During the first year of the 5G EVE project, Nokia Paris Saclay site has completed the following milestones scheduled in the project planning and reported in Table 33 in Annex A. More details about the implemented components are given below.

- **Radio coverage**:
  - Nokia Paris Saclay site is covered by LTE network. This coverage is provided by a tri-sectorial eNB using band 28 (10MHz bandwidth).
  - On top of this LTE layer a 5G-NR layer has been deployed covering all Nokia site using band n78 (100MHz bandwidth).
  - To have a good 5G coverage four sectors have been deployed using Nokia Solution.
  - From core side a Non-Standalone architecture (NSA) is used. In this architecture the LTE system serves as signalling anchor and 5G-NR is added as secondary RAT/cell.
- **Shared cloud infrastructure**:
  - Private compute resources (VM based) have been reserved on Nokia Innovation Platform (NIP).
  - NIP is connected to Orange Châtillon through a direct VPN connection (key generation is under finalization on Orange side). Once connected, Orange ONAP will be able to deploy VMs on NIP.
  - NIP is connected to cable and OTA radio system via an internal network called RDNet.
  - As planned at end of Y1, NIP performs the gateway between Orange ONAP and radio system and will be supporting all EVE operations.

- **Private cloud infrastructure**
  - 1 direct fibber connection was established between BellLabs resources and Nokia EEC.
  - This configuration will enable more research-oriented configurations than NIP (e.g. ORAN).
- **Software platform**
  - An operational 5G CORE based on micro-service PaaS is already deployed on NIP. Interconnection tests with gNB are about to start.
  - A service orchestrator based on RDCL tool has also been deployed, able to deploy CORE, RAN and mixed services.
  - Requirements on French site mandate ONAP usage in Châtillon (star-configuration). Investigations on ONAP interfacing have started with various options envisaged:
    - Adding PNF functions to ONAP SDC.
    - Adding light proxy-VM deployed in VIM NIP.

b<>com *Flexible Netlab* Infrastructure

The b<>com *Flexible Netlab* has progressed as it was planned on D2.2 [3] for the components associated to services expected project's first year (MS5 [4]). However some issues have been identified on regarding future RAN deployments. Table 34 (0) describes the main technological achievements during this first project year:

Radio Access Network

Rennes 2.6 TDD GHz LTE eNodeB RAN has been deployed at b<>com Rennes site facility and it has been tested and validated within the scope of the defined radio cell coverage. Nevertheless it is expected to improve the OAI-RAN release running on the eNodeB.

Rennes 3.5 GHz TDD LTE eNodeB RAN USRP technical scenario has been challenged due to adjacent interferences issues. An alternative scenario has been identified based on COTS hardware. A MAN optical connection to the new transmission station has been identified and will be implemented in upcoming months. Doubts on frequency availability in short term may lead to shift to 2.6 GHz RAN eNodeB. The eNodeb is expected to be completed by M18.

Add NB-IoT support to eNodeB RAN b<>com face issues between frequencies allocated by the regulatory office and the NB-IoT standards. Compliancy with TDD is only defined starting in Release 15, but only in band 41 which is available in Europe.

In Release 13, only HD-FDD is supported in various bands. New scenario is under investigation to align band availability by ARCEP, COTS UEs availability and eNB availability based on OpenAirInterface.

First implementation won't be available before M24 in any case.

Frequency bands

LTE band 38 frequency allocation is granted for Rennes & Lannion b<>com experimentation sites as well as NR 5G band 42. These frequencies seem however compromised in short term as it is planned for commercial usage.

ISM bands: 868 MHz & 2.4GHz - 5GHz WiFi are also used to some applications.

Core Network

The WEF CN corresponding to the Wireless Edge Factory Core Network instance is available for the project within the testbed and is currently onboarded in ONAP to be deployed in all French sites facilities.

The WEF CN using ODL SDN controller: the Split of SPGW control / data plane using OpenDayLight SDN Controller has been developed and available on the 5G EVE deployed instance.

User equipment

COTS LTE devices like Motorola X Play smartphones and Huawei E8278 4G LTE USB dongles are available. SDR OAI UE based on USRP is also available.

Quectel NB-IoT UE has been purchased and is used to validate the NB-IoT development in OAI stack.

Network and infrastructure orchestration

NFVi hardware has been purchased and integrated into the datacenter. It is composed of 7 DELL R640 Servers allocated for VIM and Network storage.

NFVi hardware extension corresponding to 2 extra DELL R640 servers have been purchased and will be shortly integrated in the datacenter to extend the VIM computational capacity.

Tools

NFVi Metrics collection are generated and collected at OpenStack.

Integration

Deployment planning for initial access was scheduled for M10. The deployment included the Phase 1 to Phase 4 as defined on D2.2 to grant the initial node access. This action was done according to the initial scheduling. Here is the detail:

Phase1 (M3):

=> New NFVi servers purchased;

=> 2.6 GHz TDD LTE eNodeB validation.

Phase2 (M7): NFVi deployment (Ceph distributed storage and OpenStack VIM instance);

Phase3 (M8): Interconnection with Orange Plug'in node (VPN, Monitoring and Orchestration). The VPN interconnection has been stablished and network performance has been performed (§0). Due to some issues with Orange Plugin Orchestrator availability the orchestration and monitoring tests have been shifted and will be performed in September 2019.

Phase4 (M9): *Wireless Edge Factory* VNF instance deployment with LTE and WiFi RAN support.

Eurécom Open5GLab Infrastructure

The Eurécom campus has installed and deployed several equipment and components for the trial experimentation. About the deployment, outdoor deployment of 5G –NR RRU (with LTE-M and NB-IoT systems) are put in place. First a 16 Tx MIMO system for outdoor transmission has been installed that will upgrade to MIMO 64 during the second year of the project. The complete network infrastructure, requiring fiber connection between the gNodeB and the physical resources, has been deployed. One building of the campus is also covered for indoor coverage with 32 antenna elements.

Several frequencies allocations are also in place (or pending) allowing already some verticals to be tested:

- 3600-3680 MHz TDD (61 dBm EIRP, NR band 78) for 5G eMBB/URLLC scenario;
- 2580-2610 MHz TDD (61 dBm EIRP, LTE Band 38);
- 698 – 703 / 753-758 MHz FDD (LTE band 68) typically for long range IoT transmission;
- 733 – 736 / 788 – 791 MHz FDD (LTE band 28) typically for long range IoT transmission;
- 703-748 / 758 – 803 MHz FDD (LTE band 28 / NR band 28, 57 dBm EIRP, pending) for 5G.

For the RAN/EPC cloud

- 100% containerized by using OpenShift 4.1 x86 cluster (Xeon Gold 36-Core servers)
- CumulusOS switching fabric 20 4G RRUs (TDD band 38)
- 2 8-antenna 5G NR RRU (TDD band 78)
- 2 2-antenna 4G IoT/Sidelink RRU (bands 14 & 68)
- Control-Plane (EPC/CU) can be remoted (OAI VNFs at remote site for CU)
- Controllable in ONAP environment
- OPNFV VCO 3.0

Several physical resources are already in place for the integration of the network infrastructure. Powerful HW and SW resources are composing the Eurécom 5G EVE site facility. The Table 35 (0 summarizes the main achievements of the Eurécom site facility during the first project year.

The major software developments for 5G NR are issued from the OpenAir Interface community that relies on Opensource code. The last roadmap that was presented during the OAI workshop in New York in June 2019, mentioned:

- Phase 1 (Summer 2019): “noS1” 5G-NR only (with pre-configured gNB and UE, no core network)
- Phase 2 (Autumn 2019): non-standalone (E-UTRA – NR dual connectivity with 4G core)
- Phase 3 (2020): standalone (with 5G core)

So, currently some first PHY layer NR 5G tests are performed in lab. When the main gNodeB specifications with be tested with 5G UE device (until end 2019), the LTE Core network will be used as anchor for the devices attachment and operation tests will be possible. In parallel, 5G NR VNFs will be onboarding in ONAP to be integrated to the French 5G EVE catalogue.

Services

One of the main activities during this first project year was to identify for the different 5G EVE site facilities in Europe and also in the local French sites, the available services. Indeed, some services could be shared and integrated in a multi-French-site catalogue (or go back to the top level of the global 5G EVE catalogue). Table 2 states the main services that are implemented in the different French sites.

In the same way, the services have been categorized in 5 different classes, as specified in 2.2.Table 7 gives the availability of the different services classes in the French site facility.

To go deeper in the analysis, we have identified per service class, the service type where it could be provided (at the lowest place), the dependency and the tools and API that are available. Then, behind each of then, a cross has been put in front of each French site facility to check their usage. Table 8 gives this repartition. As related in Table 7, the French site has mainly focused on the services hosting with the implementation of the ONAP solution and different VNF based on OAI RAN and CORE components.

Table 7: Availability of the French site services classes

Common service \ Site	French site			
Release	M10	M16	M18	M24
WaaS	-	x	x	x
TaaS	-	-		x
MaaS	-	-	x	x
Hosting	x	x	x	x
Support	-	x	x	x

Table 8: Referencing of the service type, location, dependency and tools/API per French sites facilities

Site					French site			
Service class	**Service type**	**Lowest place where is it provide**	**Other services dependency**	**Tools & APIs**	**Paris**	**Sophia**	**Paris-Saclay**	**OVERALL**
Wireless Connectivity-aaS	Network Slice lifecyle	Global/Site/Location	hosting/*	ONAP/OSM/Openstack/Cloudify... RADCOM, DHCP,	x	x	x	x
	UE beacons service lifecycle	Location	hosting/*	REST			-	
	Device-to-device connectivity lifecycle	Location	hosting/*	REST			-	
	UE control	Global/Site/Location	hosting/AAA-access	REST		x	x	
	Segment configuration (RAN, CORE, MEC)	Location	hosting/AAA-access	REST, Dashboard		x	x	
Test-aaS	Test edition	Global/Site/Location	hosting/AAA-access	Robot, TestLink, Netrounds			x	
	Test execution	Global/Site/Location	hosting/AAA-access	Robot, Jenkins, Cucumber, Netrounds...		x	x	
	UE emulation	Global/Site/Location	hosting/AAA-access	OAIsim, UDP_Replay, Prox, vPE		x	x	x
Monitoring-aaS	Health Check Service	Global/Site/Location	hosting/AAA-access	ONAP/OSM/Openstack/Cloudiy...	x	x	x	
	Cloud Infrastructure metric	Location	hosting/AAA-access	Prometheus/elk/Gnocchi/...	x	x	x	
	Wireless Connectivity-aaS monitoring	Location	hosting/AAA-access & WaaS/*	iPerf	x	x	x	
	Service monitoring	Global/Site/Location	hosting/AAA-access & relevant services	WP5, OpenNetMon, EvA (Empirix Virtual Agent)			x	x
	UE monitoring	Global/Site/Location	hosting/AAA-access	WP5		x	x	
Hosting	Accounting/Authentication/Authorization	Global/Site/Location	-	Keycloak, AAA, vACL, IndraiAAA			x	x
	Local access	Location	Hosting/AAA	-		x	x	
	Remote access	Location	Hosting/AAA	BIND9, FHOSS, Hillstone		x	x	x
	VNF	Location	Hosting/Ticketing	ONAP/OSM/Openstack/Cloudiy... Open vSwitch, VyOS	x	x	x	
	PNF	Location	Hosting/Ticketing	SWITCH		x	x	
	service	Location	all other relevant services	REST			x	
	Calendar	Location	Hosting/Ticketing	-	x		x	
Support	Ticketing	Global/Site/Location	Hosting/AAA	GLPI, Bugzilla, Jira, osTicket	x		-	
	Online documentation	Location	-	wiki tool (mediawiki)?		x	-	

Test environment

Following the description of the French sites facilities, it appears that several frequencies bands are available to lead the experimentation either in **indoor** or **outdoor** environments. For outdoor radio transmission, large coverage can be achieved thanks to multi-cell deployment (Nokia Paris Saclay Campus, Eurécom campus). The tests are planned to generate “real traffic” specific to the vertical especially for eMBB (for instance virtual video content for the Virtual Reality visit) and uRLLC scenarios. The 4G/5G devices are used as modem to interface with the specific verticals equipment. For traffic emulation, TCP, UDP, RTCP and HTTP could be used for testing and debug.

As an example, traffic emulation has been used for testing the VPN interconnection between French sites facilities and Orange gardens. Some first performance has been evaluated as shown in the MS5 video. The VPN interconnection performance evaluation between the Orange Châtillon and b<>com premises that are about 300 kilometers apart in direct line. The first results have shown that the 1 Gbps tunnel was quasi filled with UDP and TCP Packets. The Jitter was very small; less than 0.06 ms and the delay is equal in average to 28 ms. The last latency value could be improved a little bit. Figure 13 illustrates the exact achieved values.

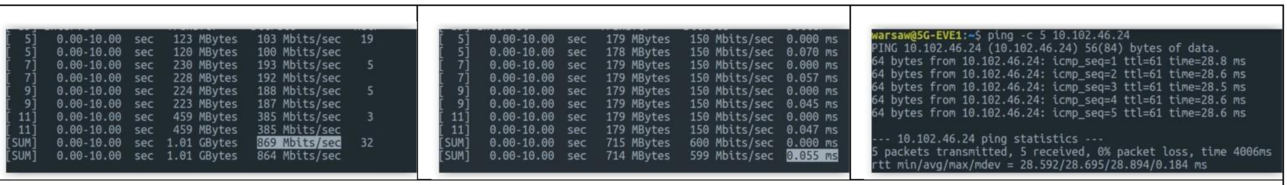

Figure 13: Orange and b<>com interconnection performance results: throughput, jitter and latency values.

3 5G EVE internal use-cases

With regards to the 5G EVE's Verticals Ecosystem activation, six main **internal** use-cases have been upon the 5G EVE proposal in order to take their constraints and requirements for the site facility design and specifications into account as early as possible. In 5G EVE consortium the following verticals sectors are involved through the presence of key players in such sectors:

- Utilities (EDF in France, and OTE with WINGS in Greece),
- Transport (TRENITALIA in Italy),
- SmartCities (TORINO MUNICIPALITY in Italy, and OTE with WINGS in Greece),
- Industry 4.0 (ASTI in Spain, and Ericsson with COMAU in Italy),
- Smart Tourism (SEGITTUR in Spain) and
- Media (Telefonica in Spain and Orange in France).

To know more about these six internal use-cases in terms of objectives and KPIs, we can refer to [1].

3.1 UC#1: Smart Transport: Intelligent railway for smart mobility

Use case **Smart Transport** has been fully developed in 5G EVE Italian Site located in the City of Turin. The focus is on intelligent railway for smart mobility in urban and sub urban area. The main aim is that of testing connectivity and typical URLL KPIs in mobility scenarios in the City of Turin. In this case, the 5G EVE's Vertical Ecosystem includes the main Italian railway operator, namely Trenitalia S.p.A., and an SME with core business in smart and electro mobility, namely Ares2t S.r.l. based on the seminal reference provided in 5G EVE, this Vertical followed up with reference KPIs and architectural proposal tailored on available 5G facility, including feedbacks and ad hoc request in terms of constraints and requirements for the site facility design and further specification.

3.1.1 Description & KPIs

The use case has been introduced in deliverable D1.1 ([1], Section 3.1) with main concept, rationale as well as main reference KPIs. Seminal elements about preliminary architecture and site facility development have been included in deliverable D2.2 ([3]). Two application scenarios have been introduced and explained:

- Scenario 1 (referred as Use Case 1.1) – *5G On Board Media content streaming* – This scenario concerns on board train services for passenger media content delivery (Video streaming and Video Conferencing) that 5G connectivity and mobility data will enable. It requires coverage, availability and reliability of connectivity considering overcoming the criticalities of High-Speed mobility communication through 5G Networks adoption, as well as continuity of the services and throughput of 5G streaming provision.
- Scenario 2 (referred as Use Case 1.2) – *Urban mobility 5G data flows analysis* – This scenario concerns integration of 5G data and mobility data from different transport operators to enhance distributed computing and pattern recognition to support urban multimodality between railway network and other collective transportation services (both public and private) and to realize more accurate and reliable Intelligent Transportation System (ITS). It requires coverage in mobility, mMTC aspects and MEC technologies where available.

In line with architecture of the Italian Site described in Section 2.3.2.1, the Use-cases 1.1 and 1.2 will be supported by the 5G EVE platform as depicted in Figure 14 where light green blocks, gold icons, dark green and grey dash dotted lines refers to Use-cases in vertical Smart Transport as explained in the following paragraphs.

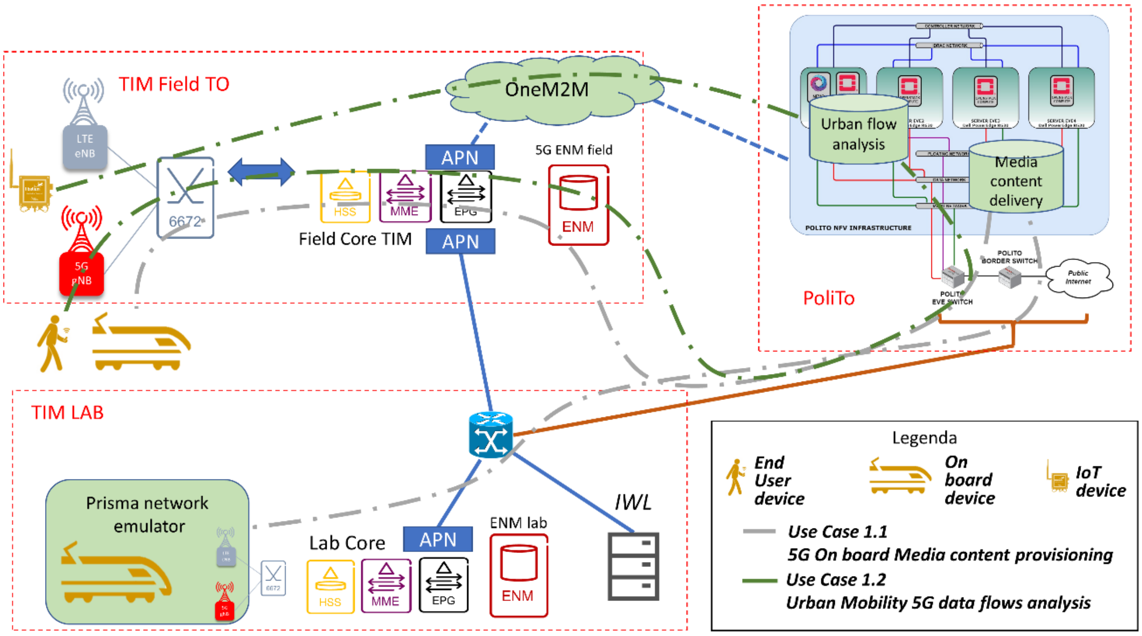

Figure 14: 5G EVE - Italian Site – UC#1 Smart Transport reference architecture

Use Case 1.1 is based on design, implementation and integration of two main services:

1. *5G EVE Media Content Service* consisting of a front-end application and a back-end system to provide high definition media content via mobile application running on 5G mobile devices;
2. *Prisma network emulator* supporting outdoor scenario emulation to measure test network KPIs.

Two series of experiments will run in the 5G EVE Italian Site. The former relies on media content communication between the 5G EVE Media Content Service front-end and back-end (see top end-to-end grey dash dotted line in Figure 14) through “TIM Field TO”: the front-end application runs on a 5G mobile device on board train and is represented by the train icon on the left; the back-end application runs on the “Media content delivery” component in “PoliTo” site on the right. The latter consists on outdoor mobility emulation by Prisma network emulator component located in “TIM LAB” (see bottom end-to-end grey dash dotted line in Figure 14 where the end-to-end connection is represented by the train icon on the left and the “Media content delivery” component in “PoliTo” on the right).

Emulation of 5G connectivity performance in the stressing condition of High Speed would provide to Trenitalia evidences to support the innovation of the current model of media content delivery towards the provision of on-board media services with Full HD/4K streaming.

In details, the State-of-the-Art model is based on the upload, storage and periodic update of media contents on the media servers of each train of the high-speed segment fleets. Introduction of high-quality streaming will be evaluated considering the connectivity technology enhancements and business implications emerged by the 5G test KPIs of the Use Case 1.1 in terms of:

- Connectivity performance improvement: Trenitalia would take advantage of the testing results to verify network performances of 5G application compared to the 4G Multi-operator technology used to guarantee high quality and coverage of on-board connectivity, considering for both technologies the same characteristics of network configuration. Testing results should demonstrate throughput delivery improvements allowing potential replacement and optimization of 4G Multiple SIM solution with 5G SIM solution per system configuration;
- Operation management efficiency: 5G technology application to media content delivery is expected to provide to Trenitalia a more efficient network solution to be applied on the High Speed in respect of the 4G Multi-operator in terms of costs of on-board deployment and installation, maintenance and final delivery to the users. High operation efficiency would imply savings in terms of infrastructural expenses;
- Technology simple usability: Trenitalia is interested in going beyond the current 4G Infrastructural service model, 5G technology is expected to simplify processed of on-board infrastructure management

due to easier architecture developments compared to the 4G Multi-operator technology, considering peer speed performances of on board media delivery on the High Speed Segment.

Use Case 1.2 is based on design, implementation and integration of three software services:

1. *5G EVE Tracking Service* is a mobile application able to
   - collect mobility data from 5G mobile devices,
   - communicate mobility data to the transportation mode recognition system (Recognition service),
   - support test network KPI measurement for Use Case 1.2.

   The application collects one data record from sensors commonly built-in in any smartphone and from network every 5 seconds. Home page and data collection session management system are showed in Figure 15;
2. *5G EVE Recognition Service* is a fully data driven transportation mode recognition system; the main objective is that of automatically inferring transportation mode by statistical learning models and machine learning algorithms being able to process massive data sets and to extract significant features to estimate transportation mode; in this project it was adopted the approach widely described in scientific literature (some scientific publications covering this matter can be found in [19], [20], [21] and [22]);
3. *5G EVE Info mobility Service* is a software application powered by 5G EVE Tracking Service and 5G EVE Recognition Service with the aim of providing aggregated information in terms of mobility flows and patterns of interest based on the OneM2M by TIM.

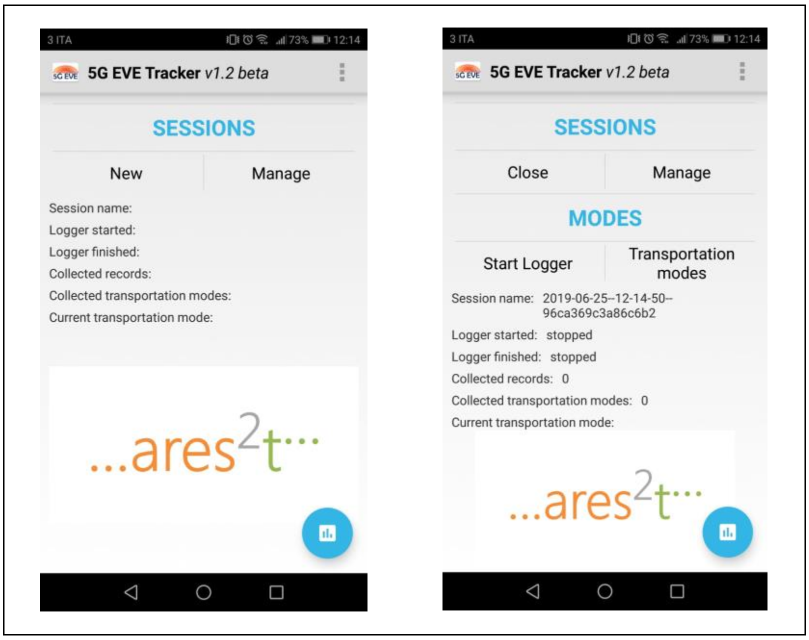

Figure 15: 5G EVE Tracking Service - Mobile application home page and session management

Back-end applications of the above-mentioned software services will be deployed in the "Urban Flow Analysis" component as depicted in Figure 14. The experiments related to Use Case 1.2 will run in the 5G EVE Italian Site. Mobility data collected by *5G EVE Tracking Service* front-end application (running on the end user's 5G mobile device on the left) are communicated via "TIM Field TO" to the back-end application running on the "Urban flow analysis" component at "PoliTo" site on the right (see end-to-end lower green dash dotted line in Figure 14). The *5G EVE Recognition Service* analyses real time data collected in the "Urban flow analysis" component and estimates transportation modes adopted in aggregated mobility flows. Finally, the *5G EVE Info mobility Service* analysis urban mobility patterns by integrating mobility flows (identified by 5G EVE Recognition Service) and ground truth mobility data collected by TIM's OneM2M operating in the 5G EVE Italian (represented by end-to-end upper green dash dotted line in Figure 14).

Roadmap for development of both scenarios is detailed in the following Section 3.1.2.

3.1.2 Integration, test and validation planning

As concerns Use Case 1.1, preliminary lab and virtual emulation tests will be conducted by end of January 2020. Integration and test will run in 2020 to allow consolidated KPI measurement, assessment and validation by the first half of 2021 according to Figure 16. Main activities are:

- Lab virtual emulation testing with 5G EVE Media Content Service
- Lab virtual emulation testing with Prisma network emulator
- Integration & Interoperability tested in emulation environment
- Test and KPI's measured: coverage, availability and reliability in mobility, throughput of 5G streaming
- Test and vertical KPI' measured & validated

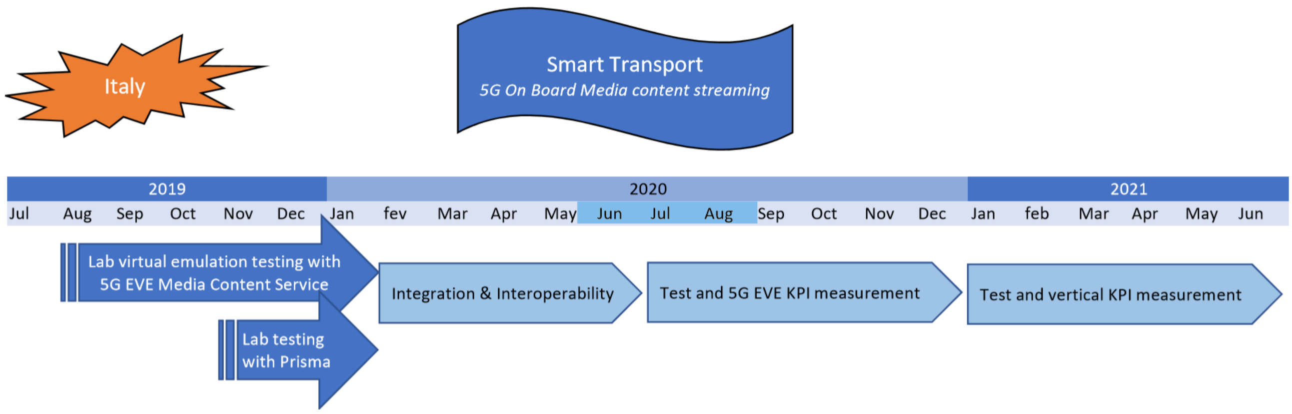

Figure 16: Smart Transport Use Case 1.1 roadmap

As concerns Use Case 1.2, 5G EVE Tracking Service has been designed, developed and tested with 4G/LTE networks in different sites (in Italy, Greece and France). 5G EVE Recognition Service is under development. Preliminary lab and virtual emulation tests will be conducted by end of December 2019. Integration and test will run in 2020 to allow consolidated KPI measurement, assessment and validation by the first half of 2021 according to Figure 17. Main activities are:

- Lab testing with 5G EVE Tracking Service and 5G EVE Recognition Service
- Integration & Interoperability tested in emulation environment
- Test and KPI's measured: latency, speed, reliability and availability in mobility
- Test and vertical KPI' measured & validated

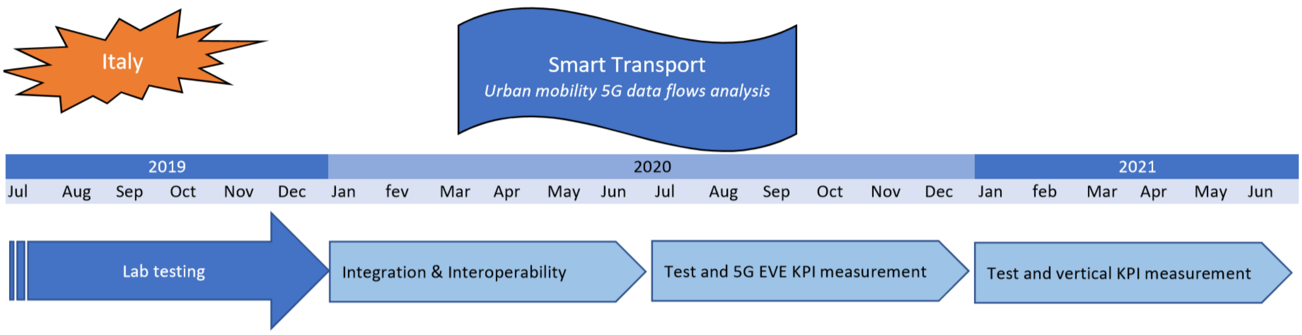

Figure 17: Smart Transport Use Case 1.2 roadmap.

3.1.3 Preliminary performance results

Since Use Case 1.1 is still in implementation phase, so far preliminary tests have been carried out for Use Case 1.2 only. 5G EVE Tracking Service has been released during the first year of project and is now available even if not yet integrated in the Italian Site. Data collection by 5G EVE Tracking Service has been performed from

April to June 2019 and produced more than 90.000 data instances collected in three countries (France, Greece and Italy). Data instances collected in 5G EVE Italian Site are depicted in Figure 18.

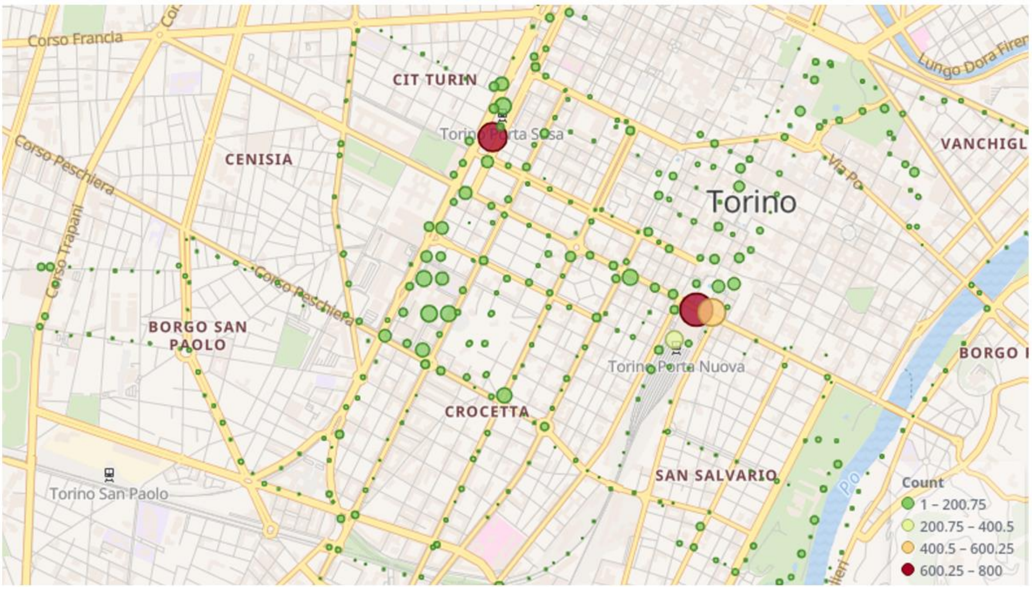

Figure 18: 5G EVE Tracking Service - Data collection area and instance distribution in 5G EVE Italian Site

Each data instance of data sample is described by a family of row data attributes (ranging from network cell parameters to device's data sensors) and labelled according to current transportation modality chosen in a set of 7 modalities (motorcycle, biking, car, bus, metro, tram, train) including no transportation mean (still, walking, running). 5G EVE Tracking Recognition back-end application pre-processed data sample by outlier filtering and linear normalization procedures. Data driven feature extraction and feature normalization methods prepared data for massive analysis to train a suitable pattern recognition system for developing the machine learning based recognition system. Training, validation and test procedures have been realized by Python Data Science libraries meant for scientific computing (namely, Pandas [23] and Numpy [24] and Scikit-learn [25]).

Machine learning is the scientific field in which the application of artificial intelligence provides to machines the ability of autonomously learning from data. There are four macro categories in machine learning: supervised, unsupervised, semi-supervised and reinforcement learning. In supervised learning the data by which the machine (also known as "learning machine") is trained include the labels or the class which they belong to, in our case the transportation mode. Consequently, the training set can be compared to a teacher who teaches the algorithm to predict the label of unknown data. In addition to the learning activity, machine learning encompasses all the activities prior to the construction of the training set, such as: preliminary analysis and manipulation of input data, feature extraction, feature selection through correlation analysis, eventual normalization operations, etc. After these fundamental phases, the choice of the most suitable algorithm to classify the data with the correct label proceeds. In general, the choice depends on the structure and quantity of data available, the objectives of the use case and preliminary assessments of comparison of scores of different candidates. Accordingly, the best parameters are identified through specific, data driven evaluation techniques, such as cross validation. Finally, the learning machine obtained on unknown data is tested and its performance is evaluated. For a complete survey on this topic, we refer to reference text books (e.g., [26], [27], [28] and [29]).

In this project several machine learning models have been trained by suitable algorithms. Among them, Logistic Regression (LogisticRegression), Random Forest (RandomForestClassifier), Decision Tree (DecisionTreeClassifier), Multi-layer Perceptron Neural Network (MPL) and Support Vector Machine for Classification (SVC) showed to get higher accuracy indicators in pattern recognition in terms of recall and precision over test set. In Figure 19 preliminary experimental results are showed for labels a) "Metro", b) "Car", and c) "Running". In pattern recognition, for each possible label *y* over 10 in the case of 5G EVE Recognition Service, *recall* measures the ratio between instances being well classified with label *y* and instances with label *y* while *precision* the ration between instances being well classified with label *y* and instances being classified with label *y*. In Figure 19 recall and precision are displayed as well as their and F Score (also known as F measure or *f1-score*) that is weighted harmonic mean of the test's precision and recall. As it can be observed by the figure, different machine learning models may have different accuracy in terms of both recall and precision. If we consider the resulting f1-score for case a) “Metro”, there is a considerable gap between Logistic Regression and Random Forest performances. On the contrary, f1-score for case c) “Running” does not show relevant difference among classifiers’ performances. Typically, best performance for each label can be often observed when precision and recall are close each other.

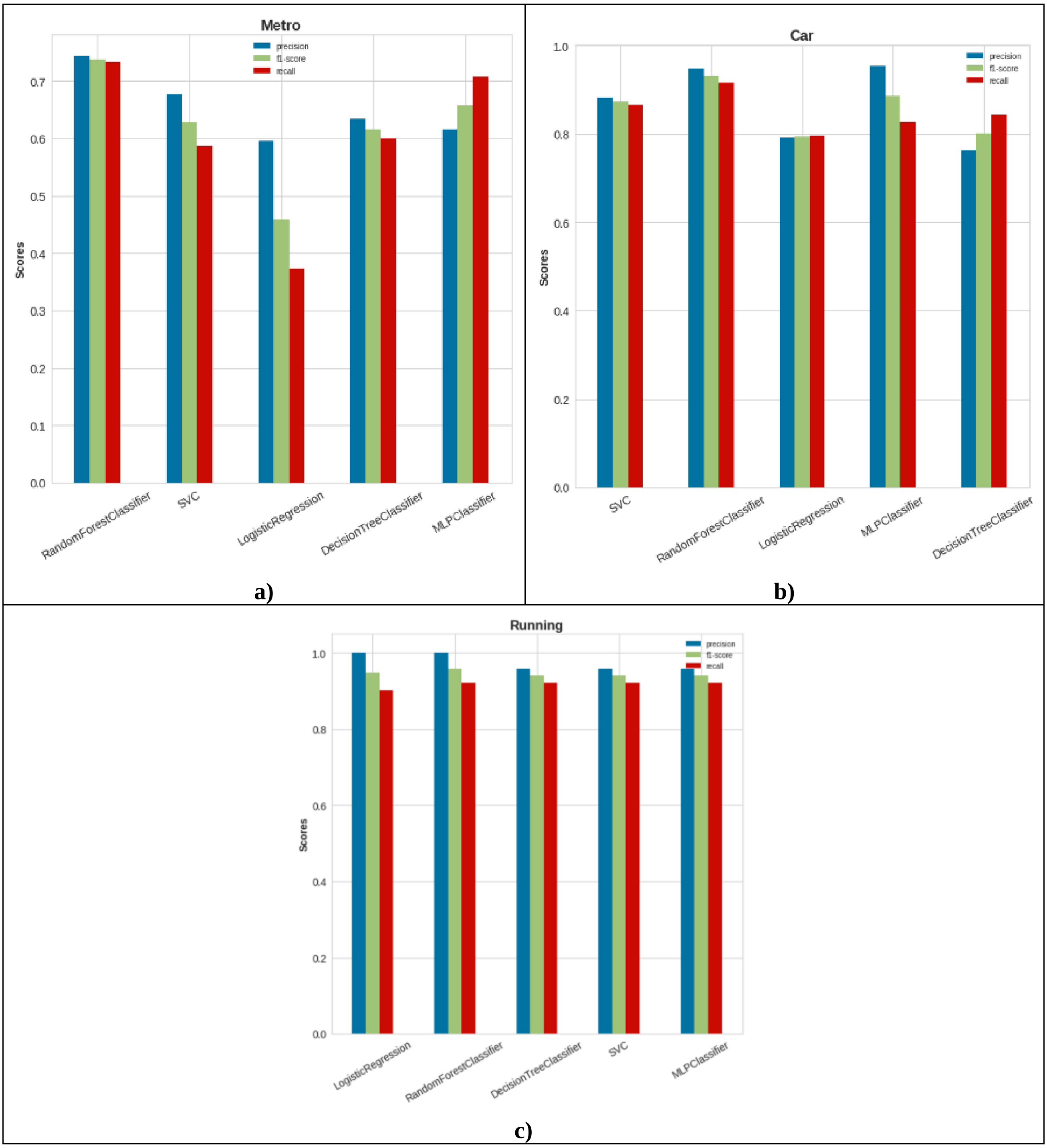

Figure 19: 5G EVE Recognition Service - Test accuracy assessment for a) Metro, b) Car and c) Running

From current experiments, thanks to good performance observed for each label, it is possible expecting that the 5G EVE Recognition Service can get more than 80% overall accuracy in recognizing different transportation modalities and in identifying aggregated mobility flows in urban mobility. Consolidated experiments will be delivered by the second year of project.

3.2 UC#2: Smart Tourism

3.2.1 Description & KPIs

5G technologies will allow tourists to enjoy an enhanced experience while visiting historical sites or architectural landmarks in a city. The Smart Tourism UC aims to develop a system of software tools to interactively access information on architectural landmarks, connecting a digital environment and the physical space of the city and overcome the limitations of traditional information tools and allow new interactions with monuments and works of art. The development of these technologies will enable historical and archaeological sites and assets to be seamlessly explored and maintainable: from offline browsing to advanced ticketing; from remote monitoring to AR exploration. The UC will use Artificial Intelligence (AI) image recognition techniques and Augmented Reality (AR) applications to enhance the visitor experience and optimize available resources.

Two apps (eventually merged into one) are being developed in support of this UC as illustrated in Figure 20. A *Detector* App will recognize a monument or a work of art just by framing it with the camera from any direction and regardless of its distance. The interface will show the name of the object and shows the related information with just a touch. From within the Detector App, if an AR extension if available for the monument, another app will be launched that allows an AR-enhanced visit of the monument or site. The AR application will rely on 3D models and other multimedia files that will be available through the 5G edge cloud. Figure 21 shows the interaction between UE and the AR server on the edge cloud.

The main KPI of the Smart Tourism UC will have its requirements addressed by existing 4G/LTE network technologies, however, enhanced performance will be provided by 5G networks in terms of Broadband Connectivity, Peak Demand and Availability, which embody the main KPIs requested by an eMMB system. No current performance results are available at the time being and will be shared very soon with the consortium.

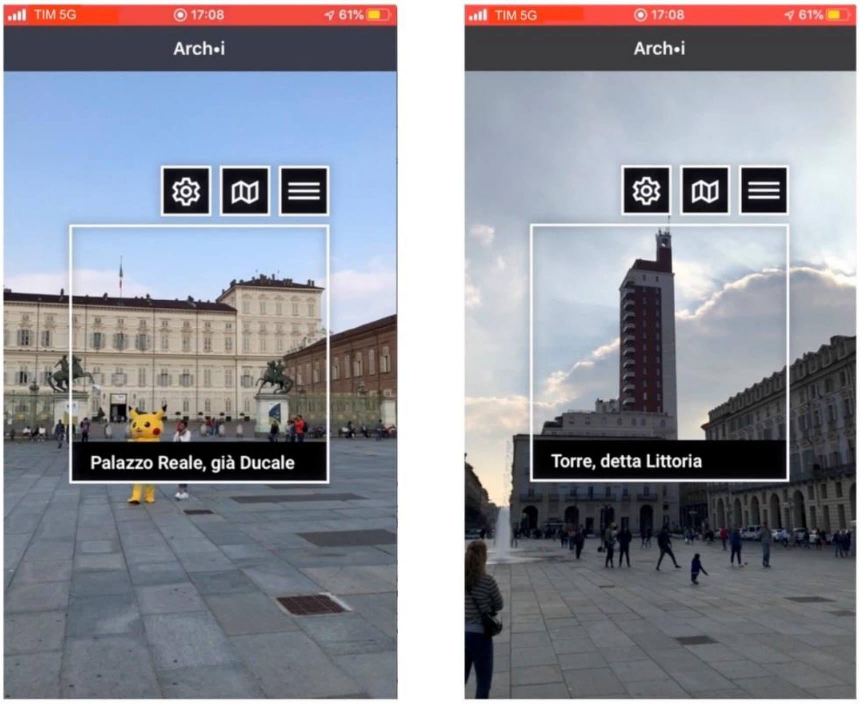

Figure 20: Screenshots of the Detector app

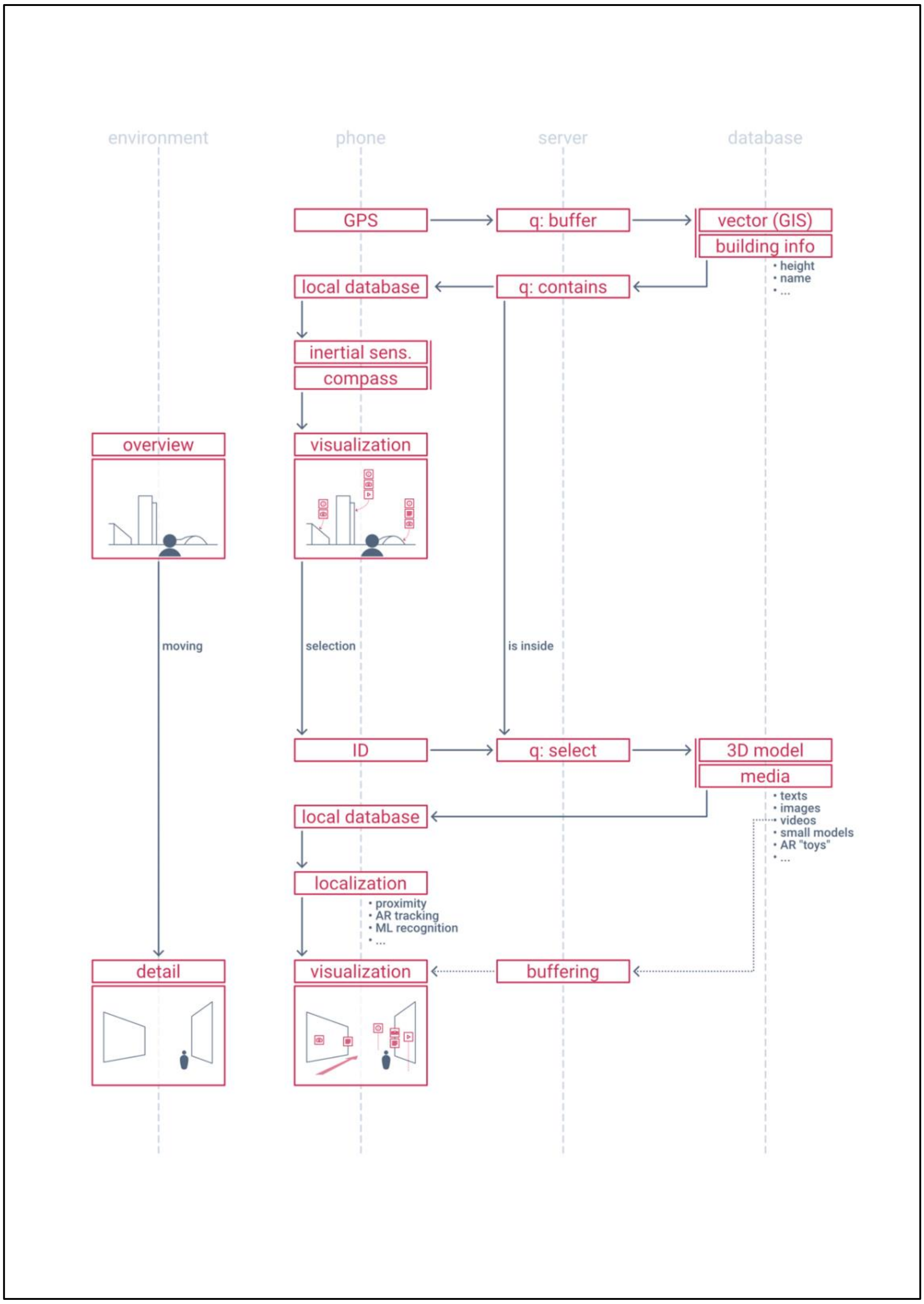

Figure 21: service interaction for the Smart Tourism UC

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3.2.2 Integration, test and validation planning

Our planned roadmap will evolve through 5 steps as depicted in Figure 22:

1. Finalization and offline testing of the Detector app and development of the AR app and backend functionalities; finalization and offline testing of the AR app and backend functionalities
2. Integration of backend in the 5G EVE platform and testing.
3. Automatic deployment of the use case in the 5G EVE platform and testing.
4. KPI validation.

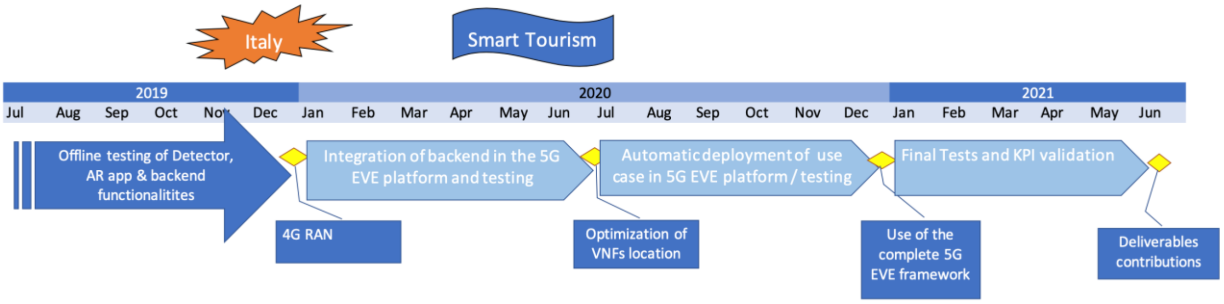

Figure 22: Smart Tourism Italy: use case roadmap

3.2.3 Preliminary performance results

Although the Detector app is ready and the AR app is under development, the backend facilities are not ready at the present time, therefore no performance results related to the KPIs addressed by the UC are available for now.

3.3 UC#3: Industry 4.0

3.3.1 Description & KPIs

5G technologies will be key to shift from the classical industry to industry 4.0, where all components in a factory have to share available information to improve the performance and reduce downtimes and costs. In this particular use case, Autonomous Guided Vehicles (AGV) are modified to centralise their control in a central point, which will be beneficial to improve the coordination among the whole fleet of AGVs. In this way, AGVs send all information captured by their local sensors to the master application placed on the edge of the network. After processing all parameters received from all AGVs, the master control application sends back commands to those AGVs to correct parameters like speed and direction. As it is clear, this communication has stringent requirements in terms of delay, so it will be necessary to measure the behaviour of the AGVs after changes in the delay imposed by the communication infrastructure. One important parameter for the AGVs is the *guide error*, which consists on the difference of corrections in the path sent by the master control application. This *guide error* will be used as the main vertical KPI to analyse in all successive trials.

3.3.2 ASTI Integration, test and validation planning

In 5TONIC, ASTI has provided two AGVs and the virtual machine where the master control application is running to control such AGVs. In a first phase, these two elements are connected using a 4G network, where the radio elements (configured to use pre-scheduling), the LTE core and compute nodes are provided by Ericsson Spain, and SIMs (and the configuration in the HSS) are provided by Telefonica. Finally, the AGVs are connected to the 4G network by using 4G routers provided by the UC3M (IMDEA Networks). In order to perform intensive tests, Telefonica has provided a server connected between the 4G base station and the LTE core to execute the *tc* command, used to add extra delays and packet losses. Furthermore, the UC3M has provided a VM with the Traffic[1] software, used to emulate the traffic of virtual AGVs.

Figure 23 shows the planned roadmap to test and validate the main KPIs described before for the ASTI use case. These are the main phases of this use case:

- Manually set up the complete configuration using a 4G network and execution of a pool of tests to check the results of the main KPIs.
- Automatically deploy the ASTI use case, from a Blueprint to the monitoring of the guided error metrics.
- Integration with a 5G network and execution of a pool of tests.
- Automatically deploy the ASTI use case in 5G and KPI validation.
- Automatically deploy the ASTI use case with several AGVs and KPI validation.

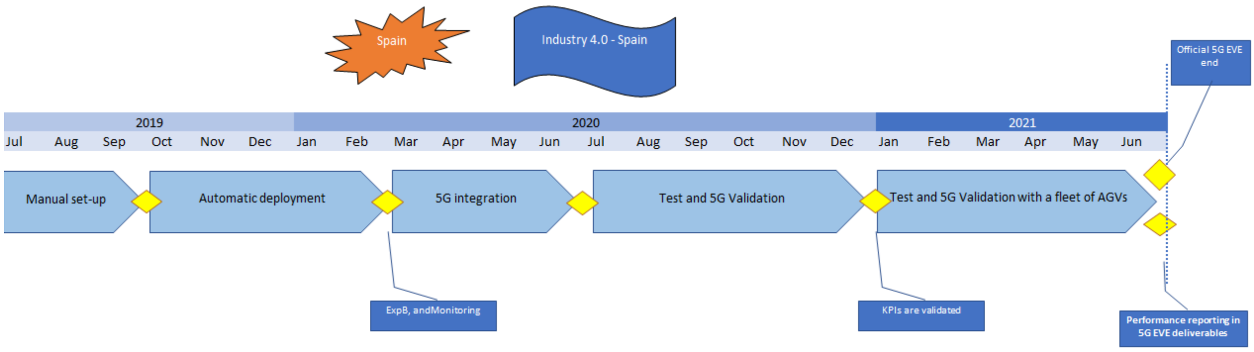

Figure 23: Industry 4.0 Spain use case roadmap

3.3.2.1 ASTI Preliminary performance results

The results presented here correspond to the first phase of the ASTI use case described in the previous subsection, where the whole set up is configured manually and using a 4G network. In the first phase, the pool of tests consisted in determining the *guided error* when an artificial extra delay is introduced in the communication channel, in this case, using the *tc* command of linux, using the *netem* discipline.

The main result extracted from these tests shows that the *guided error* is below the maximum permitted by the service when the extra delay is below *200ms*. It is important to highlight that the 4G network is configured using pre-scheduling, so a certain number of time slots are reserved in the uplink to each AGV, so the radio link is not affected by other transmissions.

3.3.3 Greek Site Facility - Integration, test and validation planning

In 5G EVE Greek site facility, realistic MCR scenarios are studied, in which traditional robots will be replaced by new ones connected to the cloud. These new robots only include low level controls, sensors and actuators and having their intelligence in the cloud means they have access to almost unlimited computing power. Altogether, they are more flexible, more usable and more affordable to own and operate.

The connection between MCR robots and the cloud is provided through the mobile network and will benefit from the expected 5G extremely low latency connections. The overall mobile network architecture for the AGV is highlighted in the following Figure 24.

[1] https://github.com/mami-project/trafic

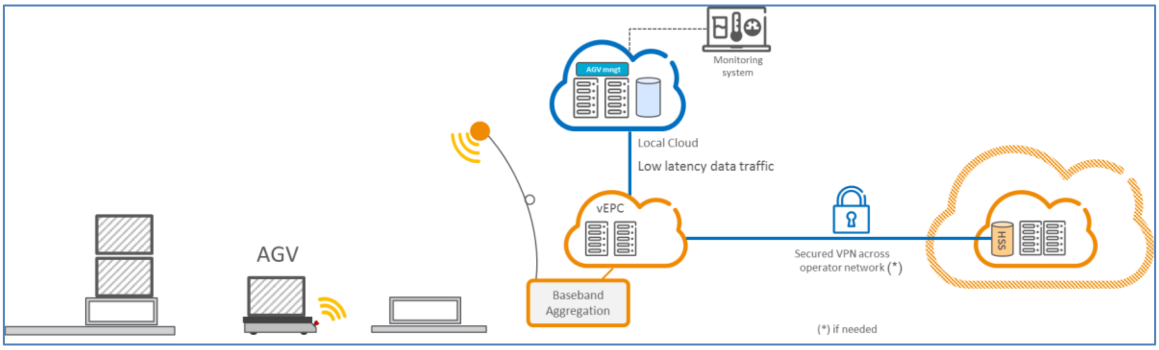

Figure 24: Overall mobile network architecture for an industrial enterprise URLLC application

In the Greek site facility, a set of KPIs, in terms of end-to-end network latency and throughput, have been monitored during the initial operation of the AGV. It is noted that in this initial phase, the network data traffic rate is considerably lower than system capabilities. This is because the initial focus is to enable a smooth setup of all applications in the site before the system is stressed to the limit. In the second phase of the project and during the last quarter of the year the 5G EVE platform will be tested under different values of system load (for example HD camera rates) in order to test the end-to-end performance under stress levels.

The measurement methodology is depicted in Figure 25. Measurements were made using ping packets and sniffing traffic using Wireshark.

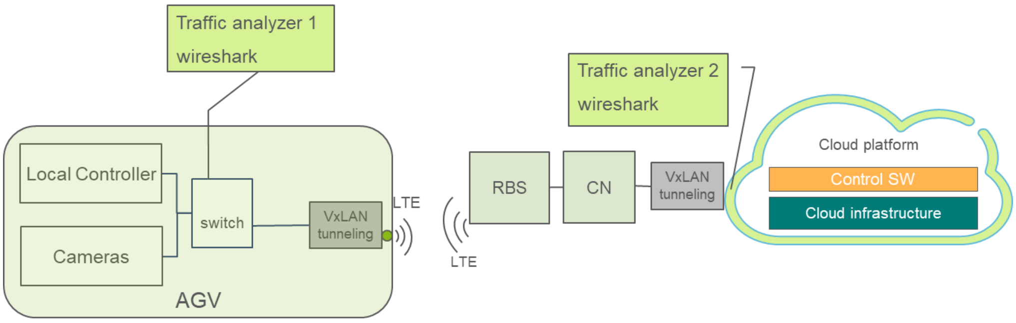

Figure 25: Greek site facility Measurement architecture

Two traffic analysers were used. They were placed at the two ends of the communication tunnel to measure the latency contribution of the LTE network. The two traffic analysers were synchronized in order to have a proper evaluation of the flight time of packets. The traces captured using Wireshark at both ends were post-processed with an analysis SW made in python and relying on the *pandas*[2] library. The SW had the purpose of identifying corresponding packets in the two captured flows and analyse the travel time between the two ends in order to build statistics. As a final step the histogram of the estimated distributions of downlink and uplink latency were drawn.

RTT measurements were made using ping packets sent between one of the computers in the cloud and the AGV controller.

Trace of data exchanged by COMAU AGV

The AGV in rest position has a negligible exchange of data with the COMAU system manager. During shuttling the bidirectional bandwidth is a bit less than the bandwidth required by a standard robotic device (e.g. industrial robotic arm) using PROFINET communication protocol with a cycle of 2 *ms*. Figure 26 illustrates the trace captured at the end of the VXLAN, including just the AGV basic control communication during a run.

[2] *Pandas* is an open source, BSD-licensed library providing high-performance, easy-to-use data structures and data analysis tools for the Python programming language.

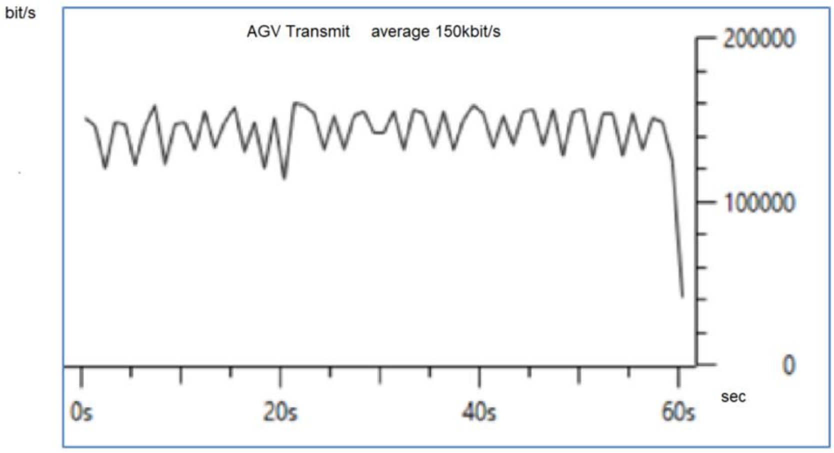

Figure 26: Bidirectional traffic flow due to the AGV control data only

The cameras on the AGV are introducing the highest rate from the AGV. At the time of initial system configuration, the cameras were transmitting a VBR traffic flow of 1 Mbps each. The traffic flow was almost constant all the time, similar to a CBR service. In total the bandwidth is 3 Mbps in UL direction (having three cameras). These streams are asymmetric with a negligible downlink flow. Images are transmitted using the MJPEG protocol.

Measured throughput is about 80 kbps in DL with peaks of about 1 Mbps at the start of a mission or in configuration phases. In UL it is about 3 Mbps with peaks of 4-5 Mbps.

Mobile Network Latency

The latency introduced by the mobile network was measured using two methods: Ping packets and analysis of synchronized Wireshark traces taken at both ends. The LTE+ network is characterized by the following values:

- LTE RTT: Min:13ms, Average :20ms, Maximum: 47ms

Figure 27 and Figure 28 show the distribution of the downlink and uplink latency respectively.

These values are compatible with the current performance of the AGV. During the 2nd phase of the AGV use case the main tests and KPI will be measured/validated:

- DL and UL Latency in the short and long run
- Throughput achievable when the application is set for high demand of bandwidth.
- Stability of the network in the long run in terms of latency, packet loss, bit errors: target is error free.
- Video streams stability (latency and frame corruption due to network errors): this affect the performance of the AGV.

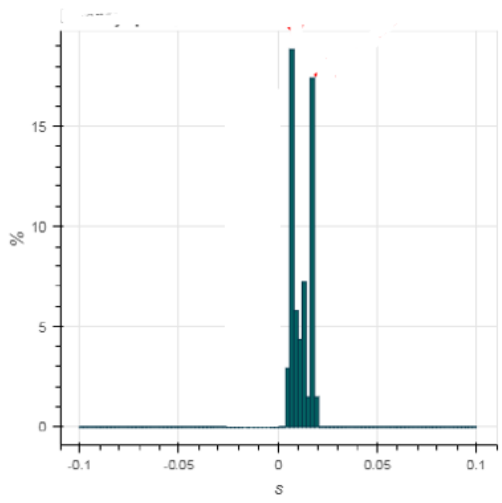

Figure 27: Downlink latency

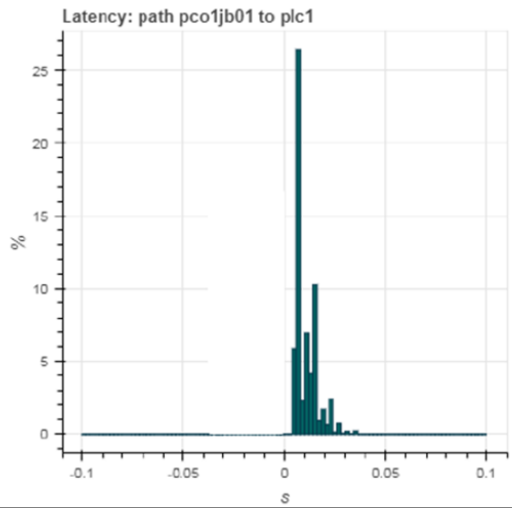

Figure 28: Uplink latency

Figure 29 shows the planned roadmap to test and validate the main KPIs specific to the AGV use case in the Greek site facility.

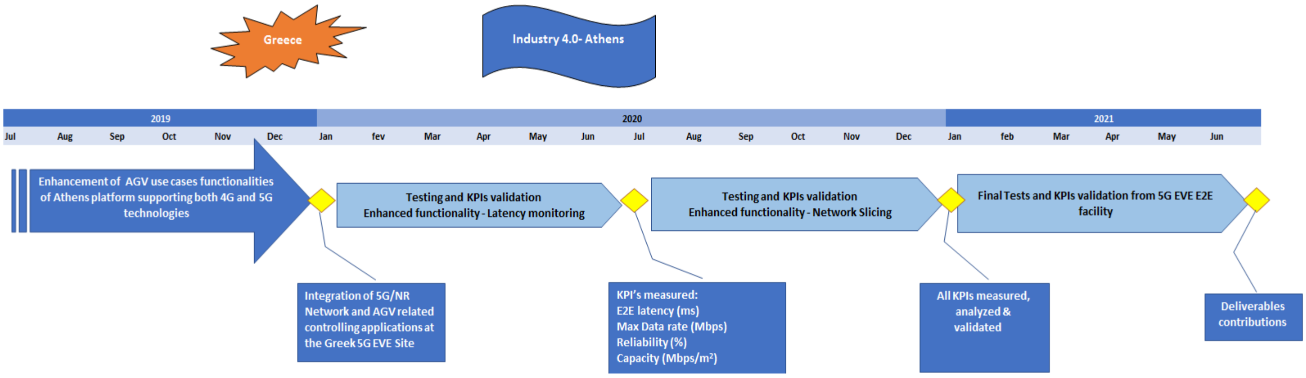

Figure 29: AGV Greek site use case roadmap

3.4 UC#4: Smart energy

3.4.1 Description & KPIs

3.4.1.1 French site facility

Critical utilities (Smart Energy), proposed by EDF deal about and focuses on fault management for distributed electricity generation in smart grids. The main issue addresses Ultra-Reliable Low-Latency Communications URLLC and critical massive Machine Type Communications (mMTC) scenario. Currently, fault detection and management in energy grids take place through fiber connectivity among the centralized electricity generation points (e.g. power plants). The move towards Distributed Generators (DG) offers great potential but also makes a fiber-communication monitoring solution prohibitive due to its deployment cost. 5G technologies can enable ultra-fast and ultra-reliable fault detection and management among an extensive number of DGs, with decreased CAPEX and OPEX. Such a fault management system is essential for modern smart grids, enabling the immediate reaction to change in the network thus avoiding unwanted islanding, providing dynamic stability and protection to the network and eventually allowing for the integration of an even greater number of DGs. The use of smart metering and fault detection mechanisms in combination with Mobile Edge Computing (MEC) functionality for ultra-fast processing could even lead towards a centralized grid protection system, elevating the level of control over the energy grid. The use of 5G New Radio (NR) may control the system and only disconnects the equipment in alarm. EDF will provide a platform emulating the system that will be linked to 5G NR transmission.

The main requirements for this use-case are being fulfilled by existing 4G/LTE network technologies. Enhanced performance should be provided by 5G networks in terms of: Latency, Broadband Connectivity or Peak Demand, Reliability and Availability that are mainly the KPIs requested by mMTC systems.

3.4.1.2 Greek site facility

For the Athens site facility Utilities pilot, the focus is on monitoring the proper functionality of a smart grid and keeping reliable and detailed records of the energy demand and consumption and to immediately react upon the detection of a fault situation, restoring the energy flow and avoiding energy waste. The scenario implements the three steps/phases of the use case (NORMAL – ALERT/ALARM - RESTORATION).

- At the beginning, there exists a specific configuration, specific sources are feeding the consumers.
- A default situation occurs
  - Shortage of energy level in some energy sources (need proactive action).
  - Problem in the network (e.g. removing the connection in the energy network, need reactive action).
  - Increase in energy demand (e.g., more fans that actually need more energy supply in the area, like with air conditions in the summer, need proactive action).
- The network is restored in a guaranteed latency, which will be demonstrated in an instant reconfiguration, i.e., lamps and fans continue to work.
  - In the case of network problem, all connected distributed generation sources to the problematic network are disconnected so that they do not feed fault current.
  - More distant distribution generation units are forced to remain connected in the grid and become active if they do not belong to the area that needs to be disconnected, so that the network is restored.
  - The decision on the network restoration is driven either by a rules-based logic or intelligence based on demand-supply matching, given that there are sensors to measure energy levels at both sources and consumers, potentially at the network edge.

WINGS Utilities platform functional architecture is depicted in Figure 30, alongside the different components that collaborate with the platform (sensors, energy consumers / producers, actuators, etc.).

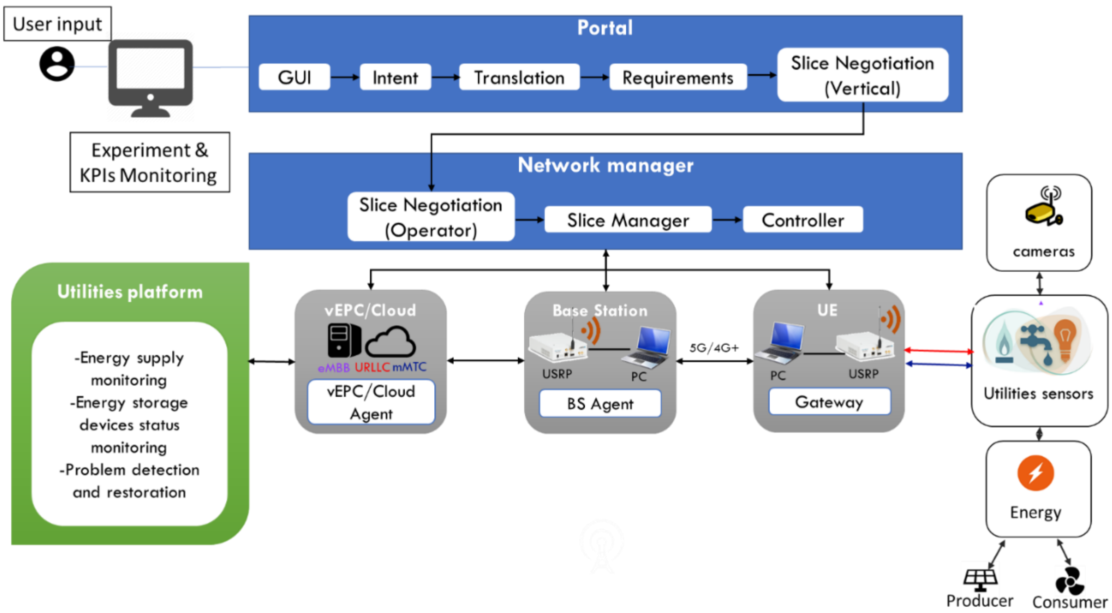

Figure 30: High-level overview of Utilities (Greece) use case architecture

Main KPIs

The main 5G and vertical related KPIs for the Athens pilot include the Table 9:

Table 9: Main KPIs for the smart energy use case in Athens site facility

5G related KPIs	
RTT Latency	Target: 20 – 100 msec, especially for the downlink (configurations)
Bandwidth	Target: 15Mbps-50Mbps, especially for the uplink
Vertical KPIs	
Power Restoration Time	Target: 1s
Power Restoration Decision Time	Target: << 1s

3.4.2 Integration, test and validation planning

3.4.2.1 French site facility

The equipment is modelled by a portable mock-up that reproduces the behaviour of a default on the electric network that needs a very fast reaction (low latency) of the system. It emulates the behaviour of the electricity network by simulating energy network disturbance. The first integration has been carried out recently in Nokia Paris Saclay premises and will be then extended to Eurécom and b<>com site facility, as illustrated in the following roadmap (Figure 31) and completed in Table 10**.**

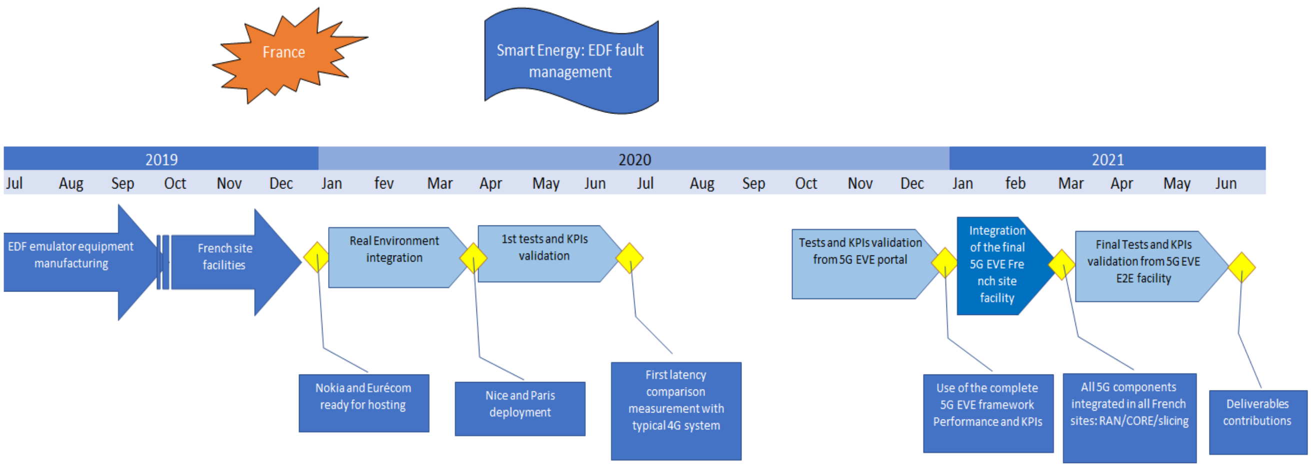

Figure 31: Integration, test and validation planning schedule for the smart energy EDF use-case

Table 10: EDF roadmap and KPIs validated in the French sites facilities

Use-Case	**Jan 2020**	**Jul 2020**	**Jan 2021**	**Jun 2021**
EDF smart energy	Integration & Interoperability tested At French sites: Nokia and Eurécom	KPI's measured: KPI-1: Latency, At French sites: Nokia and Eurécom	All KPI's KPI-1: Latency, KPI-3: Capacity measured, analyzed & validated At French sites: Nokia, Eurécom and b<>com	All KPI's measured, analyzed & validated At French sites: Nokia, Eurécom and b<>com

3.4.2.2 Greek site facility

For the Athens site Figure 32 depicts the actual topology of the experiment. A GUI is used to depict the live measurements from the various nodes of the smart grid (voltage, current, etc.) while detailed restoration time KPIs will also be implemented.

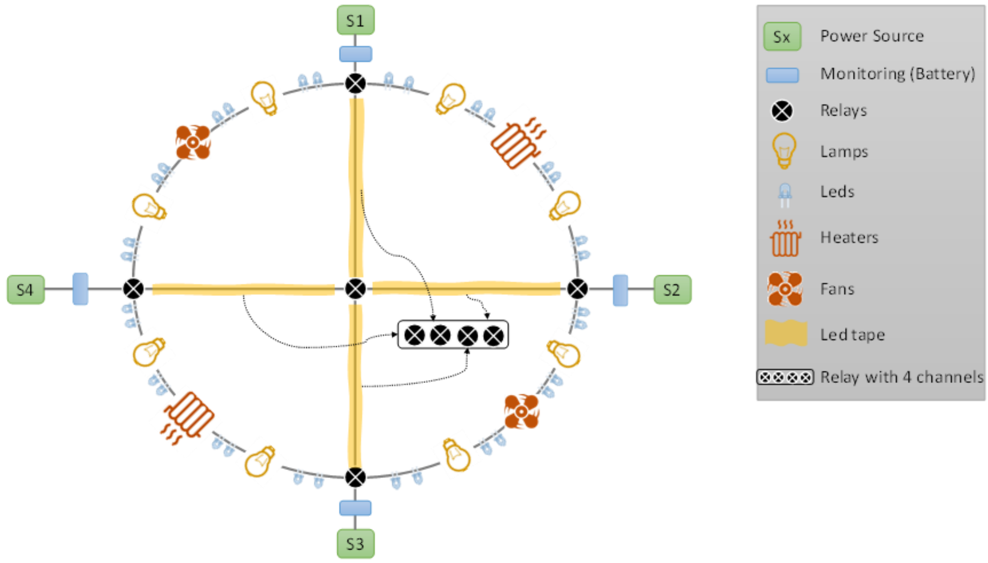

Figure 32: Smart grid topology graph for the Utilities use case

Figure 33 provides a high-level view of the currently envisaged set-up of the components and equipment related to the Utilities use case. Deployed devices include as already mentioned sensors for monitoring voltage/current and actuators in terms of relays, as well as CCTV cameras. Measurements from the various sensors/actuators are sent to the ARTEMIS Energy platform, over an mMTC slice, while cameras send over a eMBB slice and the platform monitors, analyses status, detects events, restores power and communicate actuations/actions via corresponding microservices. The ARTEMIS platform leverages diverse communication technologies and communication protocols. During the experiment different connectivity options and wireless technologies are utilized for the messages transmission / reception to and from the smart meters/sensors and actuators, ranging from GPRS to NB-IoT and 4G+/5G depending on the availability of the respective technology on the Greek site facility, during the different stages of development.

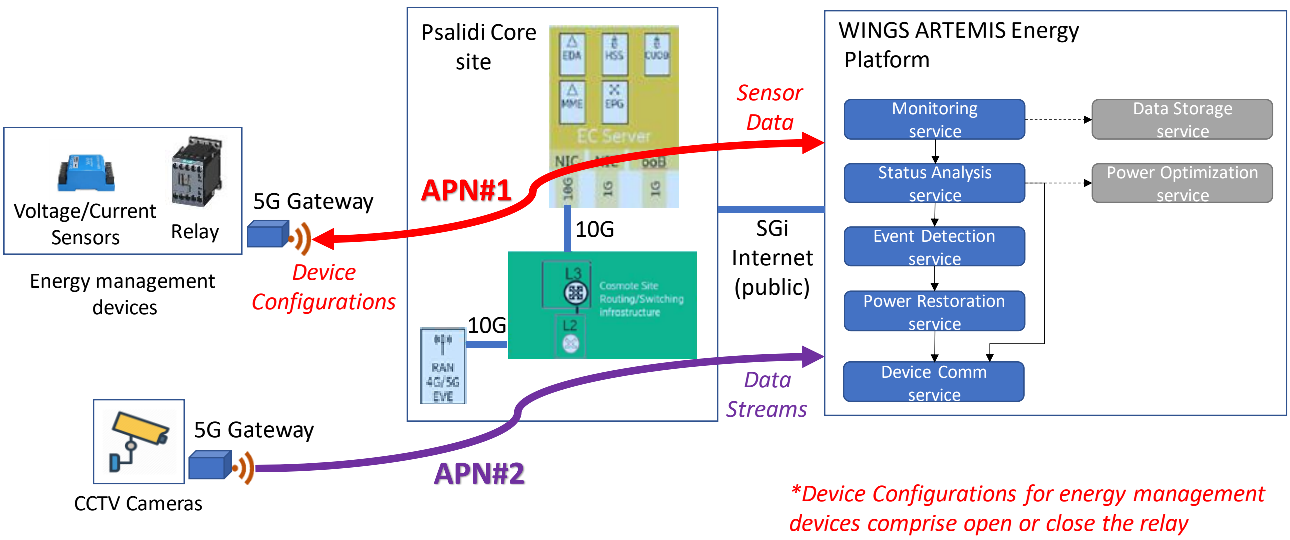

Figure 33: High-level view of Utilities pilot set-up (Greece)

The roadmap for the Athens Utilities use-case is depicted in Figure 34.

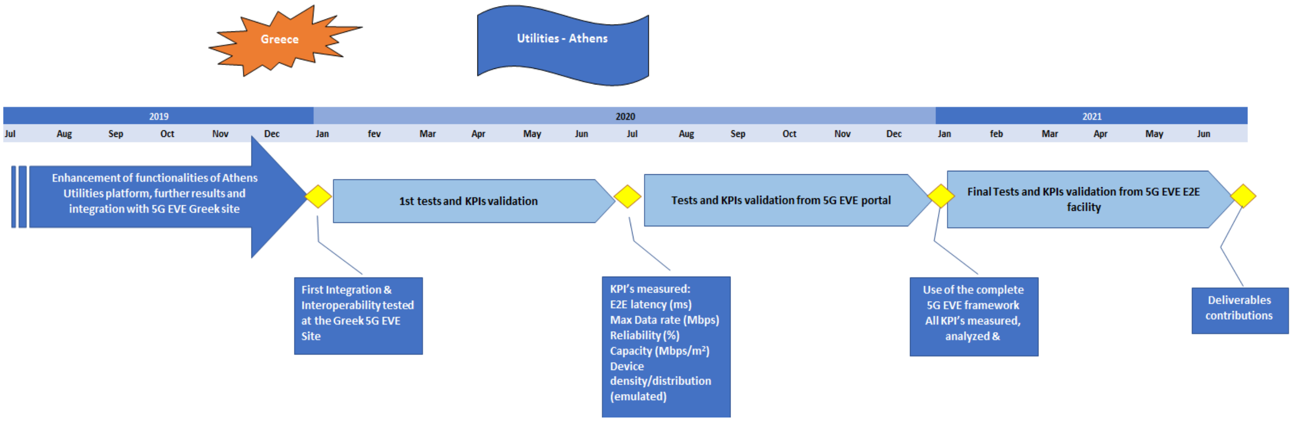

Figure 34: Utilities Athens: Use Case roadmap

3.4.3 Preliminary performance results

3.4.3.1 French site facility

Some preliminary performance results have been obtained in Lab in the French site.

Set-up in France:

As illustrated in Figure 35, two routers Nokia SAR 7705 establish a Ethernet PIPE (ePIPE) through the 5G network. This pipe makes a link of level 2, allowing to transmit the *Goose* protocol to make the communication between the two equipment controlling the Energy network.

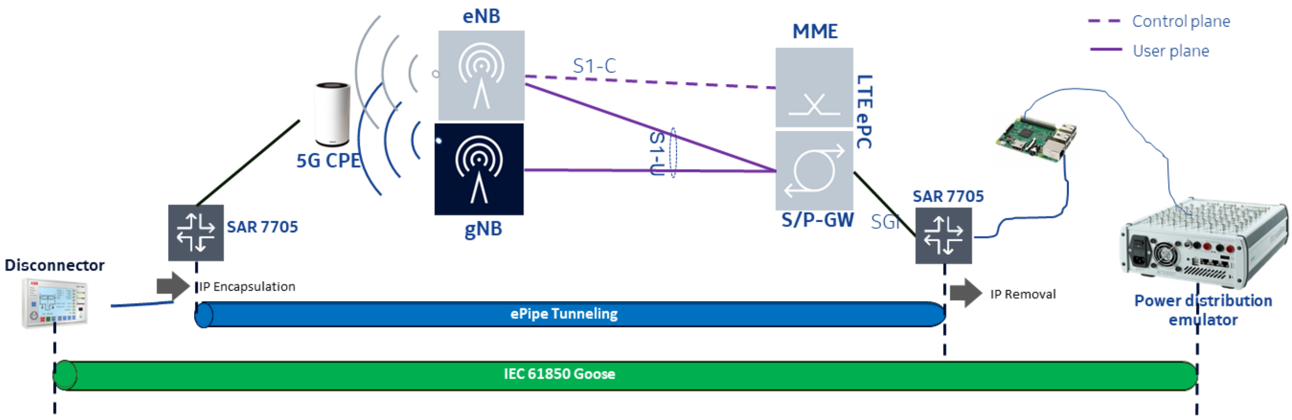

Figure 35: Set-up architecture of the first lab tests of the EDF smart energy experimentation

RAN + Core configuration:

RAN component: one 4G sector (Band 3; BW = 20 MHz) + one 5G sector (Band n78; BW=100 MHz)

Core: commercial Nokia 4G ePC

Device: Nokia 5G CPE (FastMile type)

Figure 36 shows the EDF experimentation in Nokia Paris Saclay premises.

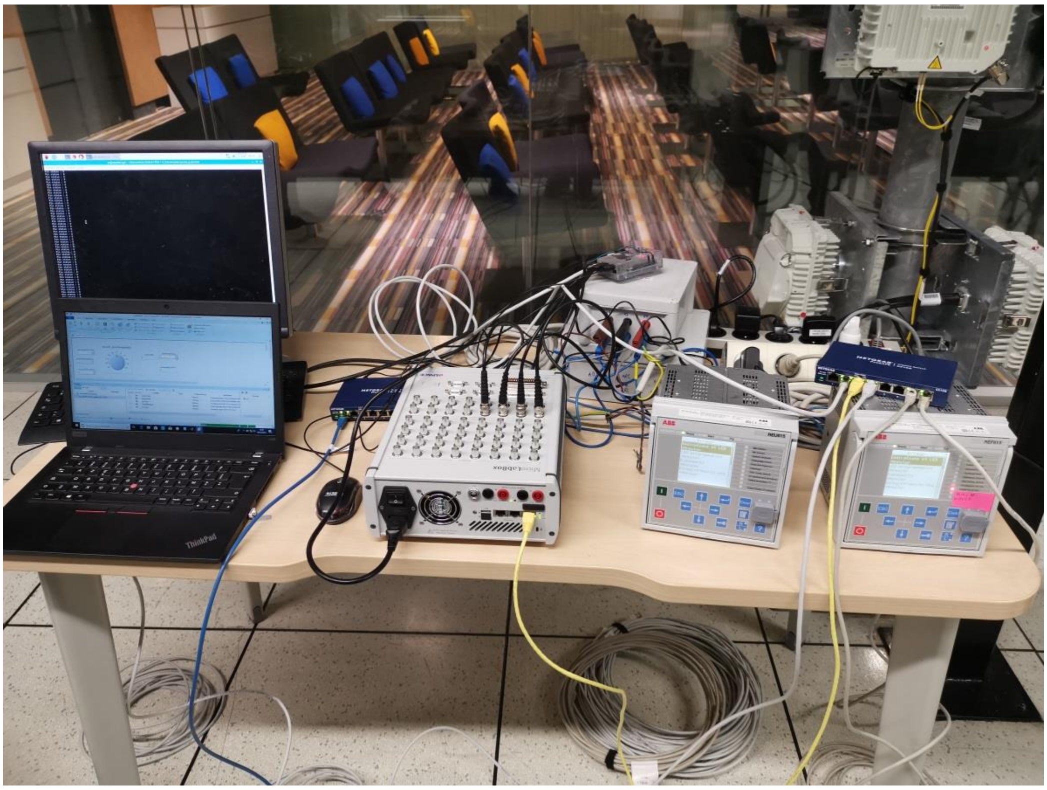

Figure 36: EDF set-up experiment in Nokia lab premises

<u>Preliminary performance results:</u>

The goal of this first step was to validate the concept with a 5G network and define the methodology how to measure the end to end latency (between the equipment sending the fault management message and the equipment controlling the energy production). During this experiment, this latency is measured between the 2 routers SAR on which a port mirroring has been configured. The measured latency to cross the network with 5G radio is in line with expectation. With a 4G radio the obtained results are the quasi-similar. This is not a surprising result given that the traffic is in downlink direction (the device sending the message is located in the core side). We made measurements by reversing the direction of the traffic (the equipment sending the message is connected to the mobile side). In that case, the 5G radio bring a significant gain in term of latency.

<u>Next step:</u>

- Use the Over the Air (OTA) network: The tests were carried out in the lab with the mobile installed in a faraday cage. We will try next time to use the OTA network covering the Nokia Paris Saclay site.
- This first test was made only with one protection equipment the ePIPE used allowed to ensure a point-to-point connection. But the goal is to be able to control several protections, the next test will be done with multipoint connection.
- Replace 7750 routers with software solutions that can be easily deployed as a service.

3.4.3.2 Greek site facility

Figure 37 below illustrates the physical set-up of the WINGS utilities small-scale pilot.

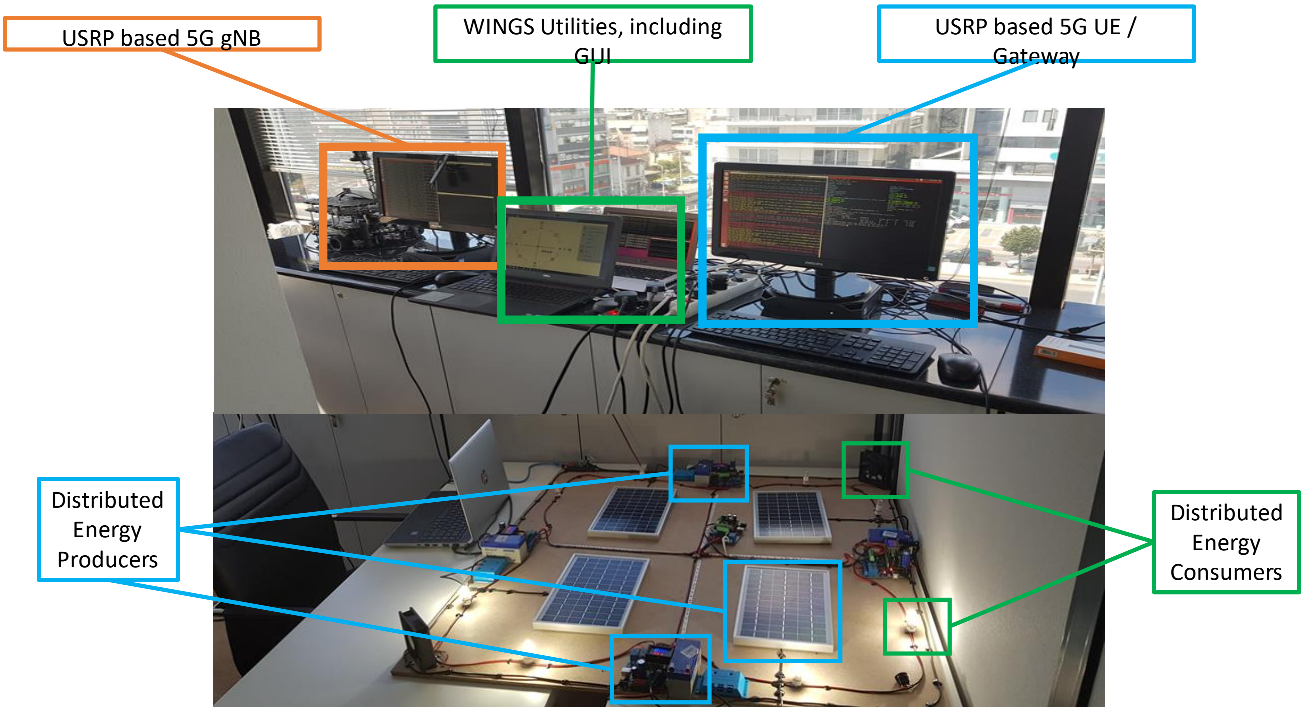

Figure 37: Utilities set-up experiment in WINGS premises

<u>Preliminary performance results:</u>

The main objective of this first version was the exploitation of data that are produced by sensors and derivation of knowledge that is useful for guaranteeing an efficient and seamless operation of smart energy grids. The result of the experiments was that the smart grid system was reliable 100% of the time. That means that when a fault situation occurred the smart grid restored itself in all experiments. The time for restoration, in this version, was a few seconds. With the utilization of 5G technologies, the expected result is that the restoration will take less than a second.

As a next step this work will be integrated and introduced to the main Greek site facilities hosted at OTE premises.

3.5 UC#5: Smart City

3.5.1 Description & KPIs

3.5.1.1 Italian site facility

Thanks to the pervasiveness of IoT devices, new applications can be devised for understand and manage the users' mobility in a town. The key observation is that most of the people moving in a city carry a smartphone, which typically allow to infer the mobility of the person in a seamless manner, specifically without the installation of any app. For example, the smartphones with enabled Wi-Fi interface send continuously messages to try to connect to nearby access point using. Thanks to the unicity of the MAC address used during the communication, it is possible to correlate the presence of the same smartphone under a sequence of passive Wi-Fi scanners and infer the mobility pattern of the corresponding user. The approach is still feasible in the presence of anonymization schemes to preserve the privacy, provided that the hash function adopted by the scanner is the same across the city.

In particular, the main objective of this use case is the management of large crowds, mainly students, in their daily commute between Politecnico di Torino and the Porta Susa railway station. The two sites are roughly 1 km apart, connected by a large avenue with many sidewalks and a bike path. It is estimated that around 20,000 students daily attend Politecnico during regular class semesters. No figures are currently available to

characterize the fraction of these students who move on the Politecnico-Porta Susa axis, and indeed one of the first objective of the use case would be to provide these figures, monitoring the flow of students during different times of day. It is to be remarked that a part of the students can be classified as "limited mobility" pedestrians, when they carry around large suitcases on their way to/from the railway station. The use case adopts real-time readings from 6 scanners that detect Wi-Fi probes transmitted by smartphones. These scanners are IoT devices connected to the 5G network and disseminated along the axis between the two sites, and on the sites as well.
The infrastructure deployed to achieve these "basic" monitoring goals will then enable additional services, which are outside the scope of this use case, but can help understanding the possible impact.

- Selection of best route/multimodality: leveraging the many vehicle-sharing opportunities provided by the City of Turin
- Crowd management at bus stops/station/classrooms and handling of critical events (severe weather/strikes/accidents/breakdowns) throughout push messages
- Real-time readings from sensors (weather/air pollution/proximity)
- Integration/merging of schedule of transportation and POLITECNICO events (classes, graduations, open days…)

The main KPIs for this use-case are provided by 5G networks in terms of Reliability and Availability that are mainly the KPIs requested by an mMTC solution.

3.5.1.2 Greek site facility

The Smart city use case pilot that will take place in the Athens site facility focuses on issues of i) Environment and smart homes, ii) Health monitoring and forecasting and iii) Smart mobility. For this pilot the WINGS STARLIT platform (Smart living platform powered by ArtIficial intelligence & robust IoT connectivity) will be exploited.

i) Environment and smart homes

According to the World Health Organisation (WHO): "Air pollution poses a major threat to health and climate". The combined effects of ambient (outdoor) and household (indoor) air pollution cause about 7 million premature deaths every year. More than 80% of people living in urban areas that monitor air pollution are exposed to air quality levels that exceed the WHO guideline levels"[3]. Part of this use case addresses ambient air quality monitoring and forecasting in outdoor environments. Alerts are issues when pollution exceeds predefined thresholds, while general health indications are provided. Air quality monitoring is achieved through a low-cost multi-sensor station measuring: O_3, CO, SO_2, NO, NO_2, PM1, PM2.5, PM10, noise, temperature and humidity. Similar parameters and functionalities are also offered for indoor environments. In terms of indoor environment STARLIT offers functions for learning the preferences of the user with respect to their indoor environment (temperature, humidity and luminosity, among others). In specific, STARLIT monitors (and learns from) the user's actions against a number of home devices installed within their home environment. For instance, actions relevant to adjusting the temperature (turning the heating/air-conditioning up/down), switching on/off or dimming the lights, etc. are recorded. Such records are accompanied by information relevant to date, time and outdoors (weather) conditions. This way, STARLIT gradually derives knowledge on the preferences of the user and starts applying this knowledge by autonomously and proactively adjusting the user's devices and home appliances. To this end, a number of sensors and actuators within the user's home environment, both COTS and ones developed by WINGS, are leveraged.

ii) Health monitoring and forecasting

With respect to remote health monitoring, this use case addresses monitoring and forecasting a user's health status and, potentially, their behaviour and identify possible irregularities that may call for medical treatment.

[3] https://www.who.int/airpollution/ambient/about/en/

Notifications/alarms are raised even in case something is not yet abnormal, but the recorded values show a trend towards a potential problematic situation. For instance, increasing blood pressure, which has still not reached a certain threshold, may still be worrying and alarms or suggestions could be offered so as to avoid reaching the aforementioned threshold. The acquired knowledge may also be exploited for automated decision-making considering the user's health status. Advanced ML algorithms are exploited for the prediction of future vital signs. Notifications are issued to an application running on the user's smartphone, informing them about possible upcoming health situations.

iii) Smart mobility: personalised navigation within the smart city

Finally, STARLIT provides personalised assistance to individuals indoors and outdoors by processing environmental data, such as pollen and pollution levels in the air, and combines them with traffic and additional weather data to provide a personalized navigation user experience within the city, e.g., avoiding routes with increased pollen count in case of allergies. STARLIT surpasses the competitive solutions, which do not usually have the user at the centre of attention or do they offer health- or wellbeing-related added-value services. STARLIT also draws information on nearby Points of Interest (POIs) or on POIs within the user's route and provides the respective suggestions, as well as real-time notifications/alerts in case there is a relevant update (e.g., cancellation of a concert due to weather conditions). The mobile application offered to the user allows the completion of a thorough user profile, personal details, preferences and limitations are completed there in favour of personalised and targeted navigation and suggestions.

KPIs
The main 5G related KPIs for this pilot include the following:

- **mMTC** slices for aggregating various kinds of information as described above in the context of continuously monitoring the users and the city.
  KPIs: latency ~20-50 *ms*
- **uRLLC** slice for disseminating critical information, such as in the case of re-routing due to urgent city incidents.
  KPIs: latency ~10 *ms*
- **eMBB** slice for providing support to caregivers through live streaming of the user's status while on route to the hospital.
  KPIs: latency ~ 20 -50 *ms*; speed spanning 15Mbps-50Mbps.

In addition, vertical KPIs have been specified including (a) accuracy of notifications and alerts (b) time required for STARLIT/STARLIT app adaptation to a home environment forecast, (c) average data retrieval (e.g., w.r.t. also to the number of data sources).

3.5.2 Integration, test and validation planning

3.5.2.1 Italian site facility

Six Wi-Fi scanners have been installed in the area between Politecnico di Torino and Porta Susa and have been integrated in the OneM2M platform of TIM. Each scanner periodically reports the list of the MAC addresses that have been passively discovered during the last sampling period, with an indication of the strength of the signal. A specific Network Function (NF) is devoted to the evaluation of the users' mobility and it is virtualized through 5G EVE NFV MANO and Experiment management system. Through REST APIs and a MQTT client, the NF interacts with the OneM2M platform to receive the updated report of the users under coverage of each Wi-Fi scanner and infer the mobility pattern of each user. Thanks to the distributed nature of the algorithm to infer the mobility of each user, many NFs can be instantiated to parallelize the computation of the mobility pattern and allow the scaling of the approach to a large number of users.

Figure 38 shows our planned roadmap in the Italian site facility that will evolve through the following steps:

1. Complete installation and testing of the 6 scanners
2. Finalization and offline testing of the flow detection NF
3. Automatic deployment of the NF on 5G EVE platform and testing
4. KPI measurement and validation

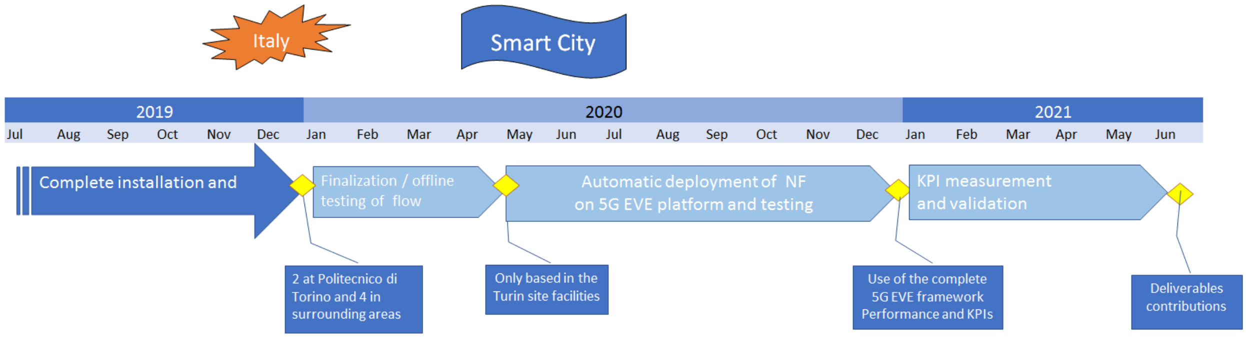

Figure 38: Smart City Italy: Use Case roadmap

3.5.2.2 Greek site facility

For the Athens site Figure 39 depicts a high-level view of the currently envisaged set-up of the components and equipment related to the Smart City use case. Deployed devices include as already mentioned sensors for measuring indoor temperature, indoor humidity, indoor luminosity, indoor and outdoor air quality (CO, CO_2, SO_2, PM2.5, PM10, O_3) and actuators for a fan and lights. These are combined with data retrieved on traffic and weather from Open APIs (Google Maps, Dark Sky) and emulated vital signs measurements (heart rate and blood pressure). Measurements from the various devices and other data sources are sent to the STARLIT platform, over an mMTC slice, and the platform processes the measurements, generates forecasts on the status of various parameters and triggers actions related to Automated indoor environment adaptation, Air Quality monitoring, Health monitoring and personalised route suggestion. The STARLIT platform leverages diverse communication technologies and communication protocols. Key functional components include Data ingestion and management, Data analysis and visualisation Dashboards.

The Data ingestion and management comprises various functionalities for deriving the data from the various devices and delivering them to any other platform components, services and applications as well as triggering actuators. The data ingested into the system is processed but also stored in a hybrid database system that comprise various types of Databases (DBs) (e.g. NoSQL, HDFS based, etc) for various types of information such as raw data from devices, knowledge derived through data analytics and learning mechanisms, information on available devices and services. Data analysis, insights and predictions comprise functionalities for monitoring, event-detection, forecasting of events and issues, large-scale data processing, image processing and automated decision making. The Data analysis mechanisms continuously run, retrieving data from available data sources and applications and update the inferred data and knowledge stored in the platform databases. As part of the STARLIT platform dashboards are provided for visualization of measurements on interactive graphs, notifications and alerts. Dashboards are provided as web-based UIs that can run from any tablet, smartphone or PC.

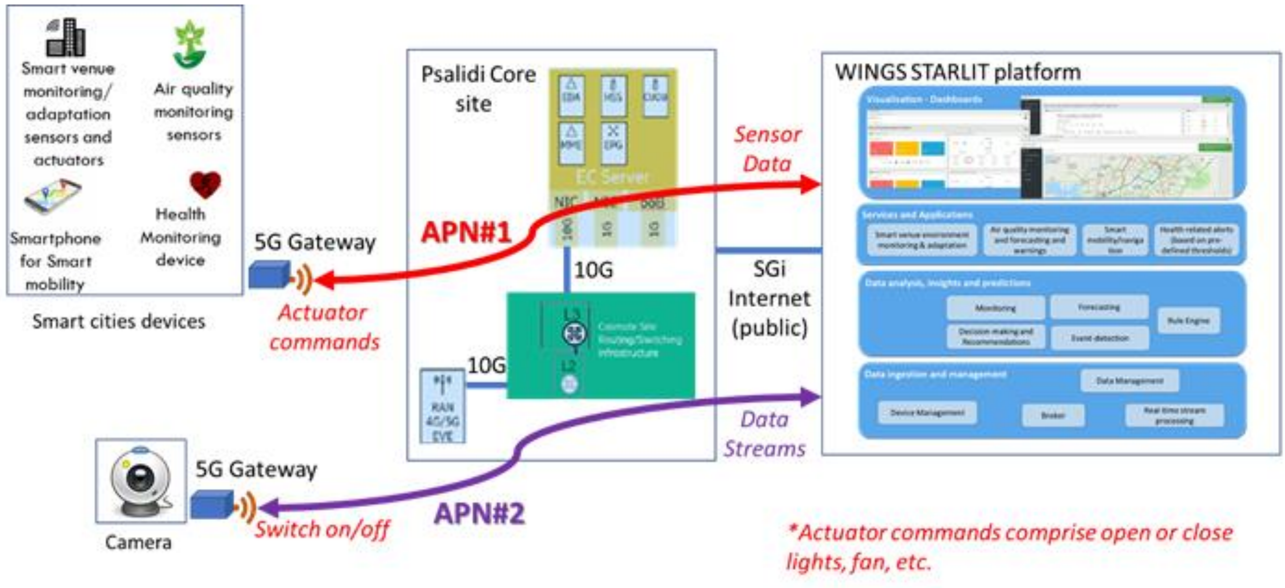

Figure 39: High-level view of Smart City pilot set-up

The roadmap for the Athens Smart City use-case is depicted in Figure 40.

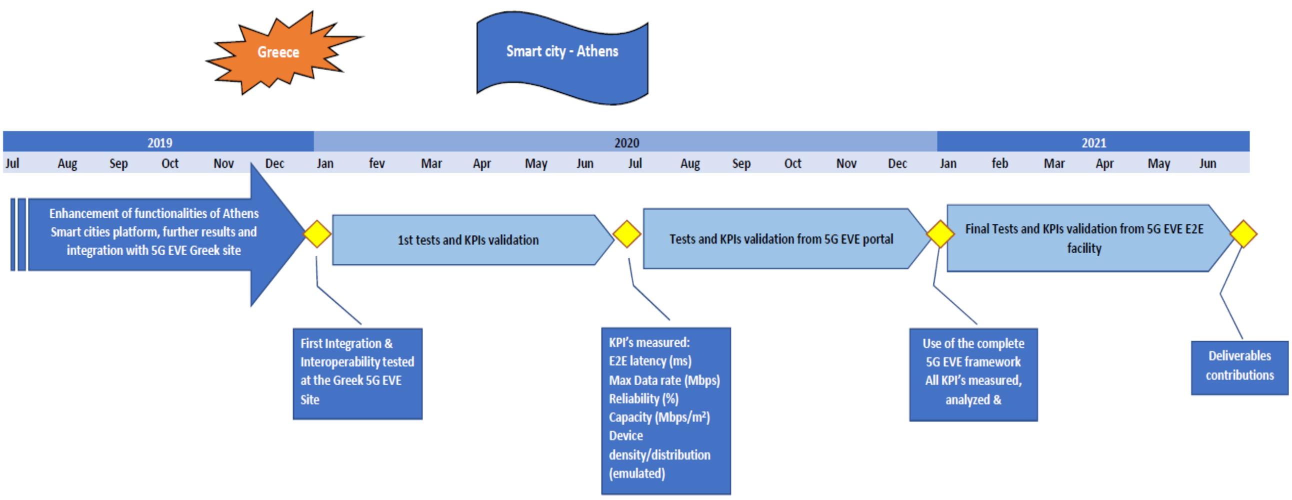

Figure 40: Smart City Athens: Use Case roadmap

3.5.3 Preliminary performance results

3.5.3.1 Italian site facility

The following graph shows the number of anonymized MAC addresses (denoted as "probes") recorded under the coverage of two Wi-Fi Scanners (#4 and #5) for a duration of three weeks. As expected, the number of probes (Figure 41) follows a double level of periodicity: i) a daily periodic pattern due to the day/night succession, and ii) a weekly periodic pattern due to the weekdays/weekend succession. Thanks to the availability of an internal database mapping the anonymized MAC addresses to a generic student (Figure 42) or a generic employee (Figure 43) of Politecnico, we were able to differentiate the probes and achieve a social-based view of the mobility of the users, as denoted in the following two graphs:

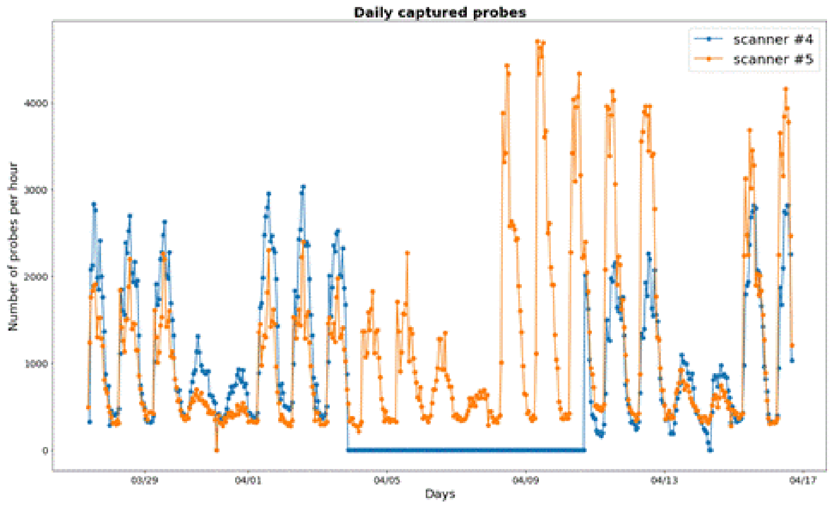

Figure 41: Number of probes under the coverage of a Wi-Fi scanner

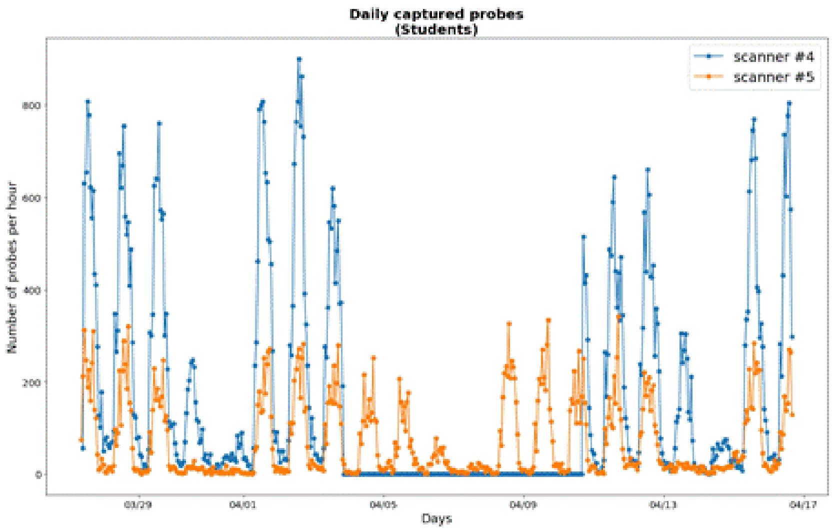

Figure 42: Number of probes for Politecnico students

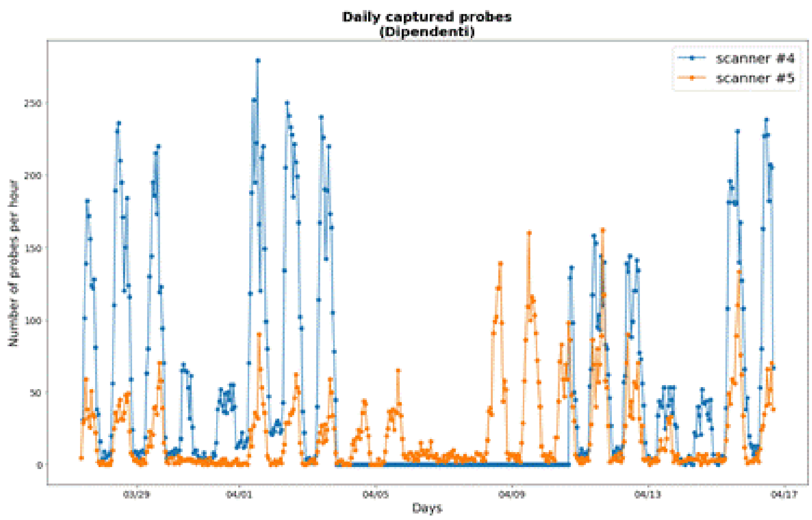

Figure 43: Number of probes for Politecnico employees

3.5.3.2 Greek site facility

For the Athens site both some preliminary results are displayed through the corresponding Graphical User Interfaces in Figure 44 - Figure 48. These have been collected from a standalone, small scale implementation. Further results will be collected as work on the integration within the Athens node continues. As can be observed in the health monitoring and forecasting scenario the average time required to predict an irregularity in the users' vital signs is 0.05 sec. In the case of indoor environment monitoring and adaptation the average data retrieval time is approximately 5.709 sec. For air quality monitoring both indoors and outdoors the average time required to identify an event such as air quality exceeding predefined thresholds is approximately 1.11 sec. For the smart mobility case the overall application adaptation time that was measured consists of the time required for the processing of the data (user health status, environmental data, weather and traffic data) and sending back to the mobile application the derived optimal route for a selected destination. The average time for this measurement was about 10.5 seconds.

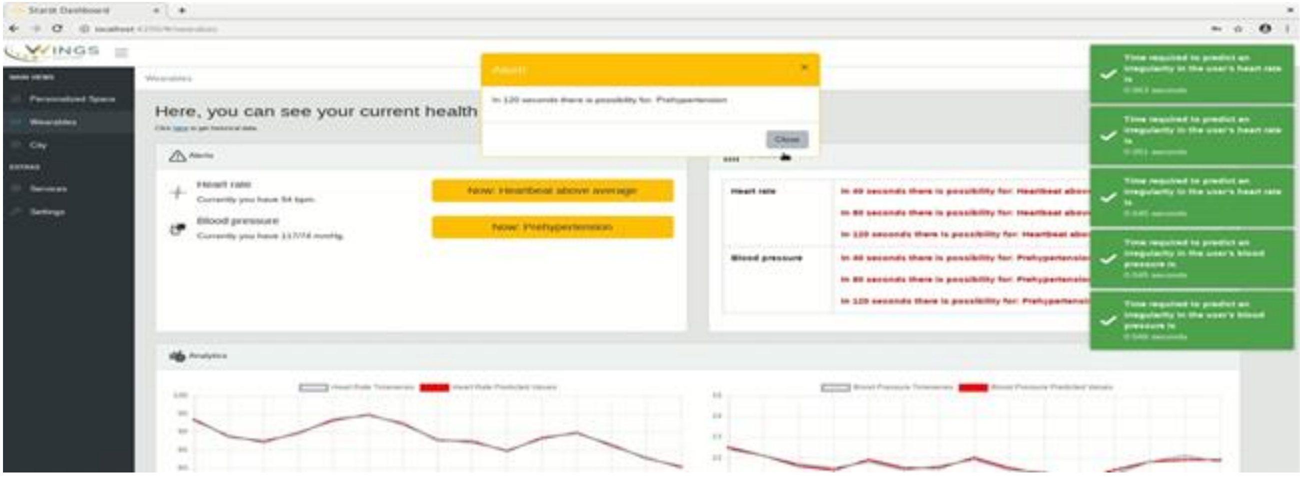

Figure 44: View of Smart City platform dashboard for Remote Health Monitoring and Forecasting

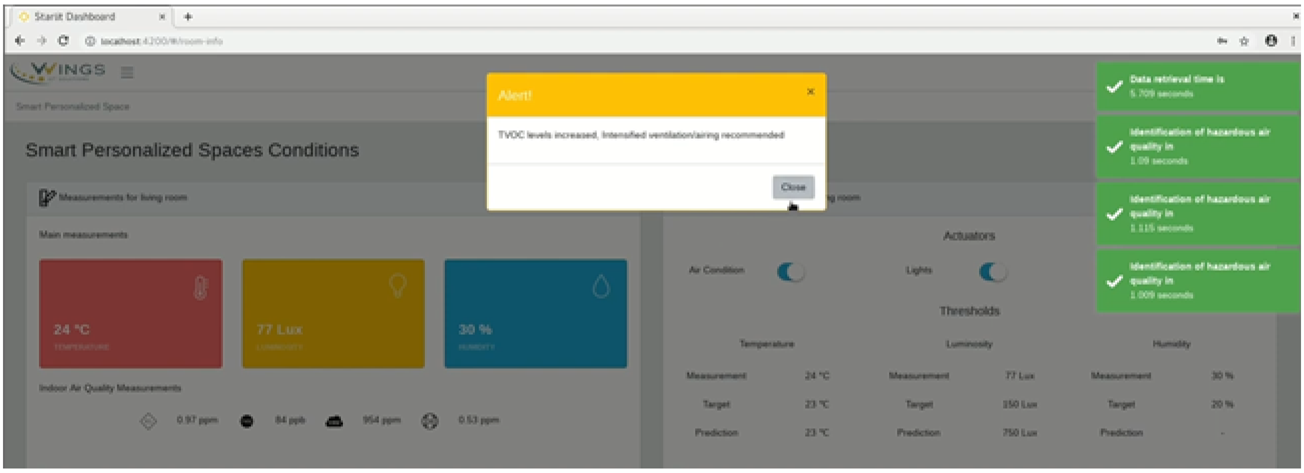

Figure 45: View of Smart City Dashboard for Automated Indoor Environment adaptation

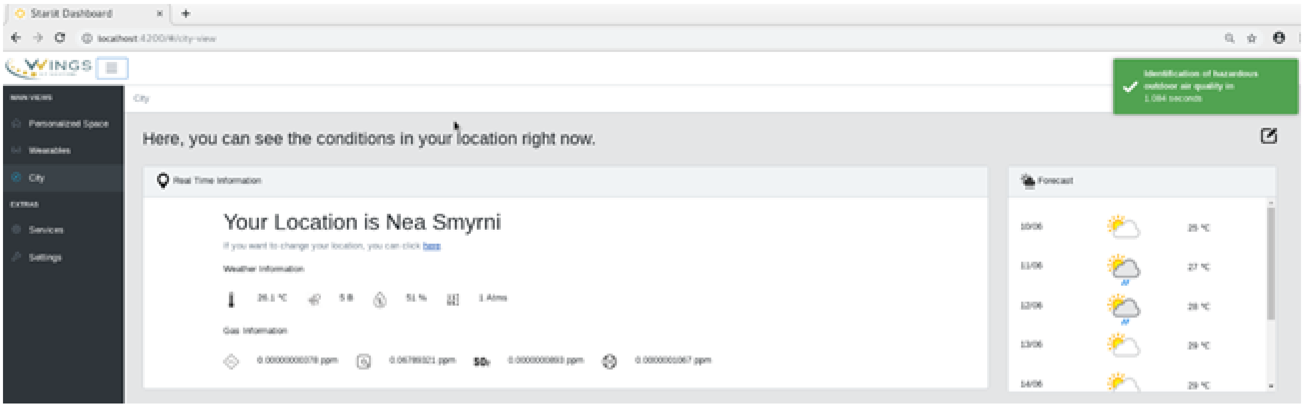

Figure 46: View of Smart City Dashboard for Outdoor Air Quality monitoring

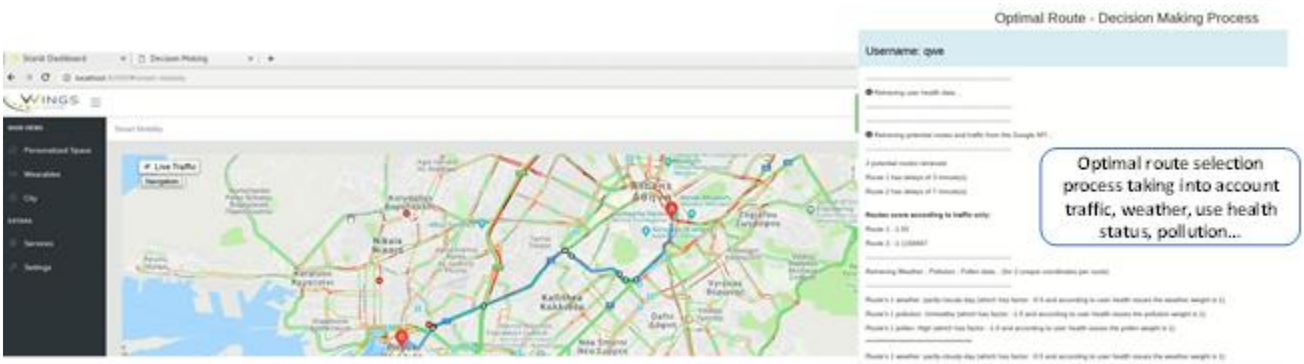

Figure 47: View of Smart City Dashboard for optimal personalised routing

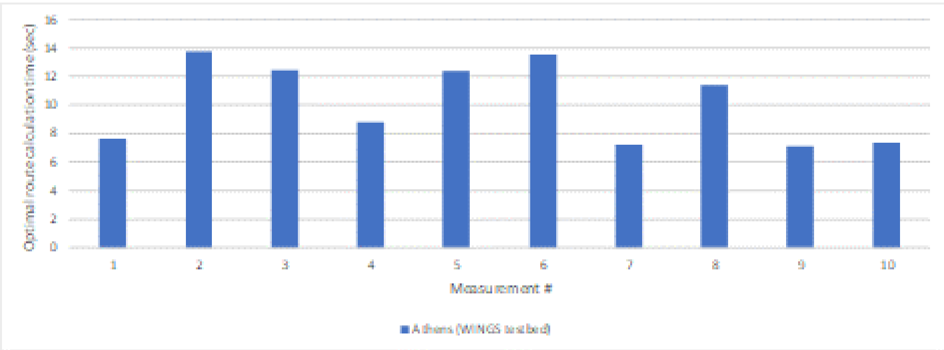

Figure 48: Application adaptation time for Smart mobility

3.6 UC#6: Media & Entertainment: UHF Media, On-site Live Event Experience, Immersive and Integrated and Virtual visit over 5G

3.6.1 Description & KPIs of the UC#6

3.6.1.1 Description & KPIs for Ultra High-Fidelity Media

Ultra High-Fidelity Media experience with highly immersive viewing experience and ultra-crisp, wide-view pictures will be made possible through the use of both linear (e.g. live programming, streaming) and non-linear (e.g. on-demand) content. To guarantee this high quality of experience, the future 5G network should be able to support efficient network management high speed transport capabilities and strategies, e.g. by means of local and network caching of content.

In Table 11, we can see the targeted KPIs, split in two phases. The latency is not a key KPI, while peek user throughput is critical. In the first phase of the project the target is 166 Mbps for cell node and 249 Mbps during the second phase.

Table 11: KPIs for Ultra-High Fidelity Media

		Units	Use Case 6: Media & Entertainment (SP-TELEFONICA)	Priority	Range	
			eMMB[10]		Min	Max
1	Latency (in miliseconds) - Min/MAX	msec	100		500	100
2	Speed (in Mbps) - Min/MAX - sustained	Mbps	0		0	0
3	Reliability (%) - Min/MAX	%	99%		99%	99%
4	Availability (%) - Min/MAX	%	99%		99%	99%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/hour	50		0	50
6	Broadband Connectivity (peak demand)	Mbps	249		166	249
7	Network Slicing (Y/N)	Y/N	Y		N	Y
8	Security (Y/N)	Y/N	N		N	N
9	Capacity (Mbps/m^2 or Km^2)	Mbps/Km^2	1,529		1,018	1,529
10	Device Density	Dev/Km2	13,804		8,282	13,804

<u>Ultra High-Fidelity Media – Phase 1</u>

2019 scenarios for initial deployments

- Urban scenarios
- Up to 100-200 Mbps TV delivery per mobile cell with allocated bandwidth of 55 MHz
- Reusing part of available spectrum currently owned by Telefonica for LTE, so Carrier aggregation on separate bands must be supported
- Configuration must support a mix of SD 60%, HD 25% and 4K 15% live channels distribution to mobile users
- Some users may be connected to 3.5 GHz band
- 90% live TV, 10% VOD

<u>Ultra High-Fidelity Media – Phase 2</u>

- 2020 scenarios for massive deployments
- Urban scenarios
- Up to 150-250 Mbps TV delivery per mobile cell with allocated bandwidth of 50 MHz in the 3.5 GHz band
- Configuration must support a mix of SD 40%, HD 35% and 4K 25% live channels distribution to mobile users
- Some users may be connected to 3.5 GHz band
- 70% Live TV, 30% VOD

3.6.1.2 Description & KPIs for on-site Live Event Experience

On-site Live Event Experience will be made possible in large scale event sites, such as cinemas, stadiums and hall parks leading to enhanced viewing experience (replay, choose a specific camera, etc). Telefonica Movistar is producing and distributing many TV events in Stadiums, car Racing, Sport Events and Telefonica wants to deliver some TV events in on-site places, on limited coverage areas. The main targeted KPIs are defined in Table 12 for this Live Event experience use case.

Table 12: KPIs for on-site Live Event Experience

		Units	Use Case 6: Media & Entertainment (SP-TELEFONICA) On-site Live Event Experience	Priority	Range	
			eMMB[10]		Min	Max
1	Latency (in miliseconds) - Min/MAX	msec	100		500	100
2	Speed (in Mbps) - Min/MAX - sustained demand	Mbps	0		0	0
3	Reliability (%) - Min/MAX	%	99%		99%	99%
4	Availability (%) - Min/MAX	%	99%		99%	99%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/hour	0		0	0
6	Broadband Connectivity (peak demand)	Mbps	122		84	122
7	Network Slicing (Y/N)	Y/N	Y		N	Y
8	Security (Y/N)	Y/N	N		N	N
9	Capacity (Mbps/m^2 or Km^2)	Mbps/Km^2	12150,000		8360,000	12150,000
10	Device Density	Dev/Km2	4000,000		4000,000	4000,000

On-site Live Event Experience – Phase 1

- 2019 scenarios for initial deployments
- Urban scenarios: Downtown areas
- Up to 40-80 Mbps TV delivery per mobile cell with allocated bandwidth of 20 MHz
- Realtime video Uplink from connected cameras (encoded video sources) of up to 4 cameras @10 Mbps - @2 Mbps (20-40 Mbps total uplink)
- Configuration must support a mix of SD 60%, HD 25% and 4K 15% live channels distribution to mobile users

On-site Live Event Experience – Phase 2

- 2020 scenarios for massive deployments
- Urban scenarios: Stadiums, Race places, Downtown open areas
- Up to 60-120 Mbps TV delivery per mobile cell with allocated bandwidth of 20 MHz in the 3.5 GHz band
- Realtime video Uplink from connected cameras (encoded video sources) of 4 cameras @15 Mbps - @3 Mbps (30-60 Mbps total uplink)
- Configuration must support a mix of SD 40%, HD 35% and 4K 25% live channels distribution to mobile users

3.6.1.3 Description & KPIs for Immersive Virtual Visitors

Immersive Virtual Visitors should benefit from 360° media delivery in a quality that may allow replacing a physical visit with a virtual one, therefore one general requirement is to support the streaming of 360° video matching the highest quality supported by high-end head mounted displays Telefonica Movistar is an IPTV Multicast platform including live and on-demand channels for high quality TV (up to 4K video service). Telefonica wants to deliver immersive and Integrated Media in massive scenarios. This is a new video delivery format, so must be introduced in the massive delivery networks like natural evolution of digital video. The new formats may be applied in many different configurations, including some for low latency as mentioned in Table 13.

Table 13: KPIs for Immersive and Integrated Media

		Units	Use Case 6: Media & Entertainment (SP-TELEFONICA) Immersive and Integrated Media	Priority	Range	
			eMMB[10]		Min	Max
1	Latency (in miliseconds) - Min/MAX	msec	100		500	100
2	Speed (in Mbps) - Min/MAX - sustained demand	Mbps	1		0	1
3	Reliability (%) - Min/MAX	%	99%		99%	99%
4	Availability (%) - Min/MAX	%	99%		99%	99%
5	Mobility (in m/sec or Km/h) - Min/MAX	Km/hour	0		0	0
6	Broadband Connectivity (peak demand)	Mbps	127		83	127
7	Network Slicing (Y/N)	Y/N	Y		N	Y
8	Security (Y/N)	Y/N	N		N	N
9	Capacity (Mbps/m^2 or Km^2)	Mbps/Km^2	12666,667		8333,333	12666,667
10	Device Density	Dev/Km2	2500,000		2500,000	2000,000

Immersive and Integrated Media - Phase 1

- 2019 scenarios for initial deployments
- Urban scenarios, very scalable, MEC required
- Up to 40-80 Mbps TV delivery per mobile cell with allocated bandwidth of 20 MHz
- Realtime video Uplink from connected cameras (encoded video sources) of up to 4 cameras @10 Mbps - @2 Mbps (20-40 Mbps total uplink)
- Configuration must support a mix of HD 75% and 4K 25% live channels distribution to mobile users
- Some users may be connected to 3.5 GHz band

Immersive and Integrated Media - Phase 2

- 2020 scenarios for massive deployments
- Urban scenarios, MEC required
- Up to 60-120 Mbps TV delivery per mobile cell with allocated bandwidth of 20 MHz in the 3.5 GHz band, but other bandwidth can be explored
- Realtime video Uplink from connected cameras (encoded video sources) of 4 cameras @15 Mbps - @3 Mbps (30-60 Mbps total uplink)
- Configuration must support 4K 100% live channels and VOD distribution to mobile users
- Some users may be connected to 3.5 GHz band

3.6.1.4 Description & KPIs for video 360° virtual visit

The Virtual Visit video 360° use case is proposed by Orange France and is related to video 360° transmission. This use case promotes enhanced Mobile BroadBand (eMBB) and URLLC scenario with high data rates and low latency requirements. The main objective is to contribute on the identification of application-layer performance metrics relevant to a 360° video streaming service as well as on the identification of 5G performance metrics that are expected to be the key drivers for the performances of a 360° video streaming service. Orange will integrate a 360° video streaming platform including contents, streaming servers, and head-mounted-displays to 5G EVE's site facility. On this basis, the tools necessary for collecting the application-layer performance metrics will be developed and integrated with the testing frameworks developed in the project in order to feed a cross-layer dataset that would then be leveraged by Orange to provide an analysis of the correlation 5G network performances and 360° video streaming performances.

As mentioned in [1] (Table 27), the 2 main requested KPIs are the data throughput around 80 Mbps max per user and the latency where the minimum requested in 10ms but without any idea about the maximum that can be supported to avoid the nausea phenomena that is the critical topic for such VR application.

3.6.2 Integration, test and validation planning

3.6.2.1 Media & Entertainment in Spanish site facility

The first E2E 5G platform has been mounted and configured in the lab to start with the Use Case Tests. Figure 49 includes all the critical elements in the lab, while Figure 50 depicts the three tests and some load tests which have been prepared for the Vertical KPIs validations, including the MEC-based video reference streamers. Finally, Figure 51 gives the different deadlines of the media and entertainment integration, tests and validation in the Spanish site.

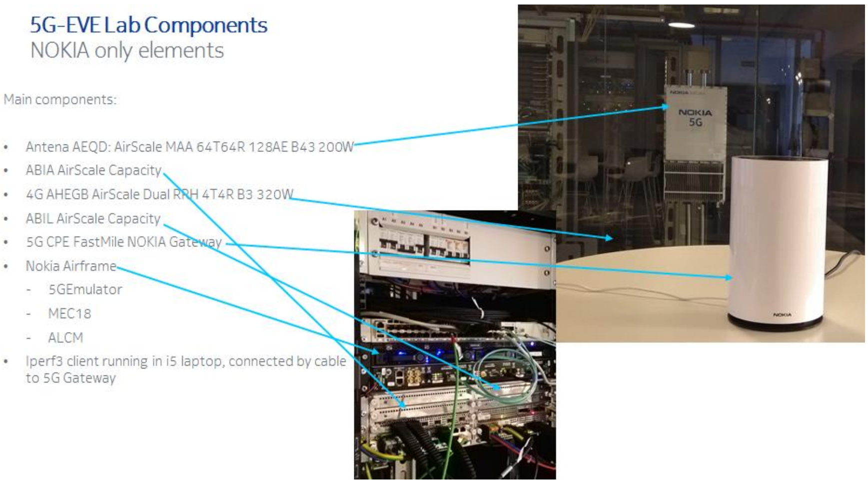

Figure 49: Initial lab Test hardware

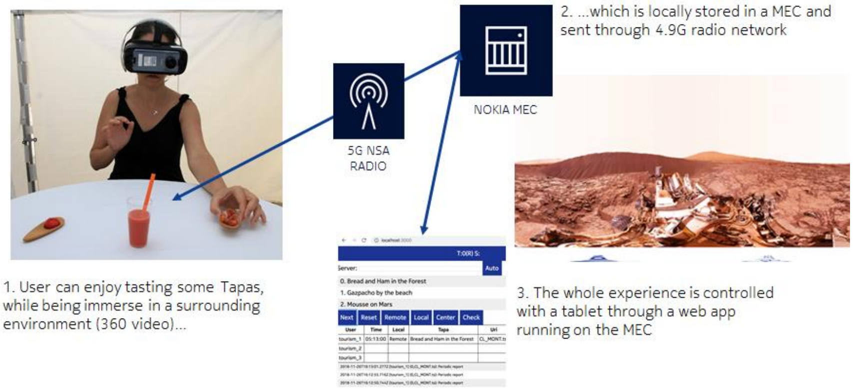

Figure 50: Tests and Measures environment deployed in virtual MEC

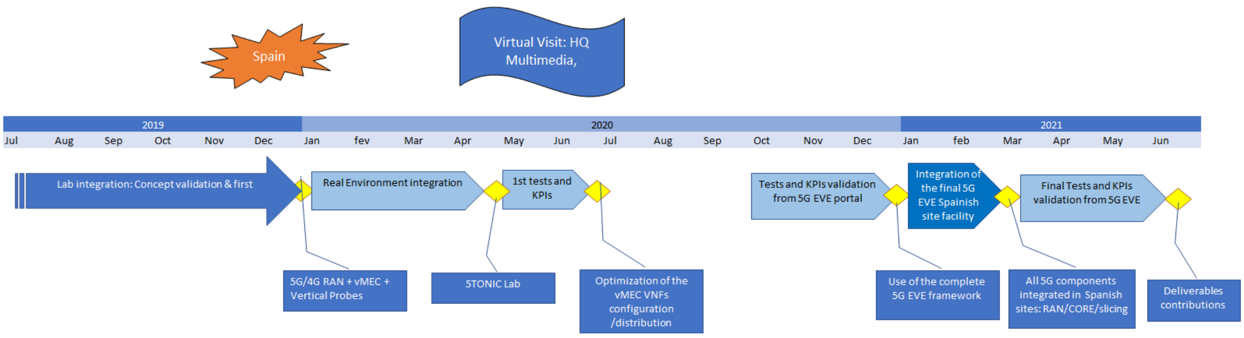

Figure 51: Integration, test and validation planning schedule for the Media and Entertainment use-case

3.6.2.2 Video 360° virtual visit in French site facility

A first and complete E2E transmission (Video server, CORE, RAN LTE) based on OAI that integrates the video 360° use-case has been implemented and validated in Lab. This set-up has been presented in video during the EuCNC conference where the general architecture is depicted in the Figure 52. Currently the different VNFs (ePC, RAN, video server) necessary to deploy this use-case from ONAP are in process of onboarding. This will lead to deploy in distant French sites the vertical by mutualizing some functionality such as the video server and the Core network that will be maintained locally in the Orange Châtillon site. Tests about the VNFs repartition in the different sites will be evaluated.

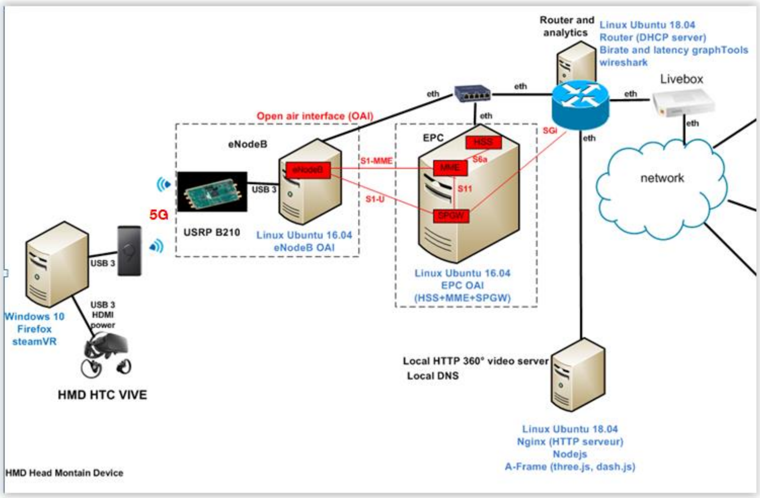

Figure 52: Video 360° use-case architecture deployment

In Figure 53 is illustrated the video 360° scene as viewed in the Head Mounted Display. Below the view, we can notice some data traffic measurement in the application level.

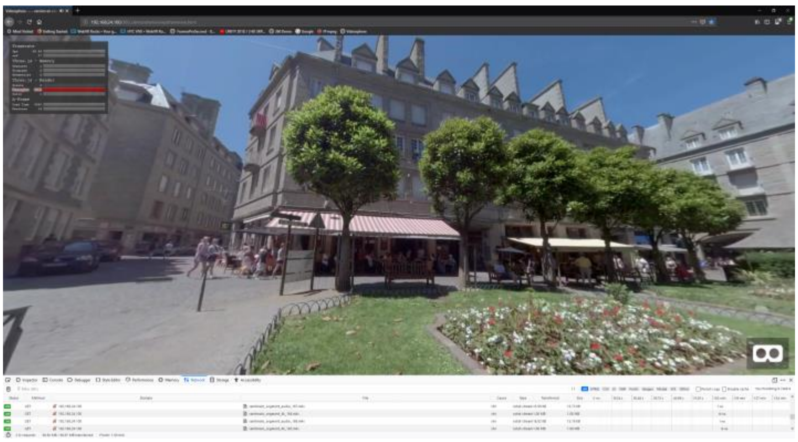

Figure 53: Video 360° scene as viewed in the HMD

As already noticed, these first preliminary tests have been carried out in lab. At short terms, it is planned to deploy this use-case in indoor and in outdoor environments to validate the behaviour in real environment and making real field trials with testers for validation of users acceptance. Figure 54 gives the main deadlines for achieving the complete tests for this use-case.

Table 14 gives a first tentative roadmap of the integration of the internal verticals with the main KPIs that are programmed to be evaluated in the French site facility.

Table 14: Video 360° roadmap and KPIs in the French sites facilities

Use-Case	Jan 2020	Jul 2020	Jan 2021	Jun 2021
Virtual video 360° visit	Integration & Interoperability tested At French sites facilities: b<>com, Eurécom, Nokia	KPI's measured in NSA: KPI-1: Latency, KPI-2: Throughput -> impact on nausea level ->impact of buffer occupancy At French sites facilities: b<>com, Eurécom, Nokia	All KPI's measured in SA, analysed & validated At French sites facilities: b<>com, Eurécom, Nokia and Orange	All KPI's measured, analysed & validated -> report on the use-case performance At French sites facilities: b<>com, Eurécom, Nokia and Orange

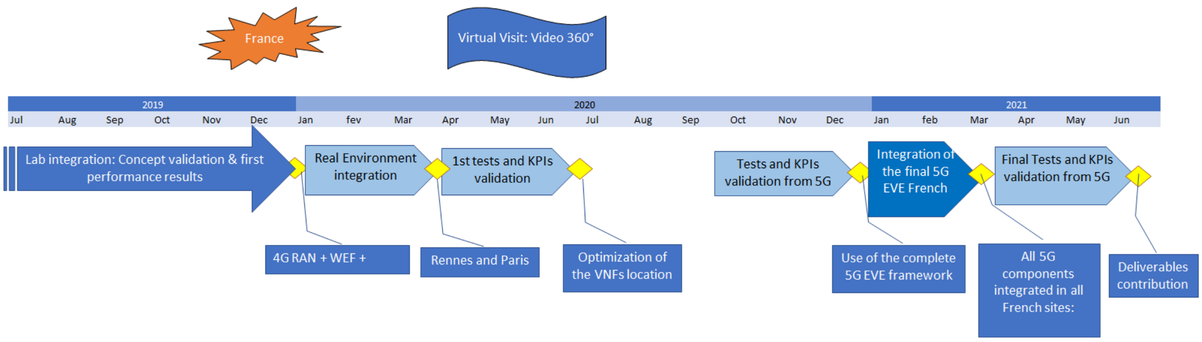

Figure 54: Integration, test and validation planning schedule for the video 360° use-case

3.6.3 Preliminary performance results

3.6.3.1 Media & Entertainment

Videos for the test can be reviewed with a mobile application. The live channels are ingested in real time in the platform from a Telefonica fibre IPTV subscription and transformed by the MEC in adaptive streaming video channels that can be delivered in real time to the 5G mobile subscribers. The Figure 55 presents the web application version for testing purposes.

Several automatic tests can be scheduled in the lab environment that can execute several tests in real mobile 5G terminals that simulate several parallel streaming clients. In the Figure 56, we can see an iterative test to verify the maximum throughput in Uplink and in Downlink in the 5G deployment. The measures are recorded in the virtualized MEC and also presented in a graph. The test results, with the logged information will be integrated with the 5G EVE vertical operator GUI.

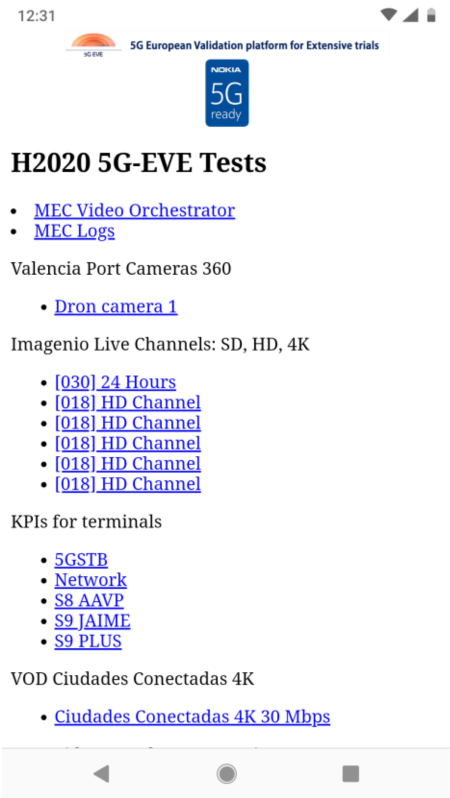

Figure 55: Web application for vertical tester

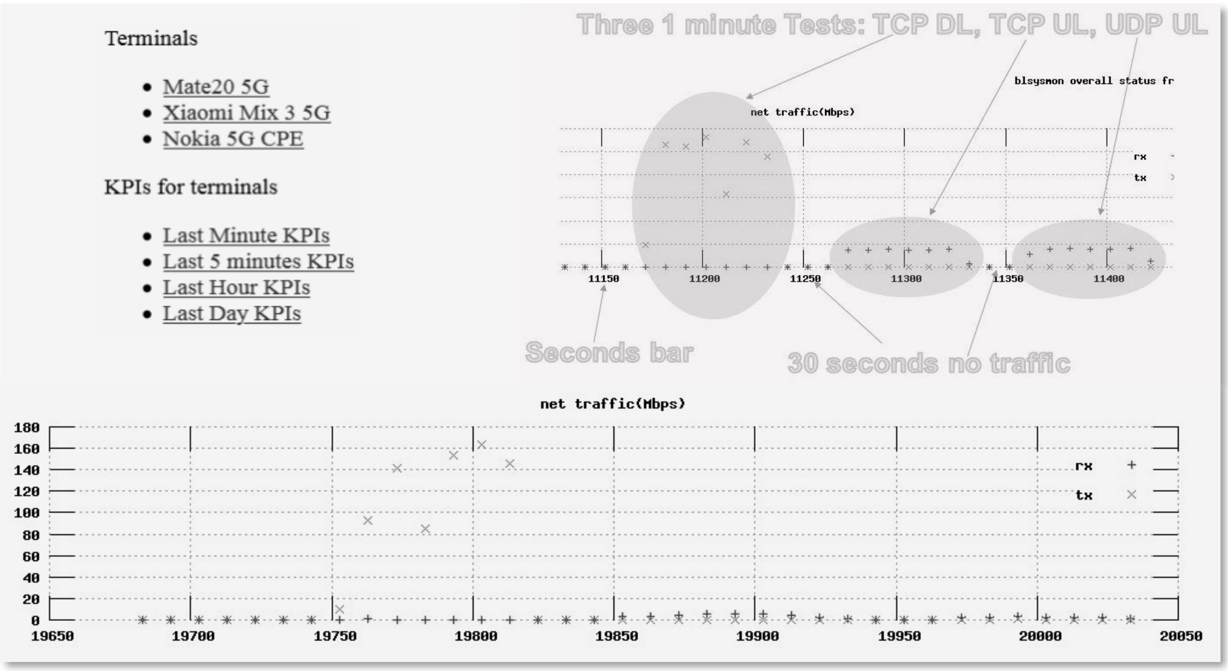

Figure 56: Automatic tests preliminary results

3.6.3.2 Video 360° virtual visit

Preliminary performance evaluation, obtained with some developed metric tools as depicted in Figure 57 has been measured **in lab** when integrating the video 360° use-case in the LTE OAI framework, validating the E2E transmission. Among the main metrics that have been measured, we can notice:

- The information about the packet data transfer and the buffer occupancy. This information is crucial for the video fluidity and for the QoE for the user;
- We have also monitored the data throughput (up to 34 Mbps in DL and 17 Mbps in UL) and the latency at different levels. The current RTT latency (OAI RAN LTE + ePC) has been measured with sporadic traffic of latency from a smartphone with very good transmission conditions:
    - with speedtest.net : 53ms
    - with nperf : 38ms
    - with a ping from a server at the edge (RAN - EPC – Server behind the Gi : in the same lab) : between 21ms and 33ms with an average between 27ms and 30ms.

During a speed test / nperf downloading (we are adding the queuing latency in the eNodeB):

- between 107 (min) and 223 ms (max) when downloading
- between 103 (min) and 425 ms (max) when uploading

In that specific case (lab environment with all materials locally installed), no nausea phenomena was detected when showing the VR video transmission that confirmed a good QoE.

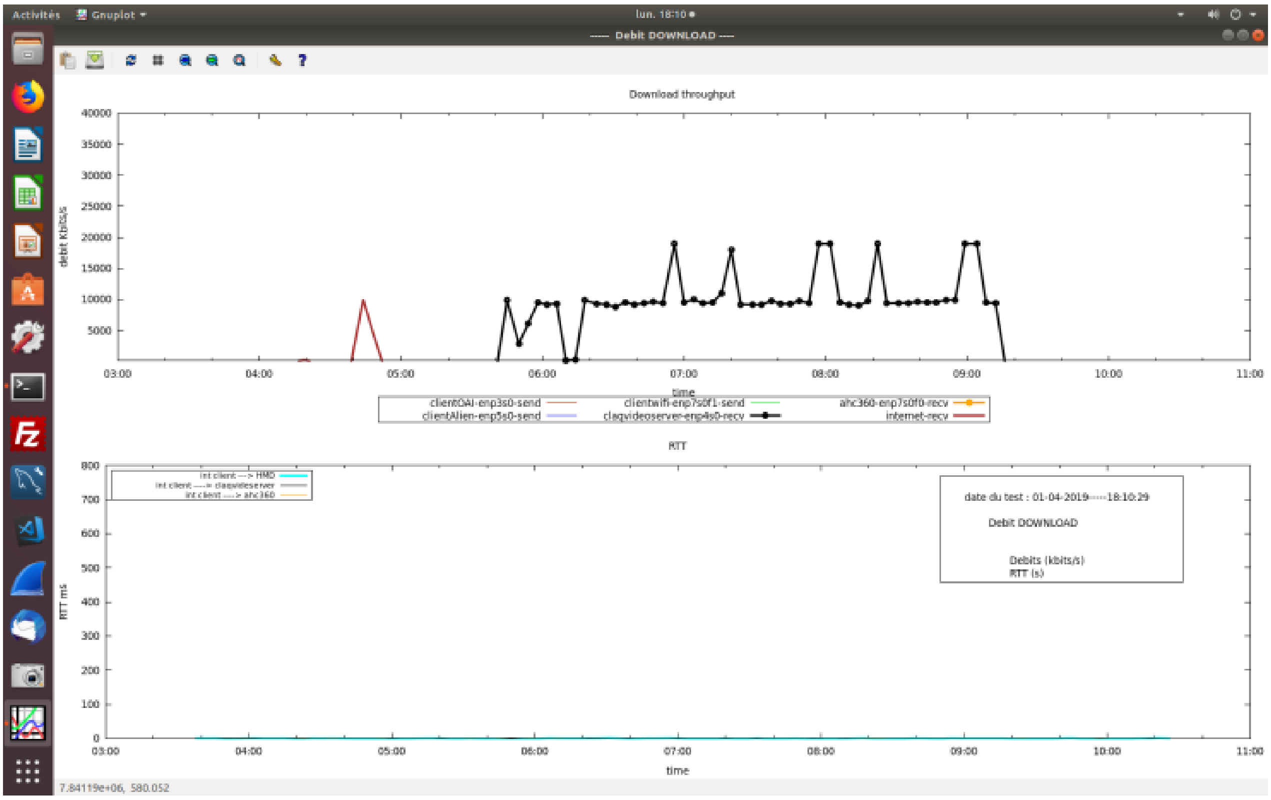

Figure 57: Example of video 360° performance results (data throughput, latency)

4 5G EVE external use-cases (ICT-19/22)

4.1 Introduction

In addition to the six first internal verticals, the 5G EVE facility shall support the validation of use-cases of a number of ICT-19/22 projects, aiming at scaling the business and societal impact of the initiative. As a relevant part of this objective the actual substantiation, validation and proactive demonstration and dissemination of these vertical use-cases over the 5G EVE Platform is also pursued. [6] gives a first KPIs analysis of the different ICT19/22 projects verticals. This analysis is similar of what was carried out for the internal 5G EVE use-cases [1].

4.2 5G TOURS (ICT-19)

4.2.1 Brief project description

5G-TOURS [18] will deploy full end-to-end trials to bring 5G to real users for thirteen representative use cases. The project will provide efficient and reliable close-to-commercial services for tourists, citizens and patients in three different types of cities: (i) Rennes, the safe city where e-health use-cases will be demonstrated; (ii) Turin, the touristic city focused on media and broadcast use cases; and (iii) Athens, the mobility-efficient city that brings 5G to users in motion as well as to transport-related service providers. These services will not only improve the quality of life for citizens and tourists, but also represent an important business opportunity as they address industry segments accounting for more than 50% of the estimated revenues generated by verticals.

The fundamental feature of the 5G-TOURS concept is the dynamic use of the network to seamlessly provide different types of services adapted to the specific needs of individual use cases. 5G-TOURS will enable different capabilities such as network slicing, virtualisation, orchestration or broadcasting as well as additional features developed by the project to bring more flexibility and improved performance. The ambition is to fully demonstrate pre-commercial 5G technologies at a large scale, showing the ability of the 5G network to meet extreme and conflicting KPIs while supporting very diverse requirements on the same infrastructure.

The 5G-TOURS mobile network system will integrate strategic components of the ecosystem, including the network infrastructure, terminals and end-devices, the vertical solutions enabled by 5G, and the vertical customers receiving the services. 5G-TOURS has devised a thorough evaluation plan to scrutinise the viability of the use cases, addressing technical performance by analysing both network service KPIs and application-level KPIs, economic impact by analysing the estimated generated revenues and, ultimately, the satisfaction of the vertical customers.

4.2.2 Use-cases

4.2.2.1 Smart Airport parking management

Description, KPIs and features

The Smart Parking Management Use case of 5G-TOURS includes the designation, implementation and deployment of a smart prinking application in the area of Athens International Airport. This implementation will take place in Athens node and will rely on 5G EVE Greek site infrastructure. An extension of the 5G EVE Greek site by OTE and NOKIA-Gr will take place in order to implement the needs of the four use cases. This use case will address 5G connectivity from the perspective of massive machine type communications. To this end, a large number of 5G enabled parking occupancy sensors and chipsets will be deployed (100) to one of the parking areas of AIA feeding an intelligent platform with real-time information on the parking positions status so as to enable targeted suggestions for an improved travelling experience.

More specifically, this use case aims to:

- Design and implement a large number of parking space occupancy recognition sensors as well as relevant software required to communicate with a mobile application. The application will be updated about the time that the parking space it was occupied, when the parking space was released and the number of the specific position occupied by the vehicle.

- Developed predictive algorithms in order to predict the availability of parking spaces, optimal management of demanding/available parking spaces, and optimal routing for the drivers these spaces.
- Develop of a mobile application for the drivers for, so they will be able to find a parking space via the optimum route and pay the parking fees for that location.
- Develop a Web-based application for controlling the parking area. This application will handle the data of the registered drivers when the position is occupied (occupied position, time, duration, etc.).
- Implement an administrative-supervisory system center through which all the individual applications can be managed centrally in order to manage the payment process.

The main KPIs for this use-case are (see Table 15):

- Latency: to offer optimum driver experience, the application should be able to provide updates on parking space availability in terms of seconds
- Reliability: this application isn't considered critical; still, as the application will be offered via mobile network infrastructure, the same service availability KPI as generally offered by the mobile networks also apply for this use case i.e. 99.999%
- Density: the network infrastructure should be able to accommodate communication for few thousand MTC devices/sensors (at full deployment) and hundreds of application users
- Mobility: the service is expected to be offered to low/moderate speed moving vehicles, so no special mobility requirements are imposed by current use case to the mobile network
- Coverage: the service is targeted to a confined geographic area, so deployed radio network should be such that all designated area is given radio connection with expected quality of service (see below) with mobile radio access network
- Data rate per user/device DL/UL: this highly depends on the info expected to be provided real-time to the driver by the parking assistance application. The application needs to provide at the minimum distance and direction to closest available parking space or provide several parking space(s) as options for the driver to select from. Overall low to moderate data in DL direction per user is expected. In addition, the data rate per MTC device – DL/UL is expected to be low to carry update(s) on parking space availability on the uplink direction. In the downlink direction, low to moderate bit rate is expected primarily during MTC device firmware upgrade/maintenance
- Location: location accuracy is terms of few meters is needed to ensure trust of users to the service

Table 15: Main KPIs of Smart Parking Management use case

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC 10 – Smart parking management			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec		10		High	10	50
2	**RAN** Latency (in milliseconds) - one way	msec		5		High	5	10
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps		50		High	10	50
4	Reliability (%) - Min/Max	%		99,9999		High	99,9990	99,9999
5	Availability (%) - Min/Max	%		99,99		High	99,99	99,99
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h		30		High	5	30
7	Broadband Connectivity (peak demand)	Y/N or Gbps		1		High	0,01	0,1
8	Network Slicing (Y/N) - if Y sercice deployment time (m	Y/N		Y		Medium	1	3
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N		Y		medium		
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2		0,1			0,1	0,1
11	Device Density	Dev/Km^2		100K		High	1K	100K*
12	Location Accuracy	m		<0,5		High	0,5	1
(*) 1 parking space = 10m^2 => 1 Km^2 = 100.000 parking spaces								

Provisional planning

The Figure 58 gives a tentative planning of the Smart Parking Management use-case deployment. The vertical is planned to be hosted in the Greek site facility in Athens where Smart parking will use the OTE and NOKIA-

GR 5G radio coverage. The implementation and test will follow two phases one in Administrative parking of AIA and one in short term parking of AIA.

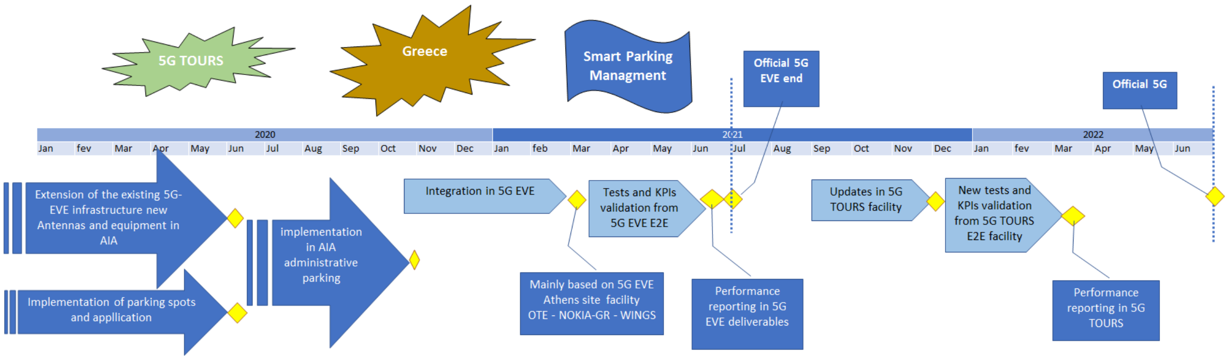

Figure 58: Provisional planning deployment of the Smart Parking Management use-case

4.2.2.2 Video-enhanced ground-based moving vehicles

<u>Description, KPIs and features</u>

The Video-enhanced ground-bases moving vehicles use case covers mobility efficiency from the scope of follow-me vehicles, which lead aircrafts to parking positions, monitor and oversee the activity at the Airport Airside area, and attend incidents, emergencies and critical events. Within the context of this use case, AIA's follow-me vehicles will be enhanced with mobile units equipped (5G routers) with high definition cameras; The scenario will demonstrate how live video feeds sent to the Airport Operations Centers (AOCs) and other stakeholders, such as Police, Special Forces, Firefighting, Ambulance, Civil Protection etc., regardless of their proximity to the airport, and how can improve both day-to-day airport operations and response activities to emergencies.

Table 16: Main KPIs of Video-enhanced ground-based moving vehicles use case

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC 12 - Video-enhanced ground-based moving vehicles			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec			100		100	500
2	**RAN** Latency (in milliseconds) - one way	msec			50		50	100
3	Throughput (in Mbps) - Min/Max - sustained demand	Mbps			50		10	50*
4	Reliability (%) - Min/Max	%			99,99		99,9	99,99
5	Availability (%) - Min/Max	%			99,999		99,99	99,999
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h			150		80	150
7	Broadband Connectivity (peak demand)	Y/N or Gbps			0,25		25 Mbps	250 Mbps
8	Network Slicing (Y/N) - if Y sercice deployment time (min)	Y/N			30		60	30
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N			Y		Y	
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2			0.00256		1 Gbps/Km^2	2,5 Gbps/Km^2 **
11	Device Density	Dev/Km^2			50		5	50 ***
12	Location Accuracy	m			1		5	1
(*) per vehicle 50 Mbps video stream is transmitted								
(**) assume 50 vehicles at 50 Mbps/vehicle in one Km^2 = 2,5Gbps/Km2 = 0,00256Mbps/m^2								
(***) 50 vehicles								

The main KPIs for this use-case are (see Table 16):

- Latency: to offer optimum live video experience, low latency, in terms of milliseconds, is expected
- Reliability: this application may be considered critical; thus, it is expected to be associated with public safety quality of service thus given priority in terms of network congestion. Overall service availability KPI should be the same as generally offered by the mobile networks i.e. 99,999%
- Density: the network infrastructure should be able to accommodate communication from few tens of video sources

- Mobility: the service is expected to be offered to moderate or even high speed moving vehicles, so no special mobility requirements are imposed by current use case to the mobile network
- Coverage: the service is targeted to a confined geographic area, so deployed radio network should be such that all designated area (in this use case, the airport) is given radio connection with mobile radio access network at expected quality of service (see below)
- Data rate per user/device -DL/UL: this highly depends on the quality of video feed. At minimum a few Mbps in the uplink direction is needed to support adequate quality video (or tens of Mbps in case of high definition video)

Provisional planning

The Figure 59 gives a tentative planning of the Video-enhanced ground-based moving vehicles use-case deployment. The vertical is planned to be hosted in the Greek site facility in Athens where video-enhanced ground-based moving vehicle will use the OTE and NOKIA-GR 5G radio coverage. The implementation and test will take place in AIA facilities.

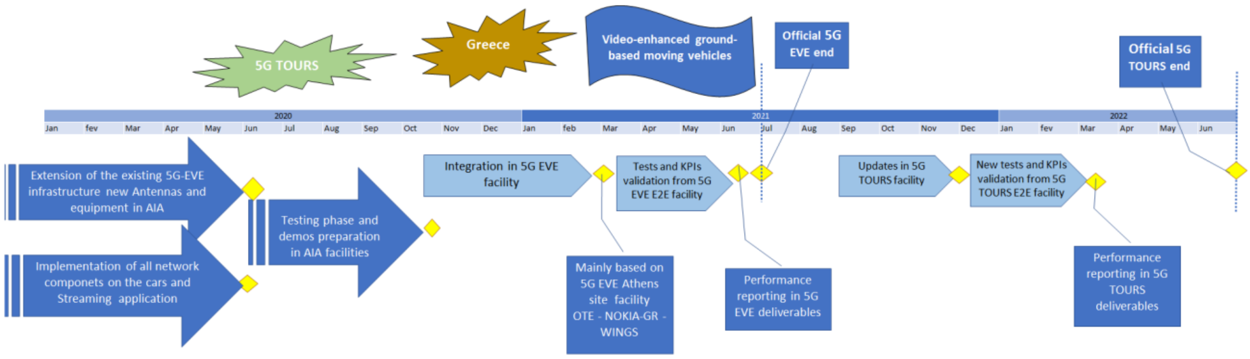

Figure 59: Provisional planning deployment of the Video-enhanced ground-based moving vehicles use-case

4.2.2.3 Emergency airport evacuation

Description, KPIs and features

The Emergency Airport Evacuation use case describes and implements the way airports, but also other massive public infrastructures, can exploit 5G capabilities so as to bring in place an effective evacuation plan where personalized, dynamic and smart instructions can be provided in a reliable, instantaneous and massive-scale manner. In the context of this use case, a section of the Athens International Airport will be provided, and real people (actors) will participate in an evacuation exercise. Naturally, such an emergency situation will call for low latency communications with high reliability of being realized, which means that a URLLC slice will have to be allocated so as to ensure that all travellers are notified and guided to the most appropriate exit immediately. A detailed 3D digital model of the section to be evacuated along with all objects contained therein, such as seats, desks and monitors, will be created and fed into the evacuation support system. Emergency exits will all be recorded and fed into the system supporting the evacuation procedure along with information on their exact location as well as their capacity, if they are accessible, etc. The system can also be used for early detection of passenger movement anomalies that can signify an evolving emergency and timely alarm airport response units. Enhanced location services will be made available with 5G after all.

This use case involves notifying all airport attendees about an emergency and providing evacuation guidance in a personalized manner through mobile application that will be implemented during the project. Overall, this use case requires an ultra-reliable and low latency communication network to support both high user data rate, primarily in the downlink direction, and high control plane traffic, primarily to support network triggered end user location retrieval.

The main KPIs for this use-case are (see Table 17):

- Latency: low latency, in terms of milliseconds, is required to provide up-to-date evacuation assist info in personalized manner
- Reliability: this application is considered critical; thus, it is expected to be associated with public safety quality of service thus given priority in terms of network congestion. Overall service availability KPI should be the same as generally offered by the mobile networks i.e. 99,999%
- Density: the network infrastructure should be able to accommodate communication towards a few thousands users (airport attendees)
- Mobility: the service is expected to be offered to low/moderate speed users, so no special mobility requirements are imposed by current use case to the mobile network
- Coverage: the service is targeted to a confined geographic area, so deployed radio network should be such that all designated area (in this use case, the airport) is given radio connection with mobile radio access network at expected quality of service (see below)
- Data rate per user/device -DL/UL: this highly depends on the info provided and the rate of updates towards the end user. At minimum a few Mbps in the downlink direction, at the user plane, is needed per user. Note that the network should be able to support moderate capacity particularly for the location service
- Location: location accuracy is terms of few meters is needed to provide evacuation assistance info in personalized manner

Table 17: Main KPIs of Emergency Airport Evacuation use case

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC 11 - Emergency airport evacuation			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec	15	25			15	100
2	**RAN** Latency (in milliseconds) - one way	msec	10	10			10	20
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	500	100			100	500 *
4	Reliability (%) - Min/Max	%	99,9999	99,9999			99,999	99,9999
5	Availability (%) - Min/Max	%	99,99	99,99			99,99	99,99
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h	10	0			0	10**
7	Broadband Connectivity (peak demand)	Y/N or Gbps	10	10			1	10
8	Network Slicing (Y/N) - if Y sercice deployment time (min)	Y/N	1	1			1	5
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	Y	Y			Y	
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2	100	100			2	20***
11	Device Density	Dev/Km^2	1000K	1000K			1000K	1000K*****
12	Location Accuracy	m	<1	<1			1	0,3
(*) Total per UE								
(**) 10 km/h running speed of a peson evacuating								
(***) 2 persons per m^2 at 10 Mbps/person								
(*****) 1 or 2 persons per m^2								

<u>Provisional planning</u>

Figure 60 gives a tentative planning of the Emergency Airport Evacuation use-case deployment. The vertical is planned to be hosted in the Greek site facility in Athens where Airport Evacuation will use the OTE and NOKIA-GR 5G radio coverage. The implementation and test will take place in AIA facilities.

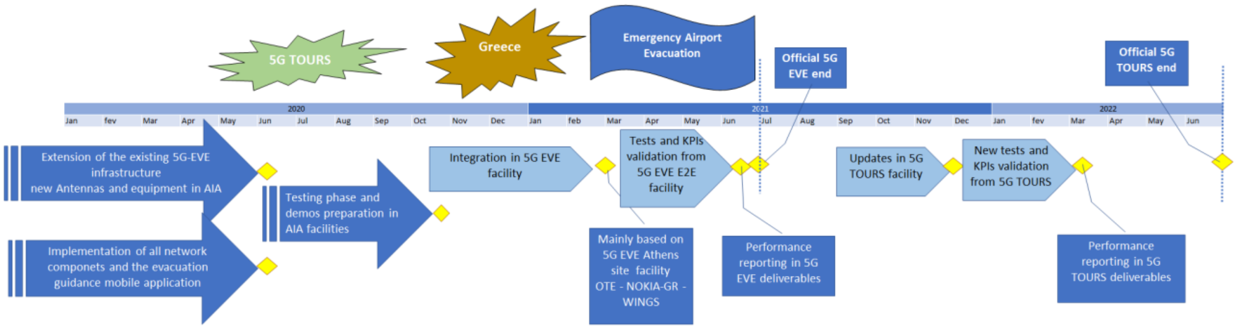

Figure 60: Provisional planning deployment of the Emergency Airport Evacuation use-case

4.2.2.4 AR/VR Enhanced Educational Bus Excursion

Description, KPIs and features

The AR/VR Enhanced educational Bus Excursion use case aims at improving the learning and entertainment (‘infotainment’) experience of the passengers of a bus that is transporting them so that they can visit a site of interest. The improved user experience will be realized in two locations: a) On the bus while traveling to the visit destination and/or returning from it and b) at the destination, while visiting the site.

In particular, the use case is materialized with a focus on the example of: a) school students traveling to AIA site of educational interest in the context of an excursion or field visit and b) the use of Extended Reality (XR) applications as the enablers of the digitally enhanced passenger and visitor experience (XR is used in this context as the umbrella term including Virtual Reality or VR, Augmented Reality or AR, and Mixed Reality or MR), i.e. involving the introduction of digital objects in the real and/or 3D virtual world. The use case includes two focal points: a) the enhanced experience on the bus travelling to AIA using VR content; and b) the enhanced experience at the exhibitions into the AIA facilities using AR content. These are presented below.

Enhanced bus experience: During their transfer to the destination, students will be presented with rich informational and educational content preparing them for the visit to the site of interest, through the use of VR technologies on the bus. Additionally (or alternatively), students can also be presented with relevant content through VR while traveling after they have completed the visit, in the context of wrap-up and follow-up learning activities. High quality rich content will be delivered simultaneously to a number of users (up to 20-25) on the bus. It is desirable that the distribution of content to the users be personalized, in accordance with their preferences and requirements. The content will include different objects (video, audio, etc.) and the user will decide which object to interact with.

Enhanced exhibit experience: While on site, students will visit an exhibit, with which they interact richly through digital content (in the form of text, images, videos, interactive 3D digital objects) blended with the exhibit and the surrounding environment thanks to the use of AR technologies. Approaching the exhibit, students will have the opportunity to use their 5G-enabled handheld devices to see and interact with relevant digital content projected on the physical world. This may include information on the exhibit and its wider cultural/historical/scientific/… context, visualizations of invisible processes or of extensions or analyses of the physical object, etc. The digital content may also include 3D items that the user will be able to interact with (e.g. by viewing and examining them from different angles and distances, etc).

<u>For the trials</u>:

- a school bus with 20-25 students will be provided by EA.
- Software to enable the VR and AR experiences will need to be developed.
- The 5G-enabled hardware required includes VR and AR equipment to be used by each of the participating students.
- In addition, parts of the applications which are location-aware (e.g. the exhibit-based AR) may require equipment such as beacons, etc.
- The AR/VR enhanced bus use case involves presenting AR/VR type educational/cultural content to the students while on the move. Different requirements are posed to the network depending on type of enriched content i.e. AR or VR. While VR type of content may be predefined and broadcasted by the network to the end user the AR type of content may be correlated to the bus surroundings. Thus, eMBB and URLLC requirements may be posed to both the access and core network to support the content delivery. Thus, the network shall accommodate high user data rate, primarily in the downlink direction, with low latency and location accuracy particularly for the AR type of content delivery. In addition, to support undisruptive service experience while the end user moves across mobile cells, the handover completion delay shall be kept to the minimum.

<u>The main KPIs for this use-case are</u> (see Table 18):

- Latency: Latency is particularly relevant to AR applications so that small movement (or change of direction) of the AR device is reflected as fast as possible in the augmented video. Thus, latency should be ~10-20ms end-to-end round-trip for optimum end user experience but also <100msec round trip would provide an acceptable end user experience.

- Reliability: this application isn't considered critical; thus, overall service availability KPI should be the same as generally offered by the mobile networks i.e. 99,999%
- Mobility: the service is expected to be offered to moderate/high speed users, so no special mobility requirements are imposed by current use case to the mobile network
- Data rate per user/device - DL/UL: At minimum a few Mbps in the downlink direction, at the user plane, is needed per user.

Table 18: Main KPIs of AR/VR Enhanced Educational Bus Excursion use case

5G-Tours - Use Cases: direct specific Technical requirements		Units	Use case 13 – Excursion on an AR/VR-enhanced bus			Priority	Range	
			URLLC	mMTC	eMBB		Min	Max
General Vertical Use cases requirements								
1	Latency (in milliseconds) - round trip - Min/Max	msec			100		100	500
2	**RAN** Latency (in milliseconds) - one way	msec			25		25	50
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps			120		80	120
4	Reliability (%) - Min/Max	%			99,99		99,9	99,99
5	Availability (%) - Min/Max	%			99,99		99,9	99,99
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h			100		4	100
7	Broadband Connectivity (peak demand)	Y/N or Gbps			0,01		2	10 *
8	Network Slicing (Y/N) - if Y sercice deployment time (min	Y/N			Y		30	5
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N			N			
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2			10		1	10 **
11	Device Density	Dev/Km^2			1000		10K	1000K***
12	Location Accuracy	m			<1		<4	<1
(*) 10 Mbps per VR device downstream = 0,01 Gbps								
(**) 1 device per m^2								
(***) 1 or 2 students per m^2 = 1000K devices (AR/VR gogles) per Km^2								

Provisional planning

The Figure 61 gives a tentative planning of the AR/VR Enhanced Enhanced Educational Bus Excursion use-case deployment. The vertical is planned to be hosted in the Greek site facility in Athens where Enhanced AR/VR Educational Bus Excursion will use the OTE and NOKIA-GR 5G radio coverage. The implementation and test will take place in AIA facilities.

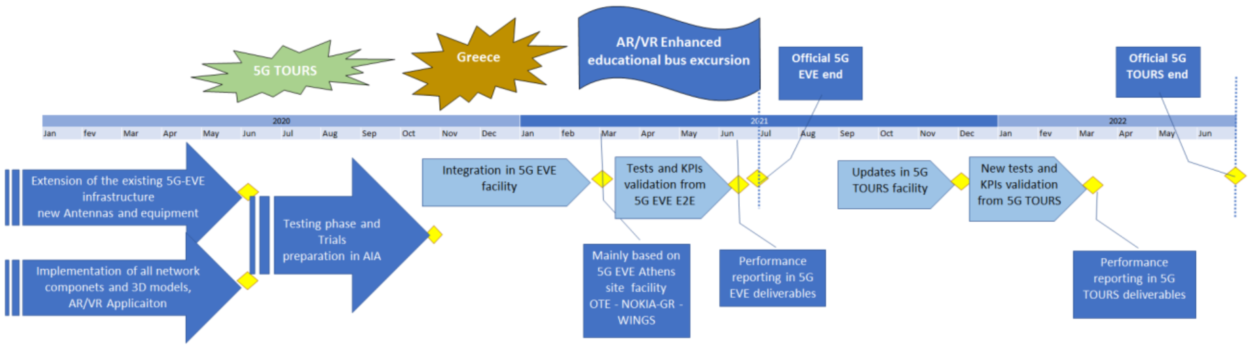

Figure 61: Provisional planning deployment of the AR/VR Enhanced Educational Bus Excursion use-case

4.2.2.5 High quality video link between ambulance and hospital

Description, KPIs and features

The 5G connected ambulance can function as the "first room of hospital", enabling the on-the-spot, direct treatment of the patient under the guidance of a remote expert so as to prevent further, and potentially irreversible, deterioration of the condition of the patient. The hospital may be far away from the patient and the ambulance, so the patient may not survive. Alternatively, permanent damage may be incurred to the patient during transport. The key to such situations is to perform a first diagnosis as fast as possible, in order to know what to do next. In particular, the emergency responders need to deter-mine the best treatment to stabilize the patient, locate the most suitable hospital and, notify it to make all necessary preparations for the patient, e.g., prepare the Operating Room (OR) and call all necessary medical staff. Especially in case of trauma, immediate intervention strongly impacts the outcome, e.g., for hemodynamic un-stable patients, in case of suffocation, internal bleeding, complicated fractures, critical prenatal cases, etc. The available equipment within the ambulance for monitoring, examining, and guiding interventions include ultrasound, which is rapid, non-invasive, portable, versatile and low cost, patient monitors and, 4K video. In addition, instant access to medical records is important to understand the patient's condition prior to the incident (AMA's Xperteye smartglasses: interactive HD head up display for monitoring patient's vitals, medical imagery, protocol; first person point of view live camera).

Next to the improvements for the staff in the ambulance, this use case will also evaluate whether the use of AR/VR over 5G can improve the situational awareness the medical staff in the hospital has, which positively impacts the quality of the teleguidance. AR/VR technology also brings enhanced video and spatial scanning features that further improve the immersion and richness of the presented information. These again should positively impact the quality of remote guidance and telepresence.

The main KPIs for this use-case are the bi-directional data throughput and the latency as well as the multi-stream management (slicing). Some values are given below:

- Three camera video streams from the ambulance to the hospital
    - HD / 4K
    - ~ 45Mbps
    - ~ 50ms latency end-to-end including compression
- Ultrasound data streams towards the hospital
    - ~720p resolution
    - ~ 5Mbps (compressed) / 30Mbps (uncompressed)
    - ~ 50ms latency end-to-end
- Guidance AR video stream towards the ambulance
    - ~720p
    - 5Mbps (compressed)
    - ~ 25ms latency end-to-end
    - For display on smart glasses
- Smart glasses position + orientation data stream towards the hospital
    - Needed to generate AR video stream
    - < 100 kbps
    - ~25ms latency end-to-end

<u>Provisional planning</u>

The Figure 62 gives a tentative planning of the e-ambulance use-case deployment. The vertical is planned to be hosted in the French site facility in Rennes where the e-ambulance will used the Orange and/or b<>com radio coverage.

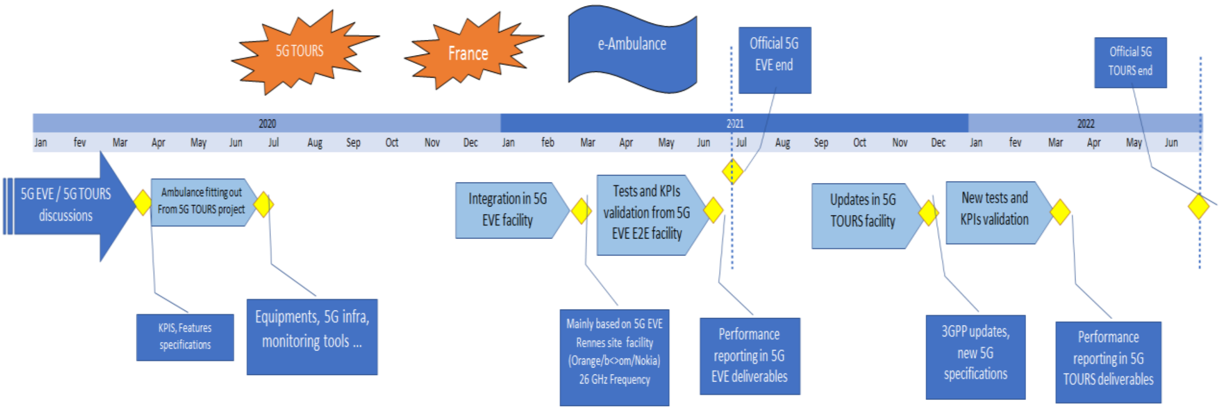

Figure 62: Provisional planning deployment of the e-ambulance use-case

4.2.2.6 Wireless Operating Room

Description, KPIs and features

5G will be deployed in a real hybrid OR comprising several pieces of equipment for interventional procedures and ultrasound guided gestures, as well as videos produced by digital cameras. A surgery enhanced with 5G connectivity improves the effectiveness of the operating room, especially in case of an unplanned procedure that needs to be performed during the operation. The quality, reliability and low latency provided by 5G makes it possible to support advanced medical applications such as, e.g., Augmented Reality Assisted Surgery and Cobotic-aided surgery. In the same network infrastructure, various types of communications can be supported (e.g., Augmented Reality Assisted Surgery, tele-mentoring using smart glasses, real-time broadcast of surgery for educational purposes, etc.) with a proper management of slices, providing the necessary degree of isolation and reliability to guarantee the quality of the critical slices and thus ensure the patient's safety. In case the patient is a tourist, the wireless operating room allows that the home doctor of the patient can provide remote assistance.

The service level requirements will be:

- ≤ 150ms (end to end) from surgeon gesture to monitor display for human interaction
- 10 Gbps video flows combination (before compression)
- Reconfiguration of slice in less than 1mn for introducing a new medical imaging equipment (network configuration pre-defined), with reduction of quality on non-high-priority video flows.

Multiple video connections should be possible at the same time sharing the transmission bandwidth. Several devices will be added in the OR as: *External camera (150Mbps to 3Gbps), Mosaic display (150Mbps to 3Gbps).*

And, finally, an Augmented Reality application will enable to combine multiple video flows:

- AR Application (150Mbps to 3Gbps).

To achieve all these requirements, the OR will be equipped with a 5G Radio coverage that will be directly connected to the b<>com 5G Core network.

Provisional planning

The Figure 63 gives a tentative planning of the operating room use-case deployment. The vertical is planned to be hosted in the French site facility in Rennes where a connection between the CHU of Rennes and b<>com will be implemented to access to the Core network deployed at b<>com that will connect the OR. A specific RAN deployment will be carried out in the OR (26 GHz frequency band seems to be at the time being the suitable solution but will be confirmed).

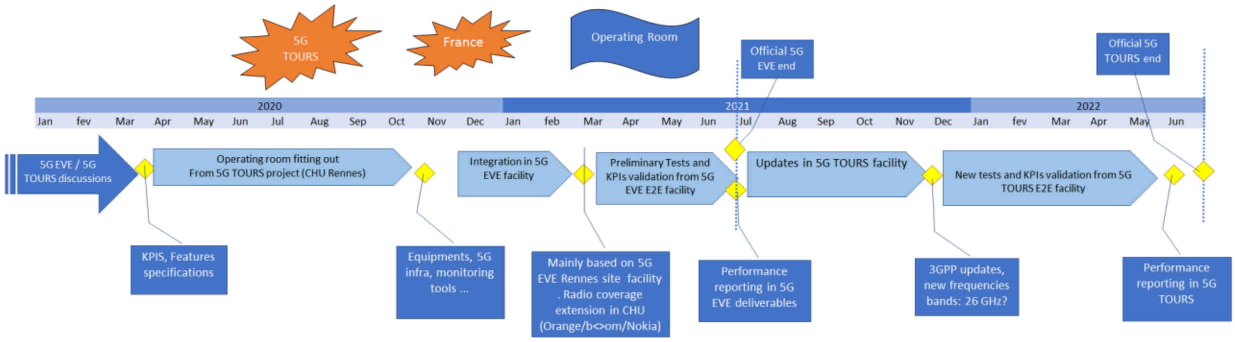

Figure 63: Provisional planning deployment of the operating room use-case

4.2.2.7 Remote health monitoring and emergency situation notification

Description, KPIs and features

Enabling remote monitoring, especially when it comes to a person diagnosed with a disease, and consultation by their medical attendants, as well as their remote collaboration with the local medical personnel leveraging advanced technology in case of an emergency is expected to act as additional motivation for travel-ling. The main features offered by this use case involve (a) remote health monitoring services leveraging a variety of datasets, including, but not limited to, health signs, air quality, weather conditions, site waiting times, transportation, traffic and location, and (b) quick, reliable notifications to nearby ambulances, medical professionals and family members in case of a health incident or a health emergency prediction. The use case will leverage wearable devices tracking the tourist's vital signs and having them aggregated inside an IoT-based platform named STARLIT (Smart living platform powered by ArtIficial intelligence & robust IoT connectivity), where they will be processed in a combined fashion exploiting also various city sources and open APIs (providing information on aspects such as weather conditions, traffic, etc.). At this point it is envisaged that devices will be connected with the rest of the system (server at the edge or cloud platform) via a gateway. This gateway will be installed in close proximity with to the devices and will be responsible i) for connectivity, ii) for acquiring data (measurements), iii) for performing a lightweight processing of these data and finally, iv) for transmitting them to the dedicated servers, using available communication technologies and protocols. This gateway will also realize the function/intelligence for switching between different reporting modes for different devices (potentially supported on this by intelligence at the edge). It should be noted that while actual devices connected in some way will be used to showcase connectivity aspects, these will need to be combined with emulated data (given the complexity of involving actual patients) to carry out detailed evaluations and to also showcase aspects such as scalability of the use case solutions. STARLIT's outcome will be the identification or the prediction of a health-related emergency situation, which will be followed by the immediate notification of the dispatch center of the Rennes University Hospital.
The main KPIs for this use-case are (see Table 19):

- Latency: Latency is particularly relevant to health-related applications so that small change in the users vital signs is reflected as fast as possible for fast notification of affected users, family members, corresponding physicians and ambulance services if/when required. Thus latency should be ~10-50ms end-to-end round-trip and <1ms on the RAN (one way).
- Reliability: this application is considered critical; thus given priority in terms of network congestion. Overall service availability KPI should be the same as generally offered by the mobile networks i.e. 99,999%

Table 19: Main KPIs of Remote health monitoring and emergency situation notification

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC6 –Remote health monitoring and emergency situation notification			Priority	Range	
			URLLC	mMTC	eMMB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec	10	10		High	10	50
2	**RAN** Latency (in milliseconds) - one way	msec	1	1		High	5	10
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps				High	10	50
4	Reliability (%) - Min/Max	%	99.9999%	99.9999%		High		
5	Availability (%) - Min/Max	%	99.99%	99.99%		High		
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h				High	5Km/h	100 Km/h
7	Broadband Connectivity (peak demand)	Y/N or Gbps		Y		High	N/A	N/A
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N		Y		Medium	N/A	N/A
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N		Y		Medium	N/A	N/A
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2					N/A	N/A
11	Device Density	Dev/Km^2					N/A	N/A
12	Location Accuracy	m		0.1		High		1m

Provisional planning

Figure 64 gives a tentative planning of the Remote health monitoring use-case deployment. The vertical is planned to be hosted in the French site facility in Rennes where the Orange and/or b<>com radio coverage will be exploited.

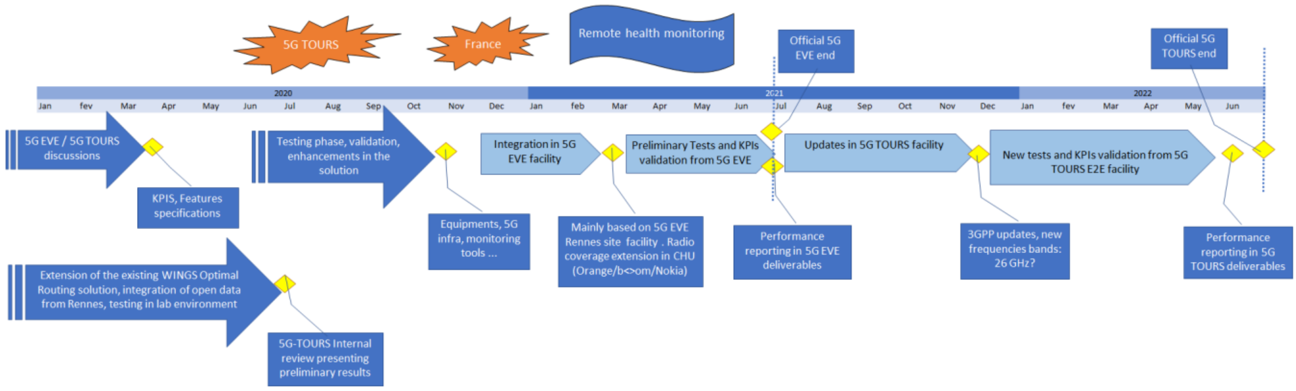

Figure 64: Provisional planning deployment of the Remote health monitoring use-case

4.2.2.8 Optimal Ambulance Routing

Description, KPIs and features

This use case essentially acts as the step following the health monitoring and emergency situation identification use case described above. In this context, this use case shows how city sources can be exploited to-wards real-time vehicle navigation taking into consideration the live status of the city, especially a touristic one with lots of cultural events being organized – potentially in public locations and streets.

This use case addresses real time navigation of the ambulance both to the site of the emergency, to ensure that medical help will be provided as quick as possible as well as for the ambulance to arrive at the hospital as soon as possible once the patient has been stabilized on site.

The WINGS's platform, STARLIT, is exploited so as to calculate the optimal route both from the ambulance dispatch location to the emergency location as well as from the emergency location to the nearest (or in another way most appropriate) hospital. Information taken into consideration, in this respect, refers to current traffic status, real-time road closures (due to demonstrations or concerts), etc. Sensors deployed within the city but also open data APIs, such as the ones offered by the Rennes Open Data Platform[4], will be leveraged for comprehensive decision-making. Real-time route updates will be performed as new information arrives.

In the meantime, the nearest hospital – that has been selected out of a list of hospitals by the medical professionals in the ambulance – will have been notified so that the arrival of the patient is expected.

The main KPIs for this use-case are (see Table 20):

- Latency: to offer optimum driver experience, the application should be able to provide updates on the route that the ambulance has to follow in terms of 10-50msec round trip.
- Reliability: this application isn't considered critical; still, as the application will be offered via mobile network infrastructure, the same service availability KPI as generally offered by the mobile networks also apply for this use case i.e. 99,999%
- Mobility: the service is expected to be offered to high speed moving vehicles (ambulance), so the mobility requirements are imposed by the use case to the mobile network are around 100km/h.
- Location: location accuracy is terms of few meters is needed to ensure trust of users to the service

Table 20: Main KPIs of the Optimal ambulance routing use case

5G-Tours - Use Cases: direct specific Technical requirements		Units	UC9 – Optimal Ambulance Routing			Priority	Range	
			URLLC	mMTC	eMMB		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in milliseconds) - round trip - Min/Max	msec		10		High	10	50
2	**RAN** Latency (in milliseconds) - one way	msec		1		High	5	10
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps		50		High	10	50
4	Reliability (%) - Min/Max	%		99.9999%		High		
5	Availability (%) - Min/Max	%		99.99%		High		
6	Mobility (in m/sec or Km/h) - Min/Max	Km/h		>=100Km/h		High		
7	Broadband Connectivity (peak demand)	Y/N or Gbps		Y (1)		High		
8	Network Slicing (Y/N) - if Y service deployment time (min)	Y/N		Y (1)				
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N		Y		Medium		
10	Capacity (Mbps/m^2 or Km^2)	Mbps/m^2		n/a				
11	Device Density	Dev/Km^2		n/a				
12	Location Accuracy	m		0.1		High		

Provisional planning

Figure 65 gives a tentative planning of the Optimal ambulance routing use-case deployment. The vertical is planned to be hosted in the French site facility in Rennes where the Orange and/or b<>com radio coverage will be exploited.

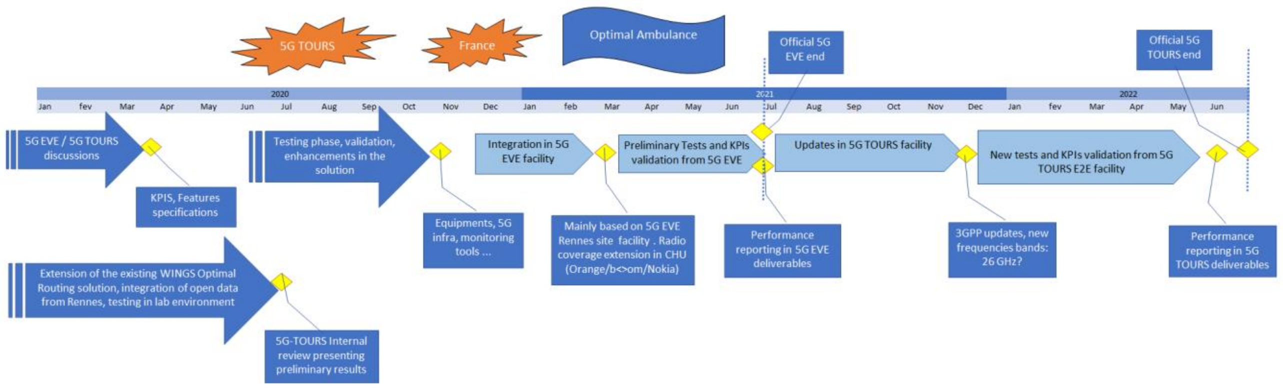

Figure 65: Provisional planning deployment of the Optimal ambulance routing use-case

[4] https://data.rennesmetropole.fr/pages/home

4.2.2.9 Augmented Tourism Experience

Description, KPIs and features

The main goal of this use case is to provide the visitors of targeted museums with an improved and more engaging experience that relies on XR technologies to augment their visit and knowledge of touristic assets offered at each site. The goal is to use of such technologies in a seamless way to provide users with the best possible experience, according to each user's hardware, location, network capacity, and needs. The concept of "immersive" experience requires the involvement of the user both indoors and outdoors, offering a set of services to the user, accompanying him from identified paths on the outside of the targeted museums to the most immersive indoor experiences. Additionally, a smart city platform will be deployed to provide touristic information, leveraging on data about the environment and the number of people in different areas. Specifically, tourists will be provided with several smart city services, giving them information on (i) indoor (comfort) and outdoor (environmental) conditions, (ii) cultural/touristic interest, and (iii) tourist facilities provided by the city. This use case is divided into the following sub-use-cases (further details can be found in [30] [31]:

- **In the very heart of Turin:** The objective of this sub-se case is to create and test an integrated, immersive and personalized experience targeted both to the museum's visitors and to tourists/citizens in the surroundings of the targeted point of interests. This will be made possible thanks to the deployment and testing of a virtual guide enabling interactive visits to targeted museums through XR technologies. These activities will be complemented through informative services provided both indoors as well as outdoors and provide an XR route for selected "City Walks". Finally, smart city services related to communication of environmental data will be provided, thanks to dedicated indoor and outdoor sensor networks, to be deployed in the surroundings of targeted museums.
- **GAM – Gamification, let's play artist:** The objective of this sub-use case is to allow the user to enter into the life of a selected artist, understand it and eventually test the art creation process as well as learn about it through gamification. Tourist/student will be invited to enter into the artist studio and try his material. They could try to collectively paint a virtual canvas to understand the importance of the artist gesture via a first-hand experience. Gamification technologies will be used to maximize end user's engagement and participation as well as to make the learning experience more amusing.

The main KPIs for this use-case are (see Table 21) [30] [31]:

- Low-Latency is one of the most important requirements to support XR Interaction. i.e. XR to provide pleasant immersive experience requires stringent latency requirements typically with values < 15ms of round-trip time including the rendering in the cloud.
- Fast Data Rate: immersive interaction requires data rates of about 200 Megabits per second (Mbps) for a VR system.
- Supports multiple wireless ad-hoc connections like WIFI, Bluetooth, telephone network such as 5G.
- The user should not have to configure connectivity channels.
- It is required Narrow Band IoT (NB-IoT) coverage in the areas considered by the trial (indoor and outdoor).

Table 21: Main KPIs of the Augmented Tourism Experience use case

Metric	Required value
Latency	≤ 15ms Ent-to-end (E2E)
Reliability	99.999%
Density	~tens per 1km^2
Mobility	N/A
Coverage	0.5 km^2
Slice/service deployment time	≤ 90 minutes
Data rate per user/device – Down Link (DL)	200 Mbps per device
Data rate per user/device – Up Link (UL)	≥ 20 Mbps
Security	"Carrier grade"
Location accuracy	≤ 1m

Provisional planning

Figure 66 gives a tentative planning of the Augmented Tourism Experience use case [30].

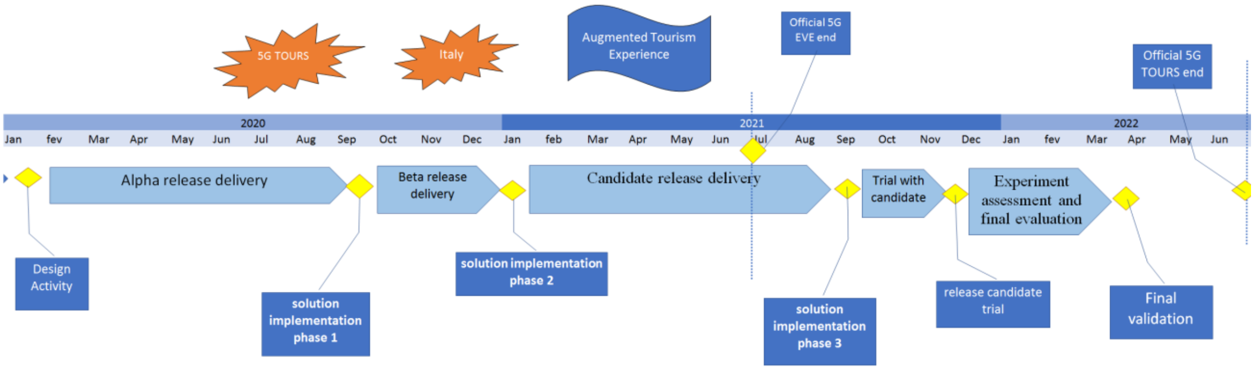

Figure 66: Provisional planning deployment of the Augmented Tourism Experience use case.

4.2.2.10 Telepresence

Description, KPIs and features

The main goal of this use case is to provide the possibility of a robot located inside a museum to be con-trolled by a remote user by leveraging an underlying 5G network. Telepresence robots have the potential to authentically extend access to historically excluded audiences such as disabled people, social disadvantaged people (e.g. substituting or complementing school field trips), people outside the country (in a way to attract tourists/users), providing enhanced education activities at schools (without moving from their own classroom) as well as offering niche experiences to a wider audience for a longer time. The most prominent applications of this teleoperation use case are a visit to the museum by a visitor located at a remote station (school, home, hospital, etc.) or the surveillance of the museum by an operator external to the museum. This use case is divided into the following sub-use-cases (further details can be found in [30]:

- **Palazzo Madama exclusive exhibitions for all:** In this sub-use case, a single visitor or a group of visitors in a remote location (e.g. different buildings, urban area, region or even country, will be able to visit the Palazzo Madama museum, moving inside the spaces and experience them as if would be physically present there. Visitors will be able to look at the museum spaces and artworks through a monitor or other more immersive equipment (such as a curved video wall) mounted in the remote room, having explanations provided by a guide or a teacher there present, or even by a touristic guide at the museum or in another location.
- **Play and visit modern art from Museum to School:** The objective here is to offer enhanced educational activities to students at school, to be integrated in their school programs. Whit respect to the previous sub-use case, the remote visit of the GAM will be enhanced by thematic tutorials and games that would improve the visit experience with additional contents, requiring also the interaction of the end users. In such a context, while visiting the GAM through the telepresence robot, the students can be involved in a “treasure hunt” game in which they should reach the different stages by solving enigmas or pursuing artefacts and paintings using the telepresence robot.
- **Surveillance of the museum:** This sub-use case addresses remote surveillance of the museum by an external operator enabling the possibility to supervise different locations during the night time without the need to reach them physically, thus improving the efficiency and security of the surveillance guards. The surveillance activity can be also enriched by informing the remote operator regarding eventual critical events that may happen in the museums such as fire or structural failures. To such extent, un underlying IoT platform will be used to convey the information gathered from oscillation and fire sensors that will be placed inside the museum

The main KPIs for this use-case are reported in Table 22 [30] [31]:

Table 22: Main KPIs of the Telepresence use case

Metric	Required value
Latency	≤ 10 ms (end to end)
Reliability	99.9999%
Coverage	The museum in the city of Turin in which the robot will operate (initially Palazzo Madama and GAM)
Data rate per user/device	A bandwidth of 15-20Mbit/s upstream and 10Mbit/s downstream

Provisional planning

Figure 67 gives a tentative planning of the Telepresence use case [30].

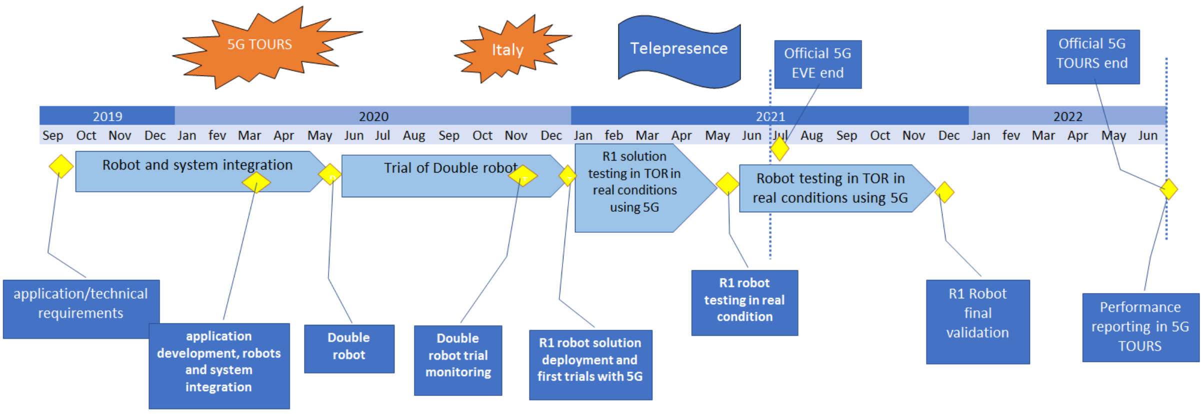

Figure 67: Provisional planning deployment of the Telepresence use case.

4.2.2.11 Robot-assisted museum guide

Description, KPIs and features

The goal of this use case is to leverage robotic technology to provide an enhanced museum visit experience [30]. In this case, a robot is deployed inside the museum and has a map of the environment enriched with the location of the main attractions. At the main entrance, or in common areas inside the museum, the robot will be able to provide basic information about collection highlights and temporary exhibitions, as well as the location of notable points, such as vest rooms, toilets and security exits. During queuing time at ticket desk, the robot will assist visitors giving them real time information about the line and prospect waiting time. Inside the museum, instead, the robot will be able to physically guide visitors to the attraction, moving through the rooms of the museum and describing the artworks. This guided tour will be performed autonomously by the robot, which will navigate in the environment following a precomputed path.

The main KPIs for this use-case are (see Table 23) [30] [31]:

- A mobile connection should be available in each room of the museum the robot is required to operate. A bandwidth of a least 10Mbit/s (UL) is required for successful high-quality video transmission from the robot cameras. An additional upstream bandwidth of ~5-10Mbit/s is required for additional robot sensors, such as depth sensor and laser range finder, which are required by the robot to autonomously navigate the museum environment.
- A bandwidth of at least 10Mbit/s (DL) is required to tele-operate the robot from the control room.
- A latency of ~10ms (or less) is recommended for both safe robot teleoperation and navigation control.

Table 23: Main KPIs of the Robot-assisted museum guide use case

Metric	Required value
Latency	≤ 10 ms (bidirectional mode)
Reliability	99.9999%
Coverage	The museum in the city of Turin in which the robot will operate (Palazzo Madama and GAM)
Data rate per user/device	A bandwidth of 15-20Mbit/s upstream and 10Mbit/s downstream

Provisional planning

Figure 68 gives a tentative planning of the Robot-assisted museum guide use case [30].

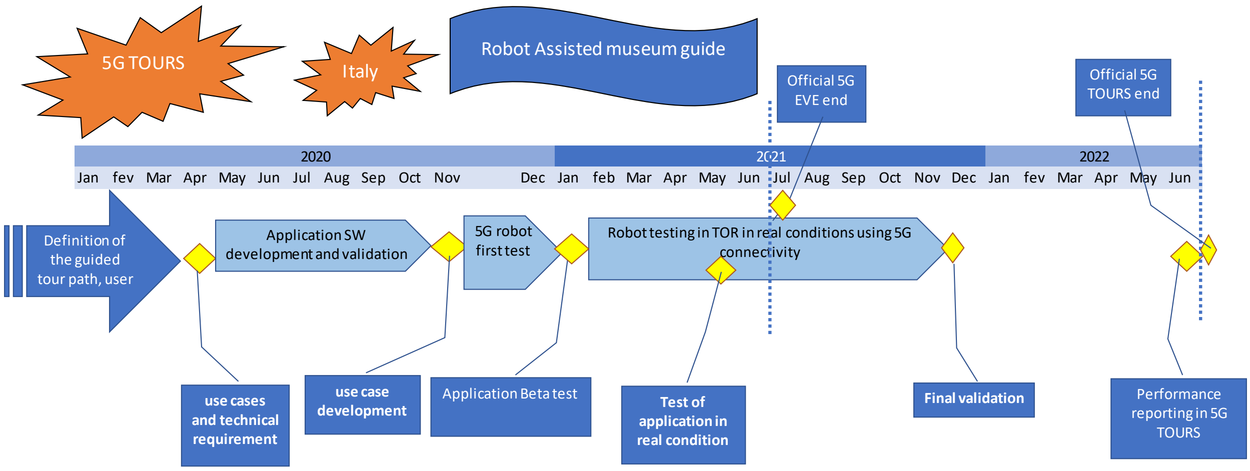

Figure 68: Provisional planning deployment of the Robot-assisted museum guide use case.

4.2.2.12 High quality video services distribution

Description, KPIs and features

This use case targets the distribution of enhanced high-quality video services for tourists providing immersivity functionalities to the user experience [30]. Users will use their smartphones, tablets, AR devices and monitors to receive educational and informative content during their visits to the city and its museums. In this use case, the contents will be simultaneously distributed to many users by relying on the use of advanced multicast and broadcast technologies. Their experience will be additionally enhanced with the use of object-based content transmission. In this type of transmission, the content is divided into objects (video elements, audio elements, captions, subtitles, music type, etc.) for delivering the information to users with different requirements and preferences thus providing a personalized experience. The objective is to provide the service by using two infrastructure deployments. The con-tents could be received from mobile cellular networks, where an MNO transmits the content using a mixed mode. In this case, both multicast and unicast components share resources. The second option is to transmit the content via broadcast networks, according to which the content is transmitted to all users at once by using a fixed amount of network resources in a consistent manner.

The main KPIs for this use-case are reported in Table 24 [30] [31]:

Table 24: Main KPIs of the High quality video services distribution use case

Metric	Required value
Latency	≤ 10 ms (bidirectional mode) N/A for Point-to-Multipoint (PTM) mode
Reliability	99.9999%
Coverage	Venue (museum, and surroundings) / Turin city (radio ~15 km).
Data rate per user/device	≥ 25 Mbps

Provisional planning

Figure 69 gives a tentative planning of the High quality video services distribution use case [30].

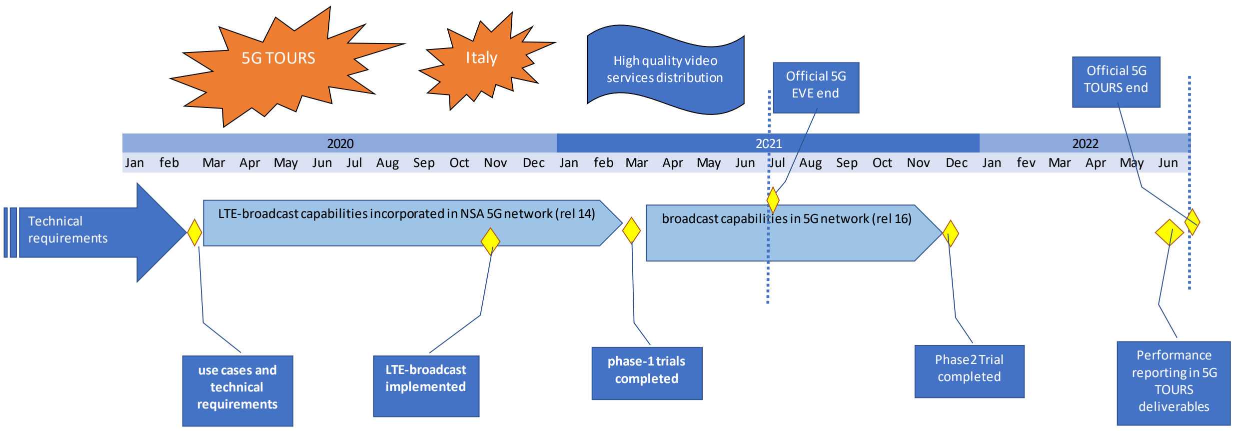

Figure 69: Provisional planning deployment of the High-quality video services distribution use case.

4.2.2.13 Remote and distributed video production

Description, KPIs and features

The main objective of the use case focuses on remote television production in various scenarios in which high-quality video (e.g., in 4K, HD/HDR or Video 360°) is generated, transmitted and mixed in a composite video production [30]. Video contents could be delivered from cameras located in places where an event is taking place to a TV studio in the broadcasting center or to a remote studio facility on the event location itself. Such video contents could be used both for immediate live broadcasting of the event or recorded to be further edited and used in TV programs to be broadcasted later on. In case the video production is distributed, the content needs to be produced by mixing local and remote audio and video contributions in the TV studio. The remote contributions need to be delivered to the main editing site in real time. One of the biggest challenges in this use case is to realize an itinerant orchestra, where, the event is a concert performed by an orchestra with some musicians located in the main concert hall and some other itinerant musicians walking in the streets while approaching the concert hall. Each itinerant musician is followed by a cameraman shooting their performance and providing cues to stay synchronized with the main orchestra performance. The high-quality AV signal is streamed to the main editing facility where it is properly processed and mixed with both the orchestra located in the concert hall and the rest of the itinerant musicians. The spectators in the concert hall will see the itinerant musicians on a LED wall and listen to their performance via an amplification system, mixed with the local orchestra, until they enter the concert hall and join the orchestra.

The main KPIs for this use-case are reported in Table 25 [30] [31]:

Table 25: Main KPIs of the Remote and distributed video production use case

Metric	Required value
Latency	≤ 10ms (bidirectional mode), taking into account to use audio streams to synchronize all content
Reliability	99.9999%
Coverage	Turin city - where remote musicians are moving The auditorium where the event take place
Data rate per user/device	≥ 25 Mbps (for each video) Note - it depends by the coding of videos, to avoid additional delay from the video coding phase some very low delay coding mode is needed.

<u>Provisional planning</u>

Figure 70 gives a tentative planning of the Remote and distributed video production use case [30].

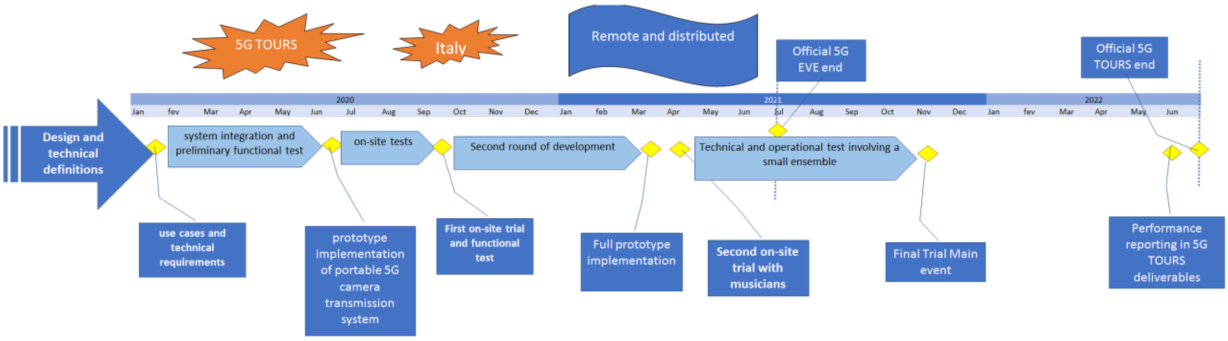

Figure 70: Provisional planning deployment of the Remote and distributed video production use case.

4.3 5G SOLUTIONS (ICT-19)

4.3.1 Brief project description

5G Solutions for European Citizens (namely, 5G-Solutions) is a H2020 ICT19 project supporting EC 5G policy by implementing the last phase of the 5G-PPP roadmap. The project aims at experimenting and validating 5G capabilities as key enablers to forward-looking services in prominent industry verticals, thus bringing the 5G vision closer to realisation. Advanced field trials of innovative use-cases are expected to involve end-users across five significant industry vertical domains, namely Factories of the Future, Smart Energy, Smart Cities, Smart Ports, Media & Entertainment. Among all vertical domains, organized in so called “Living Lab”, **Smart Energy** is the one vertical industry which is expected to run three use-cases in the **5G EVE platform**, interesting the **Italian Site** infrastructure located in Turin.

Living Lab Smart Energy deals with three use-cases referring to the broad area of **Demand Side Management** (DSM). In the transition from current power grid to smart grid, DSM favours the concept of energy consumers adjusting their consumption to reduce the electricity load in presence of suitable incentive payments. DSM programs adopted to manage the energy consumption are typically designed to induce lower electricity use in circumstances of interest, e.g., high market prices. In this scenario consisting of distributed smart-meters and sensors from one side, and IoT based monitoring, data management and energy network management and control platforms from the other, reliable communication systems are crucial to manage remote communication. Each use case intends to validate both technological and business aspects of 5G technologies in terms of increased resilience, coverage and continuity, as well as higher resource efficiency.

Living Lab Smart Energy is leaded by an Italian SME, namely *Ares2t*, and supported by an Italian research centre, the Consortium for the Research in Automation and Telecommunication (*CRAT*) as third party of Ares2t, and two large industries: *Enel X* and *IREN*. In the following sections, three use-cases are briefly described as well as main features and reference KPIs. A preliminary planning for running experiments and assessing performances is reported according to 5G-Solutions internal GANTT and organization. Project organization is based on three iterative cycles so to update the use case validation process according to 3GPP Release. Each cycle is expected to run six months and includes design, implementation and validation from both 5G and business KPI point of view.

4.3.2 Use-cases

4.3.2.1 Smart Energy in industrial environment

Description, KPIs and features

This Smart Energy use-case deals with the problem of **keeping the peak power limited** in industrial environment in presence of new tariff schemes accounting for the peak power consumption and fluttering and unpredictable Renewable Energy Sources (RES). In this respect, 5G technologies allow a prompt switch off for loads being responsible for peak/overload and, accordingly, an efficient rescheduling for above mentioned loads. A post-commercial meter will be used to detect the power peak/overload and to generate an alert, which will be transferred to a pre-selected set of control devices that will reduce the power consumption and trigger the computation of a new load schedule as a recovery action. Related **KPIs** are latency (<10 ms), reliability (>99.999%) and coverage (>99.9% indoor). Involved partners are *Ares2t*, *CRAT* and *IREN*.

Provisional planning

Smart energy use-case has been planned to run in 5G EVE Italian site located in Turin according to three cycles-based LL execution methodology. After the initial infrastructure set up period from August 2019 to May 2020, the first cycle includes time slot from June to December 2020; the second one from January to June 2021; and the third one from August 2021 to January 2022. Figure 71 gives the planning for this smart energy integration.

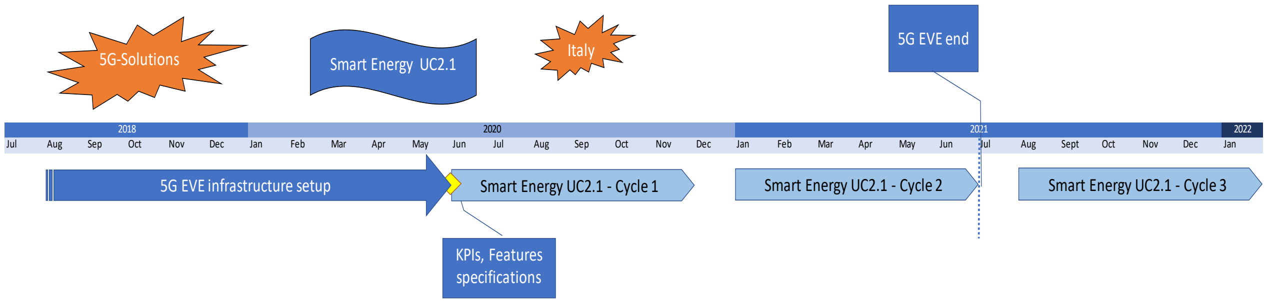

Figure 71: 5G-Solutions Smart energy in industrial environment use Case – Provisional planning

4.3.2.2 Smart energy smart charging process

Description, KPIs and features

The use case UC-5GS2.2 of interest in Smart Energy deals with the **smart charging process** as active demand in the provisioning of the electricity services. From this point of view, charging station selection Plugin Electric Vehicles (PEVs), as well as driver's experience and needs, imply a strong interaction of PEVs and electricity distribution grids by realizing the complete evolution from traditional grids to next generation smart grids. In this respect, 5G technologies allow reliable real time schedule of charging sessions as well as a fast reschedule in cases of practical interest (e.g., overload). Related **KPIs** are latency (<10 ms), reliability (>99.999%) and coverage (>99.9% indoor). Involved partners are *Ares2t*, *CRAT*, *Enel X* and *IREN*.

Provisional planning

The smart energy smart charging process has been planned to run in 5G EVE Italian site located in Turin according to three cycles-based LL execution methodology. After the initial infrastructure set up period from August 2019 to May 2020, the first cycle includes time slot from June to December 2020; the second one from January to June 2021; and the third one from August 2021 to January 2022. Figure 72 gives the provisional planning of the use case integration.

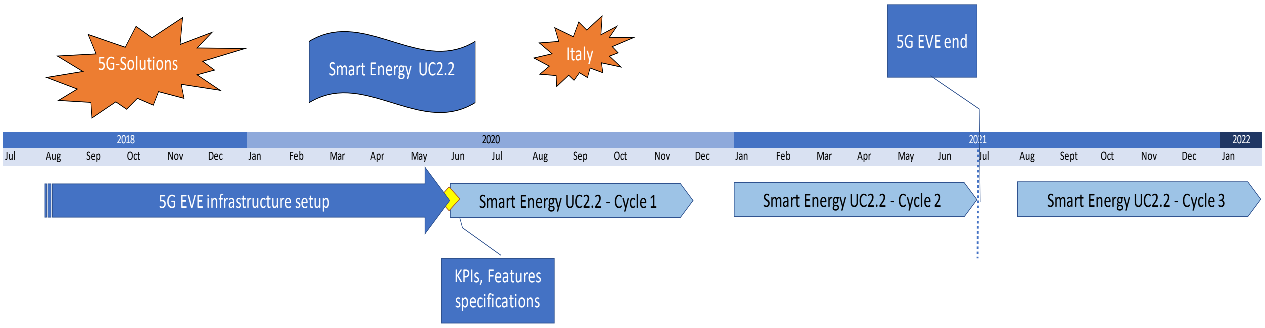

Figure 72: 5G-Solutions smart energy smart charging process use Case – Provisional planning

4.3.2.3 Smart energy: Stability of the electricity network

Description, KPIs and features

This use case of interest in Smart Energy deals with the problem of keeping **electricity network frequency** as much stable as possible by means of active demand in the provisioning of the electricity services. 5G enabled ICT solutions are increasing the potential for active demand response from all consumers, independently from their needs and size, so including Plugin Electric Vehicles (PEVs). Current smart meters installed in the charging stations take measurements every minute and measurements do not include network frequency. Therefore, each charging station should react alone and be equipped with a new, potentially expensive, frequency meter. In this respect, 5G technologies allow developing efficient control strategies to enable primary frequency regulation based on real time measurements of network frequency. Related **KPIs** are latency (<10 ms), reliability (>99.999%) and coverage (>99.9% indoor). Involved partners are *Ares2t*, *CRAT* and *Enel X*.

Provisional planning

The smart energy electricity network stability use-case has been planned to run in 5G EVE Italian site located in Turin according to three cycles-based LL execution methodology. After the initial infrastructure set up period from August 2019 to May 2020, the first cycle includes time slot from June to December 2020; the second one from January to June 2021; and the third one from August 2021 to January 2022. Figure 73gives the provisional roadmap of the smart energy electricity network stability use-case integration.

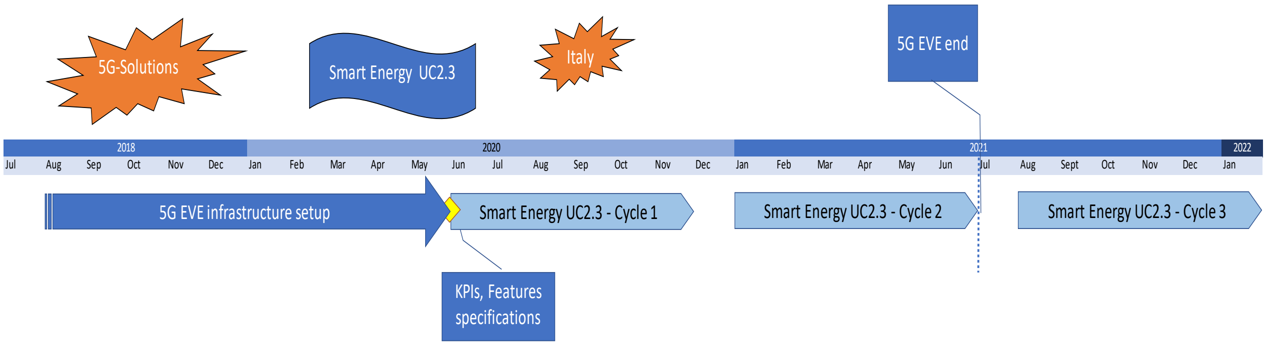

Figure 73: smart energy electricity network stability use-case – Provisional planning

4.4 5G GROWTH (ICT-19)

4.4.1 Brief project description

The 5Growth vision [32] is to empower vertical industries, such as Industry 4.0, Transportation, and Energy with an AI-driven automated and shareable 5G end-to-end solution that will allow them to simultaneously achieve their key business and performance targets. 5Growth will automate the process for supporting diverse industry verticals through:

i. a vertical-oriented frontend providing a common entry point and interface and an advanced customer portal, in charge of interfacing verticals with the 5G end-to-end platforms, receiving their service requests and building the respective network slices,
ii. closed-loop automation and SLA control for vertical service lifecycle management,
iii. AI-driven end-to-end network solutions to jointly optimize resources provided across all the network and application segments (access, transport, core, cloud, edge and fog), and across multiple technologies and domains.

The main objective of 5Growth is the technical and business validation of 5G technologies from the verticals' perspective, following a field-trial-based approach in vertical sites (TRL 6-7) to increase exploitation opportunities in products, services, and vertical markets, hence economy and society at large. Multiple use cases of vertical industries will be field-trialed in four vertical-owned sites in close collaboration with the vendors and the operators of the project. 5Growth will leverage on the results of 5G-PPP Phase 2 projects where slicing, virtualization and multi-domain solutions for the creation and provisioning of vertical services are being developed and validated with specific Proofs of Concept, e.g., 5G-TRANSFORMER.

Two ICT-17-2018 5G end-to-end platforms, 5G EVE and 5G-VINNI, will be integrated with the 5Growth platform in the trials to demonstrate the 5Growth specific vertical use cases.

4.4.2 Use-cases

4.4.2.1 Connected Worker Remote Operation of Quality Equipment

Description, KPIs and features

The objective of this use case is that an expert metrologist can configure the sweeping trajectory of the measuring machine remotely, with the help of a 4K camera, the challenge being that the real time video must be synchronized with a virtual joystick. It consists in two services, eMBB for 4K video streaming and URLLC services for virtual joystick operation. As in most industrial applications, availability is a must, as well as the latency and the bandwidth (there are thus some mild requirements about connection density, mobility –walking speed and coverage). The main KPIs are:

Availability > 99.9999 %, Latency < 5 ms, Bandwidth: 1 Gbps

The vertical will provide the on-site equipment (the activities of this pilot will span over two nearby trial sites located in the Basque Country (Spain), within the Automotive Intelligence Center (AIC) in Amorebieta) together with the main vendor (Ericsson) and operator (Telefonica). So far it is assumed that 5G New Radio coverage will be provided, together with the edge computing and networking resources required for the specific use-case vertical application. In addition to the trial sites, some of the 5G core components could be located at 5G EVE, specifically at 5TONIC site, and it is under discussion if the remote worker could also be located here. Additionally, 5G EVE is expected to be involved to perform early testing of the use case, prior to the real field trial.

Provisional planning

The Figure 74 gives a tentative planning of this "Remote Operation" use-case deployment. The vertical is planned to be hosted the Innovalia facilities, with some initial testing, prototyping and validation performed with the help of 5G EVE sites.

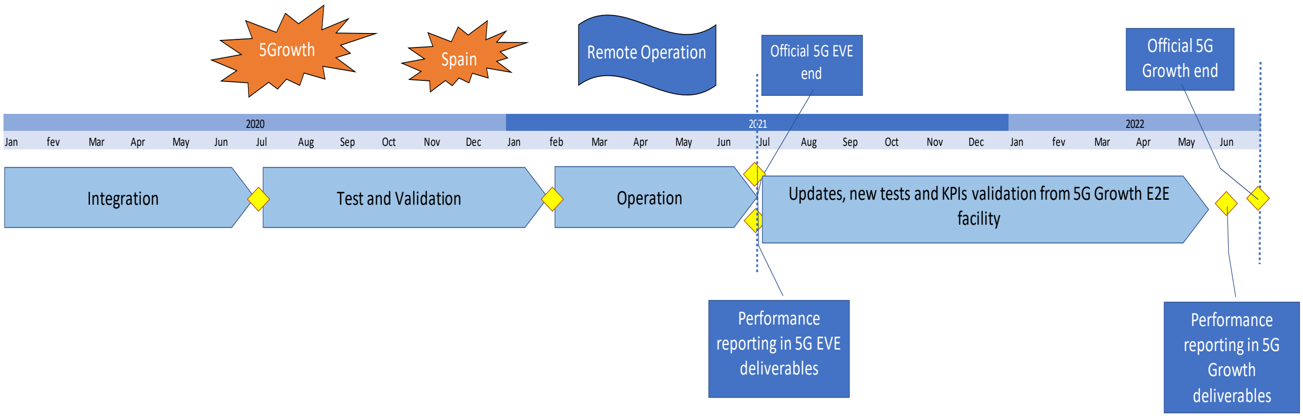

Figure 74: Provisional planning deployment of the worker remote operation use-case

4.4.2.2 Connected Worker Augmented ZDM Decision Support System

Description, KPIs and features

The objective of this use case, very related with the "Remote Operation" described above, is to provide the worker with the digital twin view and allowing him to manipulate it in real time. In this way, the inspector will be able to move within the production plant and see in his tablet the representation of the 3D Point Cloud. In addition to the latency and availability discussed before, the main challenge is the required rate for the data transmission (which is approx. 5 GB per piece). Furthermore, mobility might also be important, as the worker might be moving in the plant with a car The service would correspond to eMBB, to support the communication with the MEC server storing the 3D Point Cloud. The main KPIs are:

Availability > 99.9999 %, Latency < 5 ms, Bandwidth: 10 ~ 20 Gbps, Mobility: 3 ~ 50 km/h

Like in the previous case, some of the 5G core components could be located at 5G EVE, specifically at 5TONIC site. Additionally, 5G EVE is expected to be involved (again, the 5TONIC site) to perform early testing of the use case at Madrid, prior to the real field trial testing at INNOVALIA premises.

Provisional planning

The Figure 75 gives a tentative planning of this "Augmented" use-case deployment.

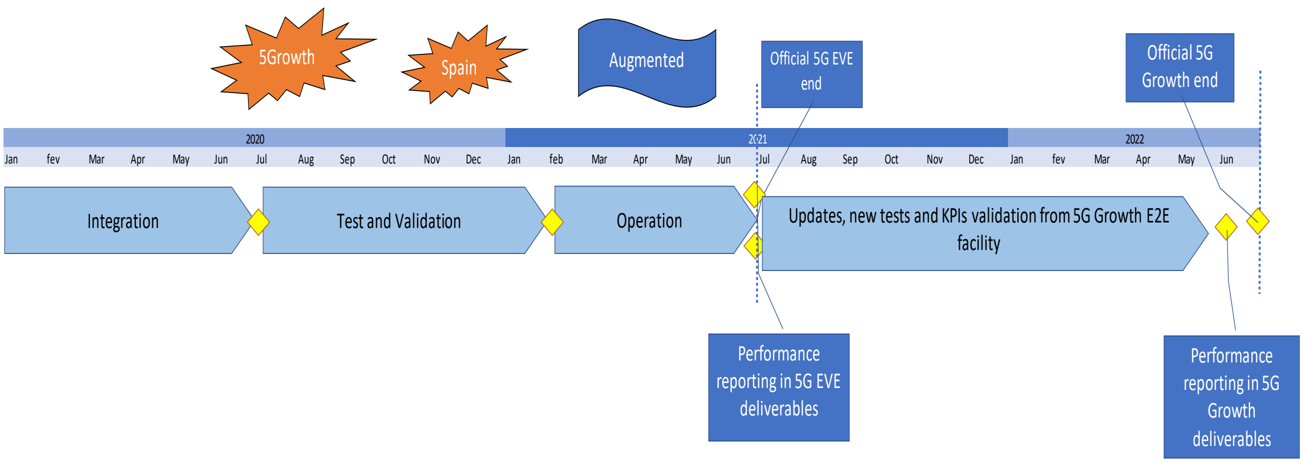

Figure 75: Provisional planning deployment of the Connected Worker Augmented use-case

4.4.2.3 COMAU Use Case 1: Digital Twin Apps

Description, KPIs and features

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

To make this possible, the real machinery is outfitted with massive sensors that send status data to the virtual reproductions on a constant basis. A requirement management system functions as a digital requirements library, gathering the incoming data and comparing it against the specifications. If a discrepancy is detected, then engineers can work on potential solutions directly on the digital twin - after which the real machine can then be updated to resolve the problem as quickly as possible. The digital twin can also be used to predict bottlenecks in the production/assembly line.

In order to have an actual and exact representation, a continuous stream of data, coming from the field (e.g. reading cycle time from PLCs and monitored parameters from sparse sensors), is needed. This requires a huge throughput and very low latency to avoid delays in the digital representation. The main KPIs are summarized in Table 26.

Table 26: COMAU use-case 1 – targeted KPIs

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

Provisional planning

Figure 76 gives the provisional planning of the integration of the digital twin use case proposed by 5G Growth in the 5G EVE site facility.

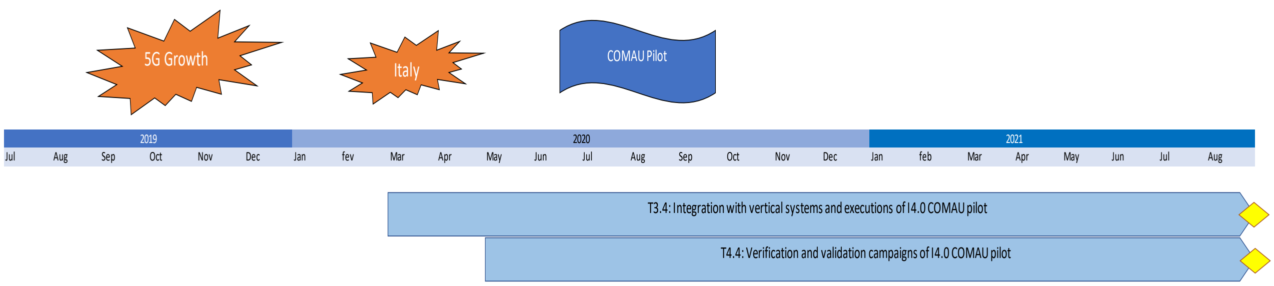

Figure 76: Provisional roadmap of the digital Twin use case

4.4.2.4 COMAU Use Case 2: Telemetry/Monitoring Apps

Description, KPIs and features

In this use case an extensive sensor deployment is in place to monitor and prevent failures of machineries and equipment through massive data collection (i.e. vibration, pressure, temperature and so on). 5G facilitates installing a wide range of different wireless sensors easy to attach on machineries. COMAU has already developed its own IIoT (Industrial Internet of Things) solution which gathers data directly from machinery as well as sensor data. This tool is constantly updated and now the next objective, addressed by the current use case, is to reinforce the fault predictive capabilities. The main KPIs for this use-case 2 are summarized in the Table 27.

Table 27: COMAU use-case 2 – targeted KPIs

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

Provisional planning

Figure 77 gives the provisional planning of the integration of the telemetry/monitoring use case proposed by 5G Growth in the 5G EVE site facility.

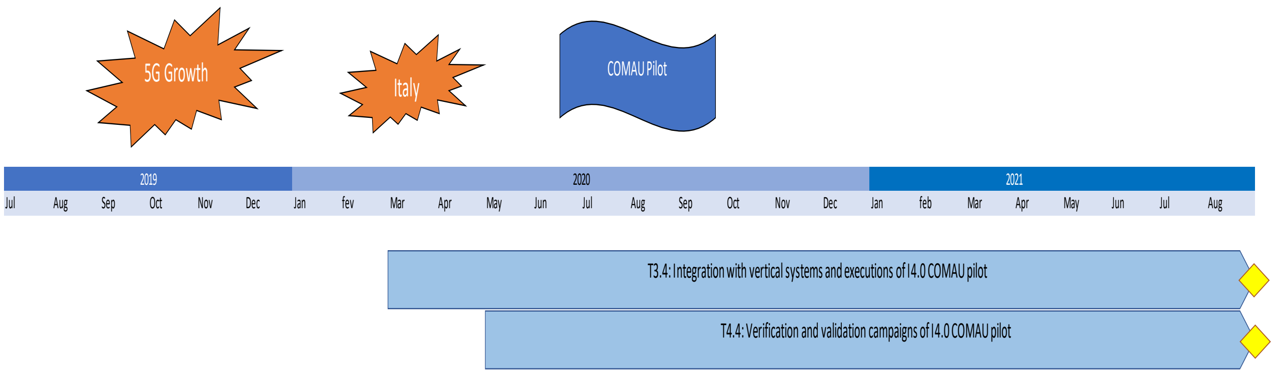

Figure 77: Provisional roadmap of the telemetry/monitoring use case

4.4.2.5 COMAU Use Case 3: Digital Tutorial and Remote Support

Description, KPIs and features

This use case aims at providing technicians and maintenance staff with digital tutorials and remote support by means of high definition videos and live connections to remote technical offices. The main objective is to reduce the MTTR using real-time streaming with a skilled technician in remote locations to support maintenance and repair operations. Other advantage is the possibility to access to tutorials and instructions for training purposes. The main KPIs for this use-case 2 are summarized in the Table 28.

Table 28: COMAU use case 3 – Target KPI's

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

Provisional planning

Figure 78 gives the provisional planning of the integration of the Digital Tutorial and Remote Support use case proposed by 5G Growth in the 5G EVE site facility.

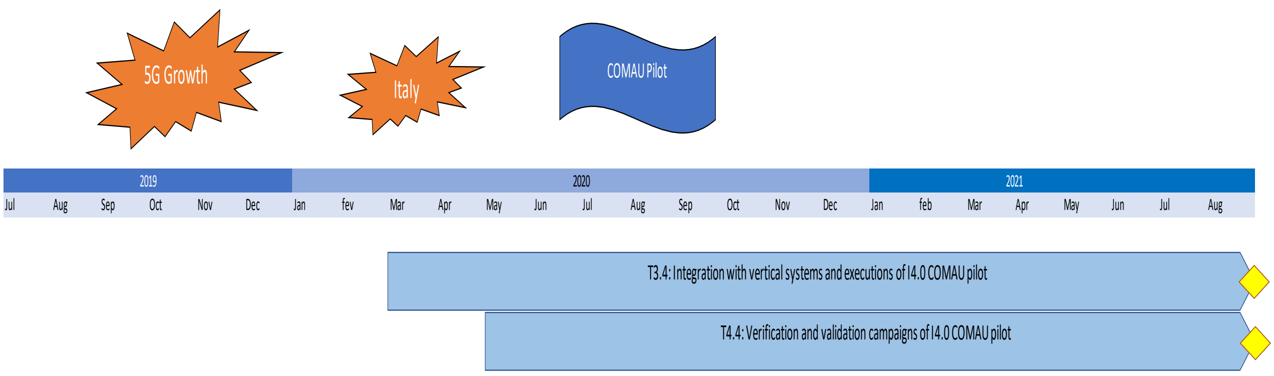

Figure 78: Provisional roadmap of the Digital Tutorial and Remote Support use case

4.5 5G HEART (ICT-19)

4.5.1 Brief project description

5G-HEART (validation trials) will focus on the vital vertical use-cases of healthcare, transport and aquaculture. In the food area, 5G-HEART focus will be on 5G-based transformation of aquaculture sector (worldwide importance for Norway, Greece, and Ireland). In the health area, 5G-HEART will validate pillcams for automatic detection in screening of colon cancer and vital-sign patches with advanced geo-localization as well as 5G AR/VR paramedic services. Regarding the transport area, 5G-HEART will validate autonomous/assisted/remote driving and vehicle data services.

The infrastructure shared by the verticals, will host important innovations: slicing as a service; resource orchestration in access/core and cloud/edge segments with live user environments. Novel applications and devices (e.g. underwater drones, car components, and healthcare devices) will be devised. In Greece, trials will run on the site of 5G EVE (Athens).

4.5.1.1 Aquaculture: Remote Monitoring of Water and Fish Quality

Aquaculture is the fastest growing animal food producing sector in the world. Aquaculture operations in 2014 supplied over one half of the fish and shellfish that is directly consumed by humans. A major challenge in EU aquaculture is the need for technical improvements; maximize the growth rate and minimize the production costs, through the optimization of production systems, while ensuring fish/seafood product quality, optimal resource use and minimisation of environmental impact. These capabilities need to be supported by an appropriate communication and data processing infrastructure.

The main motivation of the overall use case is to bring to market a new and cost-effective, networked solution to optimize the aquaculture producers' activity, through successful deployment and operation.

The sector needs to be far more efficient in utilizing productive resources. Technology has been developed to facilitate the needs of the aquaculture growth, for better control and effective management of this rising industry but the recent technology achievements are yet to be applied properly for the industry's benefit.

Description, KPIs and features

The overall installation plans to facilitate the overall motivation of the aquaculture use case, with the aim to test the 5G technology contribution to meeting the motivation's requirements along with the targeted KPIs defined by the project.
The Greek pilot will be deployed in Megara, Attica, near Athens where the Greek node of 5G EVE is located, and will be exploited to make the 5G network available to the site.

The aquaculture vertical will build a cross-border aquaculture use case with one pilot in a Greek fish-farming unit on floating facilities of fifty thousand (50000) m3 in the area of "Kato Aloni", Megara Bay, Megara, Western Attica, of the Region of Attica, operated by Skironis SA.

The unit is equipped with two floating platforms. The first is used for the daily demands of the production, and in the second there are solar panels installed to provide the unit with electricity. The network demands are covered by satellite internet and currently about 55 GB of data is used. This data are basically consumed by the already installed CCTV cameras which monitor the unit and for the needs of the staff.

The 5G-HEART project will provide a much clearer understanding of how the components of the aquaculture industry can interact, and use this knowledge to advance the production by means of targeted intervention to these components (e.g. autonomous feeding, fish health timely examination), in order to obtain total control over farm management. Currently, in the field of monitoring technologies and practices regarding water quality monitoring, the most common practices consist of water sampling or utilization of specific and dedicated sensors for parameters such as temperature, turbidity, dissolved oxygen, pH, oxidation-reduction potential, conductivity, whereas in the area fish behavior tracking, sampling and inspection outside of the normal environment is a common procedure, which is proven to be unsuccessful as this is proved to be stress event for fish, affecting the accuracy of the results.

The added value of 5G networks is multi-dimensional and can be demonstrated in a variety of cases. The main features that will be tested and are expected to enhance the operation and development of the aquaculture vertical briefly are 1. Remote monitoring of physical conditions at site - 2. Security footage site monitoring - 3. Fish monitoring - 4. Infrastructure monitoring and 5. Autonomous functionality

The data transfers considered necessary include environmental sensory data, image/video data and actuation/management information. Specifics about the actual operations that are expected to carry most of the load that is necessary for the management of the site are:

Environmental sensory data and personnel reports
It is essential for platforms providing these kinds of functionalities to support data collection from multiple data sources importing data into the management system.

Image/Video data
As already mentioned, a big portion of the data transfers that are required for the operation of the fish farming sites includes security footage obtained from cameras located on-site. However, apart from security issues, image and video footage is also exploited for monitoring purposes like fish health, feed waste management,

behavior analysis or other techniques that use image processing algorithms to extract more sophisticated information from the data and guide the management activities.

Automation and actuation functionalities

In the case of an aquaculture site, automatic feeding, maintenance or other systems precisely activating the corresponding mechanisms according to the needs of the farm stands as a major requirement for its smooth operation.

Production

Providing the fish feed that is necessary for the fish to consume in order to gain biomass. Statistical analysis has shown that 60% of the fish feed is required for the fish's energy consumption (which is basically its survival) and the 40% is required for the fish's growth.
Monitoring the sea environment (oxygen levels, turbidity, temperature, salinity) so that to provide the best conditions for the fish's health. Temperature is also a critical factor in order to decide the required quantity of fish feed that must be provided. The aquaculture network requirements measurement units and values are given in the following Table 29.

Table 29: Aquaculture network requirements

5G-Heart - UCases: direct specific requirements		Units	Use Case: Remote monitoring of water and fish quality			Priority	Range	
			URLLC	mMTC	eMBB[10]		Min	Max
General Vertical/Use Case Requirement								
1	Latency (in miliseconds) - round trip - Min/MAX	msec	10,0	50,0	25,0	High	10	50
2	**RAN** Latency (in milliseconds) - one way	msec	3,0	5,0	5,0	High	5	10
3	Throughput (in Mbps) - Min/MAX - sustained demand	Mbps	50,0	0,5	50,0	High	15	50
4	Reliability (%) - Min/MAX	%	99,9999	99,9999	99,9999	High		
5	Availability (%) - Min/MAX	%	99,99	99,99	99,99	High		
6	Mobility (in m/sec or Km/h) - Min/MAX	km/hour	10	0	0	Low		
7	Broadband Connectivity (peak demand)	Gbps	0,3	0,50	12,5**	High	1	12,5
8	Network Slicing (Y/N) - if Y Service deployment time (mi	Y/N	y (30)	y	y	High		30
9	Security (Y/N) - if Y grade i.e. "Carrier Grade"	Y/N	y	y	y	High		
10	Capacity (Mbps/m^2 or Km^2)	$Mbps/km^2$	0,300	0,050	0,5***	High	300	1000
11	Device Density	Dev/Km^2	6	100.000*	250	High		100
12	Location Accuracy	m	0,1	1	1	High		
*50 sensors cage with area of $500m^2$								
** 50 cages, 5 cameras in each cage x 50 Mbps = 12,5 Gbps								
*** In one Km2 we can fit 2.000 cages and each cage should require 250 Mbps (for the cameras)								

Accurate and effective testing, for service and network KPI measurement & validation, will be introduced, in order to verify the expected level of network quality. The KPI validation platform (KVaP), via the use of Network probes, will accumulate appropriate network parameter metrics at various points of the live network. The measurements will be transmitted and stored to a Cloud Server for further processing. The large amount of data will be analysed and presented in order to identify possible weak points and undertake corrective action for network optimization and performance improvement.

Provisional planning

In Phase 1 trials, a Proof of Concept of the proposed architecture, from the telecommunication network point of view, will take place. The devices and the application will be tested over the existing OTE $4G^+$ telecom network. The Skironis Aquaculture site will be connected, via the OTE premises at the City of Megara, to the OTE LABs in the OTE-Academy location. From there, there will be a connection to the Ericsson ePC and finally reach the Cloud and the application (WINGS). Also ACTA will install probes for network KPI measurements.

Our planned roadmap will evolve as follows and illustrated in Figure 79.

- Phase 1 trials will run during the end of 2019 and the beginning of 2020. During Phase 2 trials, an application Proof of Concept will take place, on a 5G telecom network in the OTE LABs in the OTE-Academy location.
- Phase 2 trials will run during mid-2020.

- In Phase 3 trials, a 5G network will be used, implemented over fiber optics and 10 Gbps connection. The Skironis Aquaculture site will be connected, via the OTE premises at the City of Megara, to the OTE LABs in the OTE-Academy location. From there, there will be a connection to the Ericsson ePC and finally reach the Cloud and the application (WINGS). Also, ACTA will install probes for 5G network KPI measurements.

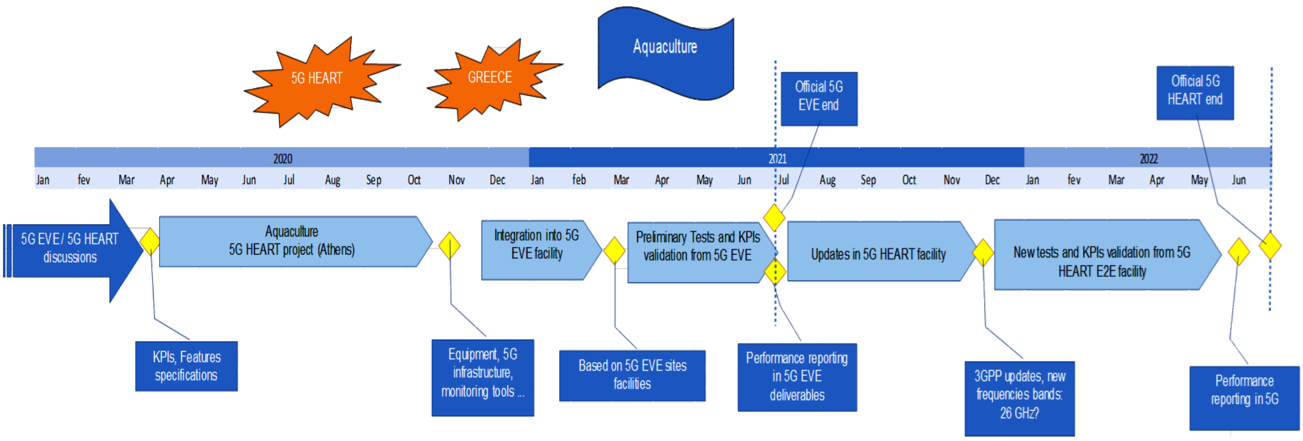

Figure 79: Provisional planning deployment of the Aquaculture use-case

4.6 5G VICTORI (ICT-19)

4.6.1 Brief project description

5G-VICTORI has been designed to answer the "ICT-19-2019: Advanced 5G validation trials across multiple vertical industries" call for proposals bringing together industrial and academic partnerships from transportation, energy, media and telecom domains. Technology and business validation of the 5G technologies developed in 5G PPP Phase-1 and Phase-2 will be carried out and will be deployed over the 5G end-to-end platforms developed under ICT-17-2018 located in Patras (GR), Berlin (DE) and Paris Saclay and Sophia Antipolis (FR), as part of the 5G-VINNI, 5GENESIS and 5G EVE projects.

5G-VICTORI will deliver a set of services to various vertical industries using different network slices. These slices will concurrently offer services for:

- the **Enhanced Mobile Broadband (eMBB) use cas**e requiring high network bandwidth and low latency providing support for safety (video surveillance for the monitoring of rail and energy assets) and infotainment applications (media broadcasting to passengers, immersive media in cities, stations, etc).
- the **Ultra-Low Latency Reliable Services** (**ULLRS**) providing suitable network and compute resources for **Critical Communications networks** addressing the needs of the *RAIL* (Signalling like Urban Rail Communication Based Train Control or Railways European Train Control System, Operational Voice communication, between train drivers, dispatchers and operational staffs, and including emergency calls & group calls), *Telecom* (fronthaul services) and *Energy* verticals (smart energy metering).
- The Massive Machine to Machine (mMTC) Internet of Things (IoT) use case serving a large number of devices offering services for transportation (Automatic Train Operation, mandatory for Autonomous driving and Driverless), energy (massive metering applications), transportation, safety and city stakeholders.

5G EVE French site at Paris and Sophia Antipolis connected with the Romanian cluster is build considering the next clusters capabilities and actions:

- 3GPP 5G NR, 3GPP 4G LTE, 3GPP 4G LTE-M, 3GPP 4G NB-IoT, 3GPP Rel 15 EPC (MME,HSS,S+PGw), 3GPP Rel 15 5GCore

- FlexRAN: a SW-defined RANs
- LL-MEC: a low-latency multi-access edge computing
- Resilient, instantaneous connectivity, which drives the need for URLLC
- 5G EVE Web Portal access for service deployment
- 4G/5G OAI extension capabilities to the sites
- ONAP capabilities extension and integration into the environment
- Cluster integration and adaptation
- RRU based on USRP N310
    - Wide Band Outdoor Antennas (800 - 3000MHz).
- Servers for computing
- Mobile/portable devices for performing calibration and testing activities, Tablets and/laptops to run tests
- End-to-End Cluster integration and adaptation

4.6.2 Use-cases

4.6.2.1 On-demand network creation for emergency services

Description, KPIs and features

Public service vehicles (buses) will be equipped with Wi-Fi connectivity backhauled over 5G connectivity. The platform provides Secure Internet access to passengers and real-time information related to GPS positioning, speed, direction of movement. Within 5G-Victori project the platform will be enhanced with an advanced SDN control plane solution to enable the creation of a network slice that can be allocated for provisioning of mission critical services (audio, video, data). Under emergency situations, network capacity dedicated to passengers' services will be reconfigured to create a LAN around the incident location and will connect to the backbone of the network (backhauling) where mission critical servers are hosted with guaranteed bandwidth (Figure 80). The creation of this infrastructure slice will be triggered either manually (i.e. by the driver of the Bus) or automatically by an external event alert.

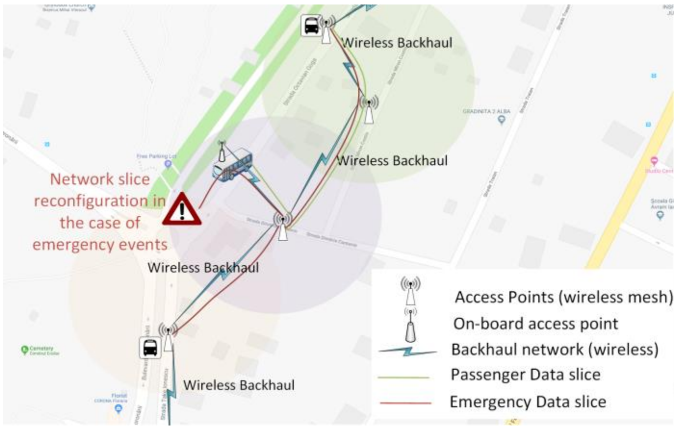

Figure 80: Network Slice reconfiguration in case of emergency events

This Use case with their respective targets are depicted in the Table 30, related to the use case family:

Table 30: KPIs for on-demand network for emergency services

Critical Services	uRLLC (Realtime) low latency (e.g. as low as 1 m E2E; Round trips latency less than 100 ms	UE-UE latency: 8 ms	0.5 ms one-way dely

Provisional planning

Figure 81 gives the provisional planning deployment for the on-demand network creation for emergency services that will take place France site facility.

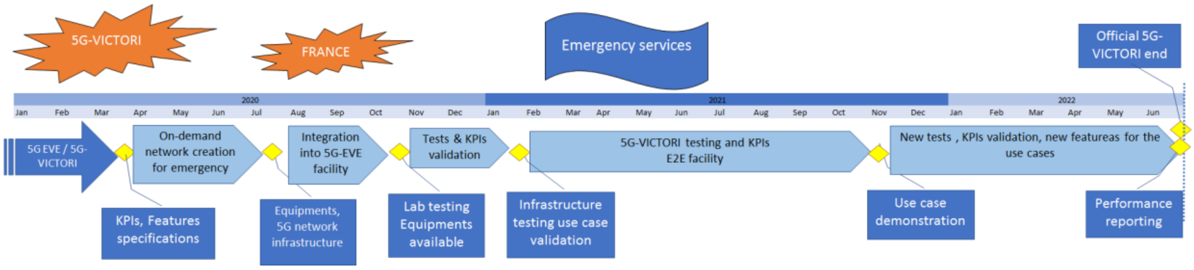

Figure 81 : Provisional planning deployment on-demand network creation for emergency services

4.6.2.2 Energy Metering LV

Description, KPIs and features

The use case is intended to demonstrate in the 5G EVE infrastructure the energy metering services for public buildings and street lighting in the Alba Iulia Smart City environment in Romania. The massive number of low cost/low energy consuming devices will be installed across the city that will operate adopting the Narrow Band-Internet of Things (NB-IoT) open source implementation of the OpenAirInterface (OAI).

The main KPI defined for this use case is depicted in the Table 31:

Table 31: KPIs for on demand on-demand network creation for low voltage use case

Energy metering LV	mMTC for LV: high density distribution (10k sensor / 10sqkm)

Provisional planning

Figure 82 gives the provisional planning deployment for the on-demand network creation for emergency services that will take place France site facility.

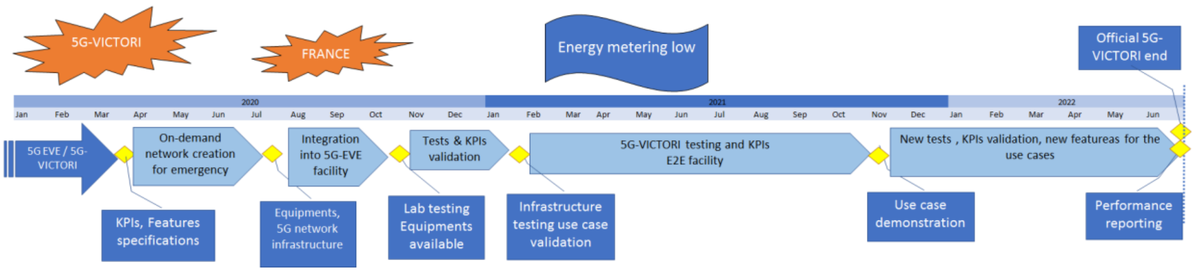

Figure 82: Provisional planning deployment on-demand network creation for low voltage

The general planning includes activities related to availability of the sites and sites survey, equipment's acquisition for the platforms, integrations of the infrastructures and extension to the Romanian cluster of the 5G EVE capabilities, testing of the infrastructure and several actions for use-cases integration in the platform, evaluating the possible needed adaptations. The two 5G-VICTORI use-cases supported by the 5G EVE for the Romanian cluster will be the validated and demonstrated, in terms of KPIs and business model.

4.7 5G DRONES (ICT-19)

4.7.1 Brief project description

Unmanned Aerial Vehicles (UAVs) have initiated a wide range of civilian and commercial applications, such as for traffic control, cargo delivery, precise agriculture, video streaming, rescue and search, and data collection for Internet of Things (IoT). Regulatory changes, technological advancements, and the reduced cost of sensory components and onboard control units have made UAVs more accessible for consumer and civilian applications. There is a wide consensus that their areas of activity will significantly expand in the years to come. To enable the wide adoption of UAVs, it is vital to build on reliable wireless networks that support ultra-reliable and low latency remote command and control of UAVs to guarantee their safe operations, and high- capacity data transmissions for bandwidth-demanding applications. In this regard, 5G systems can be envisioned as key enablers for UAV-based services and applications. 5G systems have been specifically devised to enable vertical applications, such as UAV-based ones, to be run on a common infrastructure.

Integrating UAV in 5G is beneficial for both UAV verticals and 5G actors (mainly operators). For UAV verticals, 5G will validate their use-cases and demonstrate the benefit as well as huge potential of UAV for the civilian and commercial applications, while avoiding the maintenance and operation cost related to the network platform management. For 5G actors, enablement of UAVs will allow validation of the potential of 5G and its key performance indicators (KPIs) for supporting challenging use cases, hence covering new markets. Indeed, the final adaptation of 5G requires the validation of use-cases coming from verticals, and demonstrating that 5G KPIs guarantee the performance expected by the verticals' use cases. While several EU projects have been funded to study 5G, so far, none has validated KPIs for UAV verticals. UAVs challenge 5G deployments for example, by operating at altitudes not designed for regular user equipment and hence require additional coverage planning.

The 5G!Drones project aims to trial several UAV use-cases that cover eMBB, uRLLC and mMTC 5G services, and validate 5G KPIs which apply to support such challenging use cases, and to enhance them with powerful features. Indeed, 5GDrones will drive the UAV verticals and 5G networks to a win-win position, on the one hand by showing that 5G is able to guarantee UAV vertical KPIs, and on other hand by demonstrating that 5G can support challenging use-cases that put pressure on network resources, such as low- latency and ultra-reliable communications, massive number of connections and high bandwidth requirements. Moreover, 5GDrones will propose novel methods for UAV traffic management services based on virtual reality; made possible by the underlying 5G technology.

4.7.2 Use-cases

4.7.2.1 UAV Traffic Management

Description, KPIs and features

This use case will demonstrate a common functionality for all UAV applications, by providing the necessary safe and secure incorporation of drones into the air traffic. Indeed, the dramatic growth of UAVs over the past decade and the subsequent development of commercial drone activities especially at low altitude have posed the question of drones' safe and secure flight operations in the face of increased air traffic. UTM (UAS Traffic Management) is expected to manage drone traffic in the lower altitudes of the airspace, providing a complete and comprehensive end-to-end service to accumulate real-time information of weather, airspace traffic, drone registration, and credentials of drone operators, among others. The need for UTM systems has been driven by a number of factors such as the recent increase in the number of drones in the airspace, increasing involvement of different governments and emerging regulations, as well as collaboration of key stakeholders for the development of a working architecture. In the European Union, UTM systems (level U1: E-registration, E-Identification and Geo-awareness) will be mandatory in every EU country by 2019 and the next level U2 is expected to be enforced in two years timespan. Furthermore, public security and safety concerns, privacy concerns, and vulnerability to cyber-attacks are some of the major challenges to the adoption of the UAS traffic management systems. It should be noted that drone applications will require extremely low end-to-end latency, in the order of milliseconds, in order to operate in a safe and secure way.

In this scenario, the 5GDrones project aims to demonstrate a UAV traffic command and control application, which will manage a high number of flying drones. It includes Beyond Visual Line of Sight (BVLoS) drone operations, and entails long-range commercial drone control, for applications such as drone delivery. The command and control application will demonstrate features such as automatic collision avoidance of drones, especially those flying in swarm, which requires sending large amounts of data in near real time to assess the potential risks in the sky and enable an enhanced flight awareness of all types of flying objects. Particular efforts will be drawn in this scenario to the security and integrity of command and control traffic. Indeed, ensuring that a malicious third party is not capable of taking control of operating drones is essential to deploying such unmanned device in urban and critical environments. In addition, one BVLoS application enables secure controlling of the drone (telepresence) using the VR/AR equipment.

In this use-case scenario, the 5G network needs to provide i) a cross-domain network slice for UAV traffic control – a uRLLC slice able to reduce delay and having a high priority; ii) in addition to low latency and high priority, this slice should ensure the authentication of users as well as the integrity and often confidentiality of the conveyed control traffic – in particular, end to end encryption of the slice can be a solution that would protect a third party from taking control of the drone; iii) a UAV control applications hosted at the edge; and iv) the possibility to have D2D communications in licensed or unlicensed spectrum (Wi-Fi).The KPI to measure are:

- End-to-end latency
- The time needed to deploy a UAV service using a network slice provided by the 5G facility.
- Monitor all UAV service components and their underlying network slices.
- Capacity to increase/decrease resources used by the UAV slices.
- Covered area and Security

Provisional planning

Figure 83 gives the provisional planning for the UAV traffic management use case in the 5G DRONES to be deployed in the French site.

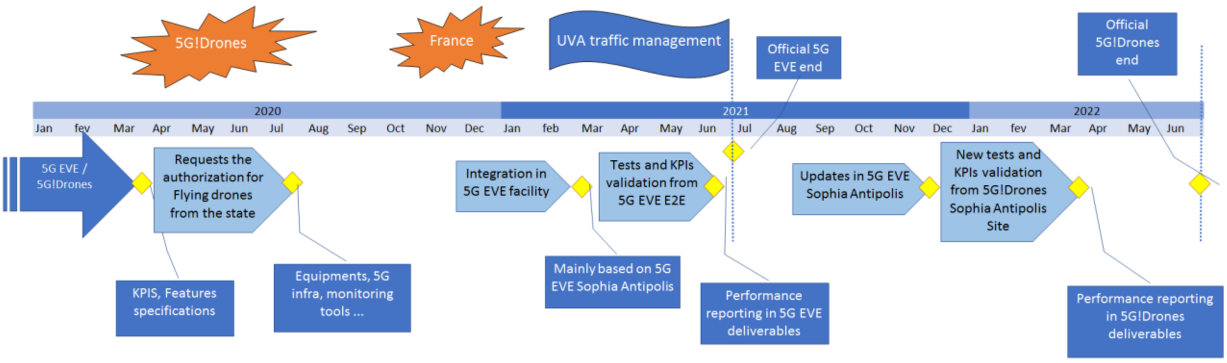

Figure 83: Provisional planning deployment of the UAV traffic management use-case

4.7.2.2 Public safety/saving lives

Description, KPIs and features

Natural and human-instigated disasters destroy environments and put public safety at risk. These situations include natural disasters such as earthquakes, wildfires, storms, landslides, Tsunami, CBRNE (chemical, biological, radiological, nuclear or explosive) related events and even terrorist attacks. In these situations, it is difficult and unsafe for relief workers to access areas and provide assistance. Furthermore, natural disasters can create physical disturbances that have the power to cause significant damage to cities and vulnerable communications equipment that is responsible for supporting these areas. Disruptions caused by physical damage to the communications equipment are likely to be incredibly expensive and time-consuming to restore, hindering the process of providing emergency response to those affected by the disaster. At the same time, communication networks tend to become congested with high levels of data traffic during disasters as those impacted seek to contact family and friends, and hundreds more upload pictures and videos of the damage, resulting in deterioration of network service, blocking of new connections, and loss in data transmission.

Thus, measuring the damage and providing relief in these situations must be swift and effective. UAVs can play a vital role here as they have the ability to take on roles where relief workers and manned vehicles fall short. First, UAVs can be used to take high-resolution images and perform 3D mapping in large-scale disasters such as earthquakes, flooding and wild fires to identify hotspot areas that have sustained the most damage and upload the data in real time to coordinate relief efforts. The use of UAVs for this purpose provides greater advantages in costs and in rapid response times than traditional methods. The use of UAVs is cheaper, faster, and safer than manned aircraft. In addition, UAVs can provide high-resolution images, which cannot be provided by satellites.

In this use-case we will explore two scenarios on the 5G EVE facility:

- The first one is “Monitoring a wildfire”, where UAVs are equipped with HD cameras can be used for streaming HD video to a remote application hosted at the edge. Using AI tools, the remote application analyses the video to predict the direction of spreading of wildlife to the firefighters so they can pay immediate attention to those areas and also avoid using the potentially dangerous routes for rescue operation. In such a case, 5G-based eMBB is needed to handle the video traffic volume efficiently. Moreover, the support of a MEC server to process the video as close as possible to the rescue operation is necessary. In this scenario, the 5G network needs to provide i) two cross-domain network slices for UAV traffic control and drones’ data, i.e., a uRLLC slice able to reduce delay to offer the appropriate level of security and isolation, and having a high priority for UAV traffic control and an eMBB slice with high-priority for the HD video stream sent by the drone. Given the nature of the monitoring operation, a strict isolation between these slices spreading until the radio segment should be ensured with a particular attention to be drawn to the security of this control slice; depending of the conveyed HD video traffic and its copyright requirements a controllable level of security can be added to the eMBB slice. The network also needs to provide (ii) edge cloud resources to host both the drone control application and a data analysis server. The instantiation of resources and their dynamic configuration will leverage the virtualised 5G architectures we rely on in this project.
- The second one is “Disaster recovery”, where UAVs are considered fitted with 5G small cells and can be carried close to the disaster area using a mobile ground station. UAVs can interconnect and communicate with the ground station over direct D2D links, allowing for the rapid deployment of a wireless backhaul in situations where capacity is needed on an expedited basis, as these networks allow both victims and emergency workers to communicate when it is most important. This would then allow the swarm of tethered and untethered UAVs to be used to bridge the signal for backhaul interconnect and provide ultra-reliable low latency and other types of wireless connectivity to those who severely need it with the dynamic network coverage they offer. In this scenario, the 5G network needs to provide i) two cross-domain network slices for UAV traffic control and drones’ data, i.e. a uRLLC slice able to reduce delay and having a high priority for UAV traffic control and an eMBB slice with high-priority for the data sent by drones; ii) edge computing resources to host both the drone control application and a data analysis server; iii) enabled D2D communications in unlicensed or licensed spectrum.

The KPIs to measure are:

- End-to-end latency
- The time needed to deploy a UAV service using a network slice provided by the 5G facility.
- Monitor all UAV service components and their underlying network slices.
- Capacity to increase/decrease resources used by the UAV slices.
- Perceived quality of experience
- Covered area
- Security

Provisional planning

Figure 84 gives the provisional planning for the public safety/saving use case in the 5G DRONES to be deployed in the French site.

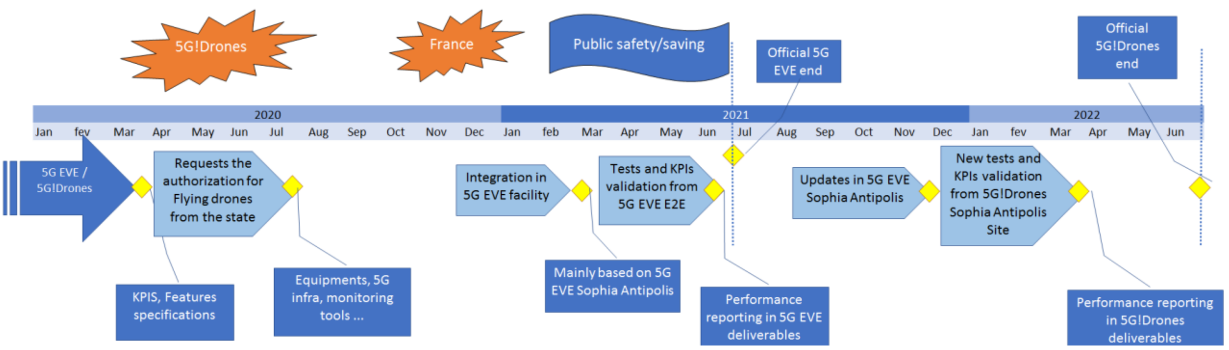

Figure 84: Provisional planning deployment of the public safety/saving lives use-case

4.8 5G-DRIVE (ICT-22)

4.8.1 Brief project description

5G-DRIVE will trial and validate the interoperability between EU & China 5G networks operating at 3.5 GHz bands for enhanced Mobile Broadband (eMBB) and 3.5 & 5.9 GHz bands for V2X scenarios. The key objectives are to boost 5G harmonisation & R&I cooperation between EU & China through strong connected trials & research activities, with a committed mutual support from the China “5G Large-scale Trial” project led by China Mobile.

To achieve these objectives and to deliver the impact for early 5G adoption, 5G-DRIVE structures its main activities into three pillars.

- The first one will test and demonstrate the latest 5G key technologies in eMBB and V2X scenarios in pre-commercial 5G networks. 5G-DRIVE will run three extensive trials in Finland, Italy and UK. The Chinese project will run large-scale trials in five cities. These twinned trials aim to evaluate synergies and interoperability issues and provide recommendations for technology and spectrum harmonisation.
- The second one focuses on researching key innovations in network slicing, network virtualisation, 5G transport network, edge computing and New Radio features to fill gaps between standards and real-world deployment.
- The third one will push EU-China 5G collaboration at all levels thru extensive dissemination and exploitation actions.

Most relevant to the use of 5G EVE facilities by 5G-DRIVE is 5G-DRIVE Objective 1 (which is part of above pillar 1):

> *to build pre-commercial end-to-end testbeds in two cities with sufficient coverage to perform extensive eMBB and Internet of Vehicles (IoV) trials. Joint test specifications will be defined through the collaborative agreement with the Chinese project.*

As of October 2019, the setup of testbeds in different trial sites is in progress. The eMBB trials in the Surrey site have been started. In the Espoo site, the 3.5GHz spectrum band has been approved for trials. The installation of 5G gNB in the Espoo site is expected until end 2019. The trial plans for eMBB and V2X have been defined. 5G-DRIVE and the twin project have agreed on how to define the joint trials. The joint test specifications are under discussion.

4.8.2 Use-cases

4.8.2.1 eMBB Network Slicing Evaluation

Description, KPIs and features

5G-DRIVE would like to utilize the 5G EVE infrastructure in order to test the eMBB slicing performance in a pre-commercial network environment which 5G EVE is assumed to provide. The tests will focus on the evaluation of the overall network performance of a slice for eMBB-type services. The vertical application domain of the testing service is Media & Entertainment, although it should be noted that a dedicated company from this vertical sector will not be involved in performing the trials.

The planned trials with network slices instantiated on the 5G EVE infrastructure will naturally require that 5G EVE has the 3GPP SA architecture including the slicing feature implemented.

5G-DRIVE is interested in performing two main evaluations:

- one is the end-to-end slicing evaluation with service chains across radio access network (RAN) and core network (CN); while
- the other is service slicing performance evaluation with the focus on eMBB services at the RAN side.

In addition, 5G-DRIVE is also interested in evaluating performance aspects related to deployment of a network slice, which includes basic performance parameters in slicing life-cycle management. Main KPIs to test are:

- Basic performance including throughput, latency in slicing against service level agreement (SLA) / quality of service (QoS)
- Service isolation performance – evaluate slicing isolation and resource sharing among at RAN and CN
- Slice deployment performance
- Mobility support - Continuity of slices when user equipment (UE) hands over between gNBs.

Provisional planning

Network infrastructure

The basic performance of the network slicing will be evaluated. No additional equipment except the regular 5G EVE network infrastructure is needed by 5G-DRIVE to perform the tests.

User equipment

5G-DRIVE considers to bring test UE and test software to the 5G EVE sites. As the tests are basic network performance tests, 5G-DRIVE will utilize its UE(s) to test the facility offered by 5G EVE site(s).

Schedule and timing

The tests could be done in two stages:

- Discussions between 5G EVE and 5G-DRIVE about the overall test framework, KPIs, test site location, schedule and further details could start from 1Q 2020.
- In the first stage, the partners from 5G-DRIVE will conduct tests through remote access to 5G EVE platforms or by visiting one (or more) 5G EVE sites. From 5G-DRIVE perspective this could start from 2Q of 2020.
- In the second stage, an interconnection of the 5G EVE platform and the 5G-DRIVE testbed may be considered for doing an overall end-to-end evaluation. However, the feasibility of implementing an interconnection and the required effort will need further investigation.
- 5G-DRIVE will end on 28 February 2021, i.e. any trialling will need to be completed by then.

Location:

5G-DRIVE is not bound to a specific 5G EVE site and is flexible to make tests at any of the 5G EVE sites. In case an interconnection between the 5G EVE platform and the 5G-DRIVE testbed will be setup, it should be noted that the 5G-DRIVE testbed will be located in Espoo, Finland.

Figure 85 gives an overview of the potential planning of using 5G EVE facility for deploying the network slicing network use case.

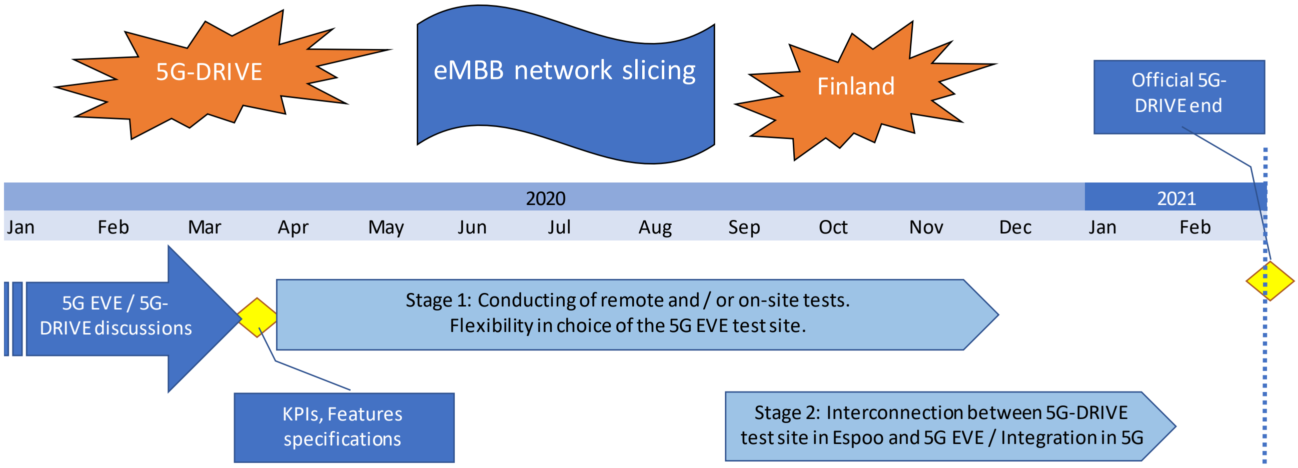

Figure 85: 5G DRIVE eMBB Network Slicing Evaluation use case roadmap

5 Conclusion

This deliverable presents a complete update about the status of each site facility of the E2E 5G EVE platform after one year of project. The main achievement is that the **internal verticals** have already been integrated in their respective site facility, even if mainly in lab environment and based on 4G Radio legacy network infrastructure. Anyway, the first and initial 5G components integration is in progress. This is mainly due to the fact that the 5G RAN and CORE components are currently in a phase of tests to validate the 5G Release 15 specifications and also to the fact that the mobile terminals (UEs) are not completely available yet. This did not prevent us to make some performance tests on the infrastructures where the verticals are implemented by validating some KPIs (throughput and latency in particular). From July to December 2019 the 5G components' integration process will intensify to propose 5G sites facilities compliant with 3GPP Release 15. Furthermore, the four sites facilities will be interconnected to be viewed as an one single 5G EVE facility through the Inter Working Layer facility that will be implemented in the next months.

Each site has been detailed in terms of function components integration in its own current state and in the next steps of new functionality (especially 5G based) implementation. Iterative process will be carried out with the internal verticals to evaluate the improvements in terms of performance regarding the site facility updates in the new 3GPP releases features.

In parallel with the integration of the 5G EVE internal verticals, discussions with ICT-19 projects are in progress to validate their requests to be aligned with the 5G EVE facility capability. The collection phase from these projects is underway, as well as their integration roadmap to evaluate the overall planning for all verticals integration/testing/validation that is supposed to start from January 2020 and continue up to June 2021. A first description of some ICT19 and ICT22 projects, especially in terms of use-cases, is made in this document as a preliminary overview of the sites facilities that are required to host verticals and the main KPIs that they plan to reach.

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ANNEX A

Table 32: Orange site facility planning

Categor	Item / Component / Functionality	Responsible Partner	HEALTH	Due Date	Status	Last Chec	Comments
Use-case	Video 360' Orange use-case (#O1) the video 360' set-up that includes: - the video platform - the head mountain display - the video content.	Orange		M9	On time for M10 T	02/05/2019	1st integration of the VR 360' with OAI - First tests in labs and 1st measurements
CC Fr RAN Infrast	Outdoor RRH implementation at Orange Gardens Châtillon (#O4)	Orange		M8	Standby	02/05/2019	This action is put in standby as Orange is mainly working in the infrastructure aspects. The B78 frequency band is available. The process has been launched to obtain the rights to install a RRH in the roof top of the building. The deadline has been reviewed for the 2nd semester of 2019. Discussion with RRH provider for interface with OAI
	NR band 78, 3700-3800 MHz (#O6)	Orange		M6	Granted	16/01/2019	Available in Châtillon Orange Gardens site
	OAI CORE components in 4G (#O5)	Orange		M4	Done	16/01/2019	Plug'in has the OAI 4G Core available as ATOM. This will be updated for 5G support
UE	User equipments (#O11)	Orange		M10	On going	10/07/2019	Some 4G UE are available. About 5G UE, pre-commercial NR 5G should be available at M10. Current discussions with UE manufacturers have been engaged. NR 5G commercial UE will be purchased end of september 2019 The OAI NR 5G UE is also one alternative for first tests.
Network Orch and Infra	Orange infra + ONAP (#O12)	Orange		M10	Done	10/07/2019	Openstack and ONAP installation ready at Orange châtillon infra
	SW infrastructure of the Orange Plug'in platform (#O3)	Orange		M6	Done	02/05/2019	Orange Plug'in Platform already hosted a lot of functionalities. Servers have been installed with OpenStack and ONAP. Platform is operational
	Network infra. L3 VPN IPsec between french clusters (#O9)	Orange		M8	Done/On going	10/07/2019	Interconnection with bcom already done. Interco with Nokia and Eurécom planned the 23th of July 2019
	Orange infrastructure deployment (#O2)	Orange		M9	Done	02/05/2019	Orange infrastructure is operational
	ONAP Casablanca Release (#O7)	Orange		M10	On going	02/05/2019	First Beijing ONAP version is currently under deployment. ONAP ready for end of May
Tools	French cluster common monitoring tool (#O10)	Orange		M8	On going	10/07/2019	Some tools are already implemented in the plug'in Platform. Discussions on the final choice are current (also with the other 5G EVE partners WP4). The service catalog specified the availability of some tools
Integration	Orange Plug'in Phase1 (#O15)	Orange		M12	Done	02/05/2019	LTE-M for extensive coverage in the scope of 3GPP evolution. Collaboration with b<>com and presentation during the Orange workshop first week of April
	Orange Plug'in Phase1 (#O13)	Orange		M6	Done	02/05/2019	2.6 GHz TDD LTE eNodeB validation based on OAI framework with slice management and flow prioritization. Collaboration with b<>com and presentation during the Orange workshop first week of April
	Orange Plug'in Phase1 (#O14)	Orange		M9	Shift to plan (M18	10/07/2019	5G NR OAI lab transmission in band 78, 3700-3800 MHz - May be some shift in the implementation (M18)

Table 33: Nokia site facility planning

Categ	Item / Component / Functionality	Responsible Partner	HEALTH	Due Date	Status	Last Check	Comments
RAN Infra	4G LTE eNB (Baseband, 3 sectors Radio Unit), gNB: Cloud Unit + Digital Unit + 3 sectors Radio Unit (REF#N1)	NOKIA		M3	Done	M12	Deployment done
	Pico-datacenter with SDR capabilities connected via the fronthaul network to the antenna site (REF#N3)	NOKIA		M8	On going	M12	Compute infrastructure is installed (M6), functions can be deployed (M7). Direct fibber connection has been set up physically to connect to Antenna System but not yet configured on the routing side therefore M8 cannot be done yet. VPN interconnection not done yet, prevening furthermore M10.
	Edge cloud (REF#N4)	NOKIA		M8	On going	M12	Compute infrastructure is installed (M6), functions can be deployed (M7). Connection to antenna system is possible (M8)
Frequency I	NR band 78, 3700-3800 MHz in Nokia - Paris-Saclay (REF#N1)	NOKIA		M10	Done	M12	
	NR band 28, (708-718/ 763-773 MHz) in Nokia - Paris-Saclay (REF#N1)	NOKIA		M10	Done	M12	
CORE	Cloud native ePC (MME, S/P GW, PCRF, SDL/HSS) (REF#N2)	NOKIA		M4	Done	M12	
	Central cloud based on NIP (REF#N5)	NOKIA		M8	Done	M12	Available but not yet conected to VPN
Network Orchestration and Infra	Research platform orchestration (REFN#3,4,5)	NOKIA		M7	Done	M12	
	iFun platform orchestration (REFN#1)	NOKIA		M8	On going	Delays due to fibber connection	
	French cluster orchestration (REF#N5)	NOKIA		M12	On going	Delays due to VPN connection	Planned in July 2019
T	Monitoring & supervision of Nokia location (REF#N6)	NOKIA		M13	On going	M12	solution identified & development on-going
Integration	Nokia Research Platform Phase1: infrastructure deployment and interconnectio	NOKIA		M6	Done	M12	
	Nokia Research Platform Phase2: end-to-end deployment of functions	NOKIA		M7	Done	M12	
	Nokia Research Platform Phase3: interconnection with iFun, validation of end-to-end services spanning iFun and Nokia Research platform	NOKIA		M8	On-going	M12	Fibber has been physically installed but not yet configured
	Nokia Research Platform Phase3: interconnection of iFun+Nokia Research Platform to rest of French cluster, offering a single interface from Nokia to ONAP	NOKIA		M10	On-going	M12	VPN not yet configured. Practical means to connect to ONAP are under investigation

Table 34: b<>com's Flexible Netlab components planning

Categ.	Item / Component / Functionality	Responsible Partner	HEALTH	Due Date	Status	Last Check	Comments
RAN Infrastructure	Rennes 2,6 TDD GHz LTE eNodeB RAN (#B2)	b<>com		M3	Done	M12	* Deployment done. Test within the scope cell radius and frequency done * OAI RAN packaging to be improved (should be based on future 5G EVE catalogue)
	Add NB-IoT support to (#B2) eNodeB RAN (#B4)	b<>com		M12 (=>M2	Not Started	M12	NB-IoT compliancy with TDD is only in Release 15, in band 41 only but not in Europe. In Release 13, only HD-FDD is supported in various band. New scenario under investigation to align band availability by ARCEP, COTS UEs availability and eNB availability based on OpenAirInterface. First implementation won't be available before M24 in any case.
	Rennes 3,5 GHz TDD LTE eNodeB RAN (#B3)	b<>com		M8 (=>M18	On going	M12	USRP technical scenario to be challenged due to adjacent interferences issues. Another technical scenario identified and to be evaluated. Discussion to host the antenan in a high tower also started. Disponibility date to be confirmed. Shifted to M18. Frequency may change depending on its availabilty (see #B7)
Frequency	LTE band 38 frequency allocation (#B6)	b<>com		M3	Granted	M12	Availability Rennes & Lannion
	NR 5G band 42 (#B7)	b<>com		M3	Granted	M12	Availability Rennes & Lannion. This frequency seems however compromised in short term as it is planned for commercial usage
	ISM bands (#B8)	b<>com		M3	Granted	M12	868 MHz & 2,4GHz - 5GHz WiFi
COR	WEF CN (#B5)	b<>com		M3	Done	M12	A new dedicated (to project) CN deployment will be done before M10
	WEF CN using ODL SDN controller (#B9)	b<>com		M3	Done	M12	Split SPGW control / data plane using OpenDayLight SDN Controller
UE	COTS LTE devices (#B11)	b<>com		M3	Done	M12	Motorola X Play smartphones, Huawei E8278 USB dongle, SDR OAI UE based on USRP
	Quectel NB-IoT UE (#B12)	b<>com		M3	Done	M12	Quectel NB-IoT UE available
	New NB-IoT UE references (#B16)	b<>com		M24	Delayed	M12	Purchase new NB-IoT UE devices delayed due to issues identified in #B4. This action is shifted from M16 to M24
	COTS 4G LTE Routers (#B20)	b<>com		M14	On going	M12	Purchase of 4G LTE router COTS devices. Target references are Bintec RS353jwv-4G and Teltonika RUT955
Orch and Infra	NFVi hardware purchased (#B1)	b<>com		M3	Done	M12	The initial hardware to setup the NFVi has been purchased and integrated into the datacenter. It is composed of 7 DELL R640 Servers allocated for VIM and Network storage.
	NFVi hardware extension purchased (#B14)	b<>com		M12	Done	M12	2 extra DELL R640 servers have been purchased and will be shortly integrated in the datacenter to extend the VIM computational capacity.
Tools	NFVi Metrics collection (#B10)	b<>com		M8	Done	M12	Metrics are generated and collected at OpenStack. Need to work with Orange to collect them at site facility level
	RBAC based on ssh key signature (#B17)	b<>com		M14	On going	M12	A SSH key signature mechanism providing RBAC will be deployed on the testbed
	Infrastructure Monitoring based on Prometheus (#B18)	b<>com		M14	On going	M12	Prometheus will replace previous tool to monitor Infrastructure. Metrics will improve the troubleshooting capacity although it is not expected to be published to the project. However they will be used to provide overall infrastructure availability indicators
Integrat	Deployment planning for initial access (#B13)	b<>com		M10	Done	M12	Inial access performed according to the initial scheduling
	Deployment planning (Midterm) (B#15)	b<>com		M18	On going	M12	NB-IoT deployment delayed. New actions planned for this period.
	Deployment planning (M24) (#B19)	b<>com		M24	Not Started	M12	Includes deployment Phase 3 NB-IoT which have been shifted due to issues .

Table 35: Eurécom Open5GLab components planning

Catego	Item / Component / Functionality	Responsible Partner	HEALTH	Due Date	Status	Last Check	Comments
RAN Infrastructure	4G RAN indoor deployment (Band 38)	EURECOM	network is live.	M6	completed	24/01/2019	
	4G RAN compute fabric	EURECOM	operational	M3	aquired and operational	24/01/2019	
	5G RAN compute fabric	EURECOM	operational	M6	acquired	24/01/2019	
	4G IoT RAN RF components (bands 68 and 28)	EURECOM	waiting for UHF FDD duplexers.	M9	on time for M9 target	24/01/2019	
	5G RAN RF components (16 antenna elements)	EURECOM	RRUs ready for deployment.	M6	acquired	24/01/2019	
	5G RAN deployment (lab)	EURECOM	running and used for 5G NR Continuous in	M6	completed	24/01/2019	
	5G RAN deployment (outdoor)	EURECOM	antennas deployed. RRUs deployment aw	M9	on time for M9 target	24/01/2019	
	4G RAN deployment (outdoor, band 38)	EURECOM	delayed until antenna and eCPRI RRU arri	M9	expected M16	22/07/2019	Decision to use commercial eCPRI RRU for Band 38.
	4G RAN IoT deployment (outdoor, bands 28 and 68)	EURECOM	delayed until antenna arrives	M12	expected M16	22/07/2019	
	5G RAN switch fabric	EURECOM	operational	M10	acquired, expected M9	24/01/2019	
Frequenc	LTE Band 38 license (2585-2605 MHz)	EURECOM	granted and renewed	M3	Granted and renewed	24/01/2019	
	NR Band 78 license (3600-3680 MHz)	EURECOM	granted and renewed	M3	Granted and renewed	24/01/2019	
	LTE Band 68 license (LTE-M/NB-IoT)	EURECOM	granted	M10	application filed	24/01/2019	
	LTE Band 14 license (LTE-M/NB-IoT/Sidelink)	EURECOM	granted	M10	application filed	24/01/2019	
C	4G Core deployment	EURECOM	operational	M3	completed	24/01/2019	
User E	COTS 4G UE	EURECOM	deployed in lab and indoor environment	M6	acquired	24/01/2019	
	COTS 5G UE	EURECOM	deployed in lab	M12	acquired	01/07/2019	
	COTS 4G IoT UE	EURECOM	deployed in lab.	M6	acquired	24/01/2019	

Table 36: French sites facilities evolvements until M24

Category	Item / Component / Functionality	Responsible Partner	HEALTH	Due Date	Status	Last Check	Comments
RAN Infrastructure	Add NB-IoT support to (#B2) eNodeB RAN (#B4)	b<>com		M12 (=>M24)	Not Started	M12	NB-IoT compliancy with TDD is only in Release 15, in band 41 only but not in Europe. In Release 13, only HD-FDD is supported in various band. New scenario under investigation to align band availability by ARCEP, COTS UEs availability and eNB availability based on OpenAirInterface. First implementation won't be available before M24 in any case.
	Rennes 3,5 GHz TDD LTE eNodeB RAN (#B3)	b<>com		M8 (=>M18)	On going	M12	USRP technical scenario to be challenged due to adjacent interferences issues. Another technical scenario identified and to be evaluated. Discussion to host the antenan in a high tower also started. Disponibility date to be confirmed. Shifted to M18. Frequency may
	5G RAN OAI VNF onboarded in ONAP (#O20)	Orange		M19	On going	22/07/2019	check with OAI roadmap and the availability of the NR 5G component
	4G RAN OAI VNF onboarded in ONAP (#O19a)	Orange		M17	On going	22/07/2019	check with Orange Romania
	5G gNB using OAI 5G NR source code and USRP N310	Orange		M17	On going	26/07/2019	check with OAI roadmap and the availability of the 5G NR component
CORE	WEF V1.3 in ONAP (#O21)	Orange		M17	On Going	22/07/2019	Check the images management with bcom
	4G CORE OAI VNF onboarded in ONAP (#O19b)	Orange		M17	On going	22/07/2019	check with Orange Romania
	5G CORE SA OAI VNF onboarded in ONAP (#O22)	Orange		M24	TBC	22/07/2019	Is dependent on the OAI CORE roadma
User Equipement	New NB-IoT UE references (#B16)	b<>com		M24	Delayed	M12	Purchase new NB-IoT UE devices delayed due to issues identified in #B4. This action is shifted from M16
	COTS 4G LTE Routers (#B20)	b<>com		M14	On going	M12	Purchase of 4G LTE router COTS devices. Target references are Bintec RS353jwv-4G and Teltonika RUT955
	COTS 5G UE (#O16)	Orange		M16	On going	22/07/2019	Availability in October or November
Tools	French cluster common monitoring tool (#O10)	Orange		M8 => M16	On going	10/07/2019	Some tools are already implemented in the plug'in Platform. Discussions on the final choice are current (also with the other 5G EVE partners WP4). The service catalog specified the availability of some tools. Some VNF will be onboarded in ONAP and refered to the catalogue
	Monitoring & supervision of Nokia location (REF#N6)	NOKIA		M13	On going	M12	solution identified & development on-going
	RBAC based on ssh key signature (#B17)	b<>com		M14	On going	M12	A SSH key signature mechanism providing RBAC will be deployed on
	Infrastructure Monitoring based on Prometheus (#B18)	b<>com		M14	On going	M12	Prometheus will replace previous tool to monitor Infrastructure. Metrics will improve the troubleshooting capacity although it is not expected to be
Integration	Deployment planning (Midterm) (B#15)	b<>com		M18	On going	M12	NB-IoT deployment delayed. New actions planned for this period.
	Deployment planning (M24) (#B19)	b<>com		M24	Not Started	M12	Includes deployment Phase 3 NB-IoT which have been shifted due to issues
	French site interconnection with the interworking layer (#O18)	Orange		M17	To be done	22/07/2019	Must be available before M18
	French sites interconnection performance evaluation (#O17)	Orange		M15	On going	22/07/2019	b<>com already done, Nokia and Eurécom in progress
	Orange Plug'in Phase1 (#O14)	Orange		M9 => M21	Delayed	10/07/2019	5G NR OAI lab transmission in band 78, 3700-3800 MHz - Shift in the implementation due to 5G RRH availability in Orange Gardens