5G EVE

5G European Validation platform for Extensive trials

Deliverable D2.4
Initial pilot test and validation

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List of Acronyms and Abbreviations

Acronym	Meaning
3GPP	Third Generation Partnership Project
4G	Fourth Generation
5G	Fifth Generation
AGV	Automated Guided Vehicle
AMF	Access and Mobility Management function
AP	Access Point
API	Application Programming Interface
APN	Access Point Name
AR	Augmented Reality
ARS	Augmented Reality Server
AS	Application Server
AWS	Amazon Web Services
BBU	Baseband Unit
BE	Back End
BP	BluePrint
BSS	Business Support Systems
CB	Context Blueprint
CDF	Cumulative Data Function
CDN	Content Delivery Network
CEE	Cloud Execution Environment
CM	Configuration Management
CN	Core Network
CNF	Cloud-Native Functions
CNO	Cognitive Network Optimizer
CNOM	Core Network Operation Manager
CPE	Customer Premise Equipment
CRB	Constant Bit Rate
CUDB	(virtual) Centralized User Database
DL	DownLink
DNS	(virtual) Domain Name Server
Dx.y	Deliverable x.y
EC	Enterprise Core
EDA	(Virtual) Ericsson Dynamic Activation
ELK	ELastiK search

eMBB	Enhanced Mobile Broadband
EPC	Evolved Packet Core
ExpB	Experiment Blueprint
ExpD	Experiment Descriptor
GRE	*Generic Routing Encapsulation*
GWu/GW-U	GateWay Userplane
HSS-FE	(virtual) Home Subscriber Server – Front End
ICT	Information and Communication Technology
IoT	Internet of Things
IS	Information Server
IWL	InterWorking Layer
KPI	Key Performance Indicator
LB	(virtual) Load Balancer
LIDAR	LIght Detection And Ranging
LTE	Long Term Evolution
M2M	Machine to Machine
MaaS	*Monitoring as a Service*
MCR	Mobile Cloud Robotics
MDB	Media DataBase
MEC	(virtual) Mobile Edge Computing
MEC	Multi-access Edge Computing
MICE	Meetings, Incentives, Conventions, and Exhibitions
MIMO	Multiple-Input Multiple-Output
MME	(virtual) Mobility Management Entity
mMTC	Massive Machine-Type Communications
MOB	MOBility
MQTT	Message Queuing Telemetry Transport
MSx	5G EVE project MileStone x
Mxx	5G EVE project Month x
NB-IoT	Narrow Band - IoT
NF	Network Function
NFV	Network Function Virtualization
NFVI	NFV Infrastructure
NFVO	NFV Orchestrator
NR	New Radio
NSA	Non-Stand Alone
NSD	Network Service Descriptor

OAI	Open Air Interface
OAM	Operations, Administration, and Maintenance
ONAP	Open Network Automation Platform
OSM	Open Source Mano
PGW	Packet GateWay
PLC	Programmable Logic Controller
PSNR	Peak Signal-to-Noise Ratio
QoE	Quality of Experience
RAN	Radio Access Network
RTT	Round Trip Time
SA	Stand Alone
SAP	Service Access Point
SDU	Service Data Unit
SGW	Serving GateWay
SMF	Session Management Function
SS-CNO	Service-Specific Cognitive Network Optimizer
TC	Test Case
TCB	Test Case Blueprint
TCD	Test Case Descriptor
TN	Transport Network
TRxP	Transmission Reception Point
TtRF	aggregated Time to Right Frame
UC	Use Case
UE	User Equipment
UL	UpLink
UPF	User Plane Function
URLLC	Ultra-Reliable and Low Latency Communications
USRP	Universal Software Radio Peripheral
VIM	Virtual Infrastructure Manager
VIS	VISualization
VM	Virtual Machine
VM	Virtual Machine
VNF	Virtual Network Function
VNI	VXLAN Network Identifier
VoD	Video on Demand
VR	Virtual Reality
VRB	Variable Bit Rate

VS	Video Server
VSB	Vertical Service Blueprint
VSD	Vertical Service Descriptor
VTEP	Vxlan Termination EndPoint
VxLAN	Virtual eXtensible Local Area Network
WHO	World Health Organization

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Executive Summary

The present deliverable is the *Initial report about the first functional tests and 5G end to end facility validation*. It provides the overall situation of the E2E facility implementation status corresponding to the project's MS9 *Second release of the 5G end to end facility* in M24. Special attention has been paid to the 5G infrastructure performance metrics.

The document also goes through all the 5G EVE pilots providing detailed information about the activities performed in the scope of 5G EVE project since last year, their implementation and integration status in the E2E site facility, and the roadmap for activities in the upcoming months. Although the obvious impact of the COVID19 on the Use Cases and Pilots deployments and executions, mostly related to the activities that needed a physical access to the facilities, the consortium has made a big effort to preserve the original roadmap. This has allowed to reach a good level of integration with the 5G EVE platform and to collect preliminary results on the Use Cases' services.

The last topic covered by the deliverable describes the methodology that has been implemented to provide support to the pilot Use Cases to carry out the Experimentation flow activities as described in D1.3 - *5G EVE end-to-end facility reference architecture for Vertical industries and core applications* [3].

This deliverable should provide future 5G EVE experimenters with all the available information to carry out experimentation within 5G EVE E2E facility, including the Blueprints used to instantiate the experiments of the 5G EVE internal Use Cases and the methodology to go through the integration process.

1 Introduction

1.1 Purpose of the document

The present document has been produced by the WP2 in charge of the *Implementation, pilot execution and validation* and it is publicly available.

It is addressed to all the H2020 community willing to have the details on 1) the current status of the 5G EVE E2E site facility, 2) the way experimentations are carried out inside the 5G EVE E2E site facility, 3) the Use Case implementation.

This deliverable provides the description and implementation status of the so called "5G EVE internal Use Cases". This information aims, among other, at helping future Use Cases to identify the tasks they should perform and the way to interact with the project. This will be especially useful for the external ICT-19/22 projects aiming at using 5G EVE E2E facility for experimenting their vertical Use Cases.

1.2 Scope of the document

The present document provides a detailed report of overall situation of the E2E Site facility implementation status corresponding to the project's MS9 *Second release of the 5G end to end facility* in M24. The site facilities implementation has been described at the beginning of the project in deliverable D2.1 *Initial detailed architectural and functional site facilities description* [4] and the planned implementation roadmap was delivered in the deliverable D2.2 *Sites facilities planning* [5]. Project's MS8 at M18 was the starting point of the E2E facility operation, aggregating the different site facilities into a single entity allowing the experiment orchestration from the 5G EVE portal via the InterWorking Layer (IWL).

It is important to highlight that a huge effort has been made by the project to perform Use Cases feasibility tests in the target site facilities. At the initial stage, the Use Case deployments have been performed in standalone mode, without using the centralized orchestration offered by the whole 5G EVE platform but operating directly on the specific orchestrators available in each site facility. This approach has allowed to quickly validate the hypothesis and to identify the missing functions in the Use Cases' vertical services and experiments, or those functions requiring additional effort towards their virtualization. This effort has been performed during the past year and, as part of MS8, it has allowed to assess the capacity of the different site facilities to host the experiments. Some of the pilot Use Cases have been able to produce initial results based on those deployments. In that sense the present document provides the results obtained during this period.

During the past months the internal Use Cases started the activities for the definition, onboarding, instantiation and execution of their experiments into the end to end (E2E) site facility using the 5G EVE portal, to reach a deeper level of integration with the 5G EVE platform. Although the COVID19 has impacted the Use Cases ongoing activities, a big effort has been made by the consortium and most of the Use Cases have reached the target goal for the MS9. In particular, they completed the Experiment Design activities (see Figure 1) and got ready for the experiment instantiation and execution phases as defined in the 5G EVE Experiment workflow (see D1.3 [3]). At the time of editing this deliverable, some of the Use Cases have been selected based on their maturity to also perform their instantiation and execution in order to demonstrate the interoperability of all the developed components and the capacity to instantiate experiments in the different site facilities, run the tests, collect the metrics and compute the experiment KPIs. This 5G EVE experimentation process was first defined in D5.1 *Disjoint testing and validation tools* [14] and it is part of the reference processes that can be followed by the vertical industries to verify the performance of their services using the 5G EVE platform, as documented in the deliverable D1.3 *5G EVE end to end reference architecture for vertical industries and core applications* [3]. The goal for the 5G EVE consortium is to provide the means for the verticals to easily go through this innovative process, allowing to automate the experiments execution and the data collection. The goal for the MS9 is to complete the Design activities on the different internal Use Cases, which will allow to "start the pilots", meaning to start the experiment's preparation and execution activities at the different site facilities as depicted in the Experiment Flow Activities diagram from D1.3 [3].

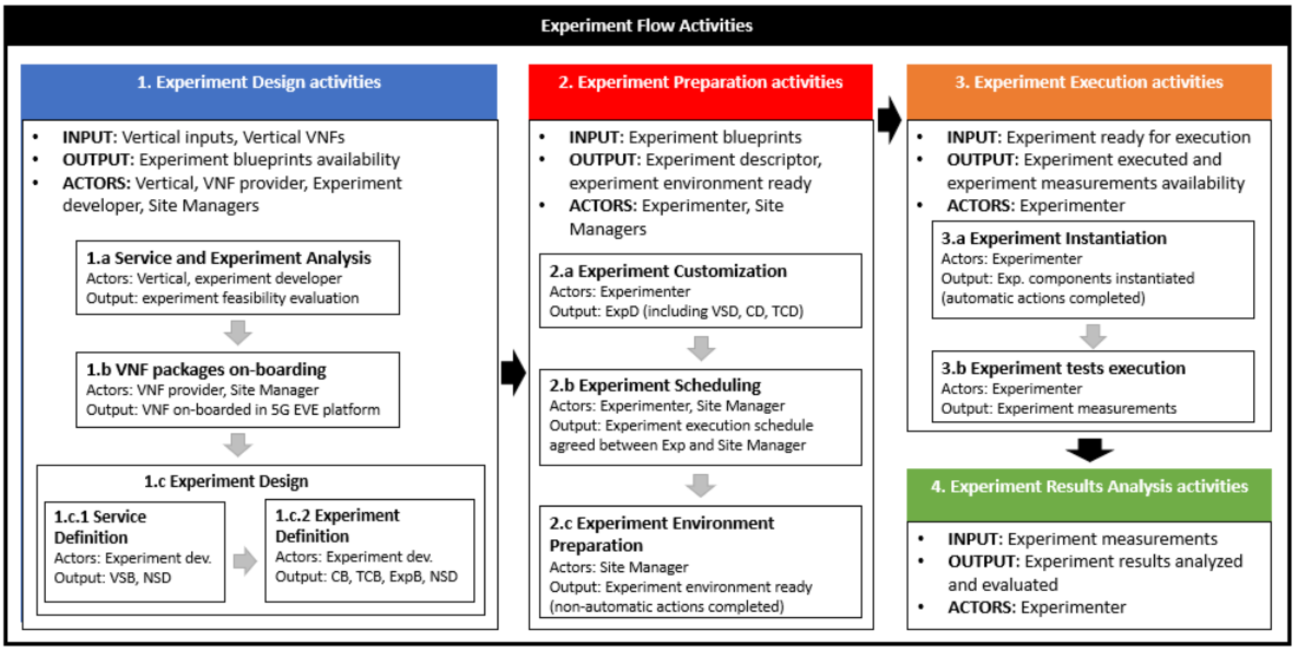

Figure 1: 5G EVE Experiment Flow Activities

A specific chapter is dedicated to the methodology used to support the Use Case activities aiming at coordinating the experimentation activities inside the 5G EVE end to end site facility and ensure that the processes defined inside the project are applied to the hosted experimentations.

1.3 Scope of the document

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This deliverable provides the description and implementation status of the so called "5G EVE internal Use Cases". This information aims, among other, at helping future Use Cases to identify the tasks they should perform and the way to interact with the project. This will be especially useful for the external ICT-19/22 projects aiming at using 5G EVE E2E facility for experimenting their vertical Use Cases.

1.4 Document structure

The rest of the document is structured as follows:

- **Chapter 2: E2E site facility status**

  It provides the 5G EVE E2E site facility status, describing the environment that is available at MS9 to start the pilot execution, with special focus on the 5G infrastructure metrics collection.

- **Chapter 3: Pilot Execution management**

  It explains the methodology that has been applied to drive the experiment activities inside the 5G EVE E2E site facility, which documents and tools are used during the process and the way this data is centralized and published.

- **Chapter 4: Pilots execution and results**

This chapter provides a report about the 5G EVE internal Use Cases, containing the available information related to the experimentation activities inside 5G EVE E2E site facility. The report is mainly focused on the design activities, while the execution is planned to start after MS9 for most of the Use Cases.

- **Chapter 5: Conclusions and future work**

  It provides the main conclusions based on the document contents and the Task roadmap, describing the work that will be accomplished from now on, until the end of the project. It includes a focus on the way to manage the Use Cases from the other ICT projects.

2 End to end site facility status

This chapter provides all the evidence that have been identified at the different stages of the project to verify the status of the 5G EVE End to End site facility. It mainly relies upon the MS8 *First release of the 5G end to end facility* and MS9 *Second release of the 5G end to end facility* milestones.

2.1 Assessment from 5G EVE project milestones

2.1.1 First release of the 5G end to end facility

The first release of the 5G EVE site facility was achieved in MS8. This milestone reads as "*The 5G end to end facility starts being used by vertical industries. It is expected that both 5G EVE and ICT-19-2019/ ICT-22-2018 vertical industries get access for initial experimentation"* and therefore can be analyzed in terms of two sub-objectives:

- Firstly, that the 5G EVE end to end facility is available for experimentation, with the initial set of planned functionalities and services deployed and ready for operation.
- Secondly, that the facility is accessed by vertical industries, so these can execute some initial experiments to refine their procedures, design the formal experiments, etc.

5G EVE performed a systematic analysis of the key performance requirements of all Use Cases from verticals participating in 5G EVE as well as verticals from ICT-19 projects interested in using the 5G EVE platform (see deliverable D1.2 [2] and D2.6 [6]). Furthermore, the overall 5G EVE architecture for supporting those requirements was specified (deliverable D1.3 [3]). At its four interconnected sites, the 5G EVE platform has enabled 12 vertical Use Cases, including the experimental validation of services and applications by verticals.

- France – The French site facility has integrated and tested the first two Use Cases: (1) A 360° video virtual visit (eMBB) Use Case, which aims at immersing the visitor in a virtual reality scene located in a real environment. (2) A Use Case on critical utilities of smart energy (URLLC and mMTC), which focuses on fault management for distributed electricity generation in smart grids. For both Use Cases, data throughput and API service latency have been evaluated when using 5G networks.
- Greece – The Greek site deployed Use Cases covering the vertical sectors of Industry 4.0, Smart Cities and Smart Energy (Utilities). Specifically, for the Industry 4.0 Use Case, autonomous control of an Automated Guided Vehicles (AGV) via 5G connectivity has been demonstrated. In parallel, multiple smart city sub-scenarios, such as automated indoor environment adaptation, air quality monitoring and remote health monitoring have been demonstrated as well. Finally, in depth experimentation has taken place with 5G-powered management functionality for addressing outages in smart grids and for automating the network's response (power redirection) to avoid islanding, as part of the Utilities Use Case.
- Italy – The Italian site facility is implementing four applications in three Use Cases: (1) Smart Transport – Urban mobility 5G data flow analysis and monitoring: the tracking and recognition services are implemented; (2) Smart Transport –5G On-Board Media content provisioning: lab testing is ongoing; (3) Smart City – Public Safety: detection of flows of people using passive smartphone probing; (4) Smart Tourism: integration of test application and backend. The infrastructure hosts the service side and offers the VNFs and the 5G coverage.
- Spain – The Spanish site has deployed several Use Cases. The first one, related to Industry 4.0, includes the implementation of virtual PLCs and real-time video processing at the network edge for the operation of AGV. In addition, the Spanish site demonstrated the use of 5G for immersive virtual reality in tourism applications at the world's largest tourism fair, FITUR, in Madrid.

Each 5G EVE site facility has already deployed the required 5G capabilities (up to Rel-15), validation tools and systems, and the secure connectivity for enabling the initial experimentation of Use Cases on them (deliverable D2.6 [6]). 5G EVE completed and released the first development of innovative features on 5G EVE's framework for advanced and intent-based validation, KPI monitoring/analysis/validation, basic interworking and openness support (D4.1 [10], D4.2 [11], D5.1 [14], D5.2 [15] and D3.3 [16]).

Figure 2: 5G EVE Portal - The 4-Step Process to 5G Validation

Overall, 5G EVE progressed as planned in executing, validating, and supporting the pilots in 2019 following the four step procedure depicted in Figure 2. The project laid the foundations for evolving the deployed 5G capabilities in all sites and for upgrading the 5G EVE framework with added-value services for the first major release of the 5G EVE platform.

2.1.2 Second release of the 5G end to end facility (MS9 - M24)

MS9 ambition is that the 5G EVE project delivers a major release of its E2E platform, enabling fully automated 5G experimentation and validation activities designed by verticals participating in the 5G EVE project as well as in ICT-19-2019/ICT-22-2018 projects, and to be executed across all 5G EVE 5G site facilities. The ninth 5G EVE project milestone is defined as: *"All APIs, web portal, and interworking capabilities of the 5G end to end facility are fully operational. Full access to the 5G end to end facility is provided to both 5G EVE and ICT-19-2019/ ICT-22-2018 vertical industries. Pilots start".*

5G EVE project has met that expectation through the fulfilment of a broad range of achievements, that can be classified into three categories: i) completion of 5G EVE functional framework for the design, scheduling and monitoring of automated validation activities, ii) readiness and evolution of 5G EVE site facilities' 5G equipment, orchestration, and performance monitoring tools as well as secure interconnection of all 5G EVE sites, and iii) Use Case readiness and progress of actual validation campaigns for fully-automated test cases.

The achievements related to the completion of 5G EVE functional framework for validation include:

- The 5G EVE framework has been developed, launched internally for use and iterative testing by Use Case experimentation activities, and finally released on June 30th 2020. The released 5G EVE framework includes all functional features for serving the purpose of a fully-automated workflow for design, scheduling, execution, monitoring and result analysis of experiments over all 5G EVE site facilities, in a homogeneous way. The following deliverables detail the 5G EVE framework:

  D3.4 - *Second implementation of the interworking reference model [8].*

  D3.7 - *Report on the execution of the interworking test suites [9].*

  D4.3 - *Models for vertical descriptor adaptation* [12].

  D4.4 - *Report on benchmarking of new features and on the experimental portal* (2nd version) [13].

  D5.2 - *Model-based testing framework document* [15].

  D5.3 - *Testing environmental conditions document with first version of testing and validation suite* [16].

  D5.5 - *Performance diagnosis mechanism and reporting methodology document* [17].
- The services provided by the released 5G EVE framework are available to registered users of the platform through a set of interfaces, namely a Portal GUI, an Intent-based Interface, and a REST Open API (D4.4 [13]).

- The released 5G EVE platform provides users with a high degree of flexibility and openness for designing their test cases. Both tools and systems are already deployed at each different site selected for experimentation. Custom-designed functions brought by each specific Use Case can be incorporated to condition, execute, monitor and validate test cases (D5.2 [15], D5.3 [16] and D5.5 [17]).
- The released 5G EVE platform enables a systematic, fully-automated collection and analysis of both network performance and service performance metrics and KPIs (D5.3 [16], D5.5 [17]).
- The released 5G EVE platform stands on the concept of roles, where different actors have different responsibilities in the experiment lifecycle. This concept simplifies the overall definition, execution and analysis of experiments. Furthermore, and together with other material delivered by the 5G EVE project like the 5G EVE Portal user manual (D4.4 [13]), multiple examples of Blueprints and descriptors (D4.3 [12]), as well as the public repositories, facilitates new users of the platform to execute their experiments.

The achievements related to the readiness and evolution of 5G EVE site facilities encompass:

- All site facilities in 5G EVE project have deployed and upgraded the required 5G Non-Standalone (NSA) capabilities (Rel-15), assessed network performance level for the deployed technologies and the chosen configurations. D2.1 [4] and D2.2 [5] describe the main components that are implemented in the different sites facilities. D2.6 [6] gives the main site facilities upgrades and verticals roadmap (including some ICT19/22 Use Cases).
- Each and every site facility in 5G EVE project has developed automatic and configurable metric systems for real-time monitoring of E2E Latency, Peak Data Rate, User Data Rate, and Reliability. These systems have been deployed and are available for incorporation in the design of test cases involving them. Section 2.2 in this document provides the main 5G infrastructure metrics collected when operating the different internal Use Cases. Tutorial and webinar demonstrations show some metric systems monitoring at the different sites.
- Each and every site facility in 5G EVE project has deployed orchestration systems and all necessary adaptors have been developed for securing seamless interworking despite the heterogeneity of orchestration technologies and solutions across the 5G EVE platform. The orchestrators implemented in the different site facilities are described in D2.1 [4]. Tutorial and webinar [18] demonstrations have been performed to prove the automatic VNFs deployment via the multi-orchestrator catalogue towards the different sites' facilities.
- All sites are connected to the IWL through secure channels, enabling the distributed deployment of 5G EVE platform portal components and the homogeneous access to experimentation at each and every 5G EVE site facility. The D3.7 *Report on the execution of the interworking tests suites* [9] provides the execution report of the tests allowing to qualify the sites interconnection.

The achievements related to Use Case readiness and Automated Test progress level are mainly consolidated within the current deliverable:

- Since Jan 2020 all 5G EVE Use Cases specified in D1.1 [1] have been fully developed, thoroughly integration-tested, executed and showcased on either manual or semi-automated mode. Chapter 4 gives the integration status of all internal Use Cases. A tutorial and webinar demonstrations have presented the E2E integration, following the 5G EVE workflow of one use-case per site facility (in each country). Moreover, a public demonstration of the SEGITTUR Use Case has been held at FITUR2020.
- Since May 2020, the 5G EVE framework is in use, on a daily basis, by about twenty registered users, and all 5G EVE Use Cases specified in D1.1 [1] have completed the design and preparation phase for fully-automated test case execution over the released 5G EVE framework.
- One Use Case, UC2.2 (Section 4.4), has completed a first cycle of automated test case execution over 5G EVE site of 5TONIC [30] (Madrid). A tutorial has been performed on the 23rd of June 2020 showing the automated test case execution for this Use Case. Two webinars are going be performed to illustrate the centralized operation of the French and Greek Use Cases in the near future (expected July 2020).
- Besides training, continued technical support has been provided to all ICT19 projects associated to 5G EVE, and all of them have planned the execution of fully-automated test cases over the 5G EVE platform in the second half of 2020. Their roadmap is described in D2.6 [6]. Moreover, ICT19 projects 5G-SOLUTIONS, 5G-TOURS and 5GROWTH are regular users of the 5G EVE framework, and they are progressing swiftly in the design and preparation stages of their validation campaigns of fully-

automated test cases over 5G EVE. A Tutorial and webinar describing the way to use the 5G EVE platform (especially the portal) have been performed targeting ICT-19 projects to explain how to use 5G EVE as support of their integration. Identification of the key persons involved in the ICT19-22 projects has been made in order to engage the integration from the beginning of July 2020.

2.2 5G infrastructure metrics

This section provides a report of the measurements of the 5G infrastructure metrics collected in the different 5G EVE site facilities. In what follows, for the sake of readability, we first present the definitions of the 5G infrastructure metrics considered, following the standard recommendations collected by the 5GPPP Test, Measurement and KPIs Validation Working Group [19]. Then, we report per 5G EVE site the numerical values obtained, along with the used configuration and tools, when appropriate.

2.2.1 Definitions

The considered KPIs are the following:

- **User Data Rate:** defined as the 5% point of the cumulative distribution function (CDF) of the user throughput. User throughput (during active time) is defined as the number of correctly received bits, i.e. the number of bits contained in the service data units (SDUs) delivered to Layer 3, over a certain period of time. In case bandwidth is aggregated across multiple bands (one or more TRxP layers), the user experienced data rate will be summed over the bands.
- **Peak Data Rate**: the maximum achievable data rate under ideal conditions (in bit/s), which is the received data bits assuming error-free conditions assignable to a single mobile station, when all assignable radio resources for the corresponding link direction are utilized (i.e. excluding radio resources that are used for physical layer synchronization, reference signals or pilots, guard bands and guard times).
- **Latency**: Two latencies are considered, the **end-to-end** (E2E) and the **Round-Trip Time** (RTT). The former characterizes the one-way transmission latency (in milliseconds) through the RAN, CN, and TN part of 5G network and is used to evaluate utilization performance of the end-to-end network, while the latter takes adds the time until a positive acknowledgement is received (also in milliseconds).
- **Reliability**: the amount of sent packets successfully delivered to the destination within the time constraint required by the targeted service, divided by the total number of sent packets. Note that this reliability is evaluated only when the network is available.
- **Availability**: refers to the percentage of time that a system is fully operational. Because of the rates at which the various 5G-EVE sites are being tested and upgraded, it would be impractical (and deceptive) to measure the **network availability**, this being defined as the ratio of uptime over the total time (uptime plus downtime). Instead, we decided to estimate the **service availability** as one minus the measured packet error rate during the operation of a service.

2.2.2 Performance figures

The following tables resume the performance values of each 5G EVE site facility.

<u>France site facility</u>

Table 1: 5G infrastructure metrics - France

Capability	Value
User Data Rate	Nokia equipment (100 MHz BW) • DL: 1.2 Gbps • UL: 100 Mbps Open Source • DL: 140 Mbit/s (5G FR1)

	• UL: 32 Mbit/s (5G FR1 and LTE)
Peak Data Rate	Nokia equipment (100 MHz BW) • DL: 1,4 Gbps • UL: 140 Mbps Open Source • DL: 150 Mbit/s (5G FR1) • UL: 40 Mbit/s (5G FR1 and LTE)
Latency	RTT (average): 10.0 ms +/- 2.0 ms E2E (average): 5.0 ms +/- 1.0 ms RTT < 15 ms (5G FR1 30kHz SCS)
Reliability	98% (average for latency below 30 ms)
Availability	Approx. 96% (average on the four French sites)

Greece site facility

Table 2: 5G infrastructure metrics - Greece

Capability	Value
User Data Rate	B/W with iperf for 100 MHz band • DL: 1,150 Gbps • UL: 51 Mbps
Peak Data Rate	B/W with iperf for 100 MHz band • DL: 1,280 Gbps • UL: 59 Mbps
Latency	RTT (average): 10.0 ms +/- 2.0 ms E2E (average): 5.0 ms +/- 1.0 ms RTT < 15 ms
Reliability	98% (average for latency below 25ms)
Availability	99% (average)

Italy site facility

Table 3: 5G infrastructure metrics - Italy

Capability	Value
User Data Rate	BW for 80 MHz band Field tests • DL: 500 Mbps • UL: 50 Mbps Lab tests • DL: 1 Gbps • UL: 67 Mbps
Peak Data Rate	BW for 80 MHz band Field tests • DL: 700 Mbps • UL: 58 Mbps Lab tests • DL: 1 Gbps • UL: 67 Mbps
Latency	RTT(average): 10.0 ms +/- 2.0 ms E2E(average): 5.0 ms +/- 1.0 ms RTT < 15 ms
Reliability	98% (average for latency <25ms)

Availability	99% (average)

Spain site facility

Table 4: 5G infrastructure metrics - Spain

Capability	Value
User Data Rate	B/W of 50 MHz (4:1) • DL: 620 Mbps B/W of 50 MHz (7:3) • UL: 54 Mbps
Peak Data Rate	B/W of 50 MHz (4:1) • DL: 715 Mbps B/W of 50 MHz (7:3) • UL: 54.3 Mbps
Latency	RTT (average): 10.0 ms +/- 2.0 ms E2E (average): 5.0 ms +/- 1.0 ms RTT < 15 ms
Reliability	98% (average for latency <25ms)
Availability	98% (average)

3 Pilot execution management

The current chapter provides the methodology that has been defined to ensure the proper management and support for the Use Cases inside 5G EVE. The goal is to ensure that the partners working in the different Use Cases are aware of the End to End Site facility tools and follow the Experimentation activities workflow described in D1.3 [3].

It is important to highlight that this methodology has been defined to meet the management needs of the internal Use Cases but must also be applicable to the Use Cases coming from other ICT19/22 projects.

3.1 Partner's role identification

The first step in order to grant the proper management of the Use Case inside the 5G EVE E2E facility is to identify the role of the different partners for a given Use Case and declare the UC referee(s). The list of actors inside 5G EVE platform has been firstly defined in D4.1 [10]. For the sake of completeness, the list of roles is also included in Table 5:

Table 5: 5G EVE Platform actors

Actor	Description	Target actions
Anonymous user	User not authenticated to the Portal	No actions are allowed.
VNF provider	Actor who provides the Virtual Network Function (VNF) packages for the vertical applications.	- Uploading of VNF packages in 5G EVE portal. - Issuing of requests (via 5G EVE portal) for VNF packages on-boarding to specific sites.
Vertical	Actor with the knowledge of the service to be tested, including SLAs and service components.	- Support in the definition of the vertical service blueprints and related experiments.
Experiment developer	Actor responsible for specifying the blueprints associated to an experiment, as well as the associated NFV network services descriptors. This user has the knowledge about the 5G EVE infrastructure and expertise about NFV network service modelling. Moreover, it interacts with the vertical to receive information about the details of the target service.	- Modelling and definition of blueprints for vertical services, experiment contexts and experiments. - Modelling and definition of NFV Network Service Descriptors (NSD) associated to the experiment blueprints, as well as related translation rules. - Definition and development of mechanisms for collecting application-level metrics from the vertical service. - On-boarding of blueprints via 5G EVE Portal. - On-boarding of NFV Network Service Descriptors via 5G EVE Portal.
Experimenter	Actor responsible for the request of an experiment and the assessment of its results. He/she defines characteristics of an experiment starting from its blueprint, requests the deployment of related virtual	- Selection of blueprints for the target vertical service and experiment, via 5G EVE Portal. - Configuration of the experiment, according to the

	environment and experiment execution and analyses results and KPIs.	blueprint parameters, via 5G EVE Portal. - Issuing of requests, via 5G EVE Portal, for scheduling the execution of the experiment in the 5G EVE facilities. - Monitoring of the experiment execution, via 5G EVE Portal. - Visualization of experiment measurements, KPIs and results, via 5G EVE Portal.
Site manager	Actor responsible for the management of the infrastructure and the orchestration systems in a particular site.	- Pre-provisioning and configuration of the physical infrastructure in the managed site. - Validation and on-boarding of VNF packages. - Preparation of resources needed to deploy an experiment.
System administrator	Actor who has access to all tools provided by the 5G EVE project.	All actions, including management functions (e.g. configuration of users and permissions, visualization of system logs, etc.). Note: the system administrator may have a limited access to the management system of the single site facilities.

It has been decided that the *Vertical* and the *Experimenter* can be considered as the main Use Case referees for establishing the communication required to follow the Use Case integration within the 5G EVE platform. The reason is the fact that they are the ones having the knowledge of the service to test and executing the experiments within a given Use Case.

For Use Cases coming from other ICT projects, the process will remain the same and all the actors will be identified for a given Use Case. Also, a referee will be designated for each ICT project and per country, to manage the exchange and the data collection from all the Use Cases that will be instantiated in 5G EVE from a given external ICT project. As the referees are not directly attached to a Use Case, they are not part of the Experimentation workflow activities, and thus they do not do part of the actors (see Table 5) linked to the 5G EVE portal activities.

Within the current deliverable, each Use Case defines the partner's roles and the description of the activity played by the partner in the given role.

3.2 Use Case integration status

Once the partner's roles have been established and the referees identified, the next stage is to build an integration calendar based on the stages defined in the experiment flow activities described in D1.3 [3] and to have regular updates on the advancement, to ensure that everything runs smoothly for all Use Cases and help them with the integration process. A calendar template is available on Annex A.

The goal of this deliverable is to provide the current integration status at project's MS9 of each 5G EVE internal Use Case (updated from the D2.6 [6]) and provide the next major milestones until the end of the project.

3.3 Experimentation workflow activities follow-up

One major objective for the consortium is to ensure that the verticals understand and are able to accomplish the activities identified in the Experimentation workflow D1.3 [3] when applying it to their Use Case. In other words, to ensure the proper accomplishment, the workflow proposes to generate outputs at the end of each stage. Figure 1 summarizes all these activities.

The way the Use Cases are presented in the current document takes the roots on these outputs to complete the Use Cases implementation description.

In this way the following elements are included to produce the ***Pilot execution and results*** in the next chapter:

- The Experiment test plan generated at the *1.a Service and Experiment Analysis* activity, which contains:
    - The Experiment description and the “high level” test plan described by the vertical, which are the starting points to analyse the experiment and its requirements, leading to the VSB implementation.
    - The “low level” test plan, which is the translation from the vertical inputs into test cases that can be implemented in the platform. This work is led by the *Experiment developer* and its outcomes constitute the input for the Blueprints definition.
- The list of VNFs used for the experiment, their implementation and on-boarding status, as part of *1.b VNF package on-boarding*. These VNFs are mainly related to the vertical service. In some cases the network services may be tightly coupled to the experiment and are also included although they will not be included in the VSB to be deployed through the portal.
- The Blueprints produced during the *1.c Experiment design* phase are considered the experiment reference implementation architecture, execution context and test plan. They will be included in the related sections describing each Use Case.

Finally, the collected results from the experiment test cases execution will be presented when available and will be used as evidences for the Experiment results analysis and conclusions, which are part of the *4 Experiment Results Analysis* activity.

4 Pilot execution and results

This chapter provides a full description of the 5G EVE internal Uses Cases including the partners involved in the Use Case and their roles, and the experimentation planning. The details of the implemented architecture are provided based on the defined Blueprints. The Test Cases for the different experiments are also included, together with the experimentation results and analysis when they are available. They have been defined based on the test plan template available in Annex B and initially defined in D5.1 [14].

Each Use Case being different from each other and addressing different challenges, the way to describe may be slightly different, but an effort has been made to follow a common homogeneous pattern. This difference between Use Cases is also impacted by the different state of achievement of the Use Cases that is reflected in the following sub-sections. In this way, a Use Case, UC2.2 (Section 4.4), has completed a first cycle of automated test case execution over 5G EVE site 5TONIC [30] (Spain) to validate the full E2E operation of the 5G EVE framework.

Notice that, when available, the TCB, by the means of the Low Level Test Cases definition, and the execution results are included in the Use Cases report.

4.1 Use Case 1.1 - Smart Transport: Intelligent railway for smart mobility: 5G on-boarding media content streaming

4.1.1 Pilot execution context

FSTechnology, working as main provider of ICT services for the railway industry, has deeply analysed during the last years how 5G technology adoption can be considered a critical technology for the development of high quality 5G based services to enhance passengers' comfort and for the customization of their on board experience.

One of these services is the innovative streaming of on-board heavy media contents for entertainment and infotainment for train passengers' segment of the daily High-Speed services, mostly commuters and tourists.

Currently, quality of on board media contents delivery is perceived as one of the most relevant indicators to evaluate the overall trip experience, therefore FSTechnology aims to test, in the 5G EVE framework, the next opportunity to offer to the passengers an innovative service of data streaming for media contents in Full HD/4K, including movies, TV Shows and Music, that can be broadcasted to the new generation of 5G mobile connections.

The scenario conceived by FSTechnology has the goal to validate the conditions of real set up of high reliable content delivery of Trenitalia multimedia in Full HD/4K with the 5G connectivity application, taking into account the technical difficulties that on board communication faces in relation with high speed environment (e.g. handover effect, doppler effect).

With this aim, two series of experiments are going to be performed in the 5G EVE Italian Site.

The first one, in the stage of integration and interoperability, relies on media content communication between the 5G EVE Media Content Service front-end and back-end (see top end-to-end grey thick line in Figure 3) 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. Preliminary tests have been performed with a content server on a public cloud. With APN (lab and/or field availability), a dedicated VM will be created and tested to access the platform considering also the introduction of Virtual Content Delivery Network (CDN) Cache functionalities

The second one, currently in the stage of lab testing, consists of an outdoor emulation. The 5G Prisma network emulator component located in "TIM LAB" would simulate conditions of 5G connectivity for the media content delivery in specific conditions of communication feeding that commonly characterize the High Speed railway framework (see bottom end-to-end grey thick dotted line in Figure 3, 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.

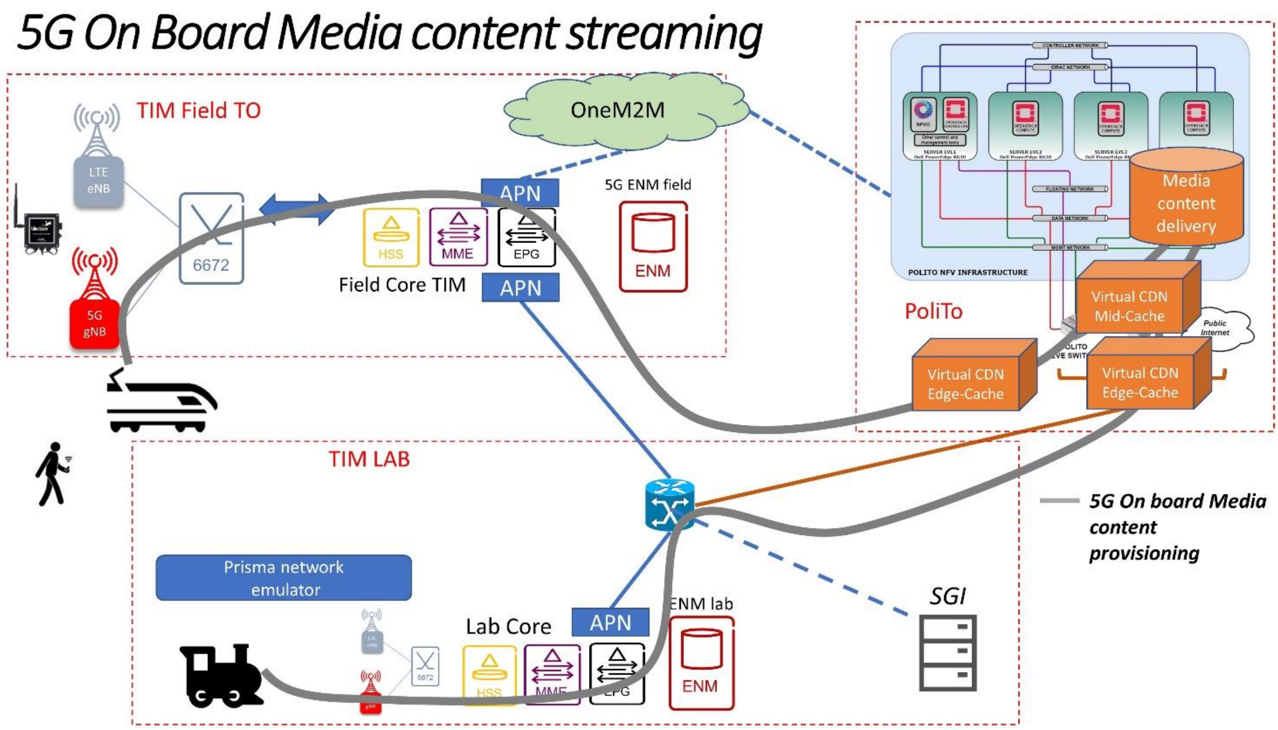


Figure 3: Smart Transport (Italy) UC1.1 - Reference architecture

Experiment test execution results will be validated by FST from a service point of view taking into account the QoE (Quality of Experience) Questionnaire in order to understand real quality of Full HD/4K video performance enabled by 5G in the stressing condition of high-speed railway environment.

Therefore, FST will analyze at which throughput or latency the QoE does not fulfil the network metrics criteria considering the stressing test conditions of the high speed simulated by the 5G Prisma Emulator (e.g., handover effect to be considered for high speed) on the basis of pre identified modem simulated features. This will be possible by setting the emulator throughput and latency parameters to realize a sensitivity analysis.

The QoE analysis would validate the effects of the variation of throughput and latency on the video quality, considering network stress conditions of specific simulated variations of the train high speed (Graphical representation of the behaviour of the network KPIs on different high speeds range will be considered in order to validate the achievement of the QoE Treshold). 4G vs 5G differences will be tested.

4.1.1.1 Actors

Vertical FSTechnology will provide the knowledge of the on board media service features to be tested considering the communication stress conditions of the railway high speed environment, including the definition of services KPIs and service components. Therefore, FSTechnology will offer support to the Experiment Developer in the definition of the vertical service blueprints and related experiments.

VNF provider(s) Nextworks will provide the software components of the media vertical service, as illustrated in Figure 3. Three VNFs will be on boarded on the 5G EVE platform:

- the media content delivery

- the virtual CDN Mid-Cache

- the virtual CDN Edge-Cache

Experiment developer(s) Nextworks and Ares2T will develop the Experiment according to the objectives indicated by the Vertical. They will define suitable blueprints for vertical services, experiment contexts and experiments, as well as the necessary NFV Network Service Descriptors (NSD) associated to the experiment blueprints once defined and validated.

Experimenter(s) FS Technology will underpin the request of an experiment and the evaluation of its results. FST will define, supported by the experiment developer and site manager, the features of an experiment starting from its blueprint, requesting the deployment of related virtual emulation testing environment, filling the test cases for the experiment execution and analysing results and KPIs.

Site Manager(s) TIM will manage the entire definition and execution related to the Experiment.

4.1.1.2 Planning & Status

The two series of experiments that are currently performed in the 5G EVE Italian Site for the Use Case 1.1 of "5G On-Boarding Media content streaming" are facing different stage of implementation:

- **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 3) **through "TIM Field TO":** the lab virtual emulation testing with the 5G EVE Media Content Service has already been underpinned.
  At M21 (April 2020) the laboratories activity are facing an integration and interoperability phase.
  FST is providing commercial media content in Full HD/4K to be tested in the laboratory.

- **Emulation by 5G Prisma network emulator component located in "TIM LAB":** preliminary analysis on the technical features of 5G Prisma emulator have been performed to understand potential scenario of lab testing of 5G communications considering stressing condition of high-speed railway environment. The activity is in the phase of lab testing.

With respect to the initial planning reported in [6] and depicted here in Figure 4, Integration & Interoperability activities are still on going and planned to be accomplished by end of next June. Preliminary field tests are scheduled in the second half of 2020.

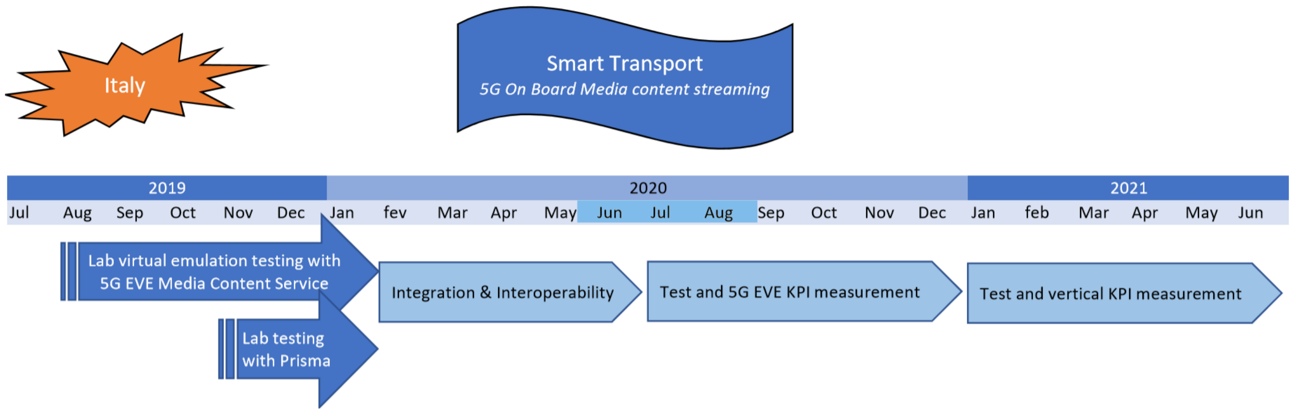


Figure 4: Smart Transport (Italy) UC1.1 – Roadmap

According to the roadmap for UC1.1, the VNF Packaging on-boarding will be completed by July 2020.

4.1.2 Pilot architecture

The *Smart Transport: 5G On-Boarding Media content streaming* pilot leverages on the 5G EVE Framework to validate the reliability of a Full HD/4K vCDN, relying on the 5G connectivity.

The scenario of the pilot for the Use Case is depicted in Figure 3. It describes the VNFs and the infrastructure where the pilot will run.

The service contains a vCDN service that is composed of a media content delivery server, a vCDN Mid cache and a vCDN edge cache. Additional VNF components are available to enrich the full functionality of the service.

The following table describes all VNFs and PNFs that compose the service and their cardinality.

Table 6: Smart Transport (Italy) UC1.1 – Components of vCDN

Name	Type of function	Cardinality
Media content delivery	PNF	1
Virtual CDN Mid Cache	VNF	1..n
Virtual CDN Edge Cache	VNF	1..n

The media content delivery or origin server, built on Plex Media Server [20] contains the HD/4K media content available for the end users. The transcoding of the content is held by this service, based on network statistics auto-adjusting the quality of the video in a real-time adaptation scenario. The vCDN caches provide caching functionality, with the aim to serve the media content near to the user, reducing latency and improving the QoS and QoE. The deployment of the caches is based on a hierarchical architecture.

In 5G EVE, the service is composed by the media content delivery service, one vCDN Mid Cache and one vCDN Edge Cache.

The interconnection among the VNFs and the user equipment on the RAN part is described in the Vertical Service Blueprint. Figure 5 depicts the described service, based on the VS blueprint.

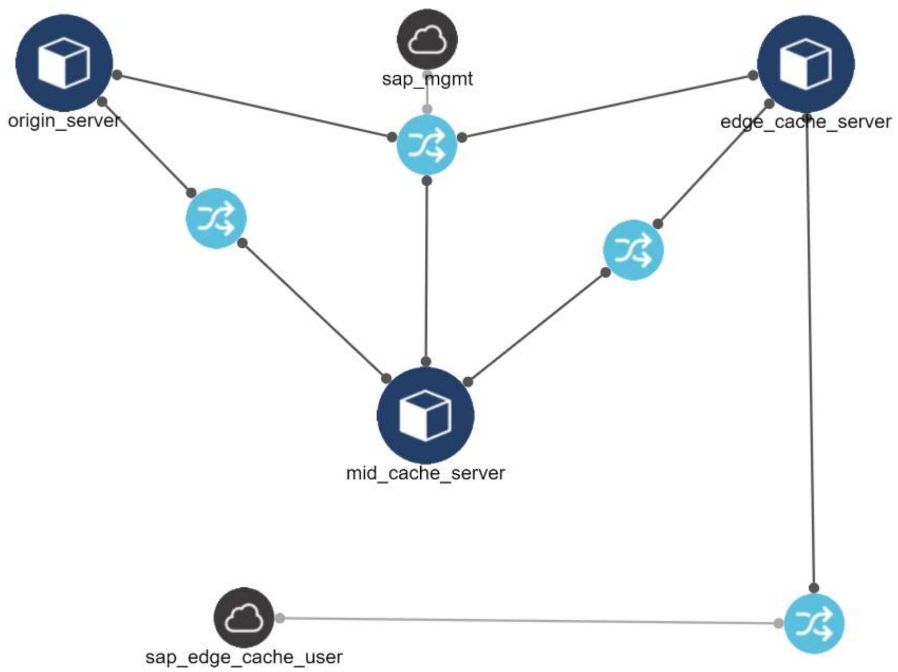


Figure 5: Smart Transport (Italy) UC1.1 - VSB Service design

As shown above in Figure 5, the service VNFs are reachable from the management network, through the sap_mgmt. This network is used only for configuration purposes. The users access the service only from the user network. The only VNF exposed to the user is the vCDN Edge cache.

In the following Test Plan Template, dataset of relevance for the definition of Context Blueprint and Experiment Blueprint have been defined.

Table 7: Smart Transport (Italy) UC1.1 - Test Case 1

Test Case 1	
Test Name:	**On media content communication between the 5G EVE Media Content Service front-end and back-end**
Target KPI:	User Throughput, End2End Latency, Packet Loss rate (to verify reliability and availability of network service), Video Streaming Vertical QoE
Measurement Method:	Vertical Application running on 5G mobile devices
Parameters:	The network will change from 4G to 5G, for comparison QoE will be evaluated on Video in Full HD/4K
Validation Conditions:	Validation of the QoE of Video Streaming with the achievement of the indicated Target KPIs, through the Vertical Application. QoE would be validated (using Mean Opinion of a score of questionnaires below a threshold) with the assessment of impact of the variations of target KPIs on the video streaming quality in a framework of train urban mobility

Table 8: Smart Transport (Italy) UC1.1 - Test Case 2

Test Case 2	
Test Name:	**Lab virtual emulation testing**
Target KPI:	User Throughput, End2End Latency, Packet Loss rate (to verify reliability and availability of network service), Video Streaming Vertical QoE, Number of on board devices simultaneously connected with video streaming service, Network On board Capacity (Mbps/End Point)
Measurement Method:	5G Prisma Emulator simulating conditions of railway High Speed
Parameters:	The network will change from 4G to 5G, for comparison QoE will be evaluated on Video in Full HD/4K. High speed stress conditions will be simulated with the 5G Prisma Emulator
Validation Conditions:	Validation of the QoE of Video Streaming with the achievement of the indicated Target KPIs, considering the stressing conditions of the High speed simulated by the 5G Prisma Emulator (e.g. Handover Effect to be considered for high speed) on the base of pre identified modem simulated features. QoE would be validated (using Mean Opinion of a score of questionnaires below a threshold) with the assessment of the impact of the variations of target KPIs on the video streaming quality. Network KPIs variations would be specifically simulated considering train high speed stress (Graphical representation to be validated).

The pilot has not been fully integrated in the 5G EVE platform. However, a first version of the Vertical Service Blueprint, Context Blueprint, Test Case Blueprint and Experiment blueprint and related NSDs have been tested into the 5G EVE portal and are available in 5G EVE Github repository:

- Vertical Service Blueprint [22]
- Context Blueprint [23]
- Experiment Blueprint [24]

The Context Blueprint depicted in Figure 6 describes the service. The service has one VNF connected to three different sap. The sap_dg_mgmt is used by the platform for the configuration purposes. The other two sap, sap_dg_in and sap_dg_out, are used respectively for incoming and outgoing traffic.

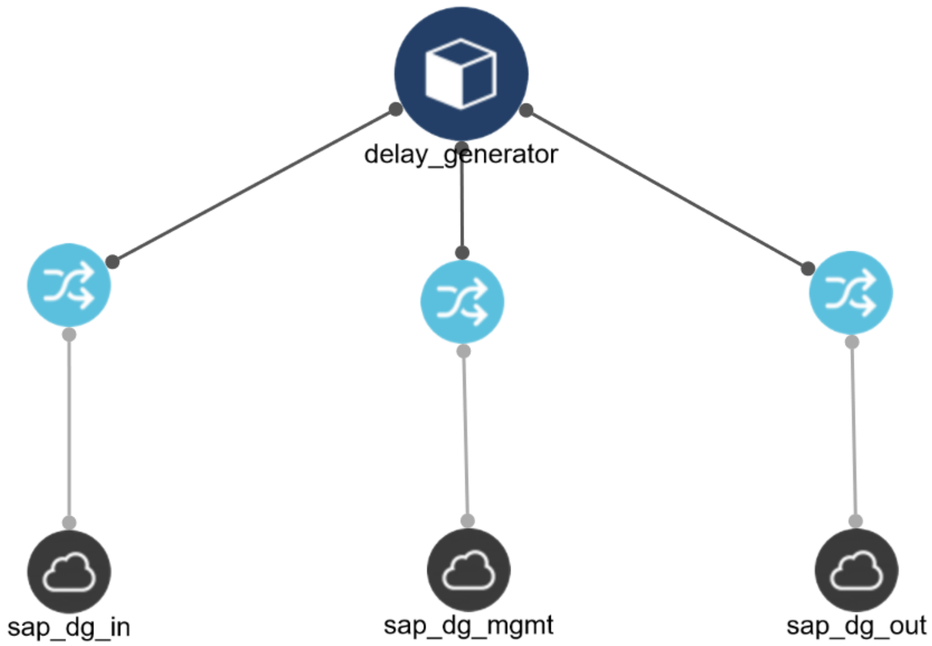


Figure 6: Smart Transport (Italy) UC1.1 - NetEM: Delay Generator

The Delay Generator VNF allows the experimenter to configure dynamically the emulation of packet loss, delay or packet corruption, as well as bandwidth limit.

The VNF offers a reverse proxy service, built on NGINX [21]. It can be configured as the entry point of the experiment, allowing the traffic generated by the end user to pass through it, applying to that flow the traffic control rules configured for the experiment.

The experiment, depicted in Figure 7, contains three VNFs that compose the service.

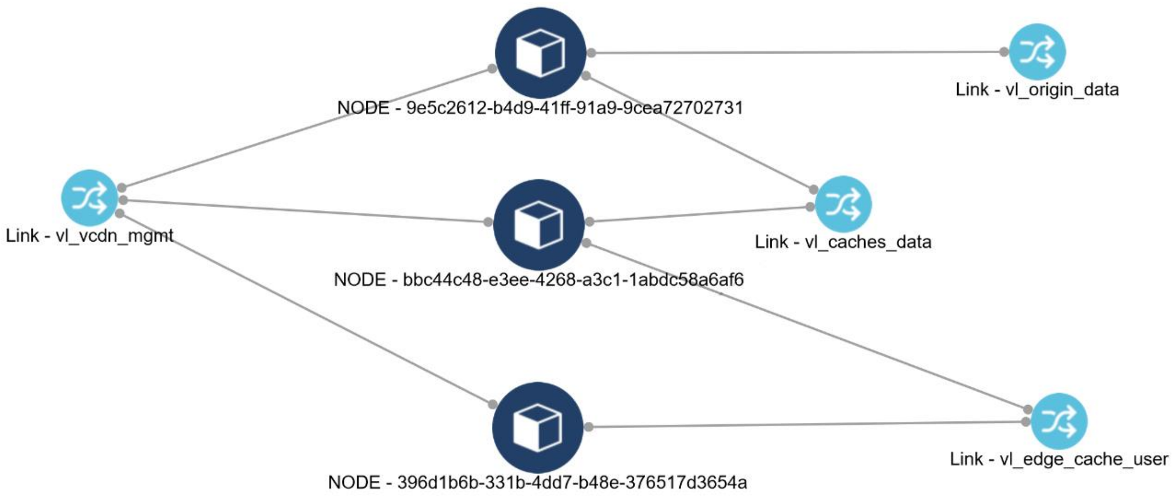


Figure 7: Smart Transport (Italy) UC1.1 - Experiment

The three VNFs are:

- **edgeCache** is the nearest element to the end user. It is usually placed in an edge node. It is connected to three different virtual links.
    - vl_vcdn_mgmt: Management network, used for configuration purposes
    - vl_edge_cache_user: User network. The vCDN service is bound to this network.
    - vl_caches_data: Intra-cache networking. It is used by the edge cache to connect to the parent cache (midCache)

- **midCache** is the parent cache for the edge. It is usually placed not far from the end user. It is connected to three different virtual links
  - vl_vcdn_mgmt: Management network, used for configuration purposes
  - vl_caches_data: Intra-cache networking. It is used by the midEdge cache to connect to the edge cache.
  - vl_origin_data: This network interconnects the midCache with the MediaContent server, where the video content is stored.
- **Context VNF** is placed in the edge as the edgeCache. It is connected to two virtual links
  - vl_vcdn_mgmt: Management network, used for configuration purposes
  - vl_edge_cache_user: User network. During the execution of the experiment, the end user will contact the context VNF instead of the edgeCache, which will redirect the requests to the edgeCache, applying to that connection all the network degradation configured for the experiment.

4.1.3 Test Case Blueprint & Execution results

Once the experiment is instantiated into the 5G EVE portal, the execution of the experiment is described in the test case blueprint associated to it.

The TCB to achieve the results of the first test case described in Section 4.1.2 is already available in [29]. It consists in two different type of actions: configuration and execution of the experiment, as described in the following Table 9.

The TCB defines a list of parameters, user and infrastructure ones, that provide the required data to the configuration and execution scripts. The values for the user parameters are provided by the experimenter during the experiment creation. The infrastructure parameters on the other hand, are automatically gathered and translated by the Experiment Execution Manager when the execution of the test case is requested.

Table 9: Smart Transport (Italy) UC1.1 – Low Level Test Case

Test Case	
TCB Name:	**Smart Transport UC Test case with artificial network degradation**

Configuration tasks	***CTX VNF:***
	• The following command limits the bitrate of the traffic
	  ○ sudo tc qdisc add dev ens5 root handle 1: tbf rate $$rate burst 1600 limit 3000
	• The above command generates a delay, packet loss, duplication and corruption of packed.
	  ○ sudo tc qdisc add dev ens5 parent 1:1 handle 10: netem delay $$delayms 40ms 25% loss $$loss% 25% duplicate 1% corrupt 0.1% reorder 5% 50%
	vCDN VNFs:
	• There are two different configuration scripts that configures respectively the midCache and the edgeCaches elements of the vCDN
	  ○ /bin/bash /home/ubuntu/config/origin_configure.sh <mediaContent-IP> <mediaContent-PORT>
	  ○ /bin/bash /home/ubuntu/config/origin_configure_edgeips.sh <midCache-IP> <midCache-PORT>

Execution Task:	The automation of the execution is not possible at this stage. Due to this, the execution task, into EVE portal, consist in a DO_NOTHING action to allow the end user manually starting the experiment by connecting to the vCDN and start watching the desired video content. ○ sleep $$sleep$$time

User Parameters:	• username: $$user • password: $$password • bandwidth_limit_rate: $$rate • delay: $$delay • packet_loss: $$loss • experiment_exec_time: $$sleep$$time

Infrastructure Parameters:	• vnf.396d1b6b-331b-4dd7-b48e-376517d3654a.extcp.cp_dg_mgmt.ipaddress
	  ○ Management IP of CTX VNF used by the RC to connect to the VNF configuring purposes
	• vnf.bbc44c48-e3ee-4268-a3c1-1abdc58a6af6.extcp.cp-ens3.ipaddress
	  ○ Management IP of edgeCache used by the RC to connect to the VNF configuring purposes
	• vnf.9e5c2612-b4d9-41ff-91a9-9cea72702731.extcp.cp-ens3.ipaddress
	  ○ Management IP of midCache used by the RC to connect to the VNF for configuring purposes
	• vnf.9e5c2612-b4d9-41ff-91a9-9cea72702731.extcp.cp-ens6.ipaddress
	  ○ IP of midCache on vl_caches_data link. The service running on the midCache is bind on this IP. It is required to configure the edgeCache.

During the first step, different configuration jobs are performed in order to configure the context VNF and the vCDN caches based on the user parameters provided by the experimenter.

The second step, the execution task, is the task where the experiment starts running, the metrics are generated and after the termination of it, the validation of the KPIs is performed.

The context VNF, an Ubuntu machine, fully configurable to generate delay, packet loss or bitrate limit, is already present in the 5G EVE platform ready for use.

4.1.4 Pilot Initial validation status

Test Case Execution will be performed between February 2021 and April 2021. The Test Case Blueprint & Execution results will be report in D2.5 “Final pilot test and validation”.

4.1.5 Summary & next steps

Site facilities would be exploited by FST as testbed for the potential development and deployment of 5G on board media services on the basis of the validation of the evidences related to URLLC and mMTC.

In particular, Test Case 1 described in Table 7 will support the validation of video streaming vertical QoE using a vertical application running on 5G mobile devices, to collect KPIs in a real urban environment related to the thresholds from which 5G application can support video on board services due to limited package loss, high user throughput and limited E2E Latency.

This first KPIs validation is functional to the Test Case 2, described In

Table 8. Here the video streaming vertical QoE will be tested in a simulated on board high speed environment, using the 5G PRISMA emulator to reproduce where network conditions stressed by handover effects. User throughput, E2E latency, packet loss rate, number of on board devices simultaneously connected with the video streaming service and network on board capacity (Mbps/End Point) will be tested in order to support assessment of investment in 5G technology for on board network provisioning.

Indeed, the results collected in the site facilities could be the starting point to scale the solution to a wide industrial application testing on large segment of the high speed segments. This will be fundamental when future relevant investments will be realized for the deployment of 5G infrastructure that will physically cover relevant sections of railway infrastructure not only in the large city framework, but mostly in rural area, that are the once where current solutions do not guarantee suitable coverage.

4.2 Use Case 1.2 - Smart Transport: Intelligent railway for smart mobility: Urban mobility 5G data flows analysis

4.2.1 Pilot execution context

The Use Case 1.2 ***Urban mobility 5G data flows analysis*** aims at demonstrating that, thanks to 5G mobile communications, it is possible to analyze real time mobility data through large scale data analytics to provide added value information for decision making in traffic congestion management. Moreover, combining Use Cases 1.1 and 1.2 as Vertical Smart Transport, enriched information about passenger's mobility flows enables E2E on board and off board customized info-mobility services.

The Use Case has been developed step-by-step adopting a top-down approach for design, implementation, and deployment. Three main services have been developed.

With reference to Figure 8, the three services are represented as three distinct VNFs on boarded on the Polito NFV Infrastructure. The *5G EVE Tracking Service* collects and transmits data from different sensors from user's 5G mobile device (on the left in the figure) to the 5G EVE Recognition Service on the Polito VNF Infrastructure (on the right in the figure). The *5G EVE Recognition Service* automatically analyses data and identifies user's transportation modality in real time by a suitable machine learning trained on high volume data set collected in the preliminary phase of the Use Case. The *5G EVE Urban Mobility Service* automatically aggregates flows as mobility patterns and related transport modalities and publishes added value information on the TIM's ICON platform via OneM2M protocol. For the whole experiment's design and implementation, the main actors, the pilot architecture referring to the Italian Site and the test case initial status are reported in the following sections.

The experiment will allow end user equipped with 5G device to automatically send mobility data to the 5G Tracking Service that manages mobility data and gets in real time the estimated modality adopted by the end user from the 5G Recognition Service. The enriched data, namely mobility data with estimated modality, will be managed by the 5G Urban Mobility Service: this service sends enriched data to the TIM's platform ICON accessed by mobility operators and transportation system managers as third parties. In this sense, the Use Case shows how real time machine learning based recognition can support decision making in traffic congestion management, from the urban and railway operator's point of view. Relevant KPIs from the vertical's point of view include *tracking response time* and *memory usage* concerning the 5G Tracking Service and, mostly important, the *recognition delay* concerning the 5G Recognition Service.

A further experimental purpose of the experiment is to include data from Libellium scanners (on the left in the figure) adopted in Use Case of vertical Smart City (see Use Case 5.1, Section 4.9) in the analysis of urban mobility flows. The main expectation is that data blending can play a crucial role in automatically refining mobility patterns and favoring synergies between Smart Transport and Smart City scenarios in case of critical and/or risky situations.

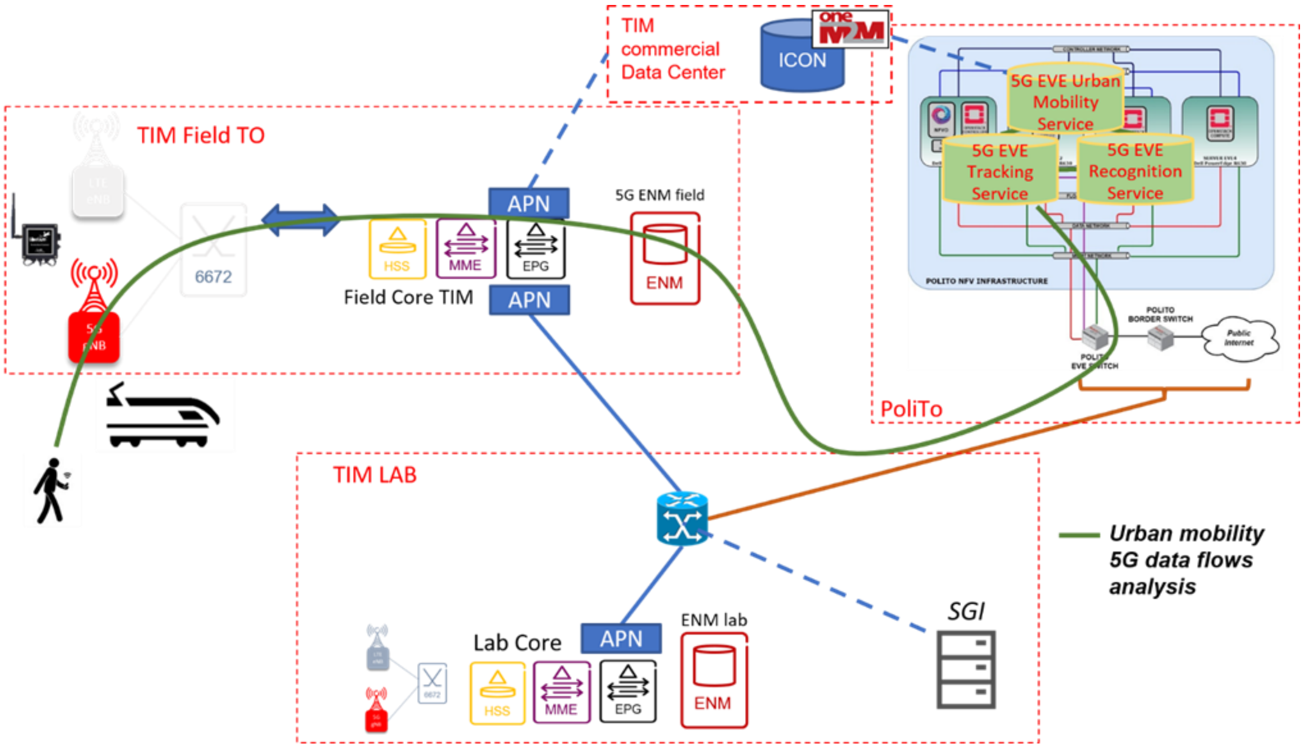


Figure 8: Smart Transport (Italy) UC1.2 - Reference architecture

4.2.1.1 Actors

The main actors of the experiment are the following ones:

<u>Vertical</u> Ares2t designs the experiment according to the own knowledge in the field of urban mobility, in line with considerable experience in Electro Mobility and related services in huge urban environments. Moreover, the concept behind the Use Case is based on both scientific literature and market needs relevant in urban mobility.

<u>VNF provider</u> Ares2t provides the entire set of VNFs enabling the experiment. Each VNF implements one of the three services described in the previous section, namely:

- *5G EVE Tracking Service* – The VNF collects data from different sensors from end users' 5G mobile devices;
- *5G EVE Recognition Service* – The VNF analyses data and automatically identifies each end user's transportation modality in real time by a learning machine (being part of the service);
- *5G EVE Urban Mobility Service* – The VNF aggregates flows as mobility patterns and related transport modalities and publishes added value information on the TIM's ICON platform via OneM2M protocol.

<u>Experiment developers</u> Ares2t is responsible for specifying the blueprints associated to the experiment, as well as the associated NFV Network Services Descriptors. This task has been preliminarily performed by Ares2t in cooperation with a site integrator for the Italian site, namely Nextworks.

<u>Experimenter</u> Ares2t is responsible for the request of the experiment described in the previous section and related assessment of results from the 5G network and the business point of view. Ares2t has defined the characteristics of the experiment managing blueprints and requests for the deployment of the related virtual environment (Polito VNF Infrastructure). Ares2t is ready for the execution of the experiment to complete the analysis of actual results and KPIs with respect to tests already performed in lab (see Section 4.2.3).

<u>Site Manager</u> TIM is the Site Manager responsible for authorizing and managing the experiment in the Italian site according to requirements and specifications indicated by Vertical and Experimenter.

4.2.1.2 Planning & Status

In line with the roadmap presented in [6] (see Figure 9), lab testing was concluded by the end of 2019. Integration and Interoperability phase is still ongoing and will be finished by mid-2020. The second half of the year will be focused on the Test phase.

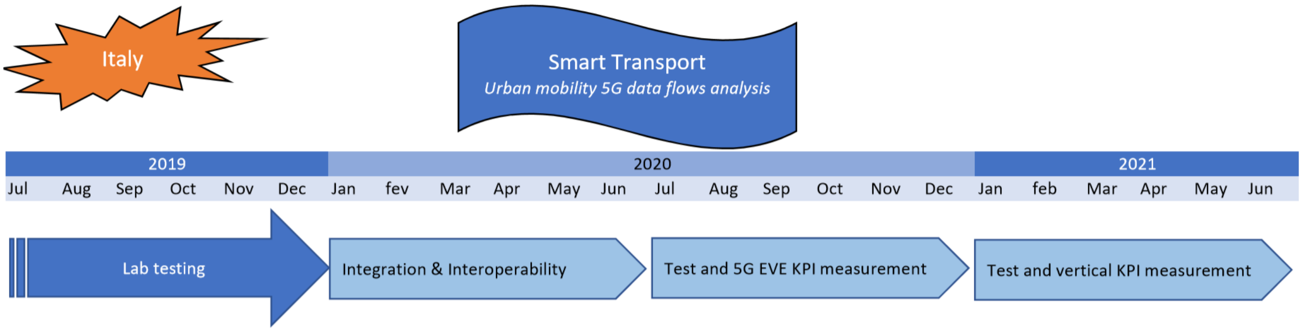


Figure 9: Smart Transport (Italy) UC1.2 - Roadmap

4.2.2 Pilot architecture

The experiment described in Section 4.2.1 can be deployed and executed according to the reference architecture depicted in Figure 8 with respect to the Italian site implementation status. Deployment requirements are indicated in Table 10.

Table 10: Smart Transport (Italy) UC1.2 - Deployment requirements

Component Name	Description	Deployment requirements
User Equipment (UE)	User 5G terminal (smartphone)	End user's terminal to connect to 5G infrastructure.
Android App	App collecting mobility data from smartphone sensors.	End user's terminal equipped with mobility sensors (GPS, accelerometer, gyroscope, magnetometer)
Backend	Virtual machine hosting 5G Tracking backend service, 5G Recognition backend service and 5G Urban Mobility backend service.	Virtual machine to run Linux Ubuntu + required software to run the service (e.g., python, anaconda)
Visualization tool	Virtual machine hosting data visualization tool.	Virtual machine to run Linux Ubuntu + ELK Stack.
Delay configurator	Means to add random or programmable network delay.	Device to adjust the network delay.
Background Traffic	Means to inject traffic into the network.	Used to inject traffic into the network, simulate numbers of virtual UEs and other external traffic.

The complete architecture for the implemented services and the related VNFs is depicted in Figure 10 to Figure 12, where each service of the three illustrated in Section 4.2.1 is completely described from the deployment point of view.

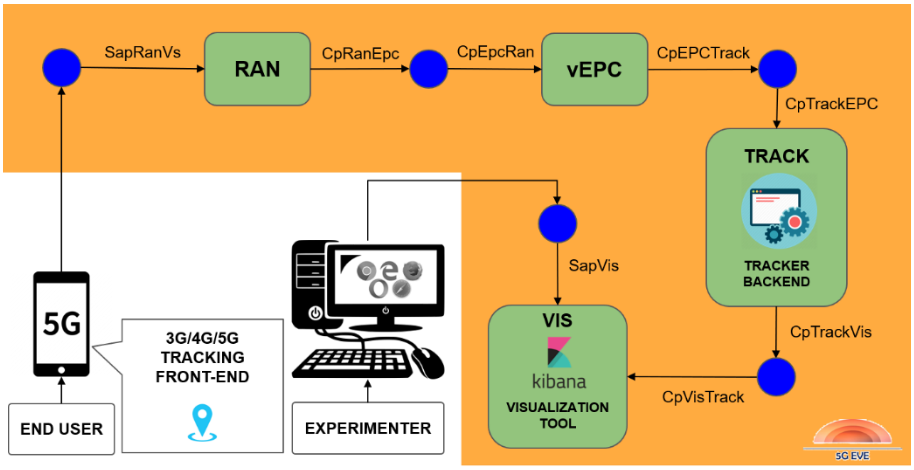


Figure 10: Smart Transport (Italy) UC1.2 - Architecture for 5G EVE Tracking Service

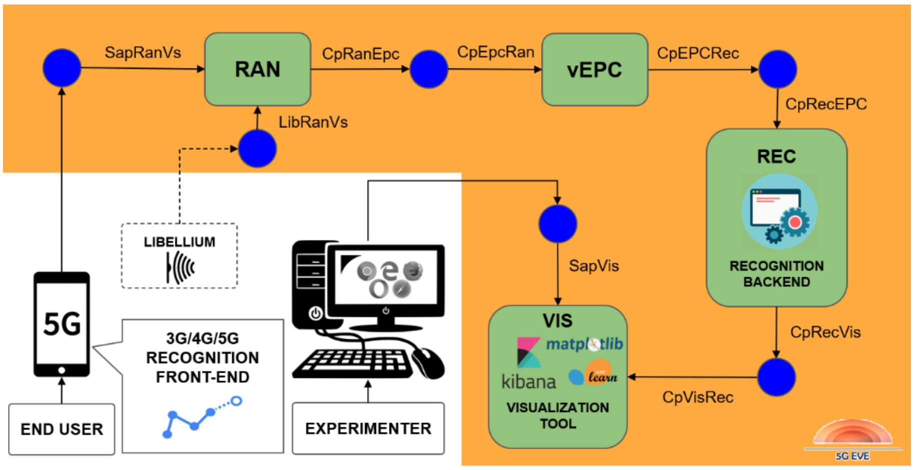


Figure 11: Smart Transport (Italy) UC1.2 - Architecture for 5G EVE Recognition Service

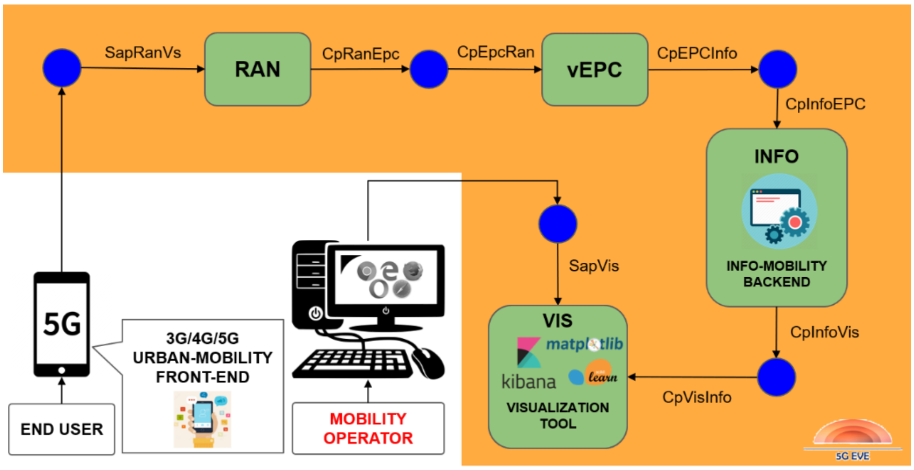


Figure 12: Smart Transport (Italy) UC1.2 - Architecture for 5G EVE Urban Mobility Service

The Vertical Service Blueprint associated to the pilot architecture is depicted in Figure 13.

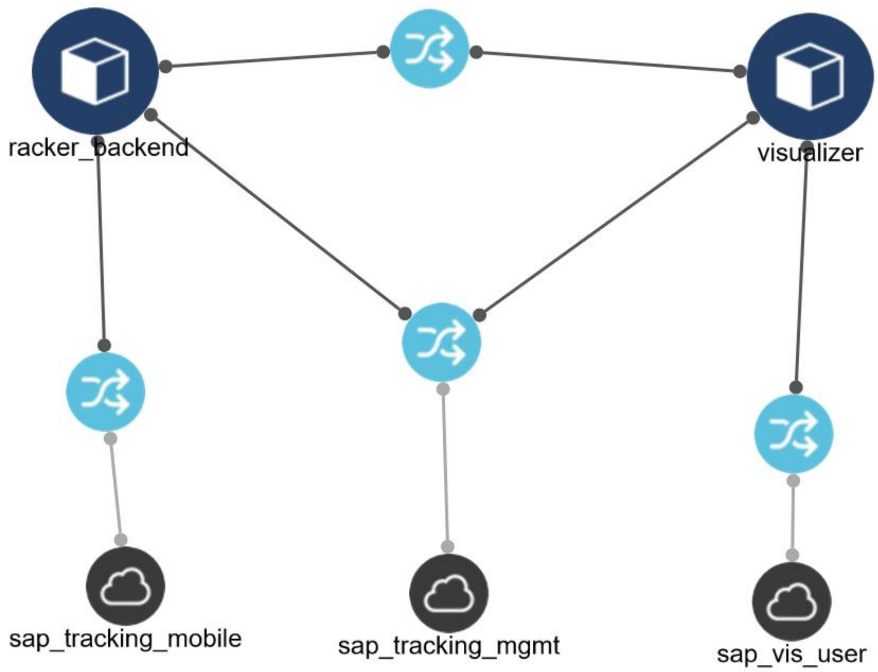


Figure 13: Smart Transport (Italy) UC1.2 - Vertical Service Blueprint

The Context Service Blueprint for the Experiment is depicted in Figure 14.

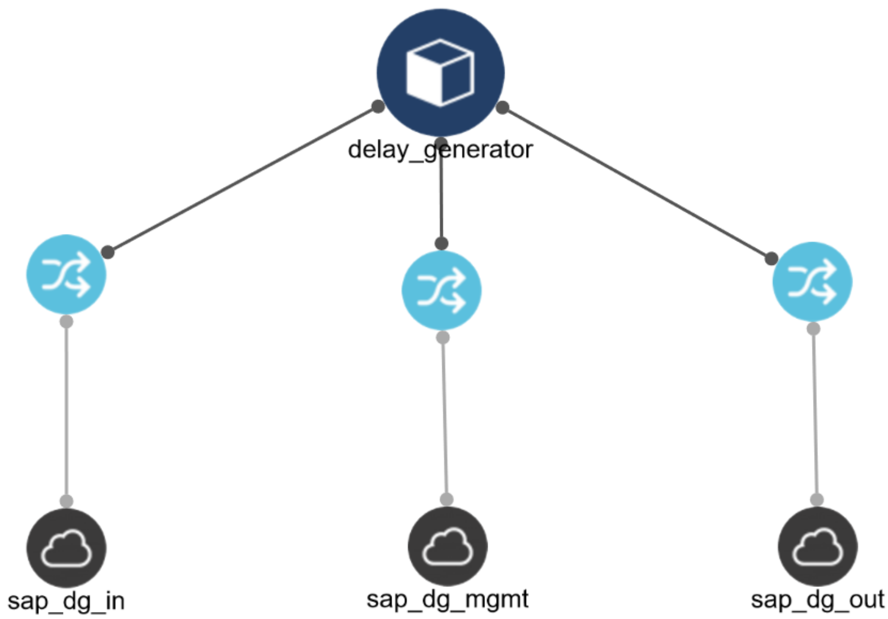


Figure 14: Smart Transport (Italy) UC1.2 - Context Blueprint

Figure 15 illustrates the Experiment Blueprint.

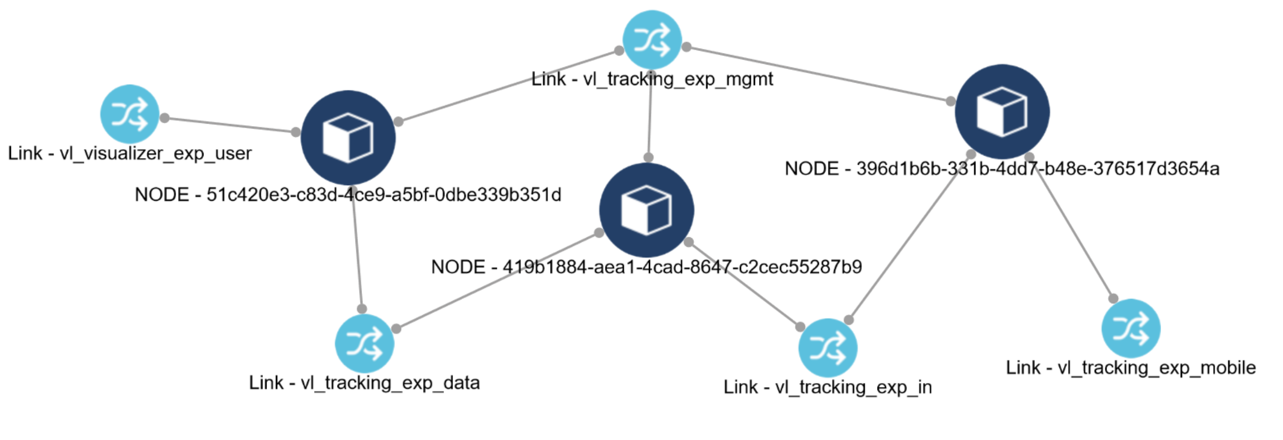


Figure 15: Smart Transport (Italy) UC1.2 - Experiment Blueprint

All the Blueprints displayed are available on the 5G EVE Github repository as follows:

- Vertical Service Blueprint [26].
- Context Blueprint [27].
- Experiment Blueprint [28].

4.2.3 Test Case Blueprint & Execution results

For the UC 1.2 three low level test cases have been planned according to the vertical KPIs of interest for the Experimenter. The first and the second one aim at measuring the vertical KPIs involving the 5G Tracking Service, while the third one the vertical KPI involving the 5G Recognition Service. The three test cases are reporting in the following tables.

Table 11: Smart Transport (Italy) UC1.2 - Low Level Test Case 1

Test Case 1	
Test Name:	Effect of number of connected devices on *tracking response time* performed at MEC
Target KPI:	*Tracking response time*
Measurement Method:	The tracking response time will be measured by the Kibana visualization tool: it measures the time spent to evaluate the selected amount of data and visualize them
Parameters:	No external traffic. Number of users: from 1 to hundreds
Validation Conditions:	Tracking response time <= 200ms

Table 12: Smart Transport (Italy) UC1.2 - Low Level Test Case 2

Test Case 2	
Test Name:	Effect of number of connected devices on MEC *memory usage*
Target KPI:	*Memory usage*
Measurement Method:	The memory usage will be measured by the Kibana visualization tool: it measures the percentage of used memory over the total available memory
Parameters:	No external traffic. Number of users: from 1 to hundreds
Validation Conditions:	Memory usage < 90%

Table 13: Smart Transport (Italy) UC1.2 - Low Level Test Case 3

Test Case 3	
Test Name:	Effect of network delay and availability on the transportation mode recognition capability
Target KPI:	*Recognition delay*
Measurement Method:	The recognition delay will be measured by the backend recognition service: it measures the time needed to estimate the correct transportation mode, when a transportation mode occurs
Parameters:	No external traffic. Number of users: from 1 to hundreds Delay: 1ms, 10ms, 100ms, 1s
Validation Conditions:	The impact of network delay is less than 10% of the recognition delay

The Test Case Blueprint is available on the 5G EVE Github repository at [29].

4.2.4 Pilot Initial validation status

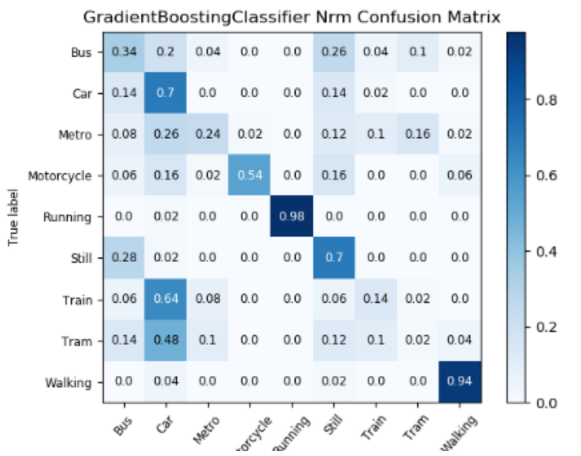
Compared to preliminary performance results (cfr. [6], Section 3.1.3), data analysis has been finalized on the entire available dataset and some changes were made to the machine learning process already described. In particular, the entire dataset was obtained by 5G EVE Tracking service with different data sampling frequency (from 1 to 5 seconds per data sample), to find the best parameter value for this service. Accordingly, the time window considered for extracting the most suitable features was changed. Currently, segments consisting each one of 3 records are now defined with the two most recent records overlapping. For example, if a segment is composed of records relating to time 0, 1 and 2, the next segment will be composed of records relating to time 1, 2 and 3. This has led to a significant increase in the number of segments useful for creating the features and therefore the training instances. New features were extracted. For each sensor, for each axis and for each magnitude (the square root of the sum of the squared value of the three sensor axes x, y and z), to the already calculated statistics were considered the skewness and the inter-axial correlation. In this way overall 136 features were extracted. The training set used in 2020 consisted of the union of the data of 2019 and those of 2020 and it was built with the procedures just mentioned, for a total of 37,574 instances. The test set was created by extracting 50 instances for each mode of transport from the data collected in 2020, for a total of 450 (we did not collect "Bike" data in 2020). In the 2019 training set we had highly unbalanced classes and this led to an under sampling of the "Car", "Walking" modes. This was not necessary in the new training set (2019 + 2020) as we had a good number of instances for each mode. To avoid overfitting and the increase in computational times, a selection of a subsample of the features with more predictive power on the dependent variable was made. The selection was made through the "Feature ranking with recursive feature elimination" method of the Scikit-learn library. By choosing the Decision Tree Classifier as the algorithm to be used within the method, the technique works recursively in search of the combination of features that guarantees the highest prediction accuracy. In this way, from the original 136 features, 101 were selected. As in 2019, through the analysis of the cross-validation scores, the most successful algorithm in terms of better f1 score and accuracy was the Gradient Boosting Classifier. The model was tuned to find the optimal parameters. Given the great number of features in relation to the number of instances, we contained overfitting by setting a low learning rate and not creating too many trees. In addition, among other tuned parameters, for each tree the maximum depth was adjusted and a percentage of subsample of features was set on which to classify the instances. By including this stochastic component, it was decided to trade a higher bias for a lower variance. Being the Gradient Boosting a tree-based model, feature scaling was not necessary. The 10-fold stratified cross validation performed on the training set resulted in an average accuracy of 97.7 and an average f1 score of 0.94 in the validation set. The same test set was used to compare the performance of the model trained in 2019 and that trained in 2020. Table 14 summarizes the differences between the two models:

Table 14: Smart Transport (Italy) UC1.2 - Urban mobility 5G data flows analysis – Experimental results

	Experiment A	**Experiment B**
Sampling **rate**	5 s.	1 s.
Feature **base set**	OVERLAPPING TIME WINDOW – NO	OVERLAPPING TIME WINDOW – YES
	39 basic features	136 basic features
Selected **features**	39	101
Undersampling "Car", "Walking" mods	YES	NO
Training set	From dataset A (7616)	From dataset A + dataset B (37124)
Test set	From dataset B (450)	From dataset B (450)
Analytics	Tuned Gradient Boosting Classifier	Tuned Gradient Boosting Classifier

The new model has far outperformed the old one. Figure 16 shows the confusion matrices obtained by the two models on the test set.

Experiment A	**Experiment B**



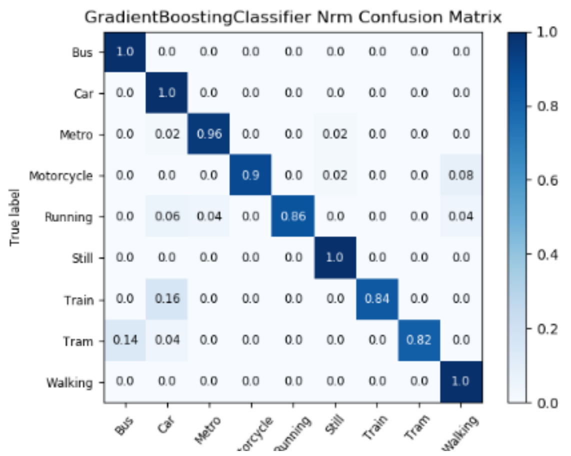


Figure 16: Smart Transport (Italy) UC1.2 - Urban mobility 5G data flows analysis – Experiment assessment

The next step beyond the work done so far will be the deployment and setup, in the pilot facilities, of the Recognition service. With reference to the Figure 17, the AS-IS deployment will be extended and completed into the TO-BE deployment. More specifically, in the AS-IS deployment, two virtual machines have been deployed in Openstack [62]: VM#1 named BE_Tracker (Tracker Back End) and VM#2 named BE_ELK (ELK Back End). The former is in charge to collect the data from the mobile phones (connected to Openstack through a VPN channel), to elaborate and store them. The latter is in charge of gathering the data stored in VM#1 (using Beat), to elaborate the data using the ELK (Elastic search + Logstash + Kibana) stack and to expose them by means of a web based GUI, accessible by any authorized external PC connected to Openstack via VPN.

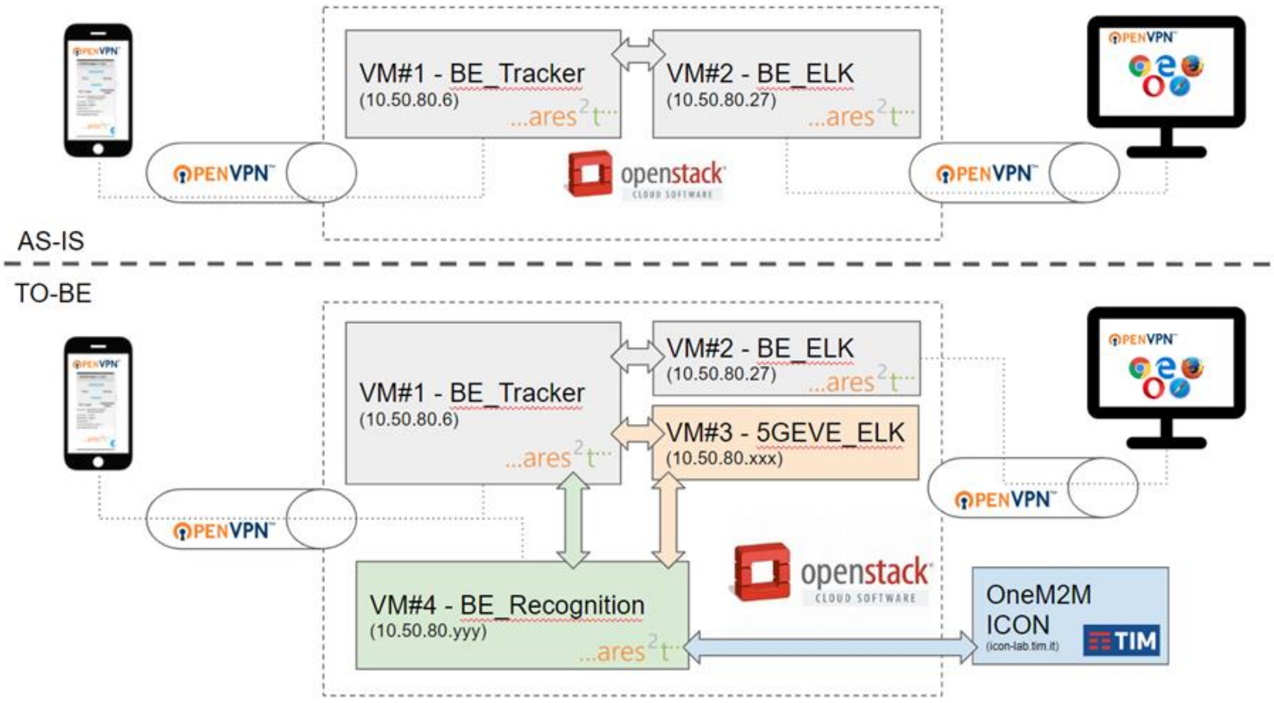


Figure 17: Smart Transport (Italy) UC1.2 -Detailed architecture

In the TO-BE deployment, two additional VMs will be deployed or involved: a VM#3 named 5GEVE_ELK and a VM#4 named BE_Recognition. The former is the VM dedicated to managing the 5G EVE Tracking service for monitoring and visualization of mobility data. The latter is dedicated to manging the 5G EVE Recognition service being in charge of gathering the data stored in VM#1, to train the recognition algorithms and to interact with the 5G mobile devices to recognize, in real time, the user's transportation modes on the basis of a bounce of sensors data. The recognition results of the BE_Recognition will be sent via 5G EVE Urban Infomobility Service to the ICON platform (by means of OneM2M protocol) managed by TIM. Furthermore, two additional interactions will be added. The BE_Tracker and the BE_Recognition will send updated metrics to the 5GEVE_ELK, to feed the KPI visualization system.

4.2.5 Summary & next steps

The expectations for future development according the roadmap depicted in Figure 9 is to run the experiment on 5G EVE infrastructure in the Italian site after completing the deployment of all necessary services, and to collect vertical and network KPIs.

With respect to the three services represented by 5G EVE Tracking Service, 5G EVE Recognition Service and 5G EVE Urban Mobility Service, relevant network KPIs include: the *network availability* to guarantee the 5G EVE Tracking Service to get mobility data from end user's mobile devices; the *network reliability* to guarantee the 5G EVE Recognition Service to get all data being necessary to identify the transportation modality, since even minor packet loss strongly impacts both data mobility tracking and transportation mode estimation. Relevant vertical KPIs include: the E2E network latency to measure the *tracking response time* for the 5G Tracking Service; backend side, on the edge server, the *memory usage* and *recognition delay* for the 5G Recognition Service. The accuracy of the 5G EVE Recognition service for automatic identification of the transportation modalities adopted by mobility flows in the 5G covered area in the City of Turin is expected to be in line with experimental results reported in Section 4.2.3 with particular attention to Experiment B shown on the right in Figure 16.

4.3 Use Case 2.1 - Smart Tourism: Augmented Fair experience (Italy)

4.3.1 Pilot execution context

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, overcoming the limitations of traditional information tools and allowing 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 maintained: from offline browsing to advanced ticketing; from remote monitoring to Augmented Reality (AR) exploration. The UC will use Artificial Intelligence (AI) image recognition techniques and AR applications to enhance the visitor experience and optimize available resources.

A mobile app has been developed by CNIT in support of this UC. The Smart Tourism app recognizes a monument or a work of art just by framing it with the camera from any direction and regardless of its distance. The interface shows the name of the object and shows the related information with just a touch. From within the app, if an AR extension is available for the monument, AR graphics will be superimposed on the image to allow an AR-enhanced visit of the monument or site. The AR application relies on 3D models and other multimedia files that will be available through the server positioned in the 5G edge cloud, which enables AR Multimedia document retrieval, AR Project document retrieval, AR navigation of 3D models and 3D maps.

4.3.1.1 Actors

Vertical

CNIT is the vertical, it has the purpose of testing the AR app it has developed for smart tourism purpose, using the 5G-EVE infrastructure.

VNF provider(s)

CNIT has provided the VNF providing the backend functionality of the Smart Tourism app, to be on boarded with the help of NXW.

Experiment developer(s)

CNIT has developed the experiments with the goal of evaluation of the Use Case.

Experimenter(s)

CNIT is also the experimenter, having set up a test suite that allows the testing of the capability of the Smart Tourism app.

Site Manager(s)

TIM is the site manager.

4.3.1.2 Planning & Status

In line with the roadmap presented in [6] and shown in Figure 18, the Use Case has reached step 2 of the planned development:

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.

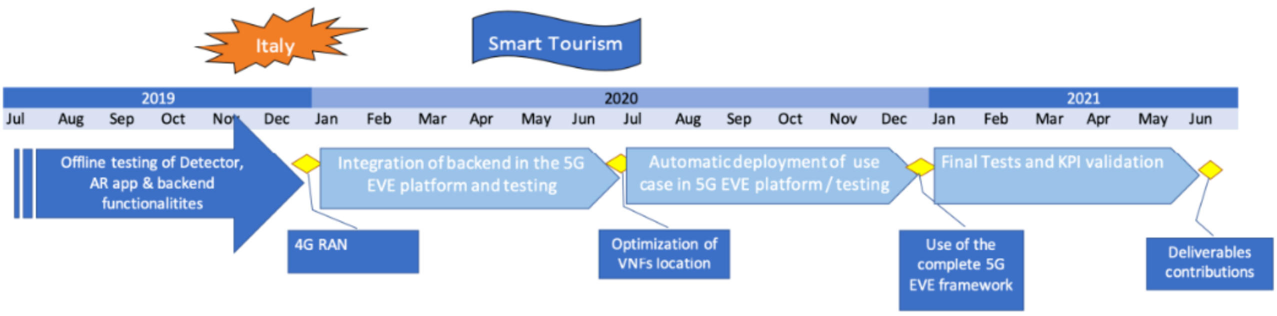


Figure 18: Smart Tourism (Italy) UC2.1 - Roadmap

4.3.2 Pilot architecture

The adopted architecture is shown in Figure 19, where the two main components of the Use Case are the AR Server (ARS) and the Media Database (MDB) NFs running in the 5G EVE edge cloud. The Smart Tourism app interacts in real time with the 5G EVE Edge Cloud to retrieve the augmented reality content.

The ARS NF is a lightweight web server using the Django Web framework, which interacts with the MDB NF, realized through Mongo DB, to retrieve the multimedia content and the 3D models.

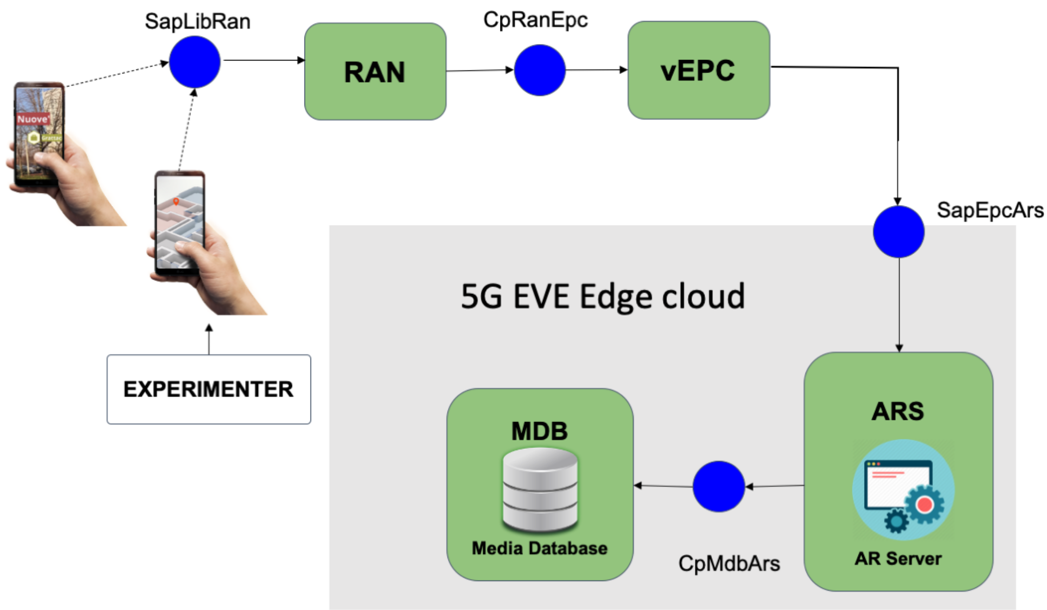


Figure 19: Smart Tourism (Italy) UC2.1 - Pilot architecture

Figure 20 shows the pilot architecture including a computer user that generates synthetic traffic simulating a human user for the purpose of automating experiments and collecting measurements

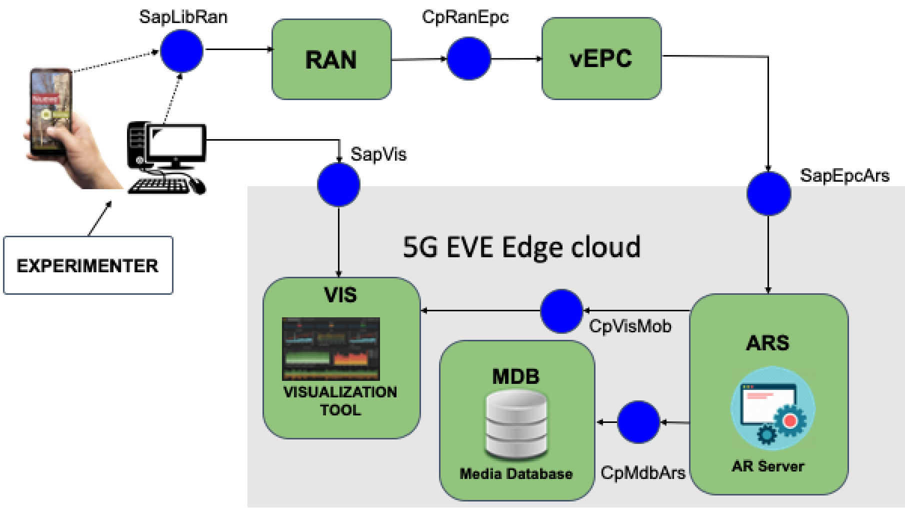


Figure 20: Smart Tourism (Italy) UC2.1 - Architecture for augmented reality for Virtual Tourism experiment

The experiment leverages the following components:

Table 15: Smart Tourism (Italy) UC2.1 - Components

Component Name	Description	Deployment requirements
User Equipment (UE)	User 5G terminal (smartphone)	User terminal to connect to 5G infrastructure.
Mobile App	App collecting localization information and contextual information (through the camera) to be sent to the server and receiving media content an AR artifact.	User terminal equipped with mobility sensors (e.g., GPS, magnetometer, accelerometer, gyroscope, ...) and camera.
AR Server	Virtual machine providing the AR superposition layers	Virtual machine running Linux Ubuntu + required software to run the web service (e.g., Django framework)
Media Database	Database hosting the media content and 3D models	Virtual machine running Linux Ubuntu + Mongo DB.

The Test Cases defined for the Smart Tourism UC are the following three:

Table 16: Smart Tourism (Italy) UC2.1 - Test Case 1

Test Case 1	
Test Name:	Effect of number of connected devices on CPU load of ARS
Target KPI:	CPU Scalability
Measurement Method:	The amount of resources required to run the ARS NF in terms of CPU will be measured by the Kibana visualization tool.
Parameters:	No external traffic. Number of users: from 1 to hundreds

Validation Conditions:	VM CPU load <= 80%

Table 17: Smart Tourism (Italy) UC2.1 - Test Case 2

Test Case 2	
Test Name:	Effect of number of connected devices on ARS memory usage
Target KPI:	Memory usage scalability
Measurement Method:	The amount of resources required to run the ARS NF in terms of memory (RAM) will be measured by the Kibana visualization tool.
Parameters:	No external traffic. Number of users: from 1 to hundreds
Validation Conditions:	VM used RAM <= 80%;

Table 18: Smart Tourism (Italy) UC2.1 - Test Case 3

Test Case 3	
Test Name:	Effect of network delay on the user experience
Target KPI:	Delay
Measurement Method:	The response delay will be measured in two parts: the time elapsed between a position update and service request sent by the app and its reception at the ARS (request delay); the time between the service request reception and the complete transfer of data as received by the app itself (response delay).
Parameters:	No external traffic. Number of users: from 1 to hundreds
Validation Conditions:	The impact of network delay is less than 10% of the response delay

4.3.3 Test Case Blueprint & Execution results

The UC is expected to show the ability of the 5G EVE platform to deliver high-volume traffic to the Smart Tourism mobile app. At the same time, it is expected to guarantee low-latency interaction between the mobile app and the virtualized servers on the platform in order to provide an enhanced augmented reality experience to its users.

The synthetic ARS mobile app queries the django-rest APIs on the ARS server described above. The ARS server provides text and multimedia files based on GIS (Geographical Information System) to the mobile application, as show in Figure 21.

The server contains the following data models:

1. Place (monuments or area enabling user interaction)

2. Event (attached to Places)

3. Videos, Images (attached to Places)

The model is based on the Places, which means other models could be considered as an attachment. In the actual implementation, we have images and videos. The purpose of the test is to be able to simulate the client, in which a set of instructions are embedded reproducing the steps used inside the mobile application.

The first step of the test confirms the Place where the user is located and starts to query all the specific data related to that given place (events, images, videos, ...). CNIT has conducted the test on the server by simulating several requests as if they were coming from different clients and measuring the response time, thus performing a load test. This should be considered as a subclass of performance testing, since the main goal is to simulate the client and observe the behaviour on the server side, even considering multiple users and requests.

The steps are the following:

1. the user requests a token (in the app this can be defined statically or done once the application is installed).
2. the user queries its Place by posting its current location (GPS coordinates), the server response is a Place, or empty when the user is outside the studied area.
3. the user queries all the details of the Place.
4. the user queries all the events attached to the Place.
5. the user queries all the images belonging to the Place.
6. the user queries all the videos belonging to the Place.

These steps are a sequence of tasks, i.e., each is executed one after another.

Below, we report a preliminary evaluation of Test Case 1.

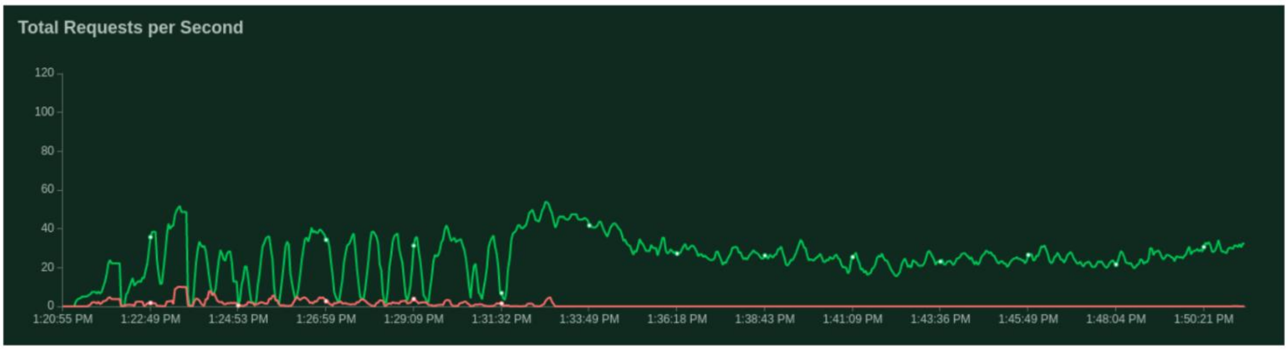


Figure 21: Smart Tourism (Italy) UC2.1 - Number of requests to the ARS server as a function of time in a 30-minute load test

As shown in the curves of Figure 21, we plotted the outcome of a 30-minute load test with the number of requests as a function of time. The green curve represents the number of requests averaged every second. The red curve represents the number of request failures: the failure is an upstream timeout on the server by passing to the port, likely due to automatic caching by reaching some number of requests so that the stream could be accessed quickly.

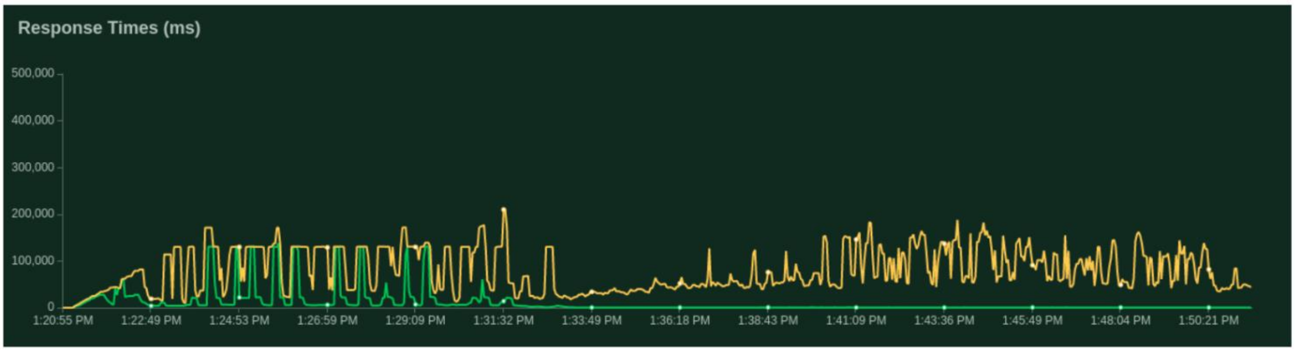


Figure 22: Smart Tourism (Italy) UC 2.1 - Recorded response times from the ARS server as a function of time in a 30-minute load test

The curves in Figure 22, show the recorded response times: in yellow average response time, while the green curve reports (one can see that whenever we do not have any more failures the average stays constant).

4.3.4 Pilot Initial validation status

The pilot has not been yet integrated in the 5G EVE platform and thus the validation has not been performed so far.

The KPIs we expect to collect are the following:

- the bandwidth required for the interaction between ARS and the Smart Tourism app for different types of content.
- the latency involved in the interaction between ARS, MDB and the Smart Tourism app for different types of content.

4.3.5 Summary & next steps

CNIT has developed a standalone client that can automate the queries to the ARS server without necessarily starting the app on a smartphone. Such a standalone client can be used as an experimenter client to test and validate the automatic deployment of the Use Case on the 5G platform.

4.4 Use Case 2.2 - Smart Tourism: Experiential tourism

4.4.1 Pilot execution context

"Experiential tourism through 360-degree video and VR" Use Case aims at transforming the experience of participants in events, conventions, presentations and meetings (professionals and the general public), to amplify their participation and improve their interactions, taking advantage of VR technology and the immersive qualities of real-time 360-degree video.

Regarding the Smart Tourism Vertical, the following sub-Use Cases can be distinguished:

Immersive events: participation in professional events has been usual in the tourism industry and now it is possible to improve the visibility of these events providing a differential experience to attendees. Combining VR technology with 360-degree video it is possible to take the experience of digital immersion to the next level, offering the option of assistance to different events taking place simultaneously in different places, including remote immersive experiences thanks to the streaming of 360º video.

First, professionals in the sector reclaim high impact content to be included in events to create attraction for target users; on the other hand, professional events attendees are able to simultaneously attend to different meetings on a real-time basis. Then both can deploy a multi-level experience into the event, as an event in event.

High definition contents (4K/8K) in the 360º video format allows the view all around, to different angles and from different cameras. It is here where 5G connectivity will play a fundamental role, because:

- Greater bandwidth will be necessary to enable visualizing this high-quality content with the proper quality.
- Latency improvement should be required to improve the user’s experience with camera change and with the optimized field of view techniques.

5G technology is also a great help in deploying this Use Case, mainly improving two key parts of the communication:

- Upstream first mile: easing the contribution of the video feed to the cloud.
- Downstream last mile: empowering the delivery of the video to the VR headsets.

The technical architecture of the solution is shown in the following picture:

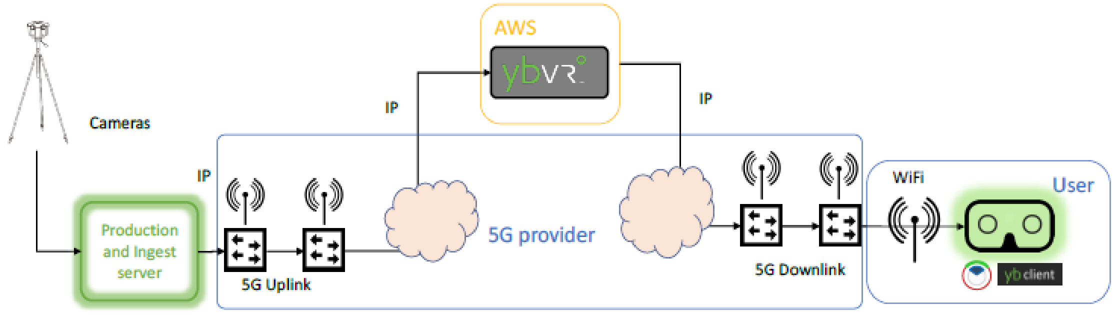


Figure 23: Smart Tourism (Spain) UC2.2 - Immersive events technical architecture

These elements are building this architecture:

- VR cameras have to be deployed in the remote venue to capture the action.
- A production set to prepare the video VR signal, adding graphics, credits, audio and other information.
- The produced video VR content is ingested into the cloud using a 5G uplink.
- YBVR platform process the video to optimize quality and streaming properties.
- The processed video VR is streamed from the YBVR platform to the headset using Internet and the 5G last mile to the local event booth.
- Currently, a Wi-Fi connection is required between the 5G endpoint to access to the headset.
- Maybe shortly, the VR headset could be connected directly to the 5G network.

Virtual tickets: the sale of virtual tickets is an opportunity to generate new income sources in any professional event of the tourism industry, especially in the case of the Meetings, Incentives, Conferencing, Exhibitions (MICE) sector. The 5G technology will facilitate the reception of content via streaming concerning any event thanks to the improvement in connectivity and bandwidth. Event organizers could define virtual tickets packaging recorded contents according to multiple market segments, creating on-demand experiences very focused on the interest of the target audience.

Virtual experience through immersive content of an event will facilitate the access and interaction between professionals and users, as well as the collection of relevant information for their organizations that, otherwise, could not have attended for reasons of agenda, location, or costs.

In order to enrich the experience related to the sale of virtual tickets, the reach of these contents through 360º video with VR devices will also provide an innovative element improving the event offering competitiveness.

5G technology is a great help to deploy this Use Case, mainly in the downstream, empowering the delivery of the video to the VR headsets.

The technical architecture of the solution is shown in Figure 24.

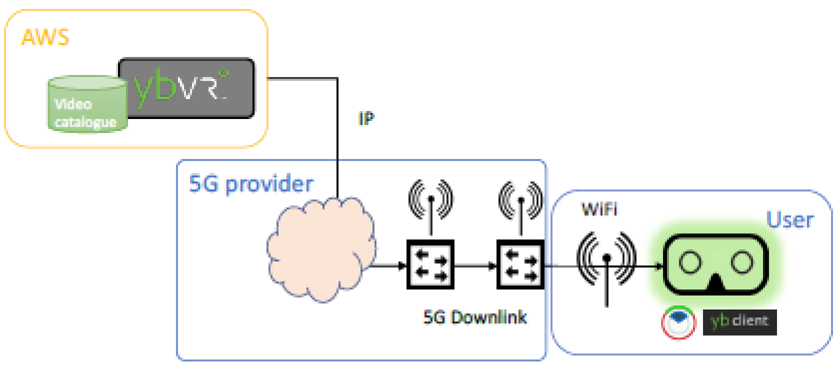


Figure 24: Smart Tourism (Spain) UC2.2 - Virtual tickets technical architecture

The following elements are building this architecture:

- The produced video VR content is ingested into the YBVR platform to build the VR experience portfolio.
- YBVR platform process the video to optimize quality and streaming properties.
- Video VR processed is streamed when the user requests this content, from the YBVR platform to the headset using the internet and the 5G last mile to the local event booth.
- Currently, the Wi-Fi connection is required between the 5G endpoint to access to the headset.
- Maybe shortly, the VR headset could connect directly to the 5G network.

4.4.1.1 Actors

Vertical: SEGITTUR and YBVR are responsible for defining the Use Case.

VNF provider(s): SEGITTUR and YBVR will provide the definition of the service to be offered in the Use Case. Note that, in this particular Use Case, both sub-Use Cases adopt over-the-top solutions, so that the services are outside 5G EVE scope and are deployed in a public cloud. In that way, it is not needed to deploy specific VNF(s) in the Spanish site.

Experiment developer(s): Ericsson Spain will support the operation related to the introduction of this Use Case in the 5G EVE workflow, with the collaboration of Telcaria Ideas for technical problems in the usage of the platform.

Experimenter(s): Ericsson Spain will take care of the experiment execution, under the supervision of Telcaria Ideas, and also with the collaboration of YBVR, which will manage the execution of the over-the-top solution.

Site Manager(s): IMDEA Networks and UC3M, as Spanish site managers, will play this role.

4.4.1.2 Planning & Status

The status evolution of this Use Case in the last months is the following:

- Different test sessions have been deployed in Jun-2019, Sep-2019 and Dec-2019 in standalone mode. 4G reference results were registered but some Internet connectivity problems left 5G tests uncompleted.
- Pilot Use Case was deployed in FITUR-2020 event (Jan-2020).
- COVID19 impact delayed the pending 5G tests, now planned by Jun-2020. These tests will repeat the test plan defined after the Internet connectivity problem is solved. In this document, some results related to these tests will be included, leaving the rest of them and future improvements for the next deliverable D2.5.

Regarding the integration in the 5G EVE workflow, three validation phases have been planned:

- The first one is scheduled for June 2020, in combination with the pending 5G tests aforementioned. In this phase, a specific set of test cases will be executed following the 5G EVE workflow from the definition of the experiment to the execution and results report. In this way, some preliminary tests have been executed during the first week of June 2020, whose results are provided in this deliverable, and which will be complemented by the pending tests to be done in June 2020.
- The second phase is expected for December 2020, consisting on the execution of all the test cases defined by following the 5G EVE workflow.
- Finally, the third phase will take place on June 2021, repeating the tests with all the functionalities enabled in the 5G EVE platform.

This point will be also extended in Section 4.4.5.

4.4.2 Pilot architecture

The two sub-Use Cases defined will be run on top of a 4G/5G network, executing the business logic in a public cloud. In that case, no services or virtual appliances are needed to be deployed within the 5G EVE site facilities, as the only requirement is to have connectivity, with the required performance, between the end-user devices.

According to this, the Figure 25 shows the infrastructure implemented in 5TONIC [30] Lab and related to the 5G EVE workflow:

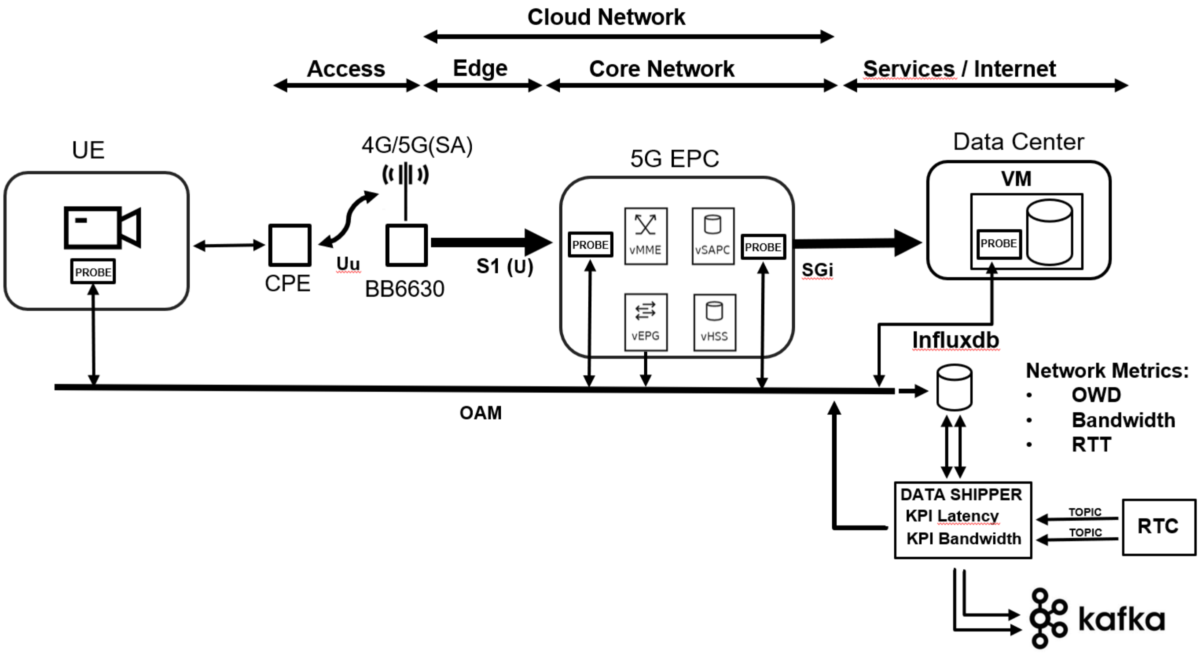


Figure 25: Smart Tourism (Spain) UC2.2 - Network infrastructure implemented in 5TONIC

The device (could be a VR glasses or a camera) connects to the CPE via Wi-Fi. The CPE is 5G/4G capable and can connect to the Ericsson 5G SA or LTE RAN (Radio Access Network) solution. Once the connection is established, data is sent through Radio, then EPC (Evolved Packet Core) towards the Data Center.

Ericsson has stablished PROBE tools in order to measure different network metrics. These tools are installed in key parts of the network. Then, a Data Shipper gets these metrics and forwards them to the 5G EVE Monitoring system (Kafka).

Having said that, the Experiment template related to this Use Case, defined in a preliminary version in deliverable D5.2 [15], has suffered several changes. In this deliverable, it will be only included the updates of that template, which are:

- A more complete architecture for each sub-Use Case, in order to properly extract the components to be defined in the blueprints and descriptors. This has been shown previously and will also be extended in [15] section 4.4.5 in the low-level test cases defined for each test case.
- The updated list of components that belong to each sub-Use Case, already provided in [15] and updated in this deliverable in Section 4.4.1.
- The list of the test cases with the KPIs[1] related to each of them. They represent the services to be executed over the 5G EVE platform; but, in the end, what will be covered by the 5G EVE workflow is the network infrastructure presented previously. They are the following:

Table 19: Smart Tourism (Spain) UC2.2 - Test Case 1

Test Case 1	
Test Name:	*Effect of delay in viewport changes*

[1] Note that the Vertical KPIs, as the service provided by the Vertical is going to be deployed and executed on top of the 5G EVE architecture, are not going to be collected and measured in the 5G EVE Monitoring and KPI Framework platform, so that only the 5G related KPIs will be processed

Target KPI:	*Aggregated viewport adaptation time, TtRF, MismatchTime*
Measurement Method:	*YBVR player simulate viewport changes and compare requested and reproduced viewport timing*
Parameters:	*The video source location will be exclusively in AWS.* *The mobile network will change from 4G to 5G, for comparison.*
Validation Conditions:	*There exist specific guideline graphics. Examples:* *Viewport change speed: 50% of viewports under 200ms delay; 90% under 350ms; 99% under 500ms* *TtRF: 500ms or less during the entire playback; 200ms or less for 95% of the playback*

The list of KPIs to be covered in this test case are the following:

Table 20: Smart Tourism (Spain) UC2.2 - Test Case 1 meaningful KPIs

5G related KPIs	Is it measurable during experimentation?	Validation Condition
E2E Latency	*Yes*	*Vertical specification*
E2E Jitter	*Optional*	*Vertical specification*
Download data rate	*Optional*	*At least, consistent 50Mbps are expected*
Download peak data rate	*Optional*	*Vertical specification*
Vertical KPIs	**Is it measurable during experimentation?**	**Can it be mathematically derived from 5G related KPIs?**
Aggregated viewport adaptation time	*Yes*	*No mathematical formula known*
Aggregated time to right frame (TtRF)	*Yes*	*No mathematical formula known*
MismatchTime	*Yes*	*No mathematical formula known*

Table 21: Smart Tourism (Spain) UC2.2 - Test Case 2

Test Case 2	
Test Name:	*Effect of delay in instant camera changes*
Target KPI:	*Camera changes, TtRF, MismatchTime*
Measurement Method:	*YBVR player simulate camera changes and compare requested and reproduced viewport timing*
Parameters:	*The video source location will be exclusively in AWS.* *The mobile network will change from 4G to 5G, for comparison.*
Validation Conditions:	*5G should get at least 50% more camera changes than 4G.*

The list of KPIs to be covered in this test case are the following:

Table 22: Smart Tourism (Spain) UC2.2 - Test Case 2 meaningful KPIs

5G related KPIs	Is it measurable during experimentation?	Validation Condition
E2E Latency	*Yes*	*Vertical specification*
E2E Jitter	*Optional*	*Vertical specification*
Download data rate	*Optional*	*At least, consistent 50Mbps are expected*
Download peak data rate	*Optional*	*Vertical specification*

Vertical KPIs	Is it measurable during experimentation?	Can it be mathematically derived from 5G related KPIs?
Camera changes	*Yes*	*No mathematical formula known*
Aggregated time to right frame (TtRF)	*Yes*	*No mathematical formula known*
MismatchTime	*Yes*	*No mathematical formula known*

Table 23: Smart Tourism (Spain) UC2.2 - Test Case 3

Test Case 3	
Test Name:	*Downstream distribution*
Target KPI:	*Download bitrate*
Measurement Method:	*VoD content uses special encoding settings: High quality VR video (up to 50Mbps of bitrate); two cameras: 360 degrees and 180 degrees; single bitrate.* *YBVR player will meter regularly download bitrate*
Parameters:	*The video source location will be exclusively in AWS.* *The mobile network will change from 4G to 5G, for comparison.*
Validation Conditions:	*5G should consistently hit the top bitrate mark of 50Mbps. The same could be achieved in 4G, although some fluctuations could happen*

The list of KPIs to be covered in this test case are the following:

Table 24: Smart Tourism (Spain) UC2.2 - Test Case 3 meaningful KPIs

5G related KPIs	Is it measurable during experimentation?	Validation Condition
Download data rate	*Yes*	*At least, consistent 50Mbps are expected*
Download peak data rate	*Optional*	*Vertical specification*
E2E Latency	*Optional*	*Vertical specification*
E2E Jitter	*Optional*	*Vertical specification*
Vertical KPIs	**Is it measurable during experimentation?**	**Can it be mathematically derived from 5G related KPIs?**
Download bitrate	*Yes*	*No mathematical formula known*

Table 25: Smart Tourism (Spain) UC2.2 - Test Case 4

Test Case 4	
Test Name:	*Upstream distribution*
Target KPI:	*Upload bitrate*
Measurement Method:	*VoD content uses special encoding settings: High quality VR video (up to 50Mbps of bitrate); two cameras: 360 degrees and 180 degrees; single bitrate.* *YBVR player will meter regularly upload bitrate*
Parameters:	*The YBVR platform will be exclusively in AWS.* *The mobile network will change from 4G to 5G, for comparison.*
Validation Conditions:	*5G should consistently hit the top bitrate mark of 200Mbps. The same could not be achieved with 4G.*

The list of KPIs to be covered in this test case are the following:

Table 26: Smart Tourism (Spain) UC2.2 - Test Case 4 meaningful KPIs

5G related KPIs	Is it measurable during experimentation?	Validation Condition
Upload data rate	*Yes*	*Target would be consistent 200Mbps*
Upload peak data rate	*Optional*	*Vertical specification*
E2E Latency	*Optional*	*Vertical specification*
E2E Jitter	*Optional*	*Vertical specification*
Vertical KPIs	**Is it measurable during experimentation?**	**Can it be mathematically derived from 5G related KPIs?**
Upload bitrate	*Yes*	*No mathematical formula known*

The relationship between the sub-Use Cases and the test cases are the following:

- Immersive events: Test cases 1, 2, 3 and 4.
- Virtual Tickets: Test cases 1, 2 and 3.

The blueprints designed for each test case are the following:

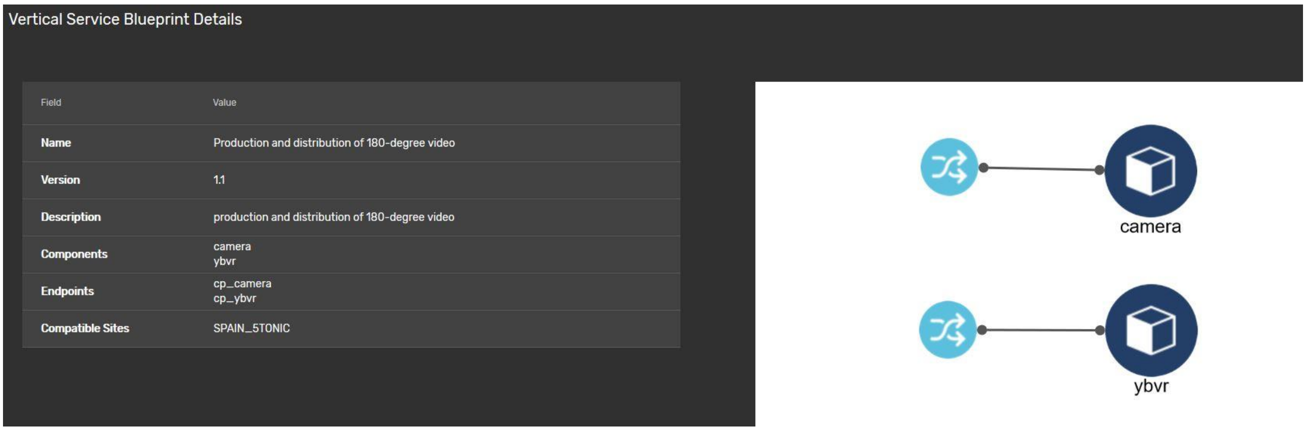
- **Test Case 1 - Effect of delay in viewport changes:**
  - The VSB [31] has to include two components: the UE system will download a video streaming, and a server in the public cloud that will provide the video streaming.
  - There is no CB in this experiment.
  - The TCB [32] in this experiment only specifies the time the experiment will be running.
  - The ExpB [33] includes the metrics and KPIs to measure latency, as well as the reference to the VSB [31] and the TCB [32].

- **Test Case 2 - Effect of delay in instant camera changes:**
  - The VSB [34] has to include two components: the UE system will download a video streaming, and a server in the public cloud that will provide the video streaming.
  - There is no CB in this experiment.
  - The TCB [35] in this experiment only specifies the time the experiment will be running.
  - The ExpB [36] includes the metrics and KPIs to measure latency, as well as the reference to the VSB [34] and the TCB [35].
- **Test Case 3 - Downstream distribution:**
  - The VSB [37] has to include two components: the UE system will download a video streaming, and a server in the public cloud that will provide the video streaming.
  - There is no CB in this experiment.
  - The TCB [38] in this experiment only specifies the time the experiment will be running.
  - The ExpB [39] includes the metrics and KPIs to measure DL data rate, as well as the reference to the VSB [37] and the TCB [38].
- **Test Case 4 - Upstream distribution:**
  - The VSB [40] has to include two components: the UE system that will upload the video and send it upstream, and the server in the public cloud that will receive the video.
  - There is no CB in this experiment.

- The TCB [41] in this experiment only specifies the time the experiment will be running.
- The ExpB [42] includes the metrics and KPIs to measure UL data rate and latency, as well as the references to the VSB [40] and the TCB [41].

The experiment ran during the first week of June showed a test of the upstream distribution of a live video, which corresponds to previously described Test Case 4.

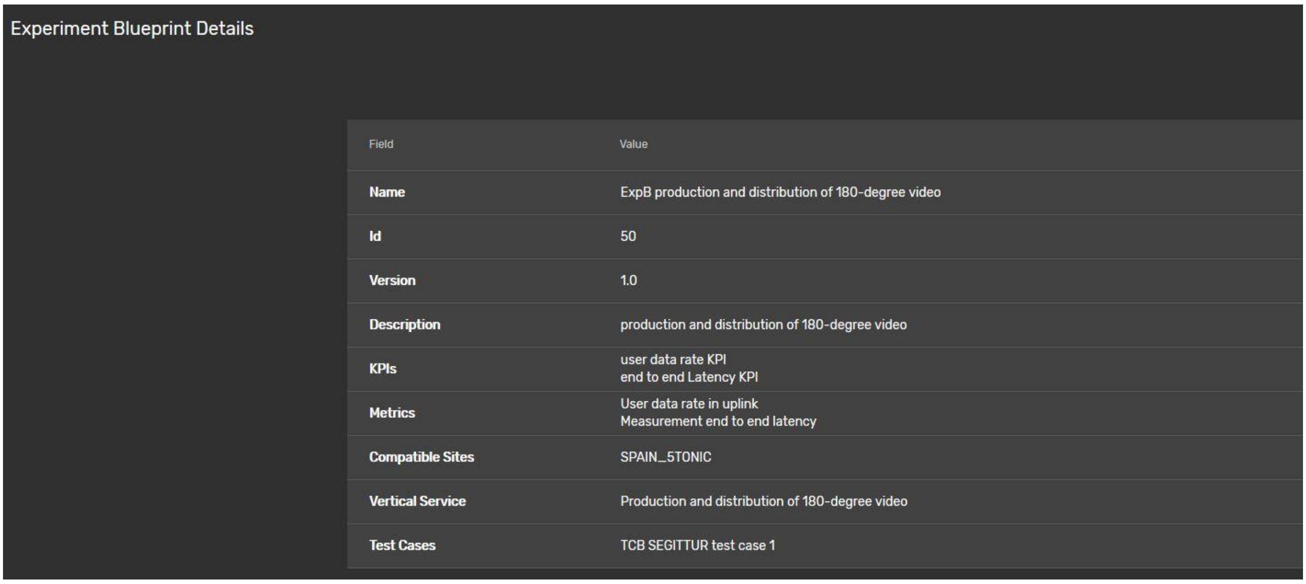
The following picture shows the vertical service diagram:


Vertical Service Blueprint Details

Field	Value
Name	Production and distribution of 180-degree video
Version	1.1
Description	production and distribution of 180-degree video
Components	camera ybvr
Endpoints	cp_camera cp_ybvr
Compatible Sites	SPAIN_5TONIC

Figure 26: Smart Tourism (Spain) UC2.2 - VSB

The details of the Experiment Blueprint are the following:


Experiment Blueprint Details

Field	Value
Name	ExpB production and distribution of 180-degree video
Id	50
Version	1.0
Description	production and distribution of 180-degree video
KPIs	user data rate KPI end to end Latency KPI
Metrics	User data rate in uplink Measurement end to end latency
Compatible Sites	SPAIN_5TONIC
Vertical Service	Production and distribution of 180-degree video
Test Cases	TCB SEGITTUR test case 1

Figure 27: Smart Tourism (Spain) UC2.2 - ExpB

4.4.3 Test Case Blueprint & Execution results

The Low Level Test Templates for this Use Case are provided, completing the Test Templates from D5.2 [15].

Table 27: Smart Tourism (Spain) UC2.2 - Low Level Test Case 1

Test Case 1	
Test Name:	Effect of network latency in viewport changes
Test Objective:	Measure how 5G latencies allow for faster viewport changes, better video quality overall, better experience.
Test Prerequisites:	-

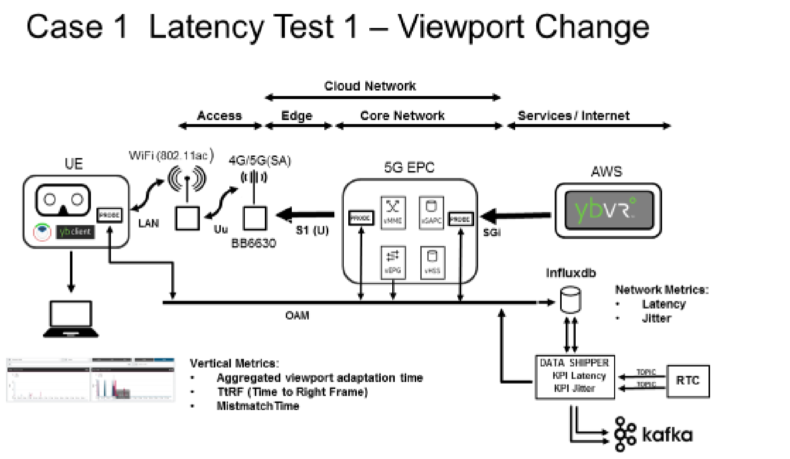
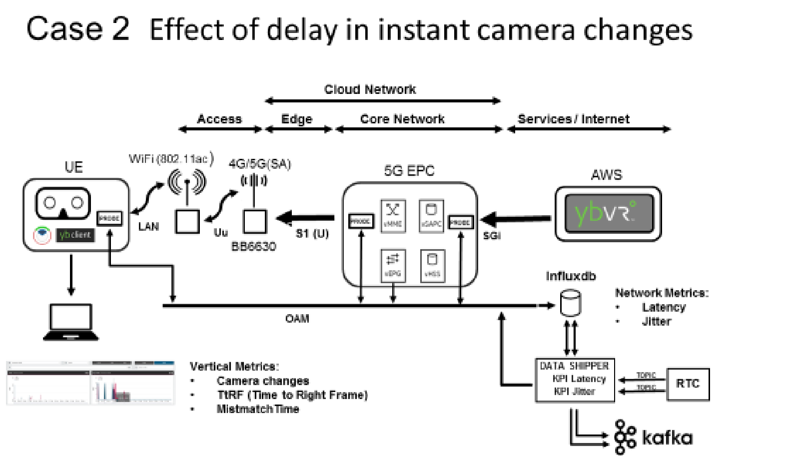
Required Capabilities:		AWS Video server, VR device, 4G and 5G network.
Sub-Case 1	**Test Topology:**	
	Test Variables:	Transport network (4G/5G), latency.
	Test Procedure:	A series of automated tests will run while the 4G network is being used. Network will change to 5G and tests will be repeated. This information will be captured by the PROBEs installed in key parts of the network and the Data Shipper will forward them to the 5G EVE platform (Kafka).
	Expected results:	The lower latency on the 5G network should allow for faster viewport changes, with less time to “adapt” to the new viewport than the 4G. This latency KPIs will be seen in 5G EVE Platform (Kafka) with the Probes installed in Ericsson network

Table 28: Smart Tourism (Spain) UC2.2 - Low Level Test Case 2

Test Case 2		
Test Name:		Effect of latency in instant camera changes
Test Objective:		Measure how 5G latencies allow for faster camera changes, better video quality overall, better experience.
Test Prerequisites:		-
Required Capabilities:		AWS Video server, VR device, 4G and 5G network.
Sub-Case 1	**Test Topology:**	

	Test Variables:	Transport network (4G/5G), latency.
	Test Procedure:	A series of automated tests will run while the 4G network is being used. Network will change to 5G and tests will be repeated. This information will be captured by the PROBEs installed in key parts of the network and the Data Shipper will forward them to the 5G EVE platform (Kafka).
	Expected results:	While on 5G, the device should be able to change cameras at least 50% more frequently than while on 4G. This latency KPIs will be seen in 5G EVE Platform (Kafka) with the Probes installed in Ericsson network.

Table 29: Smart Tourism (Spain) UC2.2 - Low Level Test Case 3

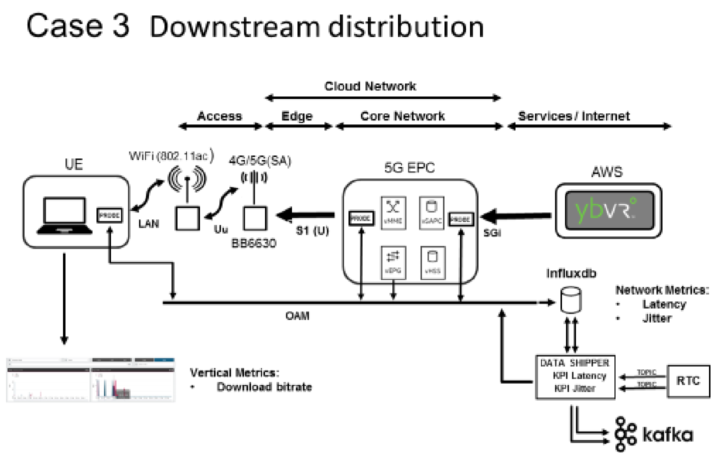
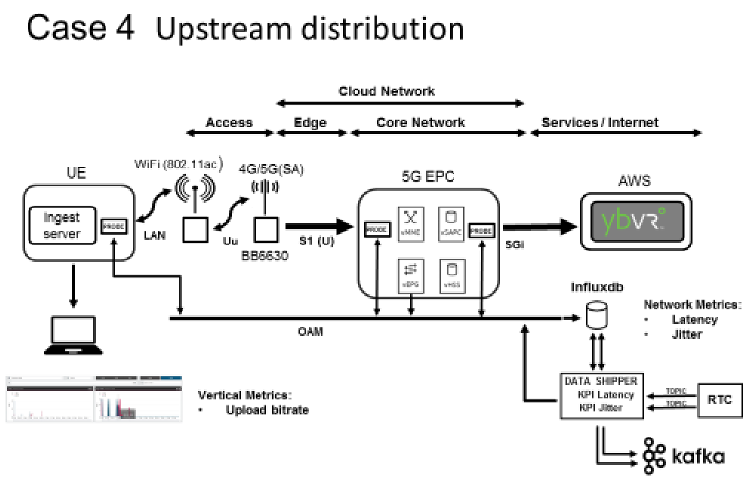
Test Case 3		
Test Name:		Downstream distribution
Test Objective:		Measure how 5G's bigger bandwidth allows for higher quality video to be streamed, which is fundamental for an immersive VR experience.
Test Prerequisites:		-
Required Capabilities:		AWS Video server, VR device, 4G and 5G network.
Sub-Case 1	**Test Topology:**	
	Test Variables:	Transport network (4G/5G), latency.
	Test Procedure:	A series of automated tests will run while the 4G network is being used. Network will change to 5G and tests will be repeated. This information will be captured by the PROBEs installed in key parts of the network and the Data Shipper will forward them to the 5G EVE platform (Kafka).
	Expected results:	The higher bandwidth of 5G should have the player constantly stream the highest bitrate available and adapt much faster on viewport changes. 4G might reach the highest bitrate some of the time but will take much longer to adapt once a viewport change occurs. The Downlink KPIs will be seen in 5G EVE Platform (Kafka) with the Probes installed in Ericsson network.

Table 30: Smart Tourism (Spain) UC2.2 - Low Level Test Case 4

Test Case 4		
Test Name:		Upstream distribution
Test Objective:		Measure how 5G upload bandwidth allows for events to be streamed in high quality without the need of fixed bandwidth.
Test Prerequisites:		-
Required Capabilities:		YBVR Ingest Server, 5G/4G uplink, YBVR AWS Server.
Sub-Case 1	**Test Topology:**	
	Test Variables:	Transport network (4G/5G)
	Test Procedure:	A high-quality video feed will be ingested locally and uploaded to a YBVR processing server hosted on AWS. The upload speed will be measure on both endpoints. The network will be switched, and the test will be repeated. This information will be captured by the PROBEs installed in key parts of the network and the Data Shipper will forward them to the 5G EVE platform (Kafka).
	Expected results:	The 4G network will not be able to cope with the video file sizes and will eventually queue so many files for upload that it will fail. On the other hand, with 5G speeds, the video will be uploaded without issues and some time to spare between uploads. The Uplink KPIs will be seen in 5G EVE Platform (Kafka) with the Probes installed in Ericsson network.

Regarding the Test Cases Blueprints related to these Test Cases, these have been already provided in Section 4.4.3, but for the sake of completeness, the links to each of them are provided below:

- TCB for Test Case 1 [32].
- TCB for Test Case 2 [35].
- TCB for Test Case 3 [38].
- TCB for Test Case 4 [41].

These TCBs are really simple, as all the logic is outside the 5G EVE project, so the TCBs only need to implement a call to a "sleep" function in order to freeze the experiment execution during the time needed to perform all the steps of the over-the-top applications.

In the Test Case Blueprints, the actions to be performed are defined. In this example, the only action to be done is to wait for a period of time for the metrics to be gathered. This is specified in the execution script, with the command “sleep $$sleeptime;”. The user parameter that will be requested to the experimenter will be “executionTime” and the variable $$sleeptime will store the time value.

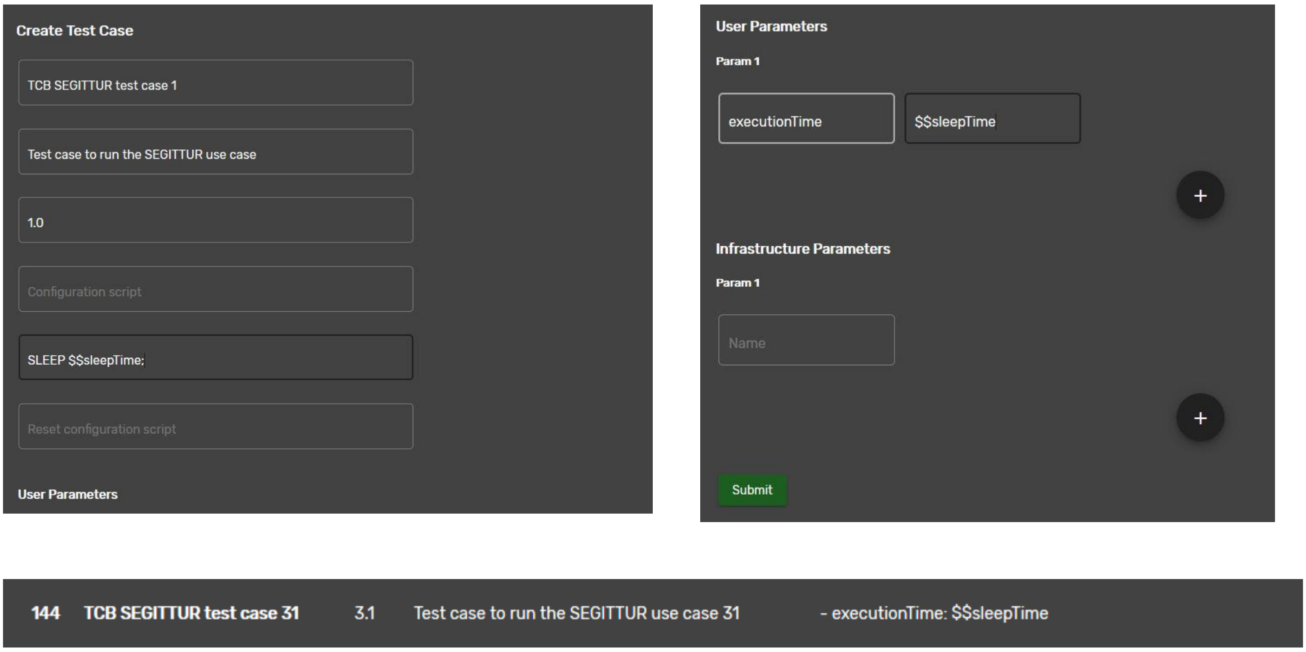


Figure 28: Smart Tourism (Spain) UC2.2 - Test Case 4 TCB

4.4.4 Pilot Initial validation status

All test cases are planned to be run on the 4G and 5G environment. Although 5G measurements are the main goal of these test cases, 4G reference could be useful to assess 5G technology quality improvement. 4G tests were run in September’19 and January’20 test sessions. The results of those tests will be presented jointly with 5G test results, after testing planned by June’20. Then, in the tests done in the first week of June, a set of descriptors were generated, related to the blueprints presented in Section 4.4.2.

The figure below shows the details of the Test Case Descriptor:

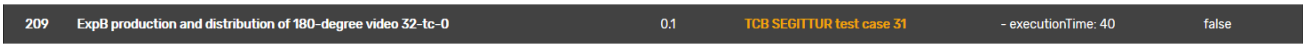


Figure 29: Smart Tourism (Spain) UC2.2 - TCD

Figure 30 shows the details of the Experiment Descriptor:

Figure 30: Smart Tourism (Spain) UC2.2 - ExpD

The metrics could be measured outside the 5G-EVE portal and results are the following:

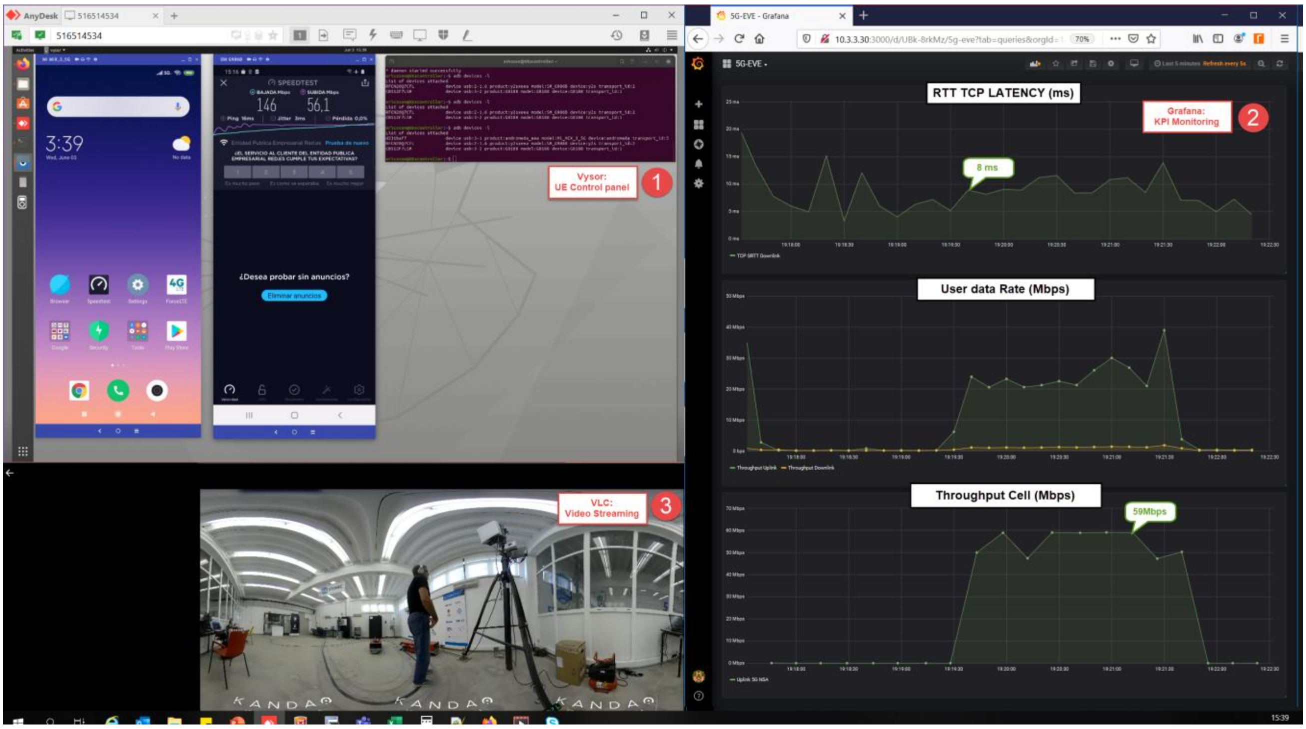


Figure 31: Smart Tourism (Spain) UC2.2 - Segittur demo results

The uplink of the 5G network reaches peaks near 60 Mbps, and it has been verified that there is a very good performance and user perception of the video when the camera is demanding a data rate of 25 Mbps.

4.4.5 Summary & next steps

It can be observed, from the information included in the last chapters, that the 5G EVE workflow has been correctly followed within the scope of this Use Case. Then, the next steps to be followed are related to the already mentioned three-phases roadmap proposed in Section 4.4.1.2, related to the Use Case integration in 5G EVE and 5TONIC. This roadmap is based on the following three main testing cycles:

- June 2020: this phase has been fulfilled by having all the resources needed to deploy an experiment ready, at least related to the fourth Test Case declared, defining its blueprints, descriptors and other required information. The complete 5G EVE workflow has been followed for that Test Case, using the current version of the components already integrated in the project. Some improvements will be introduced in the future for the final implementation of the 5G EVE platform and will be tested in the next phases.
- Between July 2020 and December 2020: after validating the execution of this first Test Case, the 5G EVE workflow will be replicated in the rest of Test Cases, using the enhanced 5G EVE tools available at that stage.
- Between January 2021 and June 2021: finally, this phase is focused on repeating the tests with the last version of the 5G EVE platform, doing a final validation of the Use Case.

The information related to some last-minute advances in the first phase and the results from the second and third phases will be described in the deliverable D2.5.

4.5 Use Case 3.1 - Industry 4.0: Autonomous vehicles in manufacturing environments (Spain)

4.5.1 Pilot execution context

The objective of this Use Case is to assess the viability of operating in factories 5G connected AGVs, with the control of the vehicle virtualized at the edge of the network i.e., moving the control of the vehicle out of the physical unit and implementing it in a computing node that meets the latency requirements for the AGV (Autonomous Guided Vehicle) operation. The AGV collects the information from its sensors and sends it to the virtual controller through a wireless connection, initially 4G as shown in Figure 32**.** This figure depicts the network functionalities that are involved in the execution of the pilot. Later, the pilot architecture is modified in order to support 5G-based wireless connectivity with the AGV as shown in Figure 33. This information from the sensors is processed in the virtual controller that generates the orders to be executed by the AGV actuators. These orders are sent again through the wireless connection to the AGV, where they lead the actions of the different actuators in the next action period.

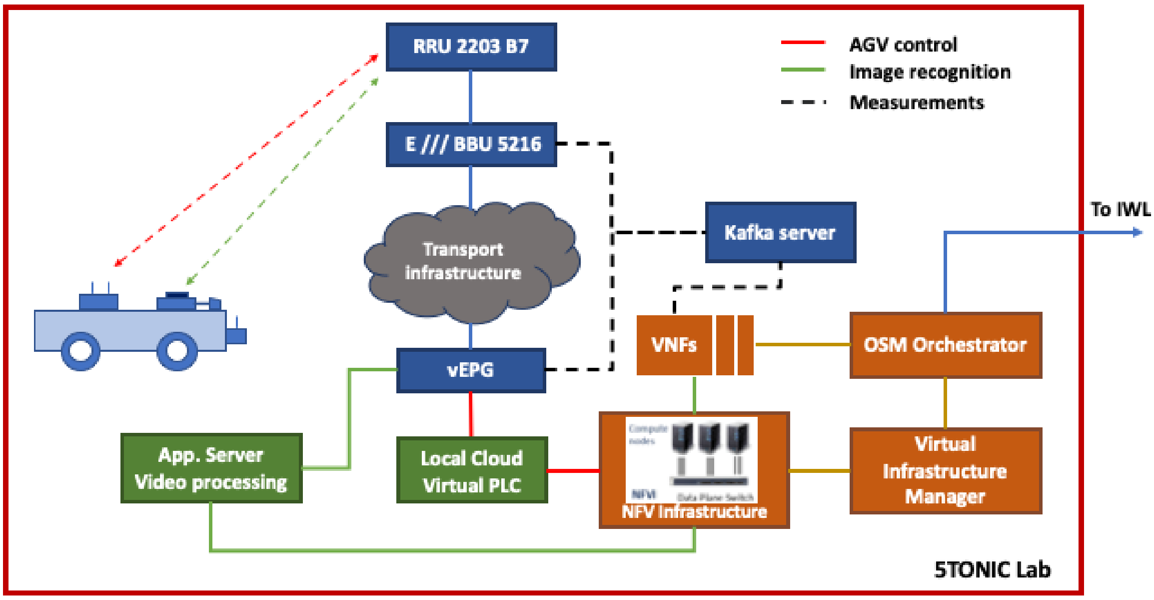


Figure 32: Industry 4.0 (Spain) UC3.1 - 4G architecture

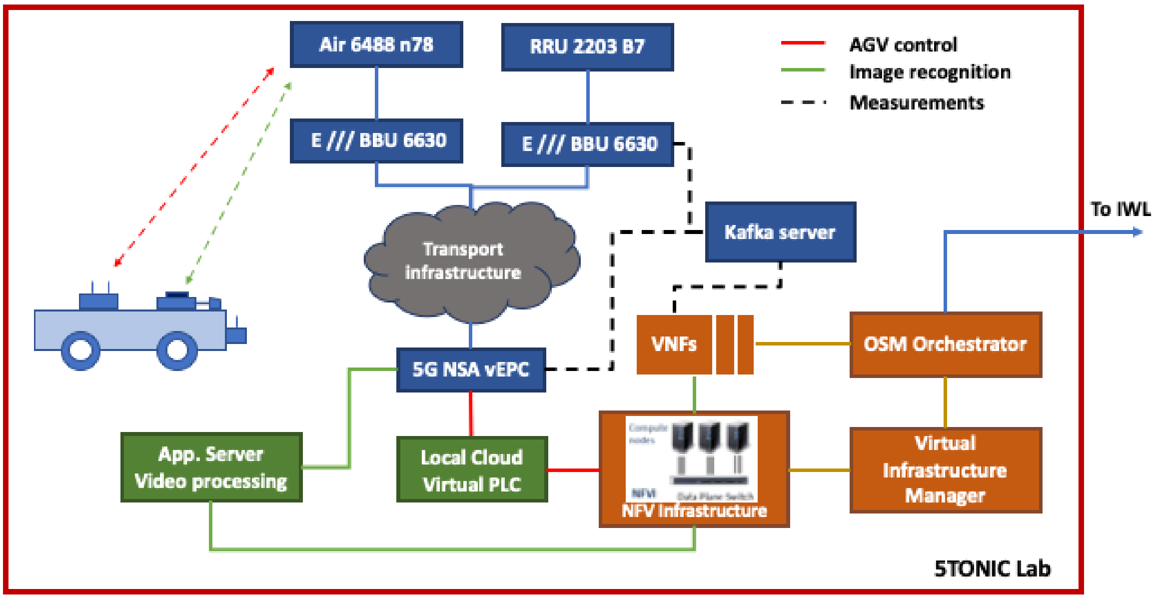


Figure 33: Industry 4.0 (Spain) UC3.1 - 5G architecture

This operational model, for being viable in a real factory, requires that the performance of the AGVs operation remains the same as if the classical, on-board control would be maintained. ASTI estimates that the following network related KPIs should be achieved:

- Latency: to ensure that the AGV works correctly in all operating conditions, the maximum delay (between the generation of the measurements by the sensors till the associated orders are received at the AGV) should not be greater than 10-15 ms.
- Reliability: 99.999% probability of correct reception of packets in both directions of the link.

Throughput and capacity are not critical parameters for this UC, although they may become in its evolution. KPIs related to mobility have not been considered for this UC as there is only one cell available, either in 4G or 5G.

In addition to these, there are other KPIs that should be taken into account, like the power consumption of the AGV that cannot be derived from measurements of the network elements but have an impact on the performance of the operational model.

Supporting this operational model has a number of potential advantages for current and future use of AGVs in factories:

- Potential coordination among AGVs, optimization of routes and rerouting in case of failure, are all facilitated implementing a centralized control of the factory's AGVs.
- Lower cost of the AGV, as it has not to incorporate the processing capabilities (which would be critical for the future, as otherwise AGVs would be required to generate maps from LIDAR measurements).
- Easier maintenance of the equipment, e.g., software upgrades have not to be carried out for each AGV.
- Higher reliability through the virtualization of the centralized processing.

In addition, the Use Case has also incorporated real-time video processing captured by a camera installed on the vehicle, which allows to recognize objects or people located in the AGV trajectory. KPIs associated with the image recognition process are also computed (processing load, latency, …).

Also, additional functionalities will be deployed using MTC capabilities, e.g., for coordinating the movement of several AGVs, which is currently based on a proprietary solution operating in unlicensed spectrum.

4.5.1.1 Actors

Vertical: ASTI Mobile Robotics.

ASTI Mobile Robotics is in charge of defining their high-level service requirements to the experiment developers.

VNF provider(s): ASTI Mobile Robotics, UC3M, Ericsson.

ASTI Mobile Robotics will provide the MasterPLC VNF.

UC3M will provide the VNFs for the context conditions (artificial delay and background traffic).

Ericsson will provide the 5G NR RAN and the 5G NSA vEPC components.

Experiment developer(s): UC3M & Ericsson

UC3M will be in charge of designing and defining all the blueprints (VSB, CBs, ExpB, TCB) related to the UC.

UC3M together with Ericsson will be responsible for defining mechanisms to collect the Application Metrics from the AGVs and KPIs.

Ericsson has installed probes to collect the infrastructure metrics related to the UC (LOST_PKT and Latency).

Experimenter(s): UC3M & ASTI Mobile Robotics

ASTI Mobile Robotics with the aid of UC3M will be in charge of preparing and scheduling their experiment.

UC3M is in charge of ensuring that the experiment is running correctly, and the defined UC Metrics & KPIs are being collected and received by the 5G EVE Data Collection, Storage and Visualization tools.

Site Manager(s): IMDEA Networks Institute, Ericsson & UC3M

IMDEA Networks Institute and Ericsson will be in charge of managing a subset of the UC experiment components (i.e., AGVs, 5G NR RAN and 5G NSA vEPC).

UC3M will be in charge of managing the virtual components of the UC that will be under the control of the 5G EVE platform (i.e., MasterPLC, delay component, traffic sink and source components).

4.5.1.2 Planning & Status

The UC has achieved significant progress that allows to support an end-to-end implementation of the UC:

- The tests can be partially launched from the 5G EVE Portal (AGVs must be manually switched on).
- Measurements to derive KPIs are delivered to the Kafka server. Ericsson has developed a software probe that collects counters from the RAN network elements.
- The virtual PLC VNF is already prepared and configured. It can be instantiated from OSM and has been configured for access through Ansible for the UC metrics collection and KPI validation.
- The context VNFs (i.e., delay and artificial background traffic) have also been already configured and await deployment.
- Other functionalities required in the testing process, like video image recognition, are being prepared to be deployed as VNFs.

Unfortunately, mainly due to COVID19 that preclude the access to the physical infrastructure supporting the UC, some milestones are being delayed:

- The connection with the Italian site in Turin is operative, but due to lack of time it could not be used for deploying the UC, working instead with a local copy of the IWL.
- The wireless connection between the AGV and the virtual PLC is still based on 4G, as we have not been able to test a 5G NR router with an Ethernet interface yet.

The UC current status and roadmap are summarized in Figure 34 below.

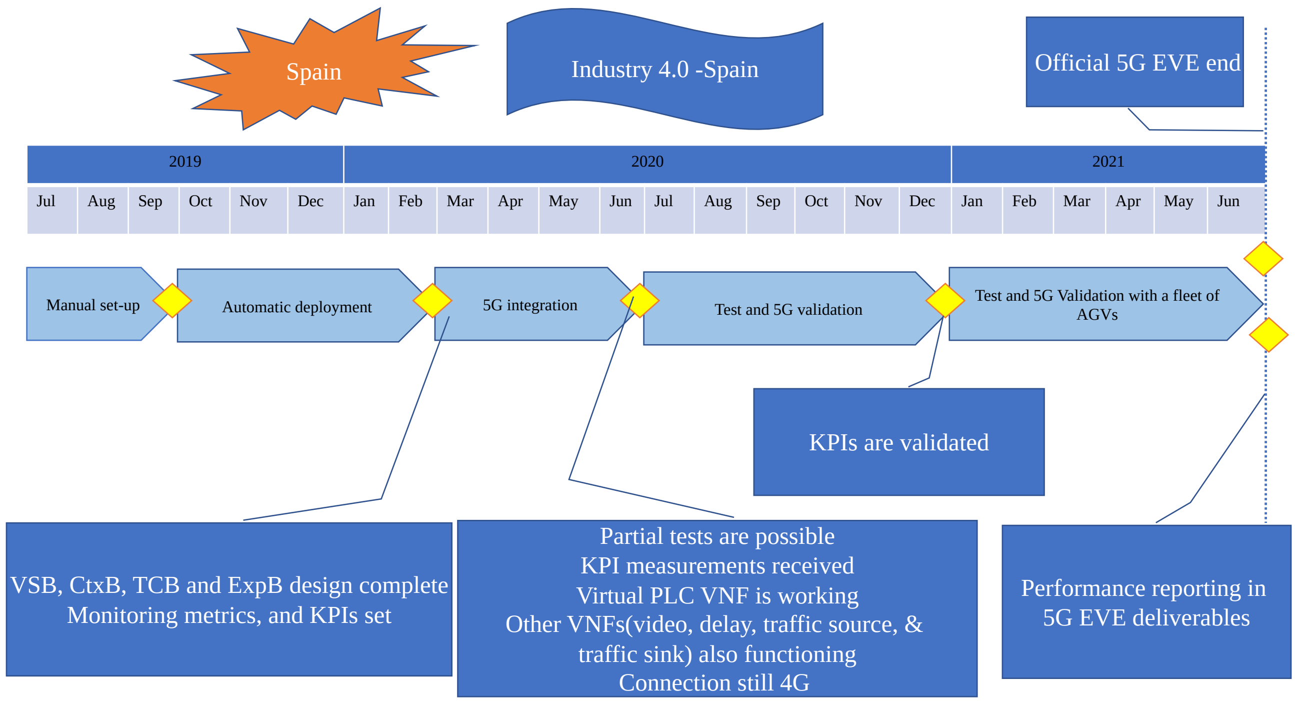


Figure 34: Industry 4.0 (Spain) UC3.1 - Roadmap

4.5.2 Pilot architecture

The experiment architecture consists of AGVs that collect information from the installed sensors and send this information to the MasterPLC through the air interface of the 5G NR RAN. From the RAN, this information will be sent to the MasterPLC, which will be located at the edge of the network. The MasterPLC VNF will also be connected to the 5G NSA vEPC on one of its network interfaces. On receiving this sensor information from the AGVs, the MasterPLC sends navigation instructions to the AGVs and these signals follow the reverse path back to the AGVs.

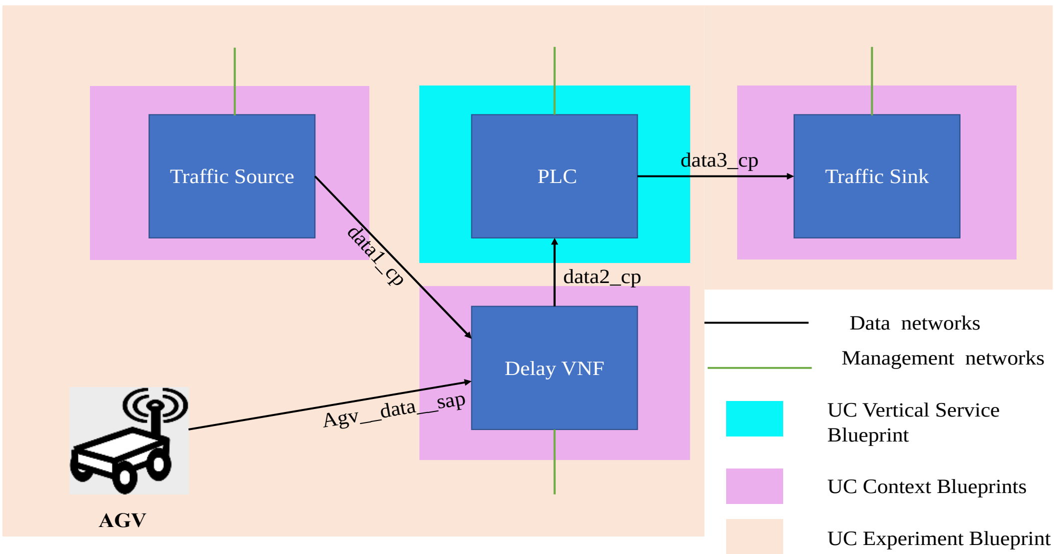


Figure 35: Industry 4.0 (Spain) UC3.1 - Use Case blueprints

This UC has been modelled using the different types of blueprints available in the 5G EVE platform i.e., Vertical Service, Context, and Experiment blueprints as indicated in Figure 35. These blueprints will be described in detail in the next subsections. To model the blueprints, we omit the Radio Access Network, MEC platform, and 5G NSA vEPC and only focus on the elements that have to be instantiated and controlled by the 5G EVE platform.

UC Vertical Service Blueprint

The UC vertical service blueprint (VSB), as indicated in Figure 36, consists of one atomic component i.e. Master PLC. This component contains three connection points i.e. data2_cp, data3_cp and mplc_mgmt for connection to the delay VNF, Traffic Sink VNF, and management network respectively.

The UC VSB captures the service parameters (in this case, the number of AGVs), atomic components (Master_PLC), connection points, virtual links, application metrics, and compatible context blueprints and sites where the UC is to be deployed, as indicated in Figure 36. A detailed VSB for this UC can be found in [22]. The associated NSD can also be found in [22].

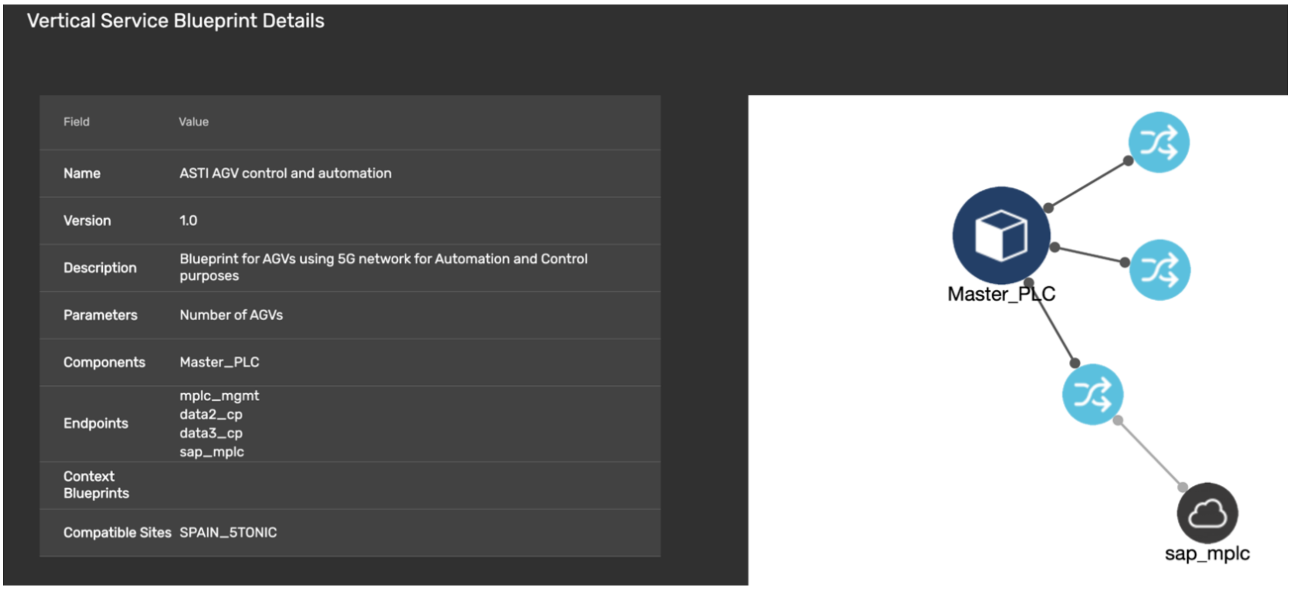


Figure 36: Industry 4.0 (Spain) UC3.1 - Use Case VSB

UC Context Blueprints

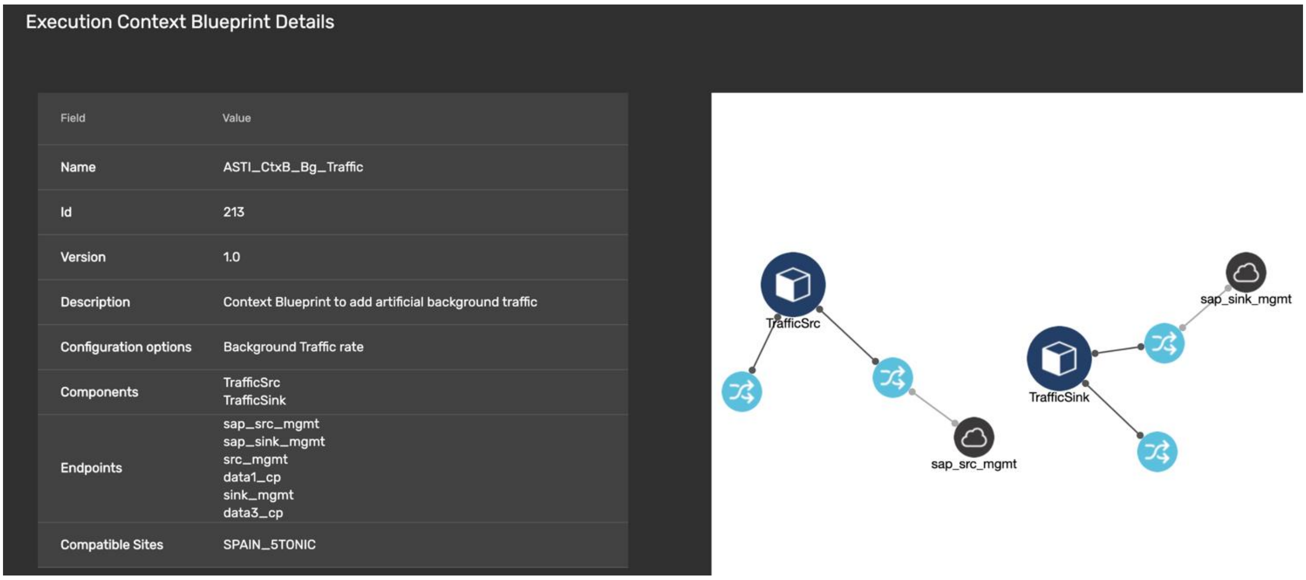
For this Use Case, we are considering two contexts i.e. delay and background traffic, as indicated in Figure 35, henceforth we have two context blueprints associated with the UC. The delay context blueprint captures the atomic component (in this case, the delay VNF), context parameters (i.e., incoming traffic load), possible configurable parameters related to the delay context, connection points, virtual links, compatible sites, and application metrics. The delay context blueprint for the UC is indicated in Figure 37. The detailed delay context blueprint for this UC can be found in [44]. The associated NSD can also be found in [44].


Execution Context Blueprint Details

Field	Value
Name	ASTI Delay Component
Id	204
Version	1.0
Description	Traffic Delay Generator Service for ASTI UseCase
Configuration options	Incoming Traffic Load
Components	delay_vnf
Endpoints	sap_agv_data sap_delay_mgmt delay_mgmt data1_cp data2_cp data3_cp agv_delay_data
Compatible Sites	SPAIN_5TONIC

Figure 37: Industry 4.0 (Spain) UC3.1 - Use Case Delay Context Blueprint

Conversely, the traffic background context blueprint consists of two atomic components (i.e., traffic source, and traffic sink VNFs), context parameters (i.e., background traffic rate), their connection points, virtual links, application metrics, and the compatible 5G EVE site, as shown in Figure 38. The detailed traffic background context blueprint for this UC can be found in [45]. The associated NSD can also be found in [45].

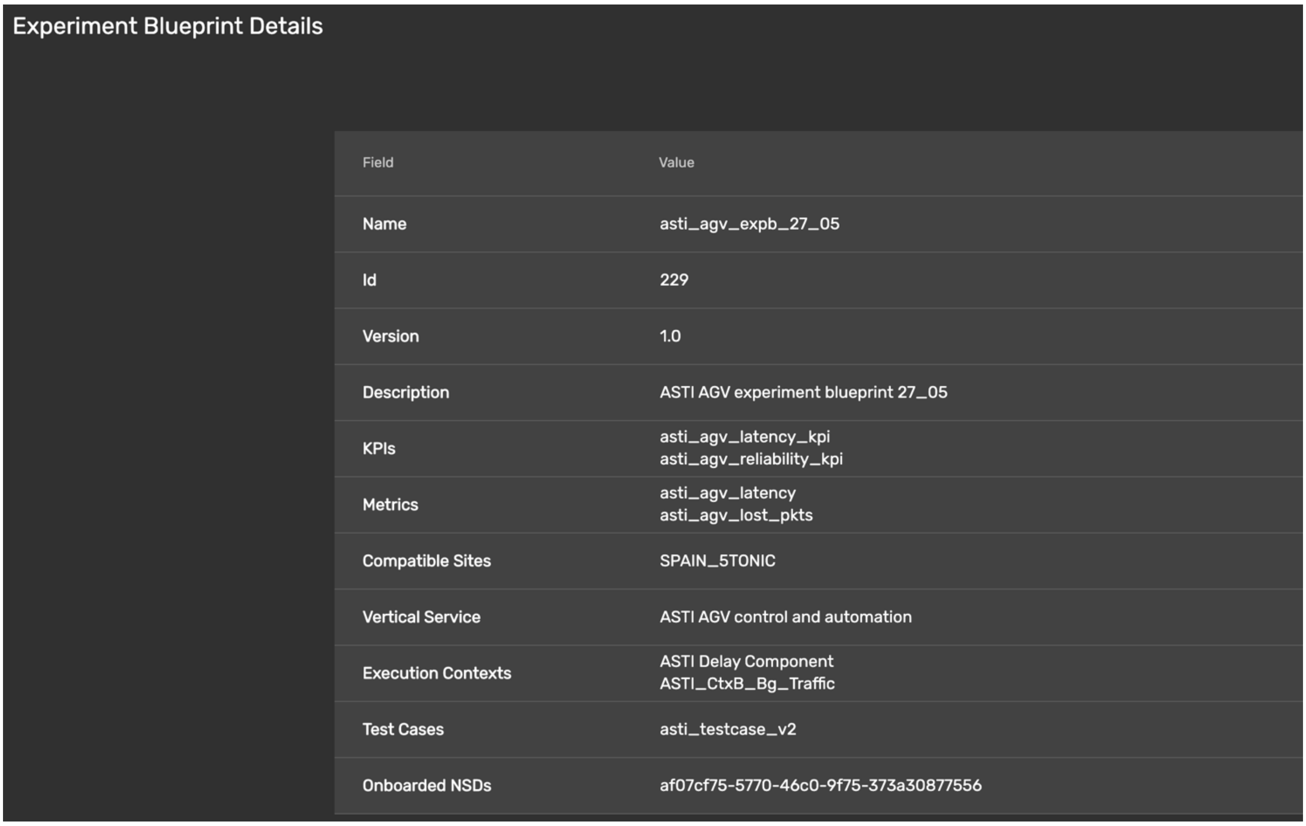

Execution Context Blueprint Details

Field	Value
Name	ASTI_CtxB_Bg_Traffic
Id	213
Version	1.0
Description	Context Blueprint to add artificial background traffic
Configuration options	Background Traffic rate
Components	TrafficSrc TrafficSink
Endpoints	sap_src_mgmt sap_sink_mgmt src_mgmt data1_cp sink_mgmt data3_cp
Compatible Sites	SPAIN_5TONIC

Figure 38: Industry 4.0 (Spain) UC3.1 - Traffic Background Context Blueprint

UC Experiment Blueprints

The UC experiment blueprint captures the vertical service blueprint associated with the experiment, the compatible context blueprints (i.e., delay, and background traffic), test cases, UC metrics (i.e., latency, and lost packets) and KPIs (i.e. latency, and reliability) and the site where the experiment is to be carried out (i.e., Spain, 5TONIC [30] laboratory). The experiment blueprint for this UC is illustrated in Figure 39 below. The associated experiment blueprint NSD is given in [46].



Experiment Blueprint Details

Field	Value
Name	asti_agv_expb_27_05
Id	229
Version	1.0
Description	ASTI AGV experiment blueprint 27_05
KPIs	asti_agv_latency_kpi asti_agv_reliability_kpi
Metrics	asti_agv_latency asti_agv_lost_pkts
Compatible Sites	SPAIN_5TONIC
Vertical Service	ASTI AGV control and automation
Execution Contexts	ASTI Delay Component ASTI_CtxB_Bg_Traffic
Test Cases	asti_testcase_v2
Onboarded NSDs	af07cf75-5770-46c0-9f75-373a30877556

Figure 39: Industry 4.0 (Spain) UC3.1 - Experiment Blueprint

Accordingly, a summary of the test cases to be executed for this UC is presented below; for each test case we specify the associated metric(s) and KPIs:

Table 31: Industry 4.0 (Spain) UC3.1 - Test Case 1

Test Case 1	
Test Name:	Measure the effect of E2E latency on Navigation Level with additional delay
Vertical KPI:	navigation level
Application metric:	navigation level
Infrastructure metric:	Latency
5G KPI	Latency
Measurement Method:	Measure the end to end latency under various delay conditions
Parameters:	Latency and navigation level
Validation Conditions:	To be specified by the Vertical

Table 32: Industry 4.0 (Spain) UC3.1 - Test Case 2

Test Case 2	
Test Name:	Measurement of maximum supported latency
Vertical KPI:	time_to_loose_guide

Application metric:	guide_lost
Infrastructure metric:	Latency
5G KPI	Latency
Measurement Method:	Measure the maximum supported latency before the "guide_lost" signal is sent from the AGV
Parameters:	Latency and guide_lost
Validation Conditions:	According to the Vertical, this latency should not go beyond 10 – 15ms (with 10ms being the most preferable value or less)

Table 33: Industry 4.0 (Spain) UC3.1 - Test Case 3

Test Case 3	
Test Name:	Measure the effect of artificial background traffic on E2E latency and Navigation Level
Vertical KPI:	navigation level
Application metric:	navigation level
Infrastructure metric:	Latency
5G KPI	Latency
Measurement Method:	Increase background traffic in incremental steps until the navigation level is severely compromised
Parameters:	Latency, and navigation level
Validation Conditions:	To be dictated by the Vertical

Table 34: Industry 4.0 (Spain) UC3.1 - Test Case 4

Test Case 4	
Test Name:	Measure the effect of packet loss on Navigation Level
Vertical KPI:	Reliability
Application metric:	Reliability
Infrastructure metric:	LOST_PKT
5G KPI	LOST_PKT
Measurement Method:	Introduce packet loss mechanisms inside the delay component and measure the round-trip packet loss percentage experienced by the AGV
Parameters:	LOST_PKT, Reliability
Validation Conditions:	Acceptable Reliability value ≥ 99.999%

4.5.3 Test Case Blueprint & Execution results

In this section, by following the UC test case templates from D5.2 [15], the low level test cases for this Use Case are provided:

Table 35: Industry 4.0 (Spain) UC3.1 - Low Level Test Case 1

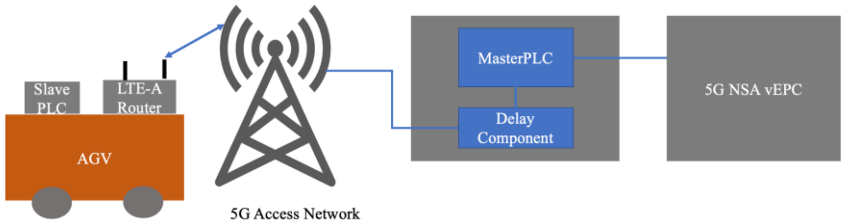
Test Case 1		
Test Name:		Measure the effect of E2E latency on Navigation Level with additional delay
Test Objective:		Infrastructure metrics: latency Application metrics: navigation level Vertical KPI: navigation level
Test Prerequisites:		The navigation level will be measured by the AGV and sent to the Master PLC, and so we need to extract the navigation level values and publish them to the IWL Kafka bus.
Required Capabilities:		5G network, MasterPLC, Delay Component
Sub-Case 1	**Test Topology:**	
	Test Variables:	Latency, Navigation level
	Test Procedure:	• Measure the E2E latency without the delay component and the navigation level • Next add the delay component and measure the E2E latency as the delay value is increased in small steps starting from zero up to a critical value beyond which the AGV navigation level is severely compromised.
	Expected results:	• The navigation level values will be compared to the specified navigation level KPI threshold, and if any of the navigation values is above the threshold, the test "FAILS" • A graph comparing both the latency and navigation level values. The critical values of the latency and delay over which the navigation level test fails will be noted.

Table 36: Industry 4.0 (Spain) UC3.1 - Low Level Test Case 2

Test Case 2	
Test Name:	Measurement of maximum supported latency
Test Objective:	Infrastructure metrics: latency Application metrics: guide_lost Vertical KPI: time_to_loose_guide

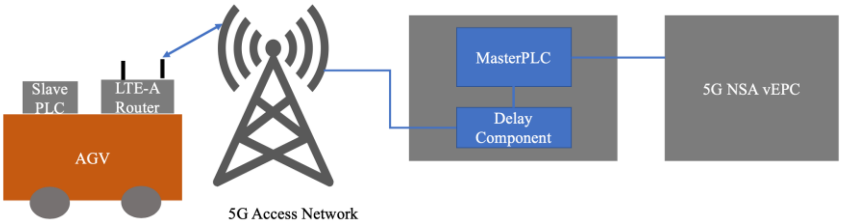
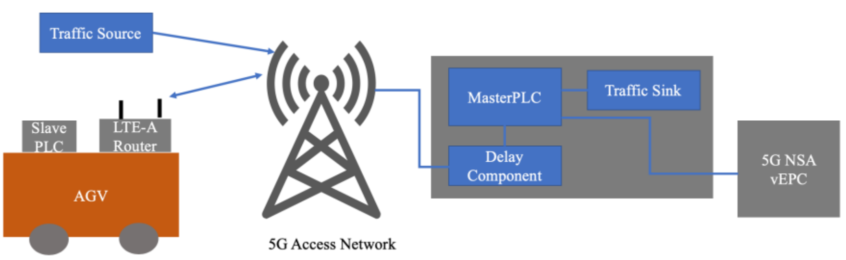
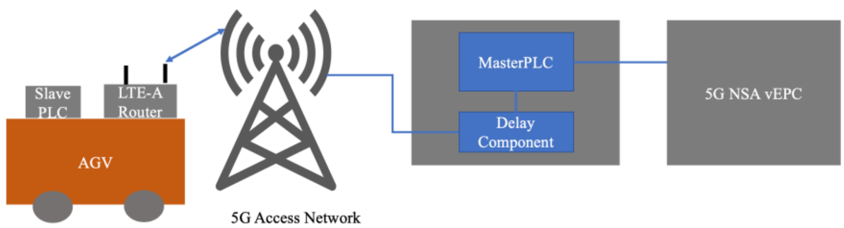
Test Prerequisites:		• The "guide_lost" message is generated by the AGV and sent to the MasterPLC where it is stored in the logs. • Need to find a way to extract this value from the MasterPLC logs and send it to the IWL Kafka bus.
Required Capabilities:		5G network, MasterPLC, Delay Component
Sub-Case 1	**Test Topology:**	
	Test Variables:	Latency, guide_lost
	Test Procedure:	The delay value is increased in small steps up to a critical value when the "signal_lost" message is sent to the MasterPLC.
	Expected results:	The exact latency value at which the "signal_lost" message was received in the MasterPLC will be noted and this will be the "time_to_loose_guide" KPI threshold value. According to the Vertical, the allowed permissible values are between 10 -15ms and values beyond 15ms are unacceptable.

Table 37: Industry 4.0 (Spain) UC3.1 - Low Level Test Case 3

Test Case 3		
Test Name:		Measure the effect of artificial background traffic on E2E latency and Navigation Level
Test Objective:		Infrastructure metrics: latency Application metrics: navigation level Vertical KPI: navigation level
Test Prerequisites:		The navigation level will be measured by the AGV and sent to the Master PLC, and so we need to extract the navigation level values and publish them to the IWL Kafka bus.
Required Capabilities:		5G network, MasterPLC, Delay component, Traffic Sink and Source components
Sub-Case 1	**Test Topology:**	
	Test Variables:	Latency, navigation level

	Test Procedure:	Measurement of the E2E latency as the background traffic is increased in small steps up to a maximum value beyond which the AGV navigation level is severely compromised.
	Expected results:	• The navigation level values will be compared to the specified navigation level KPI threshold, and if any of the navigation values is above the threshold, the test “FAILS” • A graph comparing both the latency and navigation level values. The critical values of the latency and background traffic over which the navigation level test fails will be noted.

Table 38: Industry 4.0 (Spain) UC3.1 - Low Level Test Case 4

Test Case 4		
Test Name:		Measure the effect of packet loss on Navigation Level
Test Objective:		Infrastructure metrics: LOST_PKT Application metrics: Vertical KPI: Reliability
Test Prerequisites:		• Need to measure the LOST_PKT metrics and the effects on reliability. • Reliability KPI is provided by the AGV (ratio of the time the AGV sends the sensor signal values to the MasterPLC, to the time the AGV receives a response from the MasterPLC with the instructions) • Need to extract these reliability values from the AGV and send them to the IWL Kafka bus
Required Capabilities:		5G network, MasterPLC, Delay Component
Sub-Case 1	**Test Topology:**	
	Test Variables:	LOST_PKT, Reliability
	Test Procedure:	• Introduce packet loss mechanisms inside the delay component and measure the round-trip packet loss percentage experienced by the AGV. • How to measure the packet loss on the AGVs is to be determined • Compare these packet loss values with the reliability
	Expected results:	A graph comparing both the LOST_PKT and reliability values. The critical value of the LOST_PKT percentage where the reliability is ≤ 99.999% will be noted and this will the maximum permissible LOST_PKT ratio.

4.5.4 Pilot Initial validation status

- For this UC, all the blueprints and NSDs associated to the UC have already been on boarded and validated on the portal. Currently, all the blueprints and NSDs related to this UC can be accessed and viewed from the 5G EVE portal as indicated in the above sections.
- The MasterPLC virtual network function (VNF) based on a Windows 10 image has been installed and configured for cloud access henceforth can now be instantiated from the 5G EVE portal.
- In addition, the UC context related VNFs i.e., delay, traffic source, and traffic sink VNFs have also been installed, and configured for cloud access henceforth can now be instantiated from the 5G EVE portal.
- In addition, the MasterPLC has been configured to provide the UC monitoring metrics (i.e., Latency, and Lost packets) related to the UC KPIs (i.e., Latency and reliability).

4.5.5 Summary & next steps

The results obtained indicate that:

- The use of 4G for supporting the virtual PLC is not optimal, in the sense that the latency supported is of the order of 16 ms on average (thanks to the use of uplink pre-scheduling and other optimizations of the radio interface). This latency is not low enough to guarantee an optimal performance in all operational conditions. On the other hand, the 5TONIC 5G network provides 10 ms average latency, which is the value indicated by ASTI as a target for the most challenging operational conditions (i.e., the latency should not exceed 10 ms in 99,999% of the cases when the AGV is operating at highest speed for the trajectory it is following).
- Reliability is within the expected values, although coverage and interference conditions are quite favourable in the testing area. Introducing an artificial packet error rate using a Traffic Control functionality results in a degradation of the performance in the UC.
- No results related to mobility have been produced, as the testing area is covered by a single cell and there are no handovers.

The evolution of the UC is driven from the need to support more flexible factories, as well as different operational models (e.g., AGV as a service). AGVs should be able to move around without a predefined, marked route and being able to adapt to changes in the configuration of the factories. This will be enabled by high precision LIDAR systems that may allow to create real time maps based on very precise measurements of the environment. In this context, having the possibility of centralizing the processing associated to the map generation is a very attractive proposition; otherwise, AGVs should implement processing capabilities that would result in a significant cost increase.

In the short term, there are some areas where the UC will evolve in the following months:

- Support of the 5G connectivity once devices become available and are tested, initially with the eMBB/NSA profile, evolving towards uRLLC/SA once the network has been updated.
- New AGVs, supporting odometry, will be deployed at the lab, allowing for precise location to be used for implementation of new functionalities.

4.6 Use Case 3.2 - Industry 4.0: Autonomous vehicles in manufacturing environments (Greece)

This Use Case refers to the use of autonomous vehicles for logistics and manufacturing. In the first case the vehicles are used in warehouses for shuttling freights between places. In the second case they replace also conveyors in the assembly line. The target scenarios foresee the use of a fleet of vehicles controlled remotely by applications running in a local cloud to have the possibility of introducing sophisticated control and navigation systems without affecting the vehicle. On the vehicle just low-level control, sensors data collection and connectivity are implemented.

The vehicles are connected to the remote control via LTE or 5G. The navigation of the vehicle is based on cameras and a LIght Detection And Ranging (LIDAR) system. The LIDAR is mainly used for detecting objects in front of the vehicle and for collision avoidance. Cameras are used for vision-based navigation. These control functions run remotely in the local cloud in real time.

A smart facility management system in the cloud coordinates all operations and controls the vehicles in real time.

The staff interacts with the facility management system and the vehicles using a specific App running on a tablet/smartphone.

4.6.1 Pilot execution context

Automation in manufacturing or in logistics is demonstrated by the use of wireless Mobile Cloud Robotics (MCR) application which is executed in a private 4G/5G network implemented by Ericsson and development partners.

Mobile robotics is demonstrated by the use of an Automatic Guided Vehicle (AGV) to transport goods between various stations in a process or to and from depots. Deploying AGVs can improve productivity and supports the implementation of effective lean manufacturing. As long as there are no constraints imposed in their movement capabilities caused by unexpected obstacles, AGVs/robots can carry out any sequence of events to ensure that materials arrive at the right place just in time.

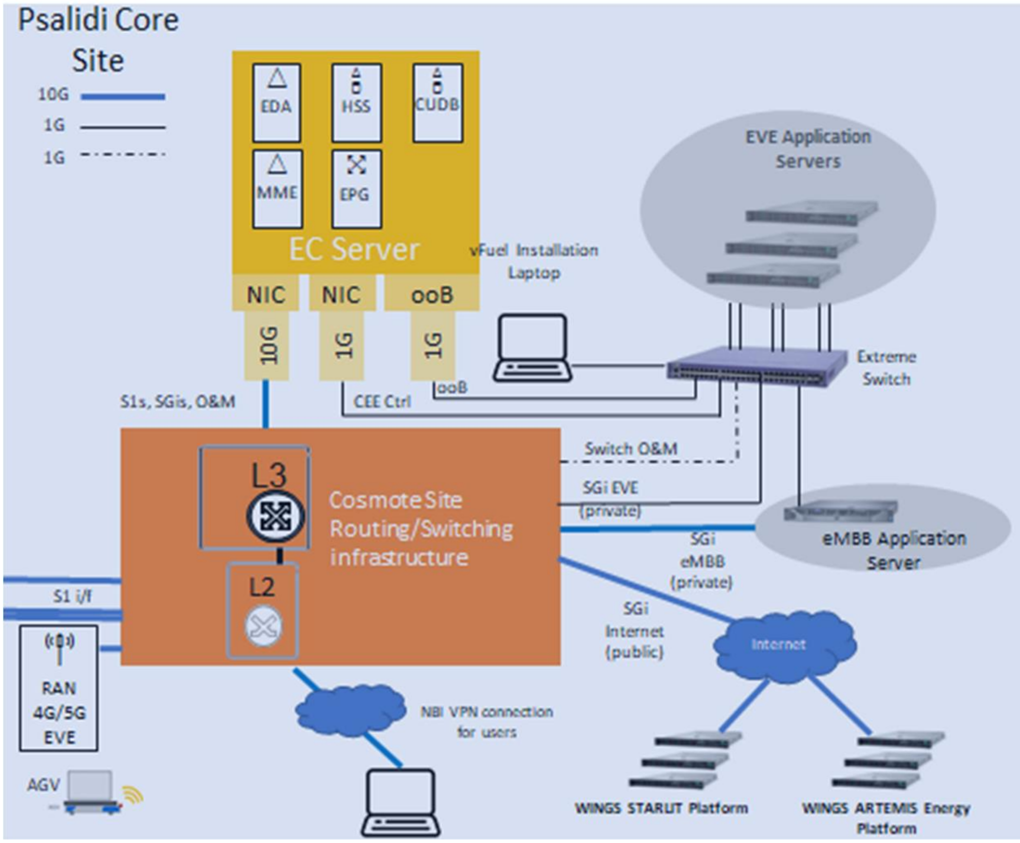


Figure 40: Industry 4.0 (Greece) UC3.2 – Psalidi facility overview

The AGV only include low level controls, sensors and actuators and having their intelligence in the cloud means that through 5G connectivity they can have access to almost unlimited computing power. The connection between AGV and the cloud is provided through the 4G/5G mobile network and it will benefit from the expected 5G extremely low latency connections. The overall mobile network architecture for the AGV is highlighted in Figure 40.

Besides the AGV Use Case, the 5G EVE platform is also used as a connectivity solution for other Use Cases with diverse network requirements. This is achieved by using a slicing mechanism to provide service isolation and Quality of Service assurance. The services will be provided in cooperation with WINGS.

Figure 41 and Figure 42 detail the implementation of the mobile and vertical services consisting of the following components:

1. Ericsson 4G/5G Access Network: Provides 4G/5G private wireless access, compatible to 3GPP R14/R15, for the AGV and WINGS smart energy and advanced city IoT Use Cases.
2. Ericsson Cloud-based EPC (vEPC Enterprise Core): Enterprise based vEPC solution designed to run on top of Ericsson Openstack IaaS i.e., Cloud Execution Environment (CEE) and use Dell PowerEdge R640 server. vEPC provides functionality for vMME (Virtual Mobility Management Entity), vPGW (Virtual Evolved Packet Gateway), vCUDB (Virtual Centralized User Database), vHSS-FE (Virtual Home Subscriber Server – Front End), v-EDA (Virtual Ericsson Dynamic Activation) and CNOM (Core Network Operation Manager).

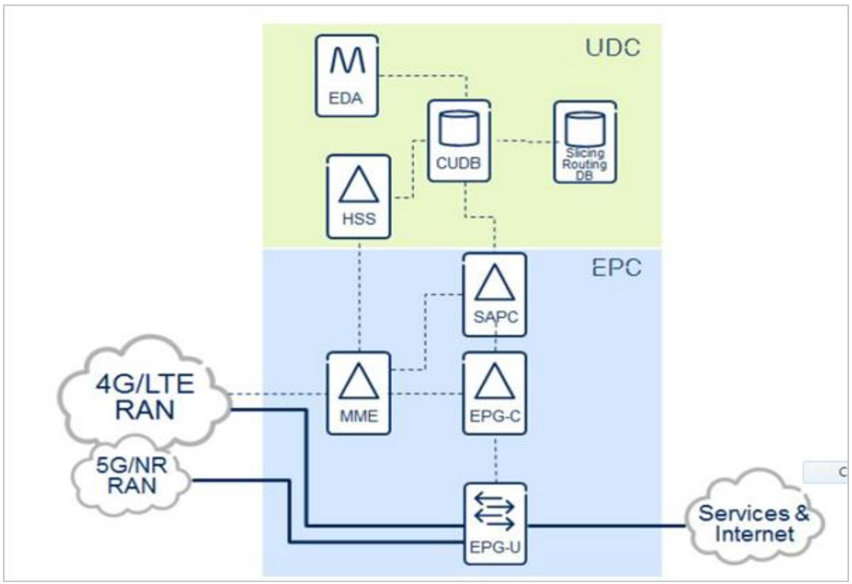


Figure 41: Industry 4.0 (Greece) UC3.2 - 5G architecture

3. eMBB Application Server: Dedicated mobile broadband application servers based on Dell Precision 3930 HW used for 4G/5G wireless throughput and e2e delay local capability testing.
4. 5G EVE application servers: Local cloud XEN servers based on Intel processor cores. The servers are interfacing the Enterprise Core (EC) through SGi interface sharing the same sub-network of SGi and are performing main control system management and the AGV system control.
5. WINGS Starlit & Artemis energy platforms: Smart energy and advanced smart city applications cloud servers.
6. Automatic Guided Vehicle (AGV- AGILE 1500): Autonomous robotic vehicle manufactured by COMAU used for the shuttling of freights between reception, storage and shipment areas in a warehouse/logistics environment. Connected via the 5G network in Non-Standalone architecture using EN-DC with LTE as anchor plane for control and signalling information. Remote motion control will rely on cloud-based server control in real time with no fixed infrastructure needed to drive the vehicle. The AGV is shown in Figure 43.

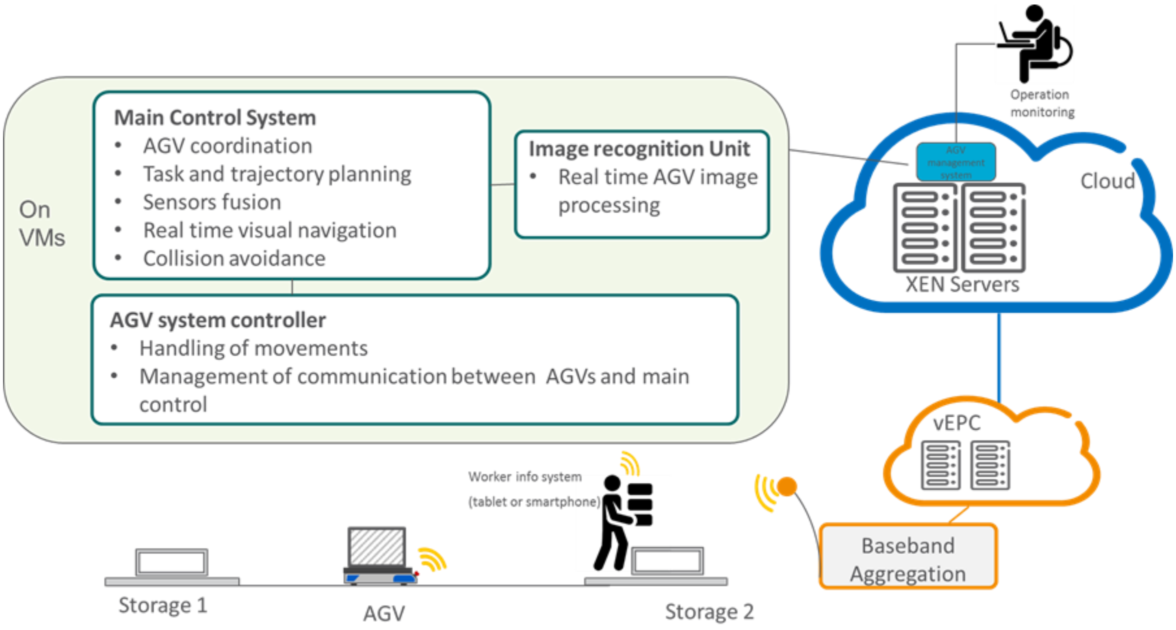


Figure 42: Industry 4.0 (Greece) UC3.2 - Vertical service architecture

Figure 43: Industry 4.0 (Greece) UC3.2 - AGV component

The Use Case refers to the shuttling of freights between places in a warehouse or a manufacturing plant using an autonomous vehicle. Missions can be launched remotely from the portal and locally by the staff. The overall high-level architecture from the portal to the control application of the vehicle in cloud is shown in Figure 44.

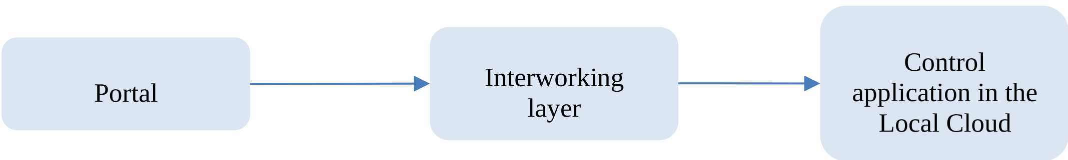


Figure 44: Industry 4.0 (Greece) UC3.2 - 5G EVE framework

The portal is used to launch and monitor the application in the local cloud using blueprints. The interworking layer interacts with both the portal and the local cloud issuing the commands described in the blueprints. The application in the local cloud manages the warehouse/manufacturing plant, launches and controls the mission of a vehicle shuttling freights, and reports the results of the operations. Missions can be started either through the portal, using the proper TCB, or locally by the workers using a dedicated App running on a tablet. Monitoring functions can also run in the local cloud to provide feedbacks on performances.

Once a new request is received by the portal or by the staff, using the tablet App, the main control system checks which vehicle can be used and determines the route it must follow to reach its destination. Then, the navigation function controls in real time the travel of the vehicle along its route. Using the cameras, the remote-control system in the local cloud localizes the vehicle in the environment. The video streams coming from the vehicle are processed to detect and recognize objects and to determine the position and orientation of the vehicle with respect to them. At each movement step, the main control system decides the next step to be executed using the motion control function also implemented in the local cloud.

In the context diagram in Figure 45 the green boxes represent the actors interacting externally with the system. For each of them the data flows exchanged with the system are shown. The round-bounded orange block represents the process. The elements are described in Table 39. At this level it represents the whole logistics control system.

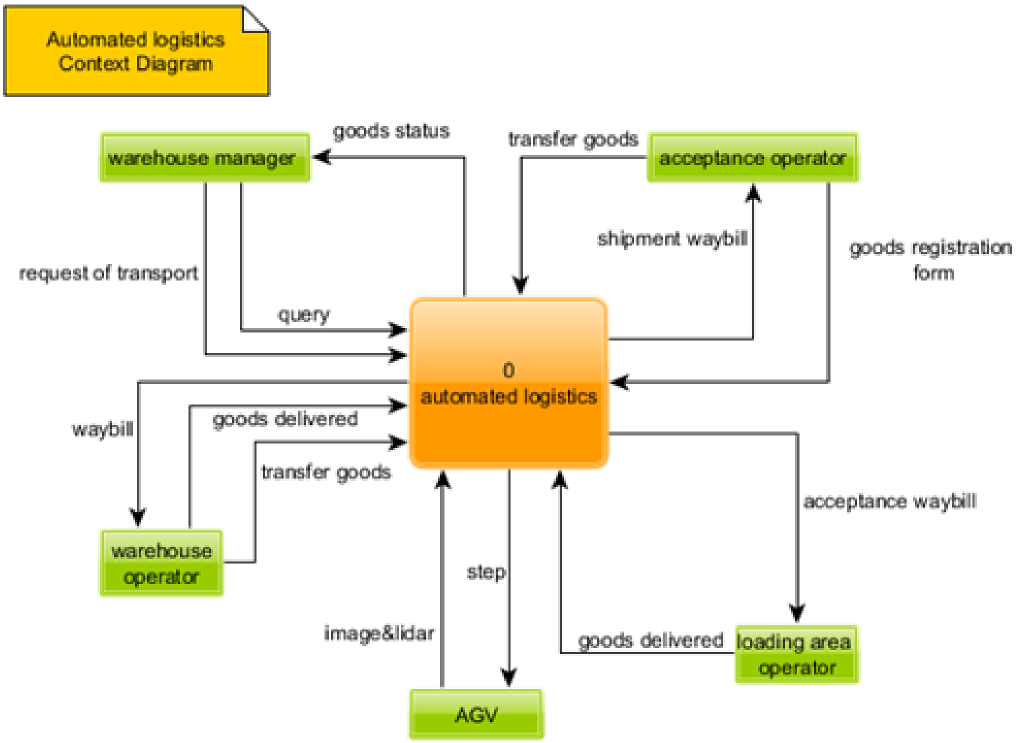


Figure 45: Industry 4.0 (Greece) UC3.2 - Context diagram of the logistics

Table 39: Industry 4.0 (Greece) UC3.2 - Context diagram elements

Graphic element	Meaning
Green box	Actor interacting with the system. It could be a machine or a human being
Orange border rounded box	Process describing the transformation of the input data flows into the output ones
Magenta bar	File or database
Arrow	Data flow describing the information exchanged between two processes

Process #0 is made of a set of interacting sub-processes as shown in Figure 46.

The process includes a file and a DB. The file "pending requests" queues the pending service requests made by the warehouse manager. The DB "AGV status" stores the information regarding each vehicle in the fleet. In the experiment a single vehicle is used. So, the DB contains a single item. However, the DB is structured to have the possibility of representing a complete fleet of vehicles.

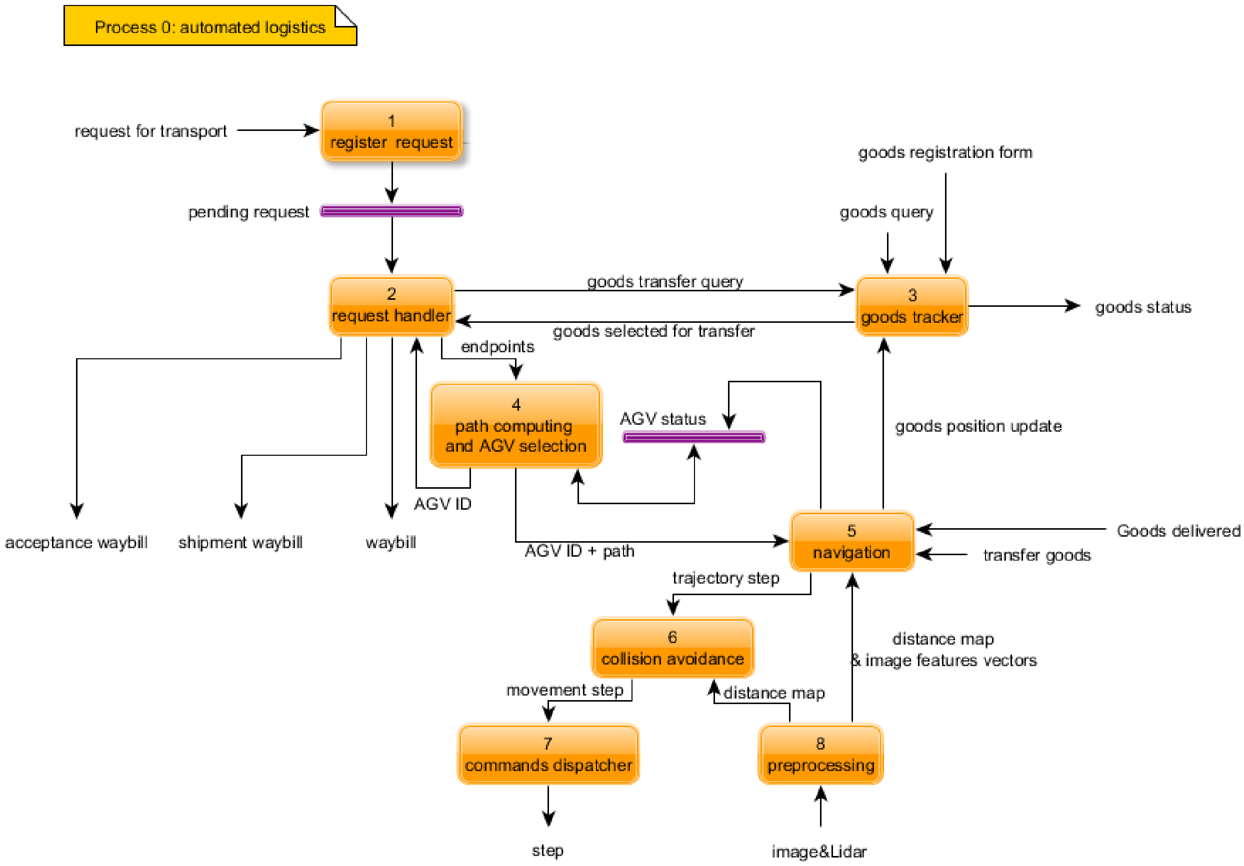


Figure 46: Industry 4.0 (Greece) UC3.2 - Process #0 automated logistics

Process #1 has the purpose to register an incoming request into the requests file.

Process #2 handles the next request to serve. It checks in the goods DB the objects to pick, determines the endpoints of the travel for the vehicle, prepares and sends the waybill to the involved parties to inform them about the transfer.

Process #3 manages the goods DB.

Process #4 computes the possible routes for the available vehicles knowing the endpoints and selects the vehicle that must run the shortest route.

Process #5 controls the navigation of the vehicle along its whole route. It uses the distance map, describing the distance from the objects in the field of view of the vehicle and the feature vectors determined, analysing the images coming from the on board cameras to define the next movement step required to follow the predefined trajectory.

Process #6 adjusts the movement step provided by the navigation system to avoid obstacles in front of the vehicle. It makes use of the distance map reporting the distance from each object in the field of view of the vehicle.

Process #7 interfaces the vehicle sending motion commands.

Process #8 pre-process the LIDAR and images coming from the vehicle to extract the distance map and the features vectors describing the seen objects. This information is used by the navigation and the collision avoidance sub-systems.

The on-site high-level architecture implemented is shown in Figure 47.

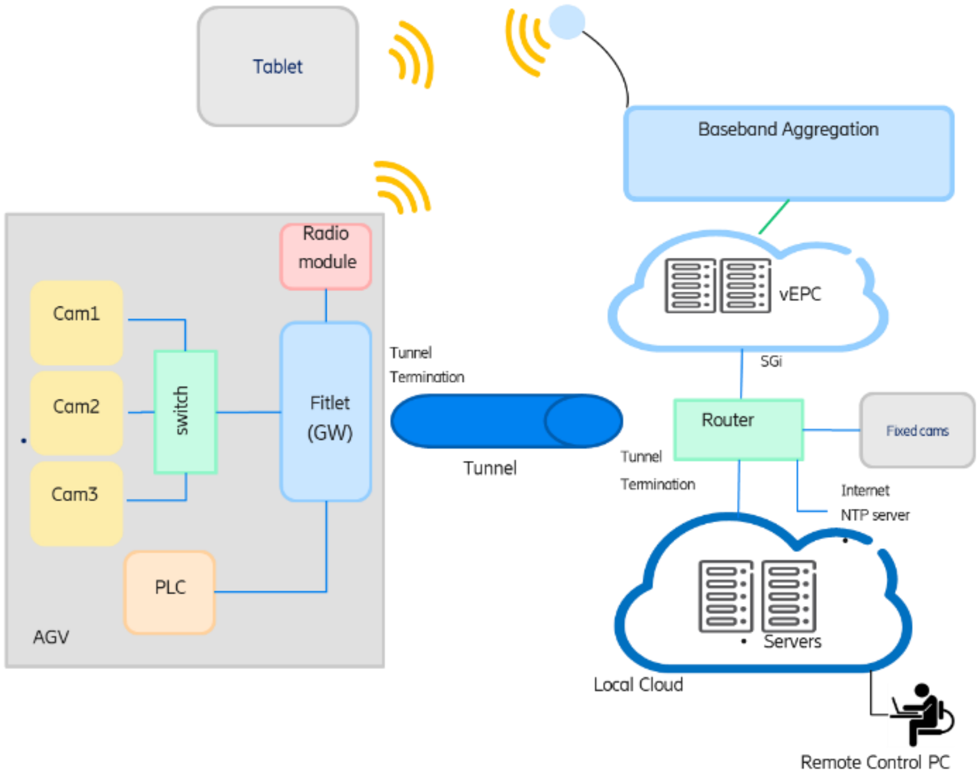


Figure 47: Industry 4.0 (Greece) UC3.2 - Local architecture on site

The functions implemented in the local cloud are shown in Figure 48.

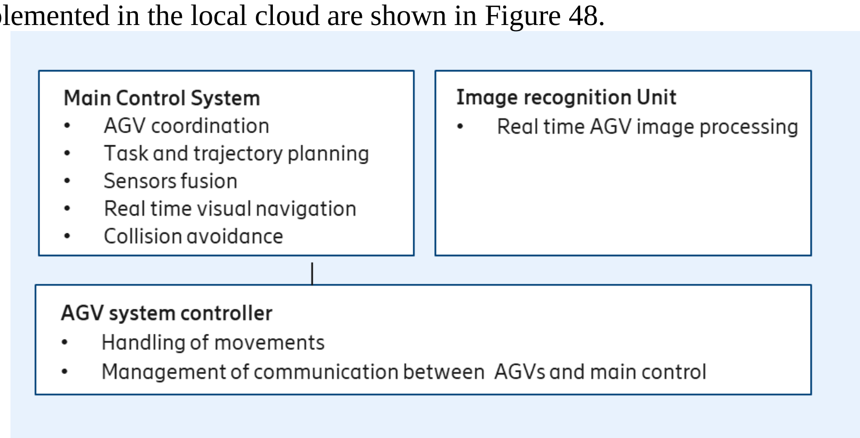


Figure 48: Industry 4.0 (Greece) UC3.2 - Functions implemented in the local cloud

They are divided among the functions managing the vehicles, the image processing unit for image recognition, and the motion controller of the vehicle.

During the execution of a test, monitoring functions can collect information regarding some KPIs (e.g. RTT - Round Trip Time) and can provide back the results.

4.6.1.1 Actors

Vertical

- WINGS: Smart city and Advanced smart city applications
- COMAU: AGV supplier

VNF provider(s)

- Ericsson S.A: Core network VNFs
- Experiment developer(s)
- Ericsson S.A: 4G/5G network, eMBB application server, AGV- control system management
- WINGS Hellas: Smart city/smart power applications
- COMAU: AGV low-level controller application

Experimenter(s)

- Ericsson S.A
- OTE/Cosmote
- WINGS Hellas

Site Manager(s)

- OTE/Cosmote

4.6.1.2 Planning & Status

The UC has achieved significant progress that allows to support an end-to-end implementation of the UC:

- Installation and integration of 5G Network Elements with respective AGV Application Server, has been completed
- Test cases of navigating autonomous vehicle for the shuttling of freights between places in a warehouse have been performed successfully, utilizing both 4G and 5G technologies.
- Connectivity solution of AGV with OSM and IWL is in progress. Plan to be completed by September 2020.
- Measured KPIs and tools for AGV have been testing and provided for the 4G Network and still to be performed for the 5G Network.
- Development and implementation of Blueprints are still ongoing.

4.6.2 Pilot architecture

For setting up a mission from the portal a specific TCB is defined. The Test Case Blueprint (TCB) contains a command to launch a python script located on a VM on the application server in the local cloud in Athens. The TCB does not require the use of parameters for configuring the script.

The python script implements the operation of asking the main control system for the transfer of a freight from one place to another, as it can be done also manually using the App provided on site for managing the whole system.

When the experiment is executed, the script in the TCB is communicated to the Inter Working Layer (IWL) that implements the command execution. The IWL is connect to the Server 1 as shown in Figure 49 in red.

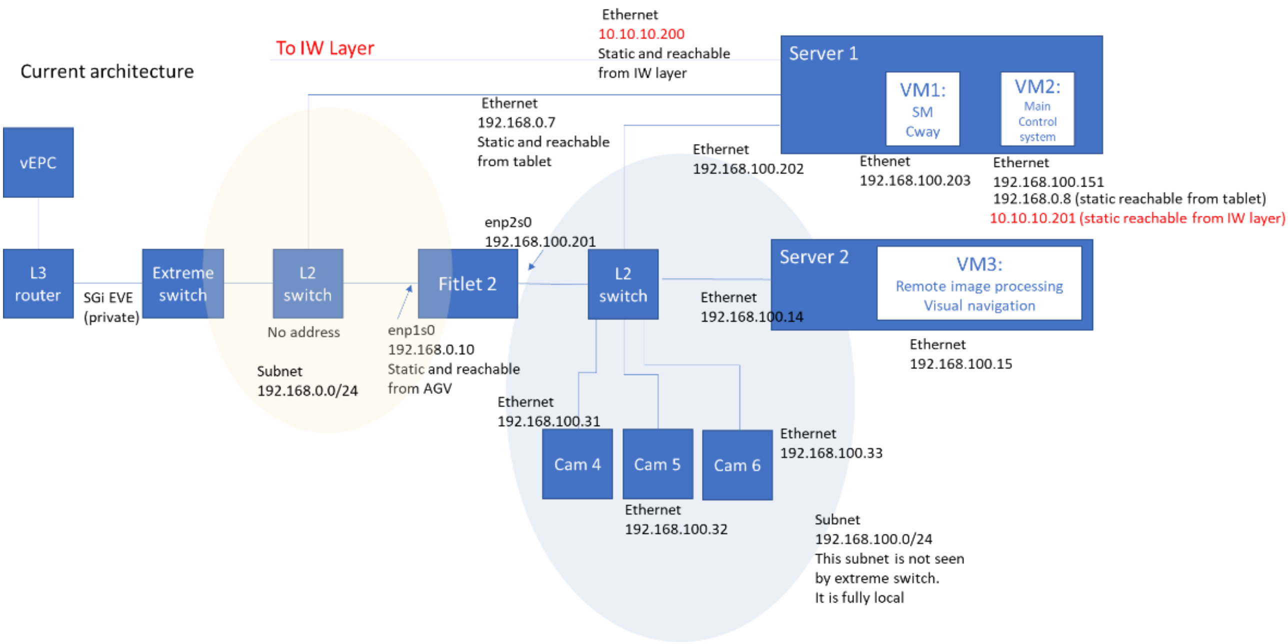


Figure 49: Industry 4.0 (Greece) UC3.2 - Local network architecture

On VM2 in server 1 an SSH server is installed. The SSH server service allows the IW layer to interconnect to the VM2 as an SSH client. The SSH connectivity is used by the IW layer to launch the python script as requested in the TcB. Then, the launched script interfaces the main control system starting the new mission. The script emulates the behavior of the tablet when asking for the transfer of a freight, first registering a freight in the relational DB used for the inventory and then it asks to move the freight from the reception to the warehouse.

4.6.3 Test Case Blueprint & Execution results

The Low Level Test Cases used to define the Test Case Blueprint are not yet available for this Use Case.

4.6.4 Pilot Initial validation status

In 5G EVE realistic AGV scenarios are studied for which the connection between AGV 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 Figure 50.

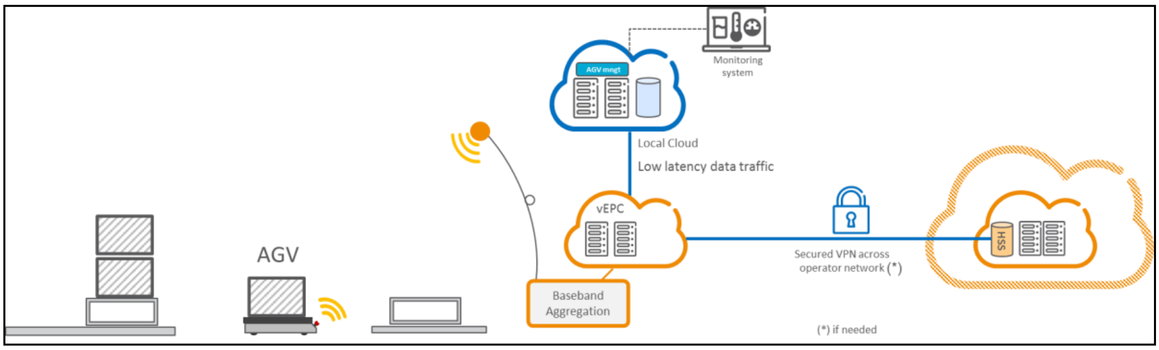


Figure 50: Industry 4.0 (Greece) UC3.2 – Overall mobile network architecture

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 the initial phase, the data traffic rate is considerably lower than system potential. 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 current phase of the project the 5G EVE platform will be tested under different values of system load (for example HD camera rates) such as to test the end-to-end performance under stress levels.

The measurement architecture is depicted in Figure 51. Measurements were made using ping packets and sniffing traffic using Wireshark.

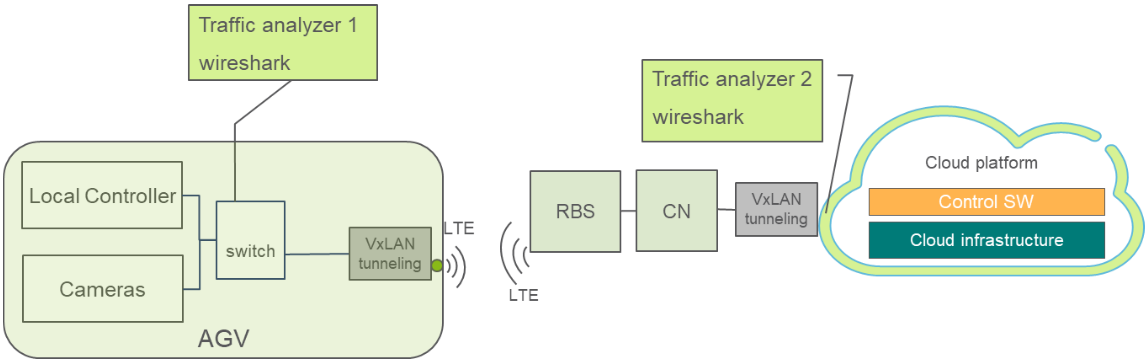


Figure 51: Industry 4.0 (Greece) UC3.2 - Measurement architecture

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 software made in python and relying on the Pandas[2] library [47]. The software has 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 52 illustrates the trace captured at the end of the VXLAN [50], including just the AGV basic control communication during a run.

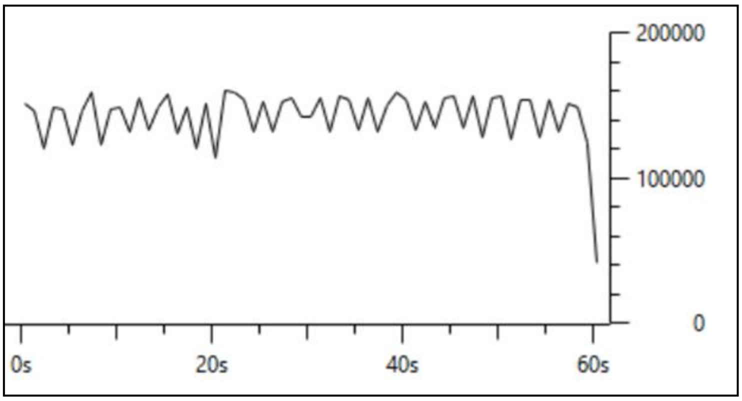


Figure 52: Industry 4.0 (Greece) UC3.2 – Bidirectional traffic flow due to the AGV control data only [bps]

[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.

The individual traffic flows from the AGV to the main control system, i.e., UL and DL from the main control system to the AGV are depicted in Figure 53.

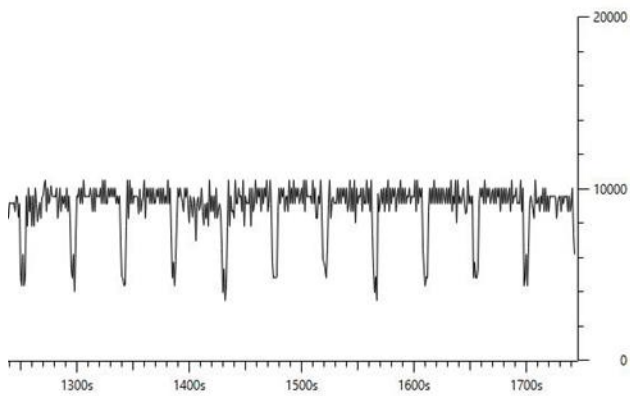
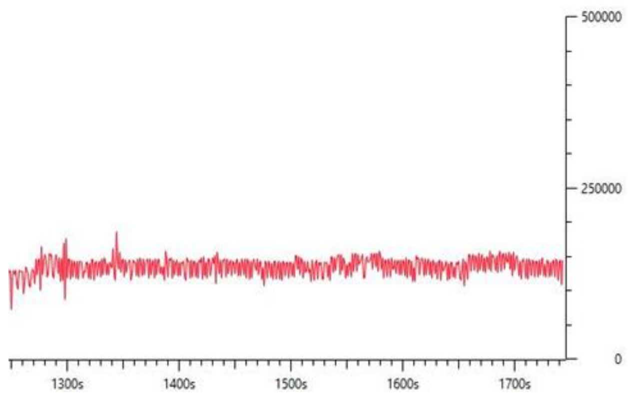
<table>
<tr>
<td>
</td>
<td>
</td>
</tr>
<tr>
<td>DL control data traffic from the main control System to AGV [bps]</td>
<td>UL Control data traffic from AGV to Main Control System [bps]</td>
</tr>
</table>

Figure 53: Industry 4.0 (Greece) UC3.2 – Individual UL/DL bidirectional traffic flow due to the AGV control data

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 Variable Bit Rate (VBR) traffic flow of 1 Mbps each. The traffic flow was almost constant all the time, similar to a Constant Bit Rate (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 54 depicts the distribution of the downlink and uplink latency respectively.

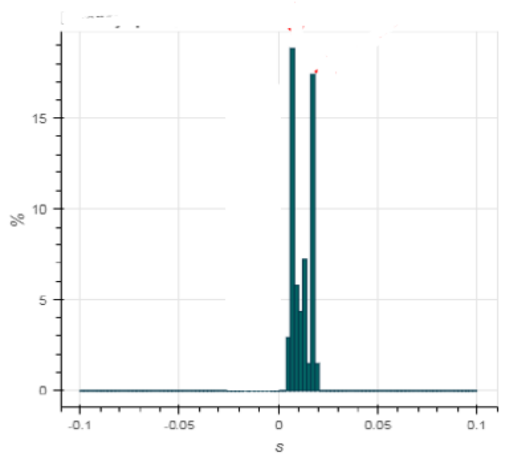
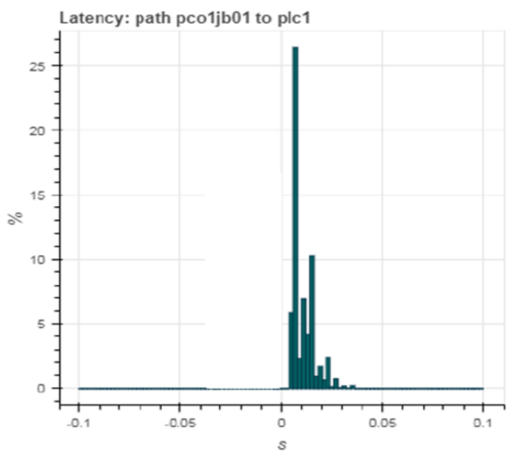
<table>
<tr>
<td>
</td>
<td>
</td>
</tr>
<tr>
<td>**Downlink latency**</td>
<td>**Uplink latency**</td>
</tr>
</table>

Figure 54: Industry 4.0 (Greece) UC3.2 – downlink and uplink latency

4.6.5 Summary & next steps

The performance values are compatible with the current performance of the AGV. During the next phase of the AGV Use Case the main tests and KPIs will be measured/validated:

- DL and UL user plane 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.

In addition, currently the following activities are planned for implementation:

- Transport network redesign achieving E2E network isolation such as to minimize exposure to existing eMBB commercial network.
- 5G network activation and AGV integration. Validation of E2E 5G network KPIs.
- Network slicing based on APN definition to support 3rd party IoT Use Case.
- Integration of ARTEMIS platform (smart energy) and (STARLIT) smart city IoT Use Cases provided by WINGS
- Monitor and process E2E KPIs for the IoT Use Cases.

4.7 Use Case 4.1 - Smart Energy: Fault management for distributed electricity generation in smart grids (France)

4.7.1 Pilot execution context

Good communication technologies are vital for fault management of distributed electricity generation in smart grids. The use of fixed networks based on optical fibers for this communication is very expensive and becomes complex to manage. The obvious solution is the use of wireless connections, but smart grid control system has special requirements on the underlying communication network in terms of latency, reliability and performance. The main requirements for this use-case are being fulfilled by existing 4G/LTE network technologies (latency). 5G NR allows new services and applications requiring lower latency, improved energy efficiency, better reliability and massive connection density.

The Use Case “Smart Energy” proposed by EDF focuses on fault management in distributed electricity generation grids:

- Due to high variability of energy generation (sun, wind…), voltage variations happen that require tight control to avoid system cascaded failures.
- Local security systems detect voltage loss and react immediately by switching off from the grid.
- Temporary and local decrease may be sustainable and they can be due to external factors (branches touching cables…). These temporary cases are not related to current energy production variations and need to be treated differently from more regional and persistent decreases due to real energy variations. In that case, we want to keep the local producer connected to avoid more serious energy losses.
- Local security systems are unable to make the difference between a normal and an abnormal case, these are known only by the regional controllers. Therefore, a tight control of security process is needed by which regional controller can supersede the local security system decision.

The proposed test environment supports real security boxes connected to real electrical but simulated network, the grid simulator. This set up enables to test the various use-cases, creating conditions where security systems need or need not be activated. To control local systems behavior, an “out-of-band” network (separate from the electric system) is used to communication instructions to local security boxes. The information is transmitted using GOOSE protocol [48], a layer 2 multicast protocol usually operating over a local Ethernet network within the substation. The layer 2 protocol is relayed over a 5G NR network.

4.7.1.1 Actors

Vertical

EDF

- Provides the smart protection system (control node).
- Provides an electric network simulator controlled by a laptop.

VNF provider(s)

NOKIA

- Provides the Openvswitch virtual switches VNFs supporting the tunnelling mechanism. Openvswitch is deployed on to-be-decided host on server side (same host as the EPC or on another host available in the same network).
- Provides the test tools for measuring the KPI.

Experiment developer(s)

EDF & NOKIA

Experimenter(s)

EDF & NOKIA

Site Manager(s)

NOKIA

4.7.1.2 Planning & Status

There are three major phases:

1- Use case integration on the lab and KPI definition and measurement.

2- Integration of the solution on EVE with ONAP [49], including monitoring.

3- Test by verticals and KPI measurement.

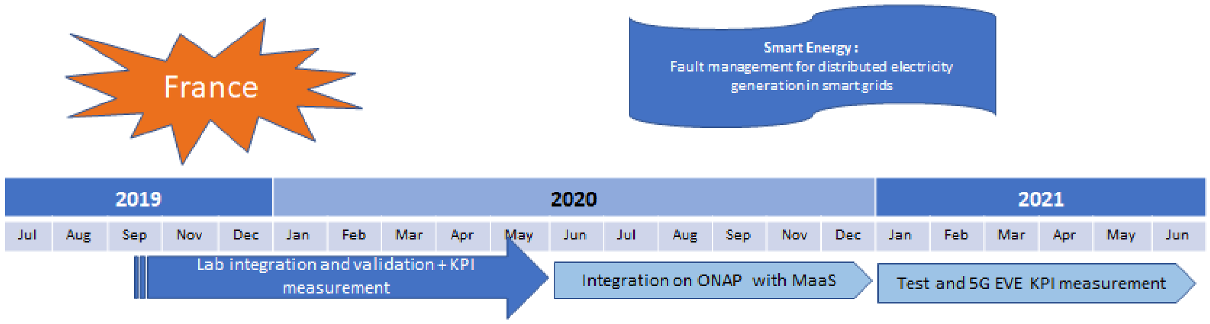


Figure 55: Smart Energy (France) UC4.1 - Roadmap

During first phase, the pilot architecture presented in the following section was tested and validated with physical network functions using hardware 7705 SAR-M routers and proprietary tunnelling protocol.

The next phase consists in virtualizing as much as possible this setup so it can be automated by the EVE platform in general and by the site orchestrator (ONAP) in particular to:

- bring up and down the network quickly in a more agile and less error-prone way,
- automate the measurements.

The final 3rd phase consists in exploitation of the platform.

4.7.2 Pilot architecture

The 2 figures below present the architecture from 2 angles. Figure 56 illustrates the Smart Grid emulator:

- all equipment is physically co-localized with the CPE
- the use-cases are controlled from a laptop
- the electric emulator generates electrical events and propagates an electrical signal (specific voltage) to a Raspberry pi
- the latter sends a GOOSE message to the network infrastructure.

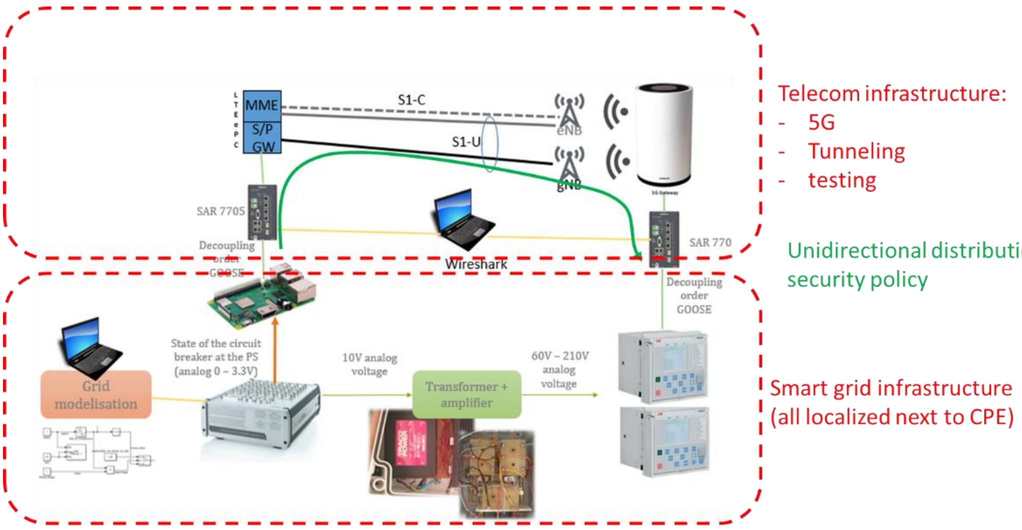


Figure 56: Smart Energy (France) UC4.1 - Smart Grid architecture (zoom on grid simulator located next to CPE)

Figure 57 depicts the network infrastructure made of 2 parts:

- The tunnelling part between two routers encapsulates in IP the GOOSE packets. An ePipe tunnelling mechanism allows to exchange GOOSE traffic between the distributed electrical devices. The ePipe tunnel encapsulates Ethernet frames generated by Raspberry pi control node according to the GOOSE protocol into IP packets and forwards them over the 5G data network. The receiving device at the end of the tunnel decapsulates the packets to obtain the initial Ethernet frames and forwards them to their destination.
- The cellular system distributes wirelessly the packets. The communication between tunnel end points is provided by an end-to-end 5G solution including a 4G/5G capable CPE with Ethernet port, a 4G/5G RAN on NSA mode and an EPC.

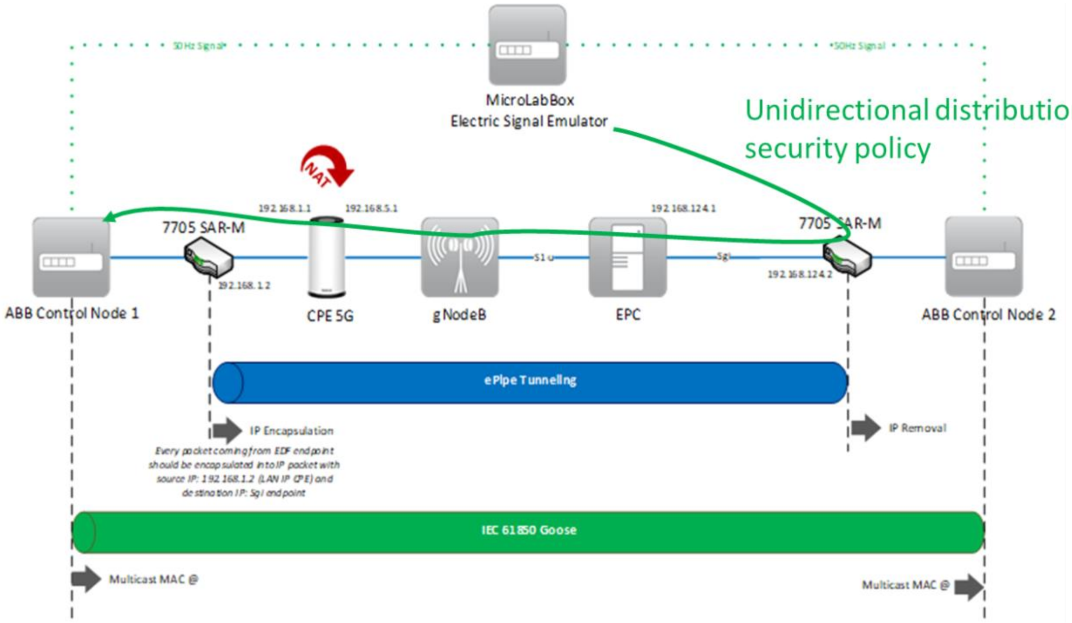


Figure 57: Smart Energy (France) UC4.1 - Smart Grid architecture (zoom on network infrastructure)

In a further step, 7705 SAR switches are virtualized as Open vSwitches instantiated automatically on demand. Open vSwitch (OVS) [51] is multilayer software-based switch providing a programmable and production quality switching platform with support for standard management interfaces (e.g. OpenFlow [53]). Openvswitch does not support the ePipe tunnelling protocol but it offers other alternatives. Two possible tunnelling protocols are being studied:

- **Virtual eXtensible Local Area Network** (VXLAN) as specified in RFC 7348 [50] is the most suitable in our case. However, Openvswitch's implementation of VXLAN does not support multicast, which can be a limitation in the case of *Goose* multicast traffic. Nevertheless, other software-based switches (e.g linux bridges) do support multicast over VXLAN. This and other alternatives are being evaluated.
- **Generic Routing Encapsulation** (GRE) [52] doesn't seem to be a suitable fit for the proposed architecture as it performs layer 3 encapsulation, but it might be tested to assess its capabilities in the given context.

Different deployment options are possible:

- At the server side (close to the EPC), the switch can be deployed on the same physical host as the EPC or any other collocated server.
- On the client side, one possibility is to initialize it on the CPE but this was subject to some technical critics due to possible low resources available on the CPE. A better scenario is to deploy the switch on a router on the client premises, offloading the CPE to a more powerful and easily managed processing hardware.

To measure end-to-end network indicators, two probes are installed in each end-point on the ePipe tunnel. The probes will measure latencies, jitter, bitrates and packet error rates.

Service KPIs are defined according to the Test Case described in Table 40.

Table 40: Smart Energy (France) UC4.1 - Test Case 1

Test Case 1	
Test Name:	**End-to-end KPIs measurement**
Target KPI:	Latency:

	• crossing time between the 2 tunnel end-points • must be below a certain threshold (~100ms) in a sustainable manner (stability) Packet Loss rate: • service reliability to avoid losing the GOOSE alarm packet
Measurement Method:	Measurements are made: • on routers by port mirroring & wireshark • on device for packet error rate Step 1: Initial system is "normal" => switch on the abnormal condition 1 (local decrease) => only the non-supervised security boxes switches off Step 2: Initial system is "normal" => switch on the abnormal condition 2 (regional decrease) => all security boxes are swiched-off During Step 2, we measure various KPIs
Parameters:	• System load: as more UEs are connected (by simulation/emulation as real UEs are limited in number), we check the impact of latencies and reliability. • Comparison between 4G and 5G: we want to test latencies with both systems, with URLLC & emBB cases
Validation Conditions:	• Latency always < 100ms • Packet Error Rate: as stable as possible (vav parameters evolution)

4.7.3 Test Case Blueprint & Execution results

The Low Level Test Cases used to define the Test Case Blueprint are not yet available for this Use Case.

4.7.4 Pilot Initial validation status

A first standalone version has been shown during 6th face to face plenary 5G EVE meeting held in Paris Saclay on December 2019 [6]. This first version has validated the end to end use case using physical equipment (L2 switches). The integration of the use case to EVE is ongoing and planned to have a first trial by 2020Q4. The blueprints (VSB, CB and ExpB) will be generated once the sofwarization of the physical switches step is completed. The results will be described in future Deliverable D2.5.

4.7.5 Summary & next steps

During past phase, we managed to integrate the security control channel using the GOOSE protocol in the 5G systems. Preliminary measurements have been accomplished as described in Section 4.7.3.

During the next phase in H2 2020, we shall integrate the test within the 5G EVE infrastructure:

- Integration with the orchestrator in the French site (ONAP). This includes:
  - automating the tunnelling part,
  - possibly virtualizing the switches.
- Test & monitoring integration, implementing the KPIs collection (MaaS):
  - automating the KPI measurements (probes deployments, log collection & processing)

During H1 2021, we shall perform test evaluation under variable system conditions (load, technology).

As defined in the Use Case Experiment Calendar, the Test Case Execution is expected by the between February 2021 and April 2021. The Test Case Blueprint & Execution results will be reported in D2.5 "Final pilot test and validation".

4.8 Use Case 4.2 - Smart Energy: Resolving Outages and Ensuring the Stability of Smart Grids by means of 5G (Greece)

4.8.1 Pilot execution context

This Use Case considers the small/medium scale experimentation of distributed electricity generation and management in smart grids. This Use Case comprises the following elements, which represent the high-level architecture of the Use Case depicted in Figure 58.

- **A network of distributed energy sources,** which can be batteries but also solar panels combined with sensors to measure the current energy level. Panels represent the prosumers.
- **A network of distributed energy consumers,** which can be actuators, like lamps, fans, heaters etc. combined with sensors to measure the energy consumption.
- **The distribution network**, connecting sources with consumers, combined with sensors measuring the energy flow (e.g. voltage, current).

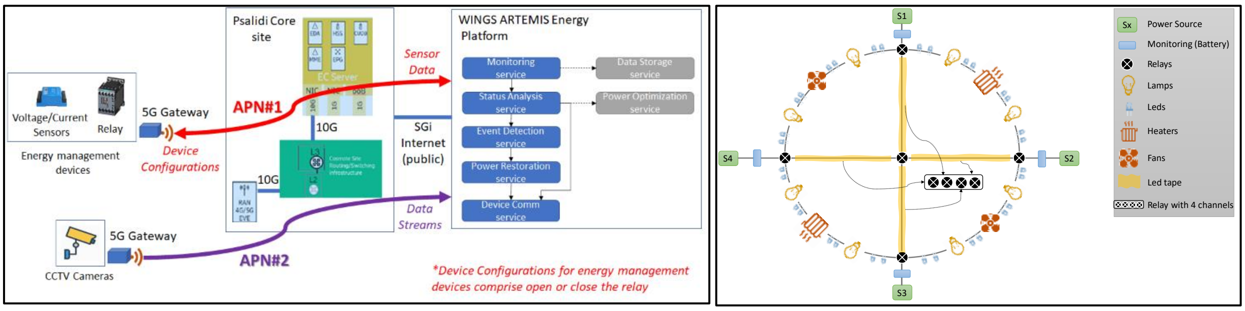


Figure 58: Smart Energy (Greece) UC4.2 - High level architecture

This Use Case comprises the following steps/phases, representing different conditions in the network.

1. At the beginning, there exists a specific configuration (NORMAL phase).
2. A fault situation occurs (ALERT/ALARM phase).
3. The topology of the grid is restructured so that power restoration can happen as fast as possible (RESTORATION phase).

The challenges that the Use Case targets to address relate to:

- Longevity of technology, deploy once and operate "forever".
- Worst case latency, thus deliver a single message within its guaranteed delivery time.
- Ongoing evolution of the power grid into a grid supporting a much more distributed generation and storage of power, being a dynamic and unpredictable environment where intermittent and variable power sources are replacing dispatchable and controllable base load generation.
- Predictive maintenance and prompt reaction.

4.8.1.1 Actors

Vertical: WINGS (Greece) provides the emulated smart grid that includes the power grid network, the power suppliers (e.g. solar panels), as well as the corresponding consumers. In addition, WINGS supports the use case with the ARTEMIS-Energy cloud platform that includes mechanisms for managing, storing and analysing data.

VNF provider(s):

1) WINGS (Greece): Node controlling VNFs,

2) Ericsson (Greece): Core network VNFs.

Experiment developer(s): WINGS (Greece) takes care of all necessary actions for the realization of the experiments.

Experimenter(s): WINGS (Greece) drives the experiment execution as well as the collection and analysis of the corresponding results.

Site Manager(s): OTE (Greece)

4.8.1.2 Planning & Status

The roadmap for the Athens Smart Energy use-case is the following:

- *2018: Analysis of requirements, development and testing in lab environment.*
- *2019 (Q1, Q2, Q3): Development and testing in lab environment.*
- *2019 (Q4): Preparations for integration at the Greek 5G EVE site.*
- *2020 (Q1): Pilot deployment - Integration and testing at the Greek 5G EVE site.*
- **2020 (Q2): Pilot deployment - First Tests and KPIs validation, First E2E integration (portal, IWL, Greek site).**
- **2020 (Q3): Tests and KPIs validation - E2E integration (portal, IWL, Greek site).**
- **2020 (Q4): Tests and KPIs validation - Exploitation of all 5G EVE framework capabilities.**
- **2021 (Q1, Q2): Final tests, complete analysis of results and delivery of outcomes.**

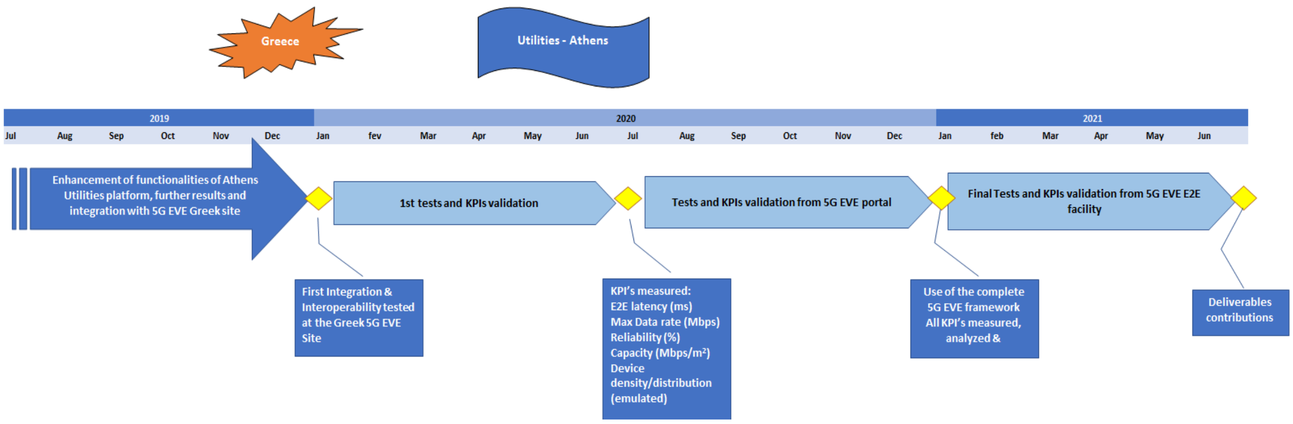


Figure 59: Smart Energy (Greece) UC4.2 - Roadmap

4.8.2 Pilot architecture

Figure 60 depicts the high-level view of the set-up of the components and equipment related to the Smart Energy 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 video over an eMBB slice. The platform monitors, analyses status, detects events, restores power and communicate actuations/actions via corresponding micro-services. The ARTEMIS Energy 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.

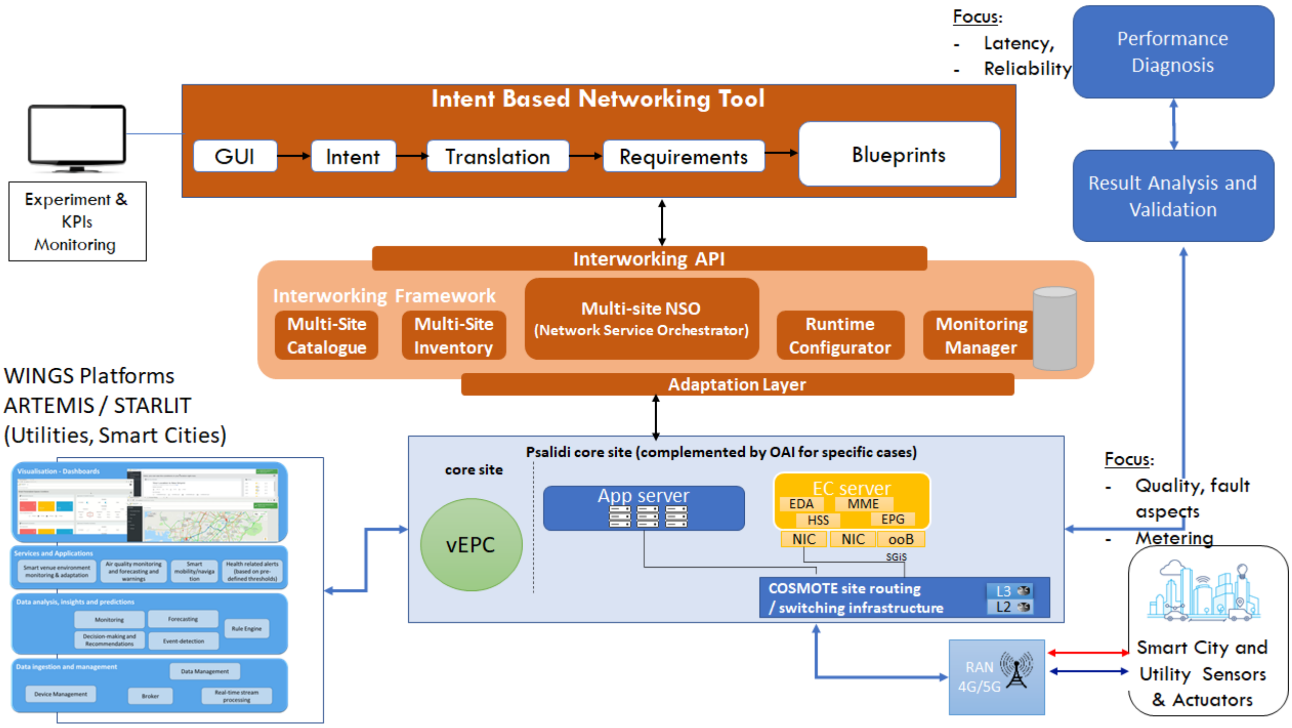


Figure 60: Smart Energy (Greece) UC4.2 - Pilot architecture

Table 41 provides the list of components been part of the Use Case.

Table 41: Smart Energy (Greece) UC 4.2 - Experiment components

Component Name	Description	Deployment requirements
Voltage/Current Sensor	Sensor measuring the values of voltage and current.	Deployed in the distributed power grid infrastructure.
CCTV Camera	Camera located in selected places of the power grid infrastructure.	Deployed in the distributed power grid infrastructure.
Relay Node	Node in the power grid infrastructure capable of relaying current to other nodes of the power grid infrastructure.	Deployed in the distributed power grid infrastructure.
5G Gateway	Node close to the sensors/cameras responsible to collect data from the sensors/cameras or send data to relay nodes. It communicates with the 5G RAN (acting as 5G terminal).	Deployed close to sensors, relay nodes and cameras to provide 5G connectivity.
ARTEMIS Energy Platform	Cloud platform in which the Utilities Services are deployed.	Deployed in a centralized server as Virtual Machine or in a distributed manner in the cloud continuum (edge/MEC, cloud).

The Table 42 provides the list of the identified Use Case KPIs.

Table 42: Smart Energy (Greece) UC4.2 - Meaningful KPIs

5G related KPIs	Comments	
RTT Latency	Target: 20 – 100 ms, especially for the downlink (configurations)	
Bandwidth	Target: 15Mbps-50Mbps, especially for the uplink	
Vertical KPIs	**Is it measureable during experimentation?**	**Can it be mathematically derived from 5G related KPIs?**
Power Restoration Time	Yes, it is measured in the 5G Gateway node. Target: 1s	End-to-end latency plus an offset time of relay node's activation
Power Restoration Decision Time	Yes, it is measured in the Power Restoration service.	No

The Test Cases that have been identified for this Use Cases are the following.

Table 43: Smart Energy (Greece) UC4.2 - Test Case 1

Test Case 1	
Test Name:	Effect of network latency in RTT Latency
Target KPI:	RTT Latency
Measurement Method:	The RTT Latency will be measured by the 5G Gateway. It is the end-to-end latency between a power failure request and the power restoration response.
Parameters:	The amount of network latency generated will be set to: 5, 10, 20, 50, 100, 200, 500 ms
Validation Conditions:	RTT Latency between < 100 ms

Table 44: Smart Energy (Greece) UC4.2 - Test Case 2

Test Case 2	
Test Name:	Effect of network latency in Bandwidth
Target KPI:	Bandwidth
Measurement Method:	The Bandwidth will be measured by the 5G Gateway. It will be measured on the egress interface for the uplink and on the ingress interface for the downlink.
Parameters:	The amount of network latency generated will be set to: 5, 10, 20, 50, 100, 200, 500 ms
Validation Conditions:	Bandwidth (both on downlink and uplink) > 15Mbps

Table 45: Smart Energy (Greece) UC4.2 - Test Case 3

Test Case 3	
Test Name:	Effect of network latency in Power Restoration Time
Target KPI:	Power Restoration Time
Measurement Method:	The Power Restoration Time will be measured by the 5G Gateway. It is the end-to-end latency plus an offset time of relay node's activation.
Parameters:	The amount of network latency generated will be set to: 5, 10, 20, 50, 100, 200, 500 ms
Validation Conditions:	Power Restoration Time < 1s

Table 46: Smart Energy (Greece) UC4.2 - Test Case 4

Test Case 4	
Test Name:	Effect of network latency in Power Restoration Decision Time
Target KPI:	Power Restoration Decision Time
Measurement Method:	The Power Restoration Decision Time will be measured by the Power Restoration service. It is the time between an arrival of a new request at the "Power Restoration Service" and the completion of this request. The time is measured as the time between the "request arrival ID" and "request completed ID" logs.
Parameters:	The amount of network latency generated will be set to: 5, 10, 20, 50, 100, 200, 500 ms
Validation Conditions:	Power Restoration Decision Time < [value under investigation]

Table 47: Smart Energy (Greece) UC4.2 - Test Case 5

Test Case 5	
Test Name:	Effect of Number of requests in RTT Latency
Target KPI:	RTT Latency
Measurement Method:	The RTT Latency will be measured by the 5G Gateway. It is the end-to-end latency between a power failure request and the power restoration response.
Parameters:	The number of requests will be set to 1, 5, 10, 20, 50, 100, 200, 500, 1000
Validation Conditions:	RTT Latency between < 100 ms

Table 48: Smart Energy (Greece) UC4.2 - Test Case 6

Test Case 6	
Test Name:	Effect of Number of requests in Bandwidth
Target KPI:	Bandwidth
Measurement Method:	The Bandwidth will be measured by the 5G Gateway. It will be measured on the egress interface for the uplink and on the ingress interface for the downlink.
Parameters:	The number of requests will be set to 1, 5, 10, 20, 50, 100, 200, 500, 1000
Validation Conditions:	Bandwidth (both on downlink and uplink) > 15Mbps

Table 49: Smart Energy (Greece) UC4.2 - Test Case 7

Test Case 7	
Test Name:	Effect of Number of requests in Power Restoration Time
Target KPI:	Power Restoration Time
Measurement Method:	The Power Restoration Time will be measured by the 5G Gateway. It is the end-to-end latency plus an offset time of relay node's activation.
Parameters:	The number of requests will be set to 1, 5, 10, 20, 50, 100, 200, 500, 1000
Validation Conditions:	Power Restoration Time < 1s

Table 50: Smart Energy (Greece) UC4.2 - Test Case 8

Test Case 8	
Test Name:	Effect of Number of requests in Power Restoration Decision Time

Target KPI:	Power Restoration Decision Time
Measurement Method:	The Power Restoration Decision Time will be measured by the Power Restoration service. It is the time between an arrival of a new request at the "Power Restoration Service" and the completion of this request. The time is measured as the time between the "request arrival ID" and "request completed ID" logs.
Parameters:	The number of requests will be set to 1, 5, 10, 20, 50, 100, 200, 500, 1000
Validation Conditions:	Power Restoration Decision Time < [value under investigation]

The service graphical view is depicted in Figure 61.

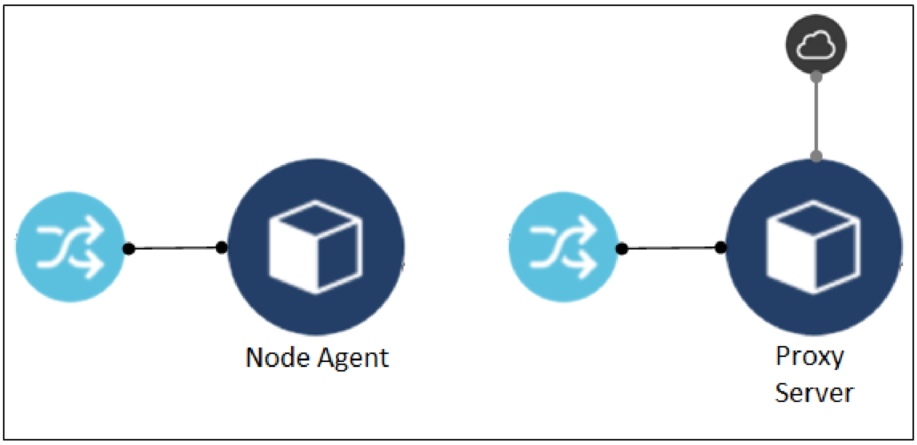


Figure 61: Smart Energy (Greece) UC4.2 – Service grapical view

4.8.3 Test Case Blueprint & Execution results

Table 51: Smart Energy (Greece) UC4.2 - Low Level Test Case 1,2,3,4

Test Cases 1,2,3,4	
TCB Name:	**Smart Energy UC Test case with artificial network impairments**
Configuration tasks	***Proxy Server VNF:*** • The Linux traffic control (tc) tool is used to inject network impairments on the proxy server in order to impact the link between the node and the Platform. Initial configuration is 0 additional injected latency. ***Node Agent VNF*:** • The node management software is started on the node
Execution Task:	The actions of the test consist of: • Triggering a power outage event • Monitoring the Restoration process • Add network latency on the interface of the proxy server and repeat the above process. This process will be repeated for various latency steps (10, 50, 100, 200, 500 ms).
User Parameters:	• username: $$user

	• password: $$password • latency: $$latency_value

Infrastructure Parameters:	• vnf.ce032cb8-51a8-486c-ae03-851f490fd923.extcp.cp_proxy_mgmt.ipaddress
	  • Management IP of proxy server used by the RC to connect to the VNF for configuring purposes
	• vnf.359c7ee7-5dfb-4509-8a56-57e72e8f5e90.extcp.cp_agent_mgmt.ipaddress
	  • Management IP of node agent used by the RC to connect to the VNF for configuring purposes

Table 52: Smart Energy (Greece) UC4.2 - Low Level Test Case 5,6,7,8

Test Cases 5,6,7,8	
TCB Name:	**Smart Energy UC Test case with artificial outage requests**

Configuration tasks	***Requests Generator VNF (CTX):***
	  • The locust tool is used to generate artificial outage requests in order to impact the link between the node and the platform's performance.
	  • Initial configuration is 0 additional requests.
	Proxy Server VNF:
	  • The proxy server is used to aggregate the requests and forward them to Platform server.
	Node Agent VNF:
	  • The node management software is started on the node using custom scripts provided inside the VNF.

Execution Task:	The actions of the test consist of:
	  • Triggering a power outage event
	  • Monitoring the Restoration process
	  • Add network latency on the interface of the proxy server and repeat the above process.
	This process will be repeated for various additional requests (10, 100, 500, 1000 requests).

User Parameters:	• username: $$user • password: $$password • requests: $$requests
Infrastructure Parameters:	• vnf.ce032cb8-51a8-486c-ae03-851f490fd923.extcp.cp_proxy_mgmt.ipaddress

	• Management IP of proxy server used by the RC to connect to the VNF for configuring purposes • vnf.359c7ee7-5dfb-4509-8a56-57e72e8f5e90.extcp.cp_agent_mgmt.ipaddress • Management IP of node agent used by the RC to connect to the VNF for configuring purposes • vnf.67f911bf-573b-410c-8ed5-c0cdc75d0ce4.extcp.cp_req_gen_mgmt.ipaddress • Management IP of the request generator used by the RC to connect to the VNF for configuring purposes

The configuration task is where the RC will connect to the VNFs to complete the initial configuration of the components.

The execution task, where the experiment starts running, is where the metrics are generated and after the termination of it, the validation of the KPIs is performed.

Both the Proxy Server VNF and the Node Agent VNF are Ubuntu machines already equipped with the necessary software to manage grid node operation and inject network impairments.

4.8.4 Pilot Initial validation status

First tests were conducted using 4G, NB-IoT, as well as other 3GPP compliant technologies (with USRPs and vEPCs). However, all test cases are planned to be executed using the 5G testbed that is deployed at the 5G EVE Greek site. RTT latency and bandwidth will be the first KPIs that will be monitored and evaluated in the operational environment. Validation process is still on going and runs in parallel with the finalization of the E2E integration activities.

4.8.5 Summary & next steps

Currently, the focus is placed on the finalization of the pilot deployment and its integration with the rest of the 5G EVE framework (portal – IWL – Greek site facility). The next step is the thorough experimentation activities and the validation of the theoretical analysis through the selected monitored KPIs.

4.9 Use Case 5.1 - Smart City: Safety and Environment – Smart Turin Wi-Fi Scanner

4.9.1 Pilot execution context

The Use Case 5.1 **Smart City: Safety and Environment – Smart Turin** aims at the identification and quantification of people in sensitive areas (e.g., for safety and security purposes, such as during large crowd gatherings) or in areas of transit (e.g., for the purpose of dimensioning transportation networks or transit/parking/sheltering infrastructure, etc.). While the detection of presence and head count is important, more valuable information would stem from the identification of flows of people. Cameras can be used for this purpose, although they require a high upfront investment, resource-consuming detection software, expensive maintenance, not to mention the privacy concerns they usually raise.

Alternative solutions exist, such as sensors that scan the Wi-Fi bands and passively capture probes transmitted by smartphones as they try to identify known nearby Wi-Fi Access Points (APs). However, these sensors have some limitations: (i) they only detect people who carry a smartphone (although it can be argued that this is now the majority of passers-by); (ii) if used in a standalone mode, they only quantify the presence of people, not the path they are following; (iii) the information they expose is non-customizable and it is largely affected by implementation nuances in Wi-Fi probe timing, hence a considerable amount of inference is required.

The Use Case of the 5G EVE project uses data collected by commercial Wi-Fi probe-detection sensors, henceforth referred to as "scanners", and infers flow densities and direction of transit of people on city streets. The scanners detect the probe-request messages sent periodically by all the active Wi-Fi interfaces and thus by the mobile devices (typically, smartphones) carried by the people moving in the area. The source MAC address of such messages (even if randomized and anonymized) allow to infer the mobility of each mobile device.

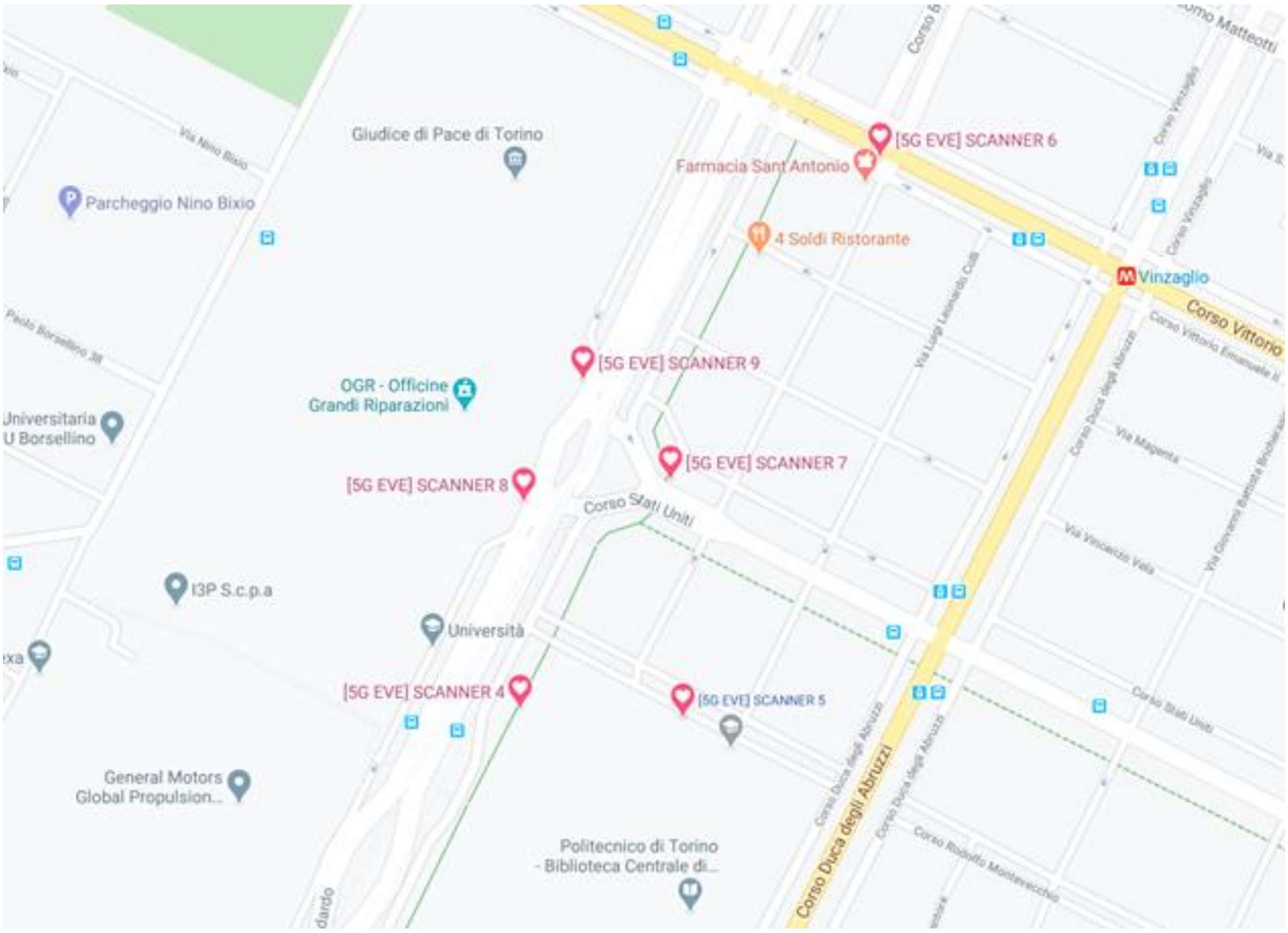


Figure 62: Smart City (Italy) UC5.1 - Coverage area map

Higher detection accuracy is achieved by increasing the density of sensors (whose coverage is limited to few tens of hundreds meters in an urban area) but it comes at the cost of increasing the computation burden, and thus a centralized solution cannot scale at all in a large urban area. Fortunately, flow densities and directions are local properties of a given area, and thus their detection can be distributed. 5G EVE platform enables the adoption of MEC, by which the computation is distributed across the mobile infrastructure, allowing to scale the approach and its accuracy.

The Use Case covers the area between Politecnico di Torino and Porta Susa Train Station. At the moment, 6 Wi-Fi scanners are active in the area, as shown in Figure 62. Notably, the area is crucial since it is one of the main transport backbones from the campus area and one of the main Torino train stations. Furthermore, during the last weeks a new COVID-19 hospital has been established in the OGR building shown in the figure, nearby three of the scanners. Thus, we expect that the Use Case will have the possibility to detect the people mobility related to COVID-19 emergency in the area. In particular, the algorithms available in the MOB NF (Mobility flow tracker, as described in Section 4.9.2) evaluate the flows of people moving on meaningful paths defined in the area based on the sequence of scanners traversed by each person.

4.9.1.1 Actors

Vertical

CNIT is the vertical, it has the purpose of testing crowd management algorithms using the 5G-EVE infrastructure.

VNF provider(s)

CNIT has provided the VNF to be on boarded with the help of NXW.

Experiment developer(s)

CNIT has developed the experiments with the goal of evaluation of the Use Case.

Experimenter(s)

CNIT is also the experimenter, processing the probe data collected through the Wi-Fi scanners to feed them to its algorithms to detect the flow of people.

Site Manager(s)

TIM is the site manager and it has collaborated with CNIT for the installation and maintenance of Wi-Fi scanners connected to the 5G architecture.

4.9.1.2 Planning & Status

In line with the roadmap presented in [6] (see Figure 63), the installation of the Wi-Fi scanners was finished by end of 2019. We have already ended the offline experiments validating the algorithm for the mobility flow tracking. The integration phase on 5G EVE platform is still ongoing and will be finished as scheduled.

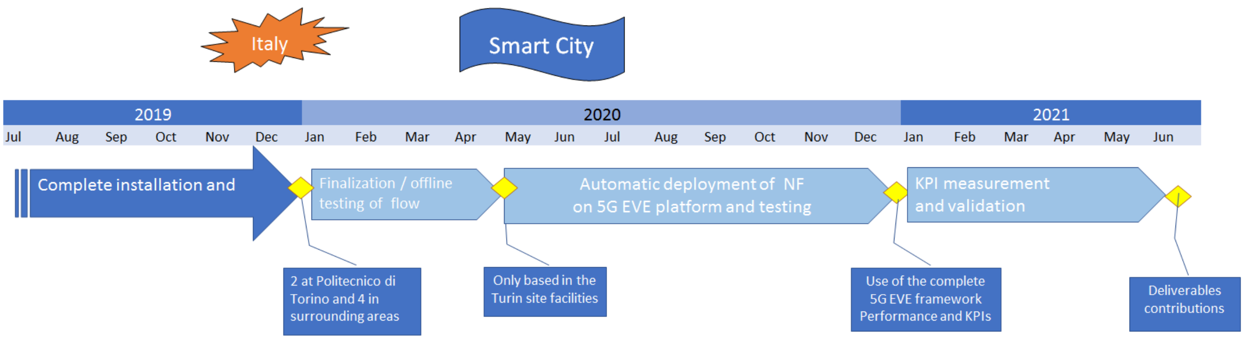


Figure 63. Smart City (Italy) UC5.1 - Roadmap

4.9.2 Pilot architecture

The adopted architecture is shown in Figure 64, where the two main components of the Use Case are the MOB and the VIS NFs running in 5G EVE edge cloud. The Wi-Fi scanners upload in real-time their data to the OneM2M platform.

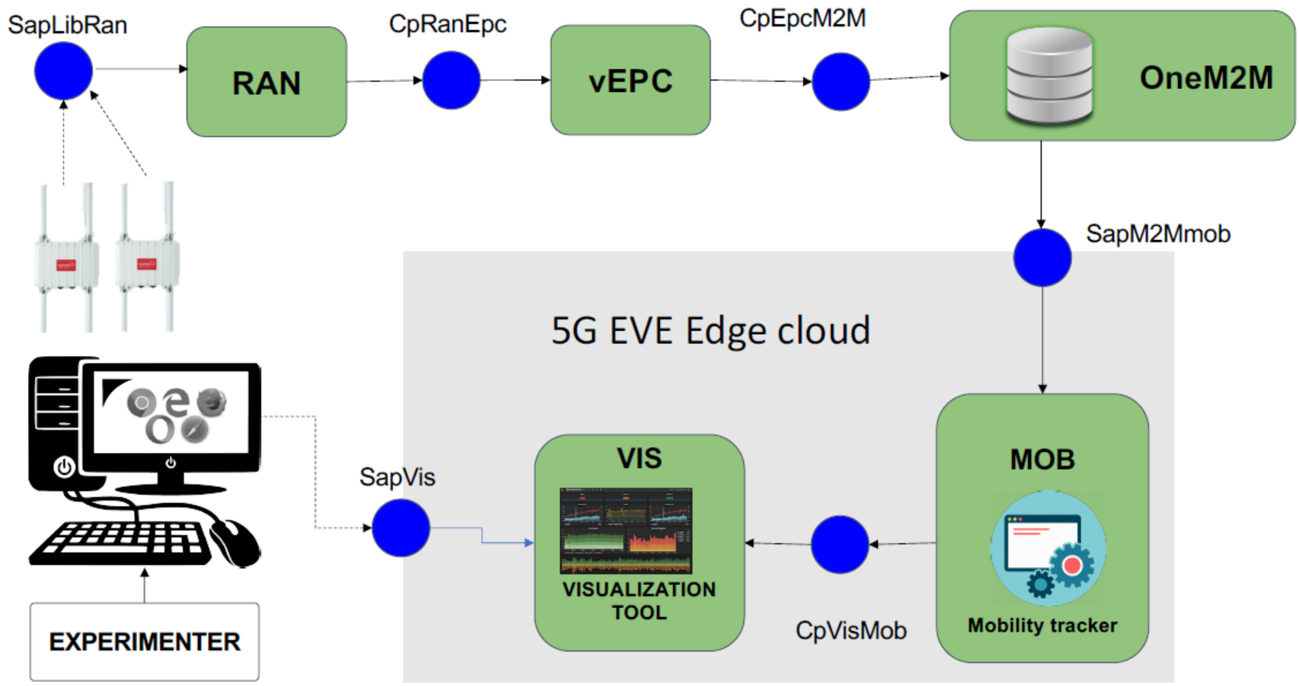


Figure 64: Smart City (Italy) UC5.1 - Pilot architecture

The MOB NF is a Mobility Flow Tracker, whose aim is to correlate the time at which each MAC address has been observed by the different scanners and to compute the corresponding path. The MOB NF interacts with the OneM2M platform and retrieves the data from the scanners in real time, adopting MQTT as publish-subscribe protocol. A more detailed explanation of the MOB NF is provided in Section 4.9.3 where we discuss how it has been validated in an off-line scenario.

Finally, the VIS NF is instead responsible to visualize the data through an interactive dashboard available to the Experimenter.

The VSB for the use-case is available and it describes in a structured format the VIS and MOB components and their interactions. More, we tested the correct on boarding of the blueprint on the 5G EVE portal where we can produce a graphic visualization, shown in Figure 65. The VSB describes only the components under the control of the 5G EVE infrastructures, indeed excluding the experimenter client and the One M2M infrastructure as shown in Figure 65. The elements in Figure 65 represent respectively atomic components (cubes in dark blue), connectivity services (circles in pale blue with arrows), end points (edges), and Service Access Points (SAP) (dark grey circles with cloud). The VIS and MOB are encoded as atomic components in the Blueprint. They communicate with each other via two connectivity services, one for data plane traffic and the other for management traffic. The latter is used by the 5G EVE infrastructure to configure the atomic components at deployment time or during their lifecycle. The MOB has access to a SAP connected to the One M2M platform, in order to receive data from sensors. The VIS component is connected to a SAP in order to provide access to the visualization dashboard.

The vertical has expressed interest in evaluating the behaviour of the service under the condition of a high rate of data records coming from sensors. Hence the Context Blueprint (CB), compatible with the VSB described above, defines a custom traffic generator capable of emulating one or more sensors sending data to the service. The goal of the experiment is mainly to put the ‘mobility_tracker’ (and eventually the ‘visualization_tool’ as well) under stress, in order to evaluate its limits and identify the correct amount of computing, network, and storage resources needed to support the expected data rate in a real world deployment.

The ExpB will include a network topology that is the result of the composition of the VSB and the CB, with the latter to be connected on the Connectivity Service placed between the ‘mobility_tracker’ and the ‘sap_tracker_m2m’ in Figure 65.

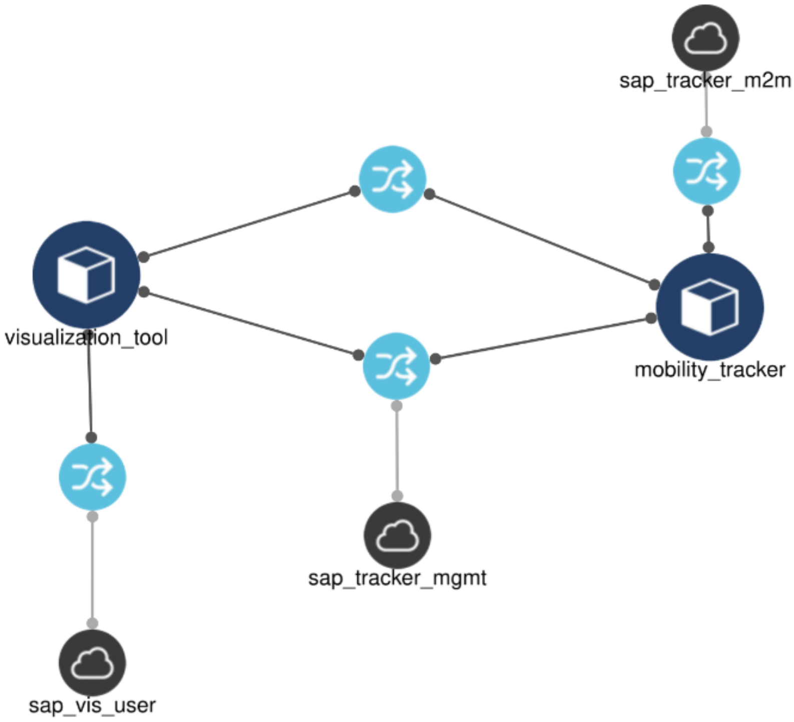


Figure 65: Smart City (Italy) UC5.1 - VSB graphical visualization

4.9.3 Test Case Blueprint & Execution results

We have performed Test Case 1, denoted as "Offline validation of the mobility flow tracking approach", which provides a preliminary evaluation of the Use Case we performed based on the Wi-Fi scanners operating during the initial deployment of 5G EVE infrastructure. We used just 2 Wi-Fi scanners (identified by the labels "libeliumscanner4" and " libeliumscanner5"). The location of the installed Wi-Fi scanners, labelled *X* and *Y*, and the layout of the streets near the testbed area are shown in Figure 66.

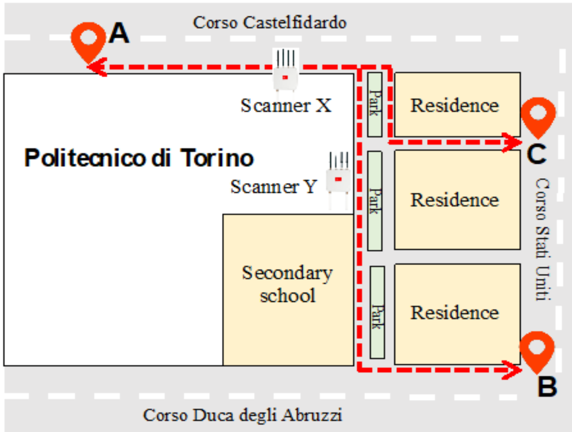


Figure 66: Smart City (Italy) UC5.1 - Wifi scanners coverage map

The sampled probe requests are logged in JSON format by each scanner every 50 seconds. An extract of the log file is shown as follows:


```
{"data":[
   {"RSSI":"-68","Vendor":"Samsung", "TimeStamp":"2020-02-15 12:32:45","MAC":"B7...BA"},
   {"RSSI":"-64","Vendor":"Apple", "TimeStamp":"2020-02-15 12:32:45","MAC":"9E...01"},
   {"RSSI":"-86","Vendor":"Unknown", "TimeStamp":"2020-02-15 12:32:45","MAC":"3F...FA"}
]}
```

Each sample comprises four fields.

- The *RSSI at the receiver* has not been considered in our methodology since the scanner documentation does not explain how the actual value of RSSI is evaluated (e.g., it is unclear if it is the average or the maximum) and how the RSSI of multiple probe requests received during the same sampling period is computed. Furthermore, as well known in the literature, the RSSI cannot be considered a reliable metric for mobility tracking.
- The *interface vendor* could not be exploited since it does not allow to identify uniquely the interface and in many cases is equal to "Unknown".
- Although given with the precision of one second, the same *sampling time* is reported for all probe requests observed during the same 50-second sampling period. Thus, it is not possible to have a detailed timing sequence of the probe requests, making the tracking extremely challenging. Furthermore, multiple probe requests from the same device during the same sampling period are collapsed into a single sample. Finally, even if the Wi-Fi scanners are synchronized through NTP, when the sampling time difference is smaller than 50 seconds it is not possible to be sure about the temporal sequence of events, making it harder to detect the actual direction of movement.
- As for the *device MAC address*, this has been obtained by digesting the device MAC address through an SHA-224 function. Since the anonymized MAC address is not considered to be personal data[3], the adopted process is compatible with EU General Data Protection Regulation. Notably, the default hash function available in the Libellium Wi-Fi scanner digests the MAC address together with the current time, not allowing the identification of the same MAC address at different times. To circumvent this problem, the hashing mechanism was modified in order to digest just the MAC address.

Every two minutes, the scanners upload the log of the Wi-Fi probe requests transmitted from nearby devices to the OneM2M platform, using their cellular link. The OneM2M platform is available through the 5G EVE infrastructure and managed by TIM.

During our initial evaluation, we evaluated two Vertical KPIs: (i) the number of monitored devices in a week, (ii) the mobility patterns in the testbed area. In addition, we evaluated the effect of MAC randomization in collecting such patterns.

We downloaded a full data trace from the 5G EVE OneM2M server corresponding to a week in October 2019. This trace comprises 195,762 distinct MAC addresses. A single device may appear with multiple MAC addresses in the trace due to MAC randomization, thus the number of distinct MAC addresses provides only an upper bound on the number of devices passing in the testbed area shown in Figure 66. In order to understand the effect of MAC randomization, thanks to the collaboration of the IT Area of Politecnico di Torino, we collected a list of 34,927 MAC addresses of devices used by community members to connect to the campus Wi-Fi network. They comprise students, professors and administrative employees. For privacy reasons, these MAC addresses were anonymized through the same SHA-224 hash function used by the Wi-Fi scanners. This allowed us to identify the subset of MAC addresses corresponding to Politecnico users in the original trace. We remark that these MAC addresses *are not randomized*, since they are collected *after* the device has associated to one of the Politecnico APs.

We analyzed the mobility patterns shown in the whole trace. For each MAC, we computed the temporal sequence T of detection events that can be represented as follows: $T = [(t_i, s_i)]_i$, for increasing values of t_i ($i = 0,1,2\ldots$). A generic pair in T represents the events according to which scanner s_i detected the device at time t_i, where $s_i \in \{X,Y\}$. We partitioned T into sub-sequences by gathering all the consecutive coverage events occurring with a time difference less than 4 minutes. Each subsequence models a different mobility pattern and has been

[3] https://ec.europa.eu/info/law/law-topic/data-protection/reform/what-personal-data_en

associated to a representative string to summarize the sequence of scanner identifiers. E.g., a string “X” means that the device was detected only by scanner *X*, instead “XYX” means that the device was under the coverage of *X* then under the coverage of *Y* and then again under the coverage of *X*. We used “Z” in the mobility string to denote the case in which the device was under the coverage of both scanners at the same time.

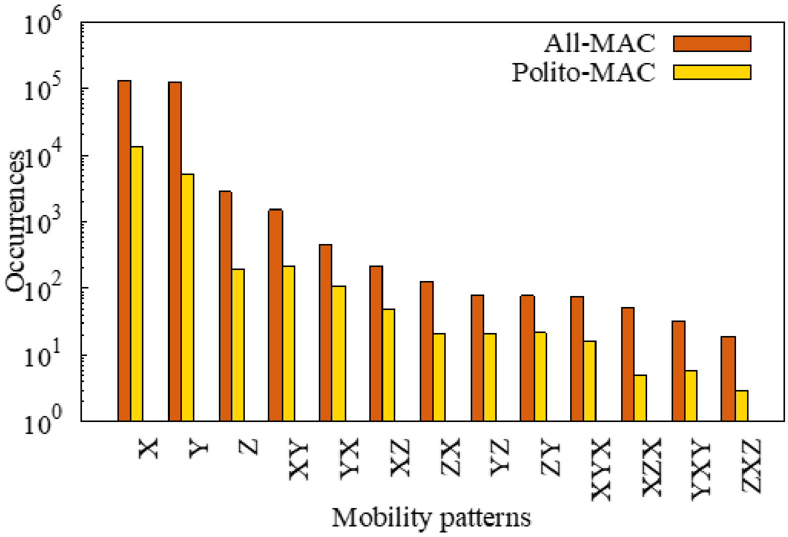


Figure 67: Smart City (Italy) UC5.1 - Popularity of mobility patterns captured in October 2019

Figure 67 shows the number of occurrences in the trace of each mobility pattern string, for all the MAC addresses in the trace (“All-MAC”) and just for Politecnico addresses (“Polito-MAC”). The most common mobility patterns are clearly the ones corresponding to the coverage of a single scanner (either “X” or “Y”). This result is affected by the randomization process that might change the MAC address between two detection events at disjoint scanners. Focusing just on the results for “X” and “Y” patterns for Polito-MAC, we can observe that they are still the most common patterns, suggesting that these two are the actual most popular mobility patterns for all the devices in the area. Indeed, both “X” and “Y” correspond to paths compatible with the expected main flows of people walking in the area and entering and leaving the campus area. It is also possible to notice that the popularity profiles for All-MAC and for Polito-MAC are almost identical, except for a scaling factor due to randomization and to the larger population of devices captured in All-MAC. We can conclude that the popularity profile of mobility patterns is not affected by the randomization, thus we can study the mobility patterns directly on All-MAC without considering the effect of MAC randomization. This observation is key to validate the approach adopted in the current 5G EVE Use Case, despite the MAC randomization operated in many mobile devices.

In summary, the system has shown the capability of managing >100,000 devices in a week. All the mobility patterns available for the two scanners have been observed. Thus, Test Case 1 has been passed.

4.9.4 Pilot Initial validation status

The pilot has not been yet integrated in the 5G EVE platform and thus the validation has not been performed so far.

The expected KPI to collect are the following:

- the amount of resources required to run the MOB NF in terms of memory (RAM), storage and CPU in function of the data generated by the scanners.
- the bandwidth required for the interaction between MOB and OneM2M in function of the data generated by the scanners.
- the bandwidth required for the interaction between MOB and VIS in function of the data generated by the scanners and of the dashboard visualizations.

All the previous KPIs are aimed at understanding the scalability of the proposed approach, required to plan correctly the dimensioning of the platform in terms of computation, storage and network resources within the edge cloud.

4.9.5 Summary & next steps

So far, a complete validation of the proposed approach has been performed outside the 5G EVE edge cloud and has shown the actual feasibility of the proposed approach, as described in Section 4.9.3, but the Use Case has not been yet integrated in the 5G EVE cloud edge and thus the validation has not been performed so far.

As next steps, we plan to integrate the current implementation of the application within the 5G EVE edge cloud. At the current state, we expect that the integration will follow the planned schedule, as discussed in Section 4.9.1.2.

4.10 Use Case 5.2 - Smart City: Safety and Environment

4.10.1 Pilot execution context

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. Considering the above, this Use Case addresses ambient air quality monitoring and forecasting in outdoor environments. Alerts are issued 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.

For the Athens site Figure 68 depicts a high-level view of the currently envisaged set-up of the components and equipment related to the Smart City Use Case. 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 Air Quality monitoring and health recommendations. 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.

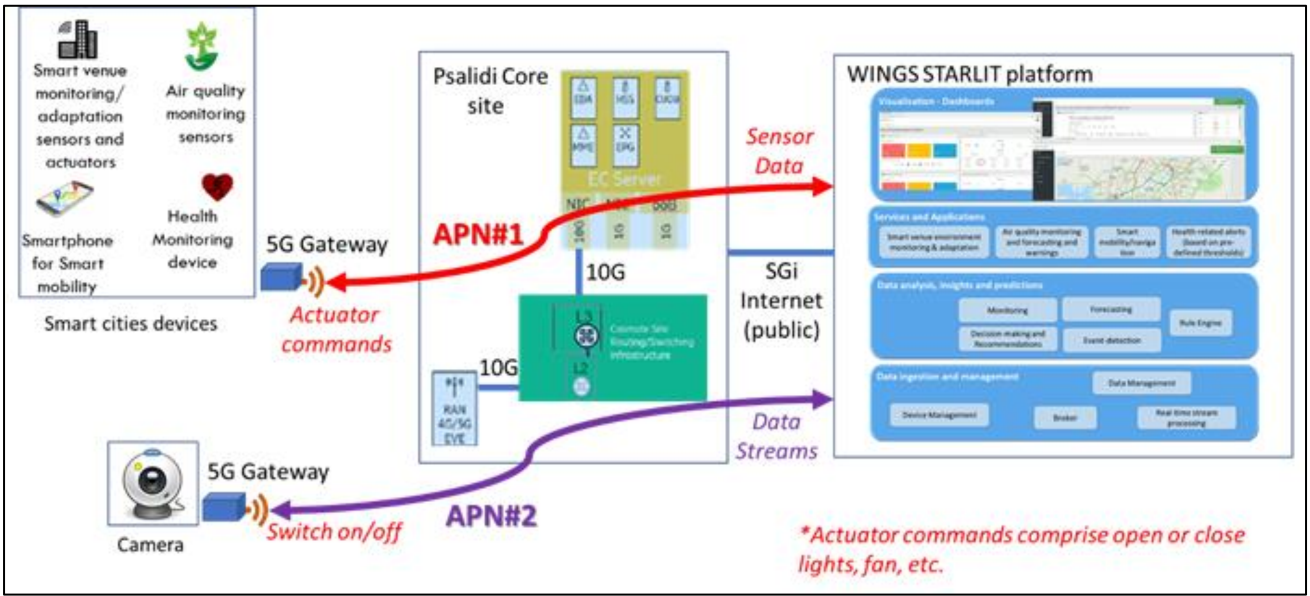


Figure 68: Smart City (Greece) UC5.2 - High-level view of Use Case setup

4.10.1.1 Actors

Vertical: WINGS (Greece) provides the Starlit platform (described above), as well as the necessary sensors and cameras that support the Smart City applications that are included in this Use Case.

VNF provider(s): WINGS (Greece), Ericsson (Greece)

1) WINGS (Greece): Node controlling VNFs.

2) Ericsson (Greece): Core network VNFs.

Experiment developer(s): WINGS (Greece) takes care of all necessary actions for the realization of the experiments.

Experimenter(s): WINGS (Greece) WINGS (Greece) drives the experiment execution as well as the collection and analysis of the corresponding results.

Site Manager(s): OTE (Greece)

4.10.1.2 Planning & Status

The roadmap for the Athens Smart Energy use-case is the following:

- *2018: Analysis of requirements, development and testing in lab environment.*
- *2019 (Q1, Q2, Q3): Development and testing in lab environment.*
- *2019 (Q4): Preparations for integration at the Greek 5G EVE site.*
- *2020 (Q1): Pilot deployment - Integration and testing at the Greek 5G EVE site.*
- **2020 (Q2): Pilot deployment - First Tests and KPIs validation, First E2E integration (portal, IWL, Greek site).**
- **2020 (Q3): Tests and KPIs validation - E2E integration (portal, IWL, Greek site).**
- **2020 (Q4): Tests and KPIs validation - Exploitation of all 5G EVE framework capabilities.**
- **2021 (Q1, Q2): Final tests, complete analysis of results and delivery of outcomes.**

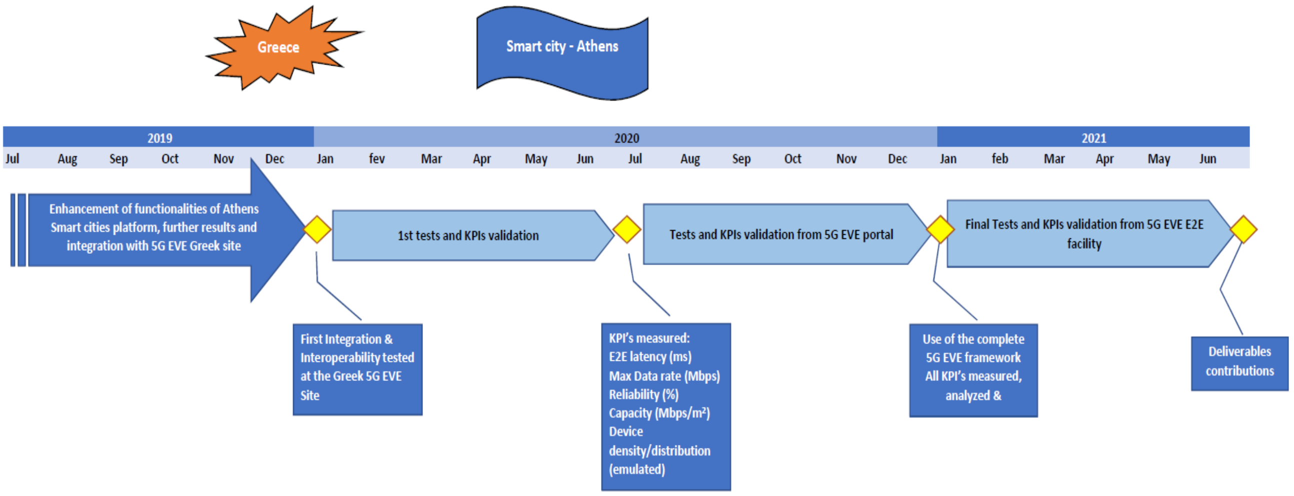


Figure 69: Smart City (Greece) UC5.2 - Roadmap

4.10.2 Pilot architecture

Figure 70 depicts the Smart City Use Case pilot architecture, including elements from the 5G EVE portal, IWL and the Greek site.

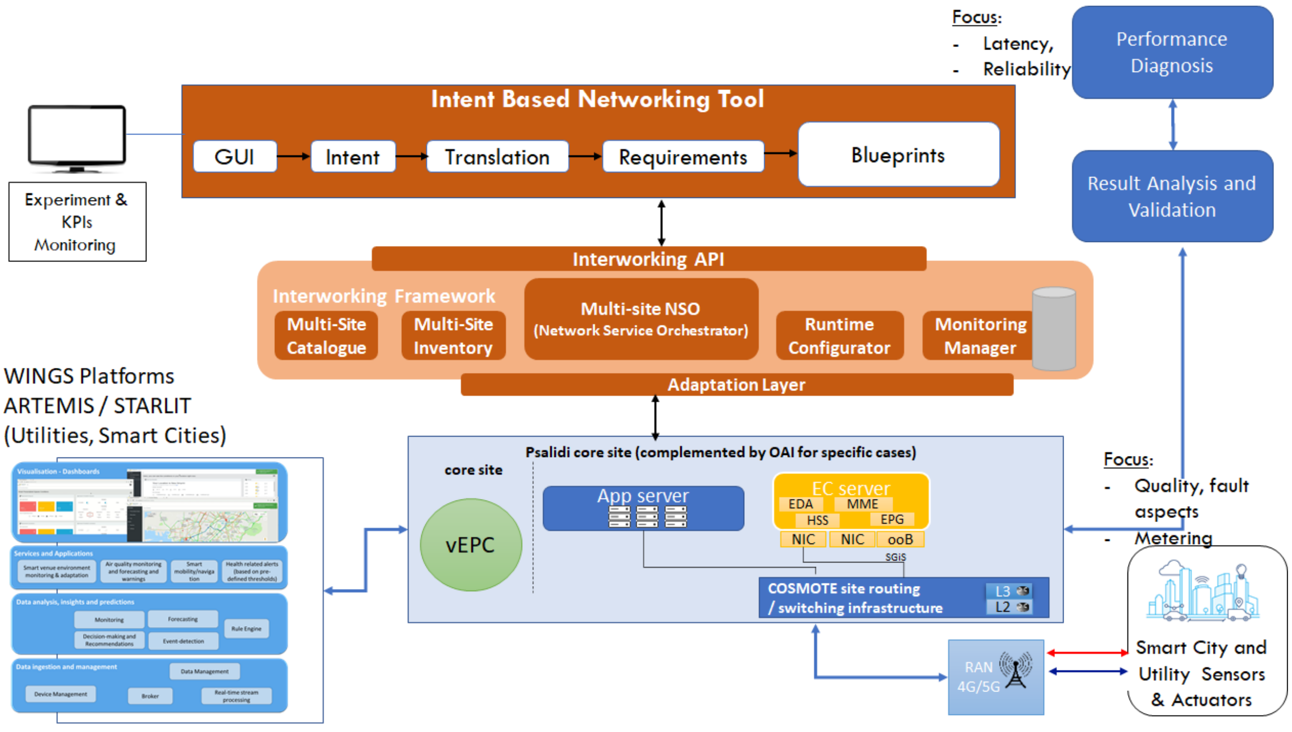


Figure 70: Smart City (Greece) UC5.2 - Architecture

The experiments will test the performance of the Smart City Use Case in a 5G network. In the deployment scenario the Monitoring Services are running on the Cloud, while the sensors are deployed in the Smart City infrastructure. The experiment will examine the performance of the Smart City Platform/Infrastructure in terms of total throughput and maximum number of supported users.

Table 53: Smart City (Greece) UC5.2 - Experiment components

Component Name	Description	Deployment requirements
Air Quality Sensor	Sensor measuring the air quality	Deployed as part of the Smart City infrastructure
5G Gateway	Node close to the sensors responsible to collect data from the sensors. It communicates with the 5G RAN (acting as 5G terminal).	Deployed close to sensors to provide 5G connectivity
WINGS STARLIT platform	Cloud platform in which the Monitoring Services are deployed	Deployed in a cloud server as Virtual Machine

Table 54: Smart City (Greece) UC5.2 - Meaningful KPIs

5G related KPIs	Comments	
RTT Latency	Target: 40 ms	
Bandwidth	Target: 50 Mbps-100 Mbps, especially for the uplink	
Vertical KPIs	**Is it measureable during experimentation?**	**Can it be mathematically derived from 5G related KPIs?**
Number of sensors supported. Target: 60K devices/km^2.	Yes, it can be measured in the 5G Gateway.	Number of sensors supported = total bandwidth / average throughput per sensor
Bandwidth	Yes, it can be measured in the 5G Gateway.	Total bandwidth = bandwidth

Table 55: Smart City (Greece) UC5.2 - Test Case 1

Test Case 1	
Test Name:	Effect of the frequency between subsequent transmission in the air quality sensor in the Bandwidth
Target KPI:	Bandwidth
Measurement Method:	For the uplink/downlink direction, we will measure in the 5G Gateway the egress/ingress throughput on the 5G wireless interface (interface between 5G Gateway and 5G RAN in the architecture figure). Alternative approach: For the uplink/downlink direction, we will measure in the Cloud Server the egress/ingress throughput on interface between 5G Core and Server (in the architecture figure).
Parameters:	The frequency between subsequent transmission will be set to 60, 30, 10, 5, 1 sec
Validation Conditions:	Bandwidth (both on downlink and uplink) Target: 50 Mbps-100 Mbps

Table 56: Smart City (Greece) UC5.2 - Test Case 2

Test Case 2	
Test Name:	Effect of the frequency between subsequent transmission in the air quality sensor in the RTT latency
Target KPI:	RTT latency

Measurement Method:	The RTT Latency will be measured by the Air quality board or the 5G Gateway. It is the end-to-end latency of a ping message between the Air quality board or 5G Gateway and the Cloud Server (in which the WINGS Starlit platform is deployed).
Parameters:	The frequency between subsequent transmission will be set to 60, 30, 10, 5, 1 sec
Validation Conditions:	RTT Latency < 40ms

Table 57: Smart City (Greece) UC5.2 - Test Case 3

Test Case 3	
Test Name:	Effect of the number of air quality sensors in the Bandwidth.
Target KPI:	Bandwidth
Measurement Method:	For the uplink/downlink direction, we will measure in the 5G Gateway the egress/ingress throughput on the 5G wireless interface (interface between 5G Gateway and 5G RAN in the architecture figure). Alternative approach: For the uplink/downlink direction, we will measure in the Cloud Server the egress/ingress throughput on interface between 5G Core and Server (in the architecture figure).
Parameters:	The number of air quality sensors will be set to 1, 50, 100, 200, 500, 1000 (emulation)
Validation Conditions:	Bandwidth (both on downlink and uplink) Target: 50 Mbps-100 Mbps

Table 58: Smart City (Greece) UC5.2 - Test Case 4

Test Case 4	
Test Name:	Effect of the number of air quality sensors in the RTT latency
Target KPI:	RTT latency
Measurement Method:	The RTT Latency will be measured by the Air quality board or the 5G Gateway. It is the end-to-end latency of a ping message between the Air quality board or 5G Gateway and the Cloud Server (in which the WINGS Starlit platform is deployed).
Parameters:	The number of air quality sensors will be set to 1, 50, 100, 200, 500, 1000 (emulation)
Validation Conditions:	RTT Latency < 40ms

The service graphical view is depicted in Figure 71.

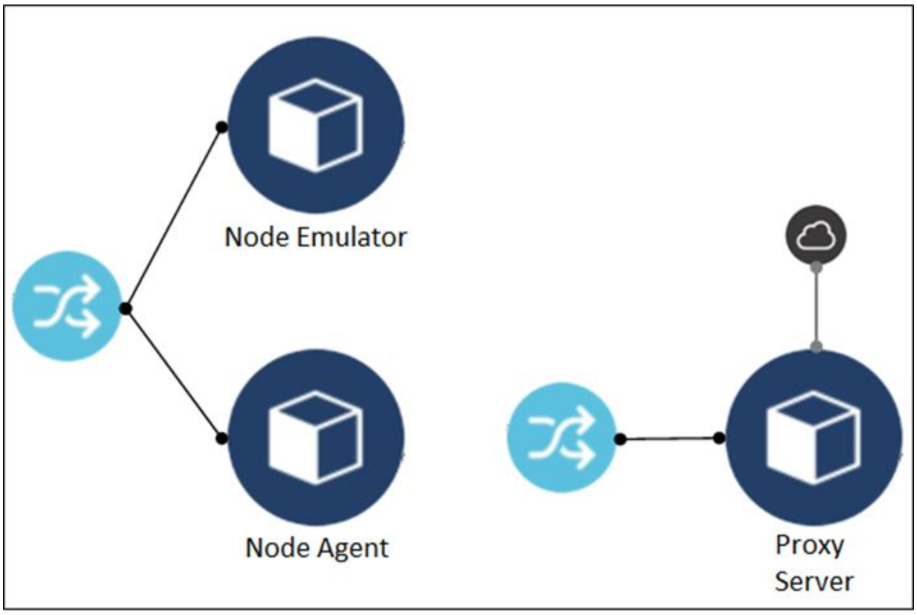


Figure 71: Smart City (Greece) UC5.2 – Service graphical view

4.10.3 Test Case Blueprint & Execution results

Table 59: Smart City (Greece) UC5.2 - Low Level Test Case 1,2

Test Cases 1,2	
TCB Name:	**Smart City UC Test case with varying inter-transmission periods**
Configuration tasks	***Proxy Server VNF:*** • The proxy server, that handles the relaying of the requests to the Platform, is started. ***Sensor Agent VNF***: • The smart node control agent is started on the device using custom scripts that are provided inside the VNF.
Execution Task:	The actions of the test consist of: • Staying idle for a time period to collect messages from the sensors. • Reconfigure the Platform, by using the Proxy Server's interface, to change the period between the subsequent transmissions of measurements. • This process can be repeated for various inter-transmission periods (60s, 30s, 10s, 5s, 1s).
User Parameters:	• username: $$user • password: $$password • inter-transmission_period: $$period • idle_time: $$idle$$time
Infrastructure Parameters:	• vnf.ce032cb8-51a8-486c-ae03-851f490fd923.extcp.cp_proxy_mgmt.ipaddress

	• Management IP of proxy server used by the RC to connect to the VNF for configuring purposes • vnf.359c7ee7-5dfb-4509-8a56-57e72e8f5e90.extcp.cp_agent_mgmt.ipaddress • Management IP of sensor agent used by the RC to connect to the VNF for configuring purposes

Table 60: Smart City (Greece) UC5.2 - Low Level Test Case 3,4

Test Cases 3,4	
TCB Name:	**Smart City UC Test case with varying number of sensors**
Configuration tasks	***Proxy Server VNF:*** • The proxy server, that handles the relaying of the requests to the Platform, is started. ***Sensor Agent VNF***: • The smart node control agent is started on the device using custom scripts that are provided inside the VNF. ***Node emulator VNF (CTX)***: • The smart node emulator is started with initial configuration of 0 emulated nodes.
Execution Task:	The actions of the test consist of: • Staying idle for a time period to collect messages from the sensors. • Reconfigure the Node Emulator to increase the number of emulated nodes. • This process can be repeated for various numbers of emulated nodes (1, 50, 100, 200, 500, 1000).
User Parameters:	• username: $$user • password: $$password • number-of-nodes: $$nodes • idle_time: $$idle$$time
Infrastructure Parameters:	• vnf.ce032cb8-51a8-486c-ae03-851f490fd923.extcp.cp_proxy_mgmt.ipaddress - Management IP of proxy server used by the RC to connect to the VNF for configuring purposes • vnf.359c7ee7-5dfb-4509-8a56-57e72e8f5e90.extcp.cp_agent_mgmt.ipaddress - Management IP of sensor agent used by the RC to connect to the VNF for configuring purposes • vnf. e9777dc3-09e8-4bd4-a570-8c934754b3fc.extcp.cp_node_emu_mgmt.ipaddress

	- Management IP of node emulator used by the RC to connect to the VNF for configuring purposes

The configuration task is where the RC will connect to the VNFs to complete the initial configuration of the components.

The execution task, where the experiment starts running, is where the metrics are generated and after the termination of it, the validation of the KPIs is performed.

The Proxy Server VNF, the Node Emulator VNF and the Sensors Agent VNF are Ubuntu machines already equipped with the necessary software to manage smart measurement devices operation, emulate smart node operation and reconfigure the devices operation using the Proxy Server's interface with the Platform.

4.10.4 Pilot Initial validation status

First tests were conducted using 4G, NB-IoT, as well as other 3GPP compliant technologies (with USRPs and vEPCs). However, all test cases are planned to be executed using the 5G testbed that is deployed at the 5G EVE Greek site. RTT latency and bandwidth will be the first KPIs that will be monitored and evaluated in the operational environment. Validation process is still on going and runs in parallel with the finalization of the E2E integration activities.

4.10.5 Summary & next steps

Currently, the focus is placed on the finalization of the pilot deployment and its integration with the rest of the 5G EVE framework (portal – IWL – Greek site facility). The next step is the thorough experimentation activities and the validation of the theoretical analysis through the selected monitored KPIs.

4.11 Use Case 5.3 - Smart City: Safety and Environment – Connected Ambulance patient metrics

4.11.1 Pilot execution context

In Figure 72 the general context of the whole solution can be found, for both of the connected ambulance Use Cases addressed by Nokia Greece (see also UC5.4 in Section 4.12).

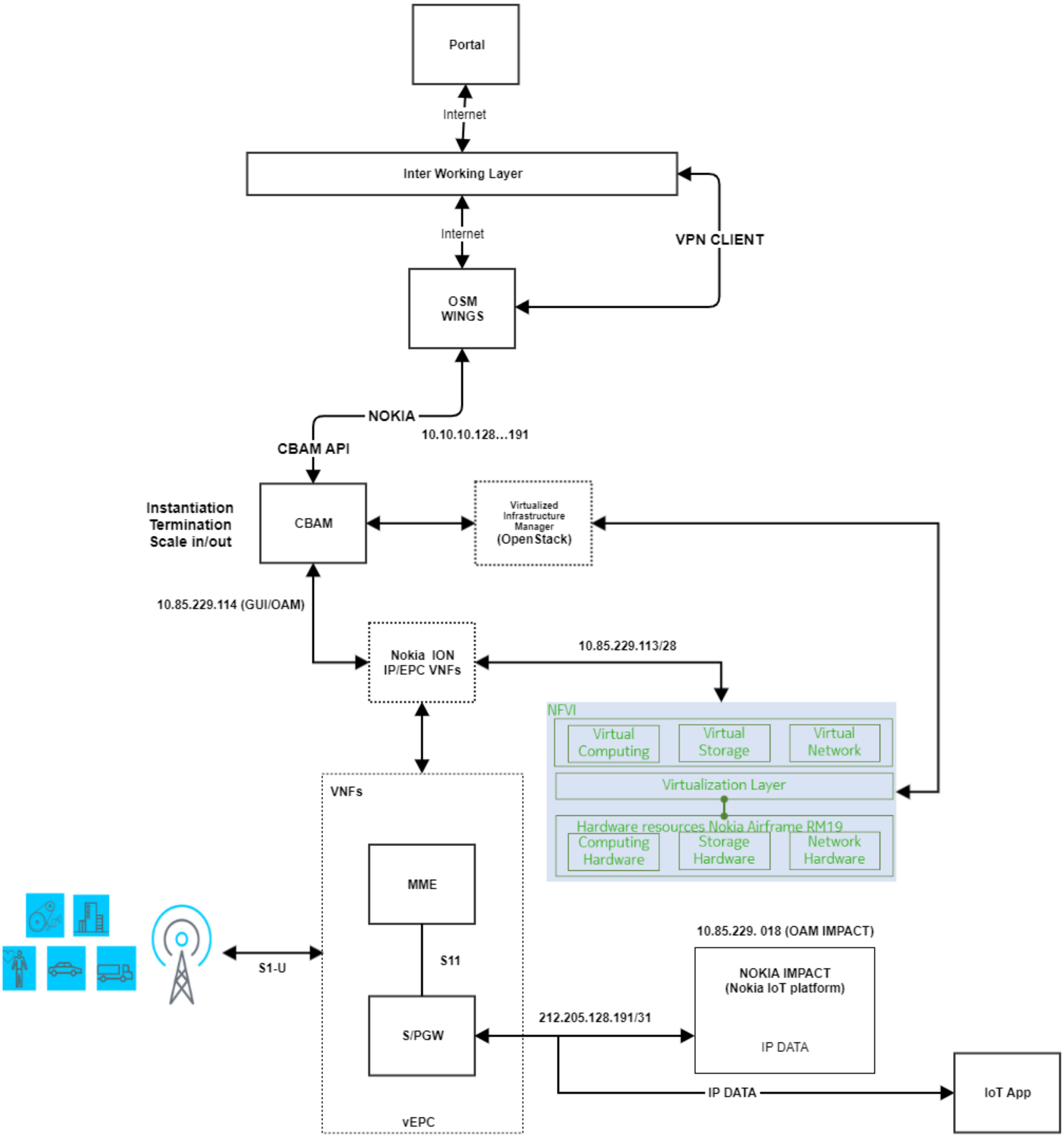


Figure 72: Smart City (Greece) UC5.3, UC5.4 - Nokia platform general architecture

Solution of the "Patient metrics" Use Case consists of the following components:

Table 61: Smart City (Greece) UC5.3 - Use Case components

Component Name	Description	Deployment requirements
IMPACT IoT Platform	IoT platform. Communication with Core over IP transmission path.	Connectivity with Internet and Core.

		Cloud based Deployment on Airframe server 3x control, 3x worker 1 x edge, 34 CPU 80 GB RAM
S/P GW	Core cloud component. Communication with MME via S11 and with IoT Platform via IP.	Openstack [62] Installation
MME	Core cloud component. Communication with S/P GW via S11 and with 5G Radio.	Openstack Installation
CBAM	VNF MANO. Communication with S/P GW and MME. Responsible for Orchestration.	Openstack Installation
Fastmile 5G Gateway	Physical endpoint (Router) that will be using inside ambulance for communication with 5G radio.	NAT Network 220 V
Node-Red adaptor	Software adaptor. Used in formatting changes.	Java script output
KPI collecting application	The VNF application for KPIs measurements.	

4.11.1.1 Actors

Vertical: Nokia Greece, Vidavo.

Nokia will provide infrastructure and will be responsible for testing of the USE Case. Components that participate in the Use Case defined in Table 44.

Vidavo will provide the health instrument that will be connected to the 5G gateway via Wi-Fi.

VNF provider(s): NOKIA Greece is the VNF provider.

NOKIA Greece is the VNF provider. Components that participate in the Use Case defined in Table 58.

Experiment developer(s): Nokia Greece.

Nokia Greece will define suitable blueprints, experiment contexts and associated experiment blueprints

Experimenter(s): Nokia Greece.

Nokia Greece will define, execute and analyse results and KPIs.

Site Manager(s): OTE (DT South)

OTE (DT South) will manage the entire definition and execution related to the Experiment.

4.11.1.2 Planning & Status

- M24: Have all components VNFs, PNFs ready for deployment, defining Blueprints, integrate portal functionalities for the management of Network Functions and KPI collections.
- M24-M30: Perform all Test Cases using the 5G EVE workflow (i.e. Test Cases initiated by the portal and data driven back to the portal by Kafka bus.
- M30-M36: Repetition of Test Cases with the last version of core and 5G EVE platform. Final validation and report in D2.5.

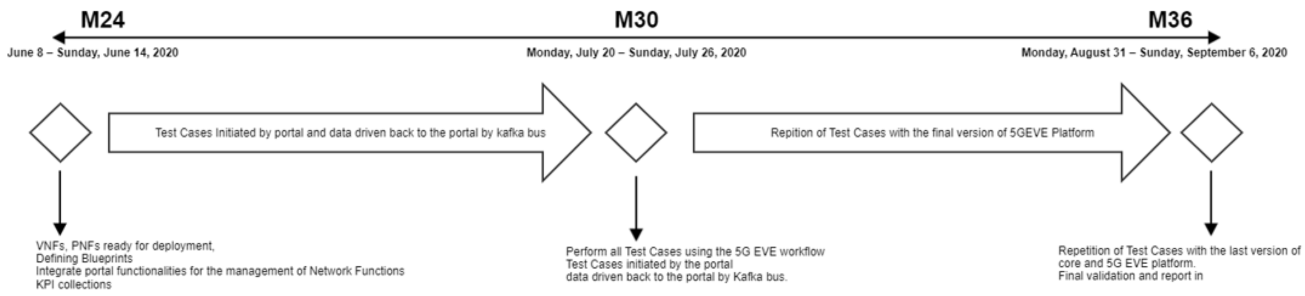


Figure 73: Smart City (Greece) UC5.3 - Roadmap

4.11.2 Pilot architecture

As shown in the Figure 74, vitals measurements will be conveyed via the 5G gateway to vEPC core and then via S/P gateway (in the option3x case) or SMF/UPF (in the 5G SA Use Case) to the Nokia IoT platform. The platform will then convey the data to an application dashboard. Platform-application connection is performed via REST API. The clock-like device which will take the patient metrics is made by the health instruments vendor Vidavo and it will be connected to the 5G gateway via Wi-Fi. Data is shipped to IMPACT using HTTP protocol functions which are relayed on the HTTP protocol adapter of the IMPACT IoT platform.

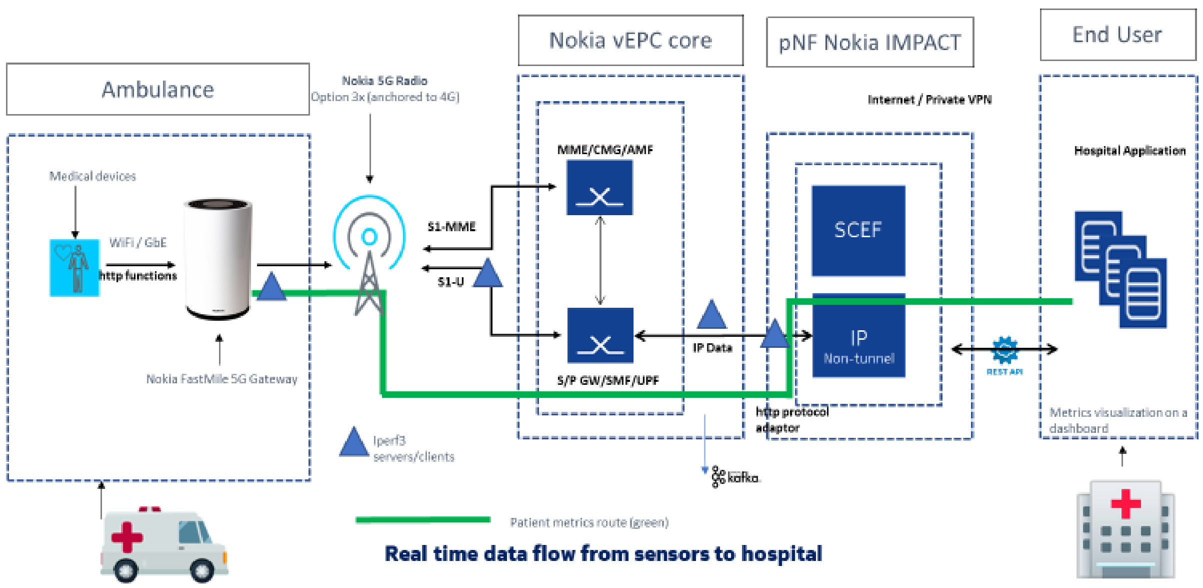


Figure 74: Smart City (Greece) UC5.3 – Pilot architecture

On the 5G SA the IoT metrics will be conveyed via an IoT network slice, administered for this reason.

Iperf [55] KPIs will be taken at the points shown in Figure 74 ( signs):

- On the 5G gateway modem,
- on the Radio/Core interface,
- on the S/P gateway (or SMF/UPF in the SA version), and
- at the IMPACT server interface.

A Kafka [56] broker will be installed in one of the vEPC servers to push the data towards the portal.

Table 62: Smart City (Greece) UC5.3 - Meaningful KPIs

5G related KPIs	Comments	
Latency	Latency will be the variable parameters in each of scenarios	
Throughput	Throughput be the variable parameters in each of scenarios	
Vertical KPIs	**Is it measurable during experimentation?**	**Can it be mathematically derived from 5G related KPIs?**
Latency of vitals transmission	Yes	No

Table 63: Smart City (Greece) UC5.3 - Test Case 1

Test Case 1	
Test Name:	Patient vitals transmission
Target KPI:	Latency
Measurement Method:	RTT Latency will be measured by the 5G Gateway
Parameters:	The number of requests will be set to 1, 5, 10, 20, 50, 100, 200, 500, 1000 sec interval
Validation Conditions:	RTT Latency bellow 200 msec

4.11.3 Test Case Blueprint & Execution results

Test Cases to be executed end to end i.e. initiated by the portal and results collected by the Kafka bus terminator:

Table 64: Smart City (Greece) UC5.3 - Low Level Test Case 1

Test Case 1		
Test Name:		**Transmission of patient vitals**
Test Objective:		(End to End) RTT Latency < 200ms
Test Prerequisites:		TBD
Required Capabilities:		The Iperf tool along with the appropriate Beat are deployed in the 5G gateway and on the IoT platform.
Sub-Case 1	**Test Topology:**	Experiment Architecture
	Test Variables:	number of requests [1, 5, 10, 20, 50, 100, 200, 500, 1000]
	Test Procedure:	Start the Iperf tool as a client in the 5G Gateway and start Iperf server on the IoT platform. Intermediate latency test results can be taken to determine possible bottlenecks in traffic. Iperf servers/clients are installed on S1U interface and on S/P Gateways.
	Expected results:	RTT Latency < 200ms for all the tests
	Test Variables:	number of requests [1, 5, 10, 20, 50, 100, 200, 500, 1000]

4.11.4 Pilot Initial validation status

First validation steps were taken on experimenting with RTT delay and bandwidth for the network. Iperf servers/clients have been installed in many network components to validate network capability in terms of throughput and latency.

Moreover, Iperf is installed in Use Case related components i.e. the 5G gateway and the IoT platform to verify KPIs across all components involved in the Use Cases. Validation process is ongoing and will be finalised by July 2020.

4.11.5 Summary & next steps

Finalisation of pilot deployment, in terms of integration of the new hardware in the IoT platform, KPIs validation and integration in the portal workflow in terms of experiments execution and KPI collection by Sep 2020. Integration with the 5G EVE framework (portal -IWL). Currently, the focus is placed on the finalization of the pilot deployment and its integration with the rest of the 5G EVE framework (portal – IWL – Greek site facility). Moreover Test Cases will be executed under real handover conditions. New KPIs will be reported containing the effect of the handovers.

4.12 Use Case 5.4 - Smart City: Safety and Environment – Connected Ambulance 4k Video from site

4.12.1 Pilot execution context

The high level network architecture for this Use Case can be also derived from Figure 72 in Section 4.11.1. This is the main architectural diagram for all the Use Cases to be implemented within the connected ambulance framework.

Components that are used for this Use case are:

Table 65: Smart City (Greece) UC5.4 - Use Case components

Component Name	Description	Deployment requirements
S/P GW	Core cloud component. Communication with MME via S11 and with IoT Platform via IP.	Openstack [62] Installation
MME	Core cloud component. Communication with S/P GW via S11 and with 5G Radio.	Openstack Installation
CBAM	VNF MANO. Communication with S/P GW and MME. Responsible for Orchestration.	Openstack Installation
Fastmile 5G gateway	Physical endpoint (Router) that will be using inside ambulance for communication with 5G radio.	NAT Network 220 V
OBS	Live streaming software.	
Live streaming server	Server used for OBS, N-Red and video capture card.	220 V
4K Camera	Will be connected to live streaming server and will transmit 4K video from ambulance to hospital premises.	220 V Blackmagic Pocket Cinema Camera 4K (body only / MFT mount) Panasonic Lumix G X Vario 12-35mm f/2.8 II Lens

		AJA HA5-12G HDMI to HDI converter
KPI collecting application	The VNF Application for KPIs measurements.	

In Figure 75, the main Use Case components can be shown: the camera, the streaming PC, containing the capture card and the OBS streaming server.

Figure 75: Smart City (Greece) UC5.4 - Use Case main components

4.12.1.1 Actors

<u>Vertical:</u> Nokia Greece

Nokia will provide infrastructure and will be responsible for testing of the USE Case. Components that participate in the Use Case defined in Table 65.

<u>VNF provider(s):</u> NOKIA Greece is the VNF provider.

NOKIA Greece is the VNF provider. Components that participate in the Use Case defined in Table 65.

<u>Experiment developer(s):</u> Nokia Greece.

Nokia Greece will define suitable blueprints, experiment contexts and associated experiment blueprints.

<u>Experimenter(s):</u> Nokia Greece.

Nokia Greece will define, execute and analyze results and KPIs.

<u>Site Manager(s):</u> OTE (DT South)

OTE (DT South) will manage the entire definition and execution related to the Experiment.

4.12.1.2 Planning & Status

- M24: Have all components VNFs, PNFs ready for deployment, defining Blueprints, integrate portal functionalities for the management of Network Functions and KPI collections.
- M24-M30: Perform all Test Cases using the 5G EVE workflow (i.e. Test Cases initiated by the portal and data driven back to the portal by Kafka bus.
- M30-M36: Repetition of Test Cases with the last version of core and 5G EVE platform. Final validation and report in D2.5.

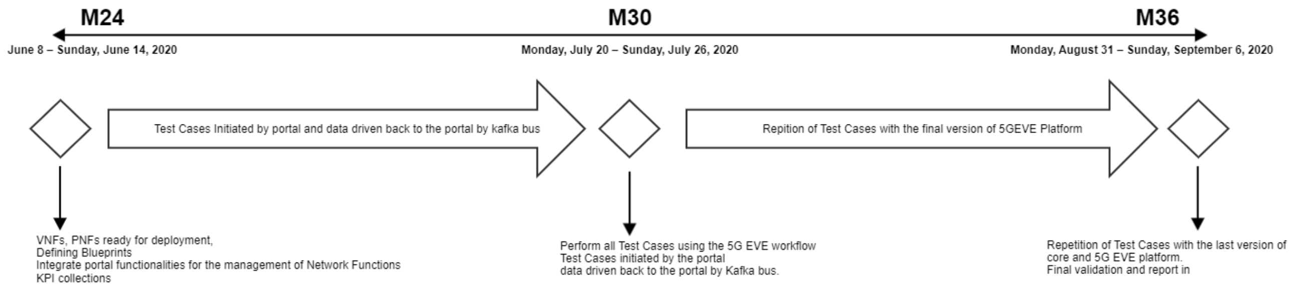


Figure 76: Smart City (Greece) UC5.4 - Roadmap

4.12.2 Pilot architecture

As shown in the Figure 72 and Figure 77, video streaming will be conveyed via the 5G gateway to vEPC core and then via S/P gateway (in the option3x case) or SMF/UPF (in the 5G SA Use Case) to the Internet. From there the End user will be able to hit the streaming URL and watch the live 4K video.

The architectural diagram (respective to Figure 77) is the following:

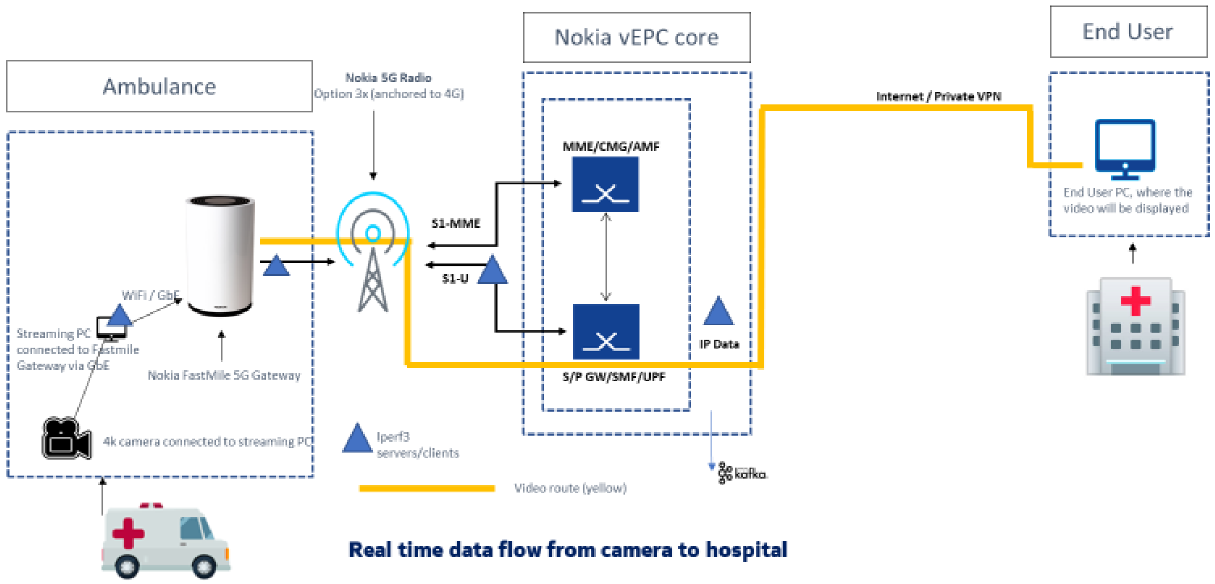


Figure 77: Smart City (Greece) UC5.4 – Pilot architecture

Table 66: Smart City (Greece) UC5.4 - Meaningful KPIs

5G related KPIs	**Comments**	
Latency	Latency will be the variable parameters in each of scenarios	
Throughput	Throughput be the variable parameters in each of scenarios	
Vertical KPIs	**Is it measurable during experimentation?**	**Can it be mathematically derived from 5G related KPIs?**
Quality of 4K Video	Yes, via throughput	No
Latency of video transmission	Yes	No

Table 67: Smart City (Greece) UC5.4 - Test Case 1

Test Case 1	
Test Name:	4K Video transmission
Target KPI:	Latency
Measurement Method:	RTT Latency will be measured by the 5G Gateway
Parameters:	The number of requests will be set to 1, 5, 10, 20, 50, 100, 200, 500, 1000 sec interval
Validation Conditions:	RTT Latency bellow 200 msec

Table 68: Smart City (Greece) UC5.4 - Test Case 2

Test Case 2	
Test Name:	4K Video transmission
Target KPI:	Throughput
Measurement Method:	RTT Latency will be measured by the 5G Gateway
Parameters:	The number of requests will be set to 1, 5, 10, 20, 50, 100, 200, 500, 1000 sec interval
Validation Conditions:	Throughput > 40Mbs

4.12.3 Test Case Blueprint & Execution results

Table 69: Smart City (Greece) UC5.4 - Low level Test Case 1

Test Case 1		
Test Name:		4K Video transmission
Test Objective:		RTT Latency < 200ms
Test Prerequisites:		TBD
Required Capabilities:		The iperf tool along with the appropriate Beat are deployed in the 5G Gateway.
Sub-Case 1	**Test Topology:**	Experiment Architecture
	Test Variables:	number of requests [1, 5, 10, 20, 50, 100, 200, 500, 1000]
	Test Procedure:	Start the iperf tool in the 5G Gateway. Intermediate latency test results can be taken to determine possible bottlenecks in traffic. Iperf servers/clients are installed on S1U interface and on S/P Gateways.
	Expected results:	RTT Latency < 200ms for all the tests
	Test Variables:	number of requests [1, 5, 10, 20, 50, 100, 200, 500, 1000]

Table 70: Smart City (Greece) UC5.4 - Low level Test Case 2

Test Case 2	
Test Name:	4K Video transmission
Test Objective:	Throughput >40Mbps
Test Prerequisites:	TBD
Required Capabilities:	The iperf tool along with the appropriate Beat are deployed in the 5G Gateway

Sub-Case 1	**Test Topology:**	Experiment Architecture
	Test Variables:	number of requests [1, 5, 10, 20, 50, 100, 200, 500, 1000]
	Test Procedure:	Start the iperf tool in the 5G Gateway. Intermediate latency test results can be taken to determine possible bottlenecks in traffic. Iperf servers/clients are installed on S1U interface and on S/P Gateways.
	Expected results:	RTT Latency < 200ms for all the tests
	Test Variables:	number of requests [1, 5, 10, 20, 50, 100, 200, 500, 1000]

4.12.4 Pilot Initial validation status

First validation steps were taken on experimenting with RTT delay and bandwidth for the network. Iperf servers/clients have been installed in many network components to validate network capability in terms of throughput and latency.

Moreover, iPerf is installed in Use Case related components i.e. the 5G gateway and the IoT platform to verify KPIs across all components involved in the Use Cases. Validation process is ongoing and will be finalised by end of Q2.

4.12.5 Summary & next steps

Finalisation of pilot deployment, KPIs validation and integration in the portal workflow in terms of experiments execution and KPI collection and Integration with the 5G EVE framework (portal -IWL). Test Cases will be also repeated under real handover conditions. New KPIs will be reported containing the effect of the handovers.

4.13 Use Case 6.1-3 - Media & Entertainment: Ultra High-Fidelity Media, On-site Live Event Experience, Immersive and Integrated Media

4.13.1 Pilot execution context

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 experience, the future 5G network should be able to support efficient network management, high speed transport capabilities and strategies.

Telefonica is currently delivering high quality TV in the Movistar TV services offer, introduced in the following figure:

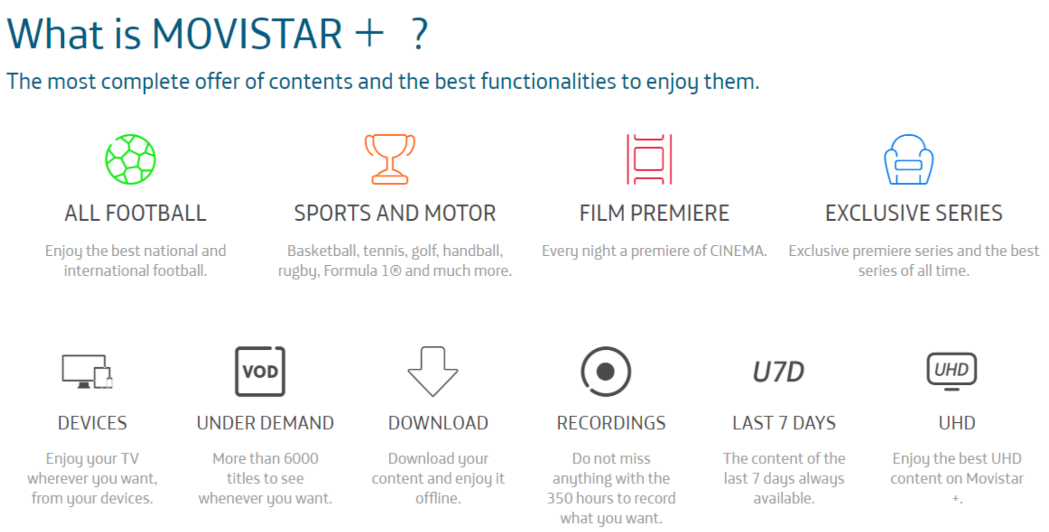


Figure 78: Media & Entertainment (Spain) UC6.1-3 - Movistar TV services offered in Spain and other countries by Telefonica

The TV delivery is key for the Telefonica results as this is used as key in convergent penetration, as it is presented in the last available trimestral report for January-March 2020.

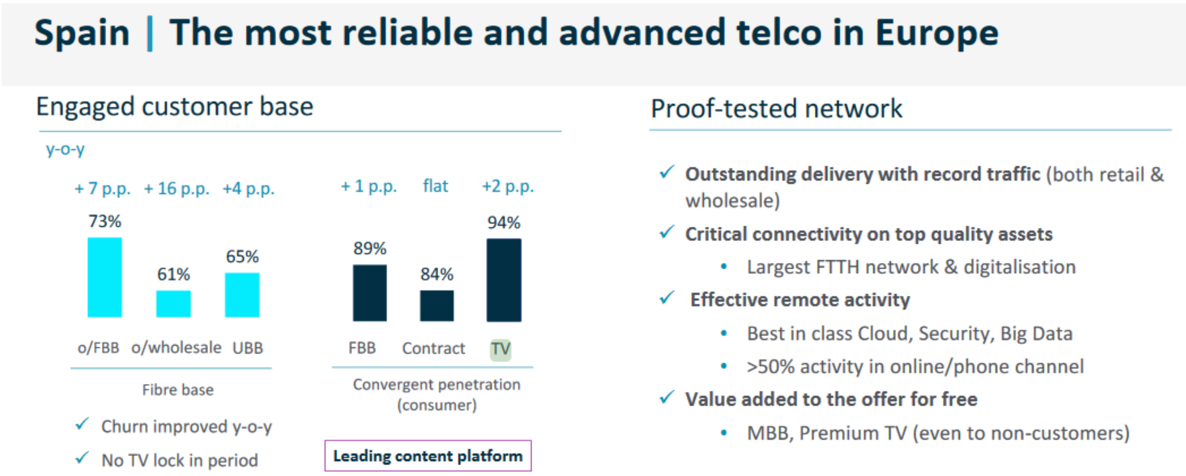


Figure 79: Media & Entertainment (Spain) UC6.1-3 - TV as a critical for convergent penetration in Spanish Market, as reported in Telefonica results January-March 2020

The delivery of high-quality TV through the mobile networks will be only possible adding the new 5G radio and 5G delivery capacity on the massive market in the conventional high-quality TV formats, or in new massively available formats as 360 degrees immersive video, or new ubiquitous TV contribution environments. We have grouped the initial validation in three different Use Cases, where the focus on the network requirements will be different:

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. The massive delivery of these contents depends on the supported aggregated bandwidth for the high-quality contents.

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. It is expected to grow the number of clients that upload real-time contents to the multimedia delivery networks for the live distribution of contents, from professional and non-professional users. The new mobile 5G networks must support the real-time video upload of contents to the Telefonica network, then the main interest is to tests the real-time ingestion of live video feeds into the 5G networks for the live video delivery.

Immersive and Integrated Media will provide ambient media consumption at home but also on the move, with content capable of following the users and adapt to his / her ambient for viewing (e.g. in the car, at home etc.). The new content formats will be using 4K or even higher resolutions, demanding very high distribution bandwidth. Telefonica wants to test how the new 5G clients will be able to download these new contents and which is the maximum aggregated bandwidth achievable with several 5G network configurations.
In Figure 80 we can see a general architecture of the proposed end-to-end testing infrastructure used with the current live content's feeds from the Telefonica TV network:

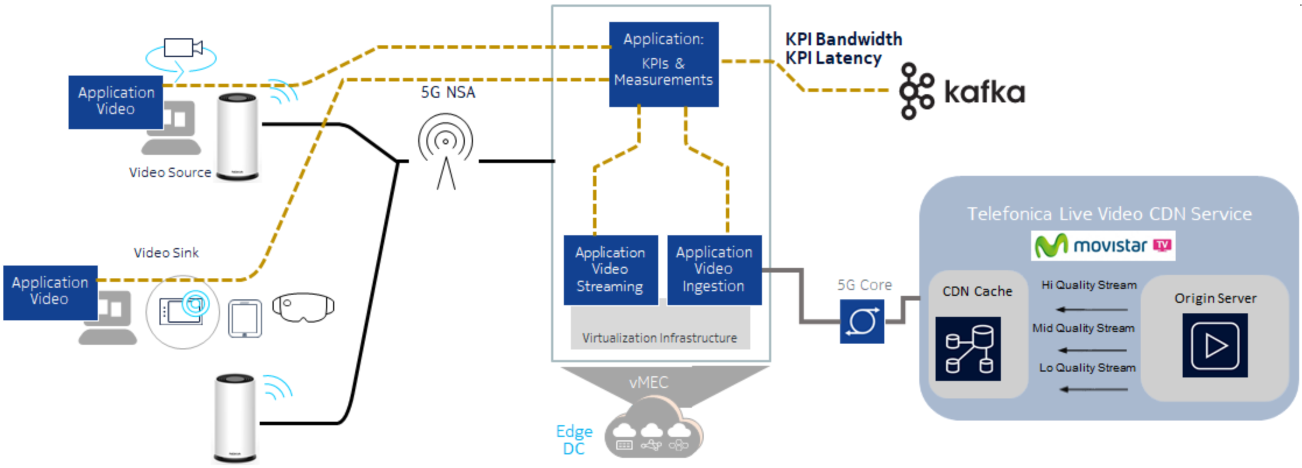


Figure 80: Media & Entertainment (Spain) UC6.1-3 - Immersive events technical architecture

The elements building this technical architecture is described in Table 71: Media & Entertainment (Spain) UC6.1-3 - Components Table 71:

Table 71: Media & Entertainment (Spain) UC6.1-3 - Components

Component Name	Description	Deployment requirements
Smartphones	Oppo Reno 5G SmartPhone, Xiaomi Mix 3 5G	Location in the lab to charge the phones and to receive the 5G laboratory radio
NOKIA 5G FastMile Gateway	NOKIA FastMile gateways are self-contained residential devices that connect wirelessly to your 4G or 5G network while creating a better and faster Wi-Fi experience within the home. The 5G gateway supports 4G and 5G, then this can be deployed today with 4G and offer 5G speeds when available in that area.	Location in the lab to charge the phones and to receive the 5G laboratory radio
Movistar TV Access Point	Telefonica Streaming Service is using a CDN for the live video delivery to the fiber and xDSL subscribers. We will use this same CDN to ingest the live video channels in the vMEC.	Fiber line subscription 600 Mbps to the Movistar TV Service available at the input of the vMEC. This fiber modem must be connected to 220 volts and the

		output 1GHz Ethernet cable connected to the vMEC switch.
VNF Application for Video Streaming	Virtualized application to support the massive video streaming service to the 5G network subscribers	vMEC Resources: 12 GBytes RAM, 20 GBytes non-volatile Storage, 6 CPUs
VNF Application for Video Ingress	Virtualized application to support the massive video ingress from the Live Video CDN	vMEC Resources: 12 GBytes RAM, 40 GBytes non-volatile Storage, 6 CPUs
VNF Application for KPI Generation	Virtualized application to support the generation and storage of measures used to generate the KPIs required by the service provider	vMEC Resources: 12 GBytes RAM, 100 GBytes non-volatile Storage, 6 CPUs
Application Video for traffic simulation	Application to simulate video traffic in the UE	Laptop or Server with 10 GEth interface to receive or send traffic to the UE

The list of meaningful KPIs associated to the Use Case is described in Table 72.

Table 72: Media & Entertainment (Spain) UC6.1-3 - Meaningful KPIs

5G related KPIs	**Comments**	
Speed - sustained demand DL	DL User Experienced Data Rate (Mbps)	
Speed - sustained demand UL	UL User Experienced Data Rate (Mbps)	
Broadband connectivity (peak demand) DL	DL peak data rate (Gbps)	
Broadband connectivity (peak demand) UL	UL peak data rate (Gbps)	
Vertical KPIs	**Is it measurable during experimentation?**	**Can it be mathematically derived from 5G related KPIs?**
UL UDP traffic	Yes	Yes in best scenario conditions, some limitation could be detected in test lab
DL UDP traffic	Yes	Yes in best scenario conditions, some limitation could be detected in test lab
UL TCP traffic	Yes	Yes in best scenario conditions, some limitation could be detected in test lab
DL TCP traffic	Yes	Yes in best scenario conditions, some limitation could be detected in test lab
Video Streaming DL TCP traffic	Yes	Yes in best scenario conditions, some limitation could be detected in test lab

Video Streaming UL UDP traffic	Yes	Yes in best scenario conditions, some limitation could be detected in test lab
Required virtualized resources in the vMEC for the tests	Yes	Not, but is related to 5G KPIs

4.13.1.1 Actors

Vertical: Telefonica, NOKIA Spain.

Telefonica and Nokia are jointly working in the evolution of video services to be provided by the operator, and thus will follow the outcomes of experimentation to apply results and lessons learnt in their future journey.

VNF provider(s): NOKIA Spain is the VNF provider.

Nokia will provide all the VNFs of all three use cases, initially in a vertically integrated way, and later on integrated with the 5G EVE Platform.

Experiment developer(s): Telefonica, Nokia Spain.

Both Telefonica and Nokia will work in developing the required blueprints, descriptors and testing scripts, starting from the required actions to be integrated with the Data Collection Manager (Kafka).

Experimenter(s): Telefonica, Nokia Spain.

Again, Telefonica and Nokia will jointly participate in the execution of the test plan at the Spanish site (5TONIC).

Site Manager(s): IMDEA Networks, UC3M (Spain).

The site manager of 5TONIC will perform the monitoring and scheduling tasks for these three Media & Entertainment use cases.

4.13.1.2 Planning & Status

Despite COVID19, from January 2020 to May 2020, the first functional tests have been developed, including the metrics generation for the 5G KPIs measurements for the different Test Cases. These developments have been tested in Nokia laboratory premises in Madrid.

In May 2020 we have started the VNF packaging of the different functional blocks, including the Kafka injection of the relevant measured information. It is expected to complete the VNF packaging by the end of June 2020. The integration tasks in the 5G EVE laboratory has been delayed due to the mobility restrictions in Spain during the months of March, April and May. We expect to speed up the laboratory integration plans by the second half of May and June.

These are the expected integration tests for the laboratory validation phases:

1. By the end of June we will execute the TC-1, TC-2, TC-3 and TC-4 of the 4.13 Use case 6 - Media & Entertainment. These first tests case executions will inject the measured parameters in the Kafka bus in order to be integrated in the 5G EVE end-to-end workflow.
2. In a second phase, expected by December 2020, all the tests executed in the first phase, plus new tests cases will be executed following the 5G EVE workflow using the functionalities already enabled.
3. In the last phase, expected for June 2021 all the tests will be executed with the new functionalities enabled. In that sense, the structure of the following sections differs from that in the other use cases.

The reason for this is that this use case, initially, will be executed at 5TONIC in a vertically integrated way (i.e., without being integrated with the rest of the 5G EVE platform). The section describing the pilot architecture, for example, does not include the associated blueprints, since this is still work in progress.

As stated above, the plan is to start the integration from the Kafka bus (first integration phase), and then extend the integration to the rest of the components, including the 5G EVE Portal.

4.13.2 Pilot architecture

The three sub-Use Cases will be run on top of a 4G/5G NSA network, executing the business logic using live TV channels from the real IPTV service in Spain.

- For the sub-Use Case Ultra-High-Fidelity Media the MEC will have connectivity to the multicast TV network of Telefonica. It will subscribe to the selected channels that will be ingested in the VNF video ingestion application, which will segment the video in adaptive streaming chunks in real time.
- For the sub-Use Case On-site Live Event the MEC will have connectivity through the 5G radio to the camera video contribution in real time. These feeds will be used by the MEC that will be ingesting the video contribution in the VNF video ingestion application.
- For the sub-Use Case Immersive and Integrated Media, the MEC will be able to ingest VOD Immersive contents in 4K or even higher resolution, storing these contents in the virtualized storage available in the vMEC storage.

For all the Use Cases the segmented chunks of video will be delivered by the VNF video streaming application to the 5G end clients that select a live video channel.

The Test Cases are defined in the tables below, and their Low Level description used to build the Test Case Blueprint is available in Section 4.13.3.

Table 73: Media & Entertainment (Spain) UC6.1-3 - Test Case 1

Test Case 1	
Test Name:	End User Video UDP TCP tests in single UE
Target KPI:	Speed - sustained demand DL, Speed - sustained demand UL, Broadband connectivity (peak demand) DL, Broadband connectivity (peak demand) UL, Speed - sustained demand
Measurement Method:	The speeds will be measured in the vMEC, the traffic will be simulated in a component installed in the UE device to simulate the traffic sink or source.
Parameters:	UE IP, UE Name, parallel sockets, test seconds
Validation Conditions:	A complete set of short and long duration tests will be required, also with some variation in the number of parallel sockets in order to observe potential service performance degradation due to concurrency. The UE type will be key to validate the results in a particular device.

Table 74: Media & Entertainment (Spain) UC6.1-3 - Test Case 2

Test Case 2	
Test Name:	End User TCP Download tests in single UE
Target KPI:	Speed - sustained demand DL, Broadband connectivity (peak demand) DL, Speed - sustained demand
Measurement Method:	The speeds will be measured in the vMEC, the traffic will be simulated in a component installed in the UE device to simulate the traffic sink or source.

Parameters:	UE IP, UE Name, parallel sockets, test seconds
Validation Conditions:	A complete set of short and long duration tests will be required, also with some variation in the number of parallel sockets in order to observe potential service performance degradation due to concurrency. The UE type will be key to validate the results in a particular device.

Table 75: Media & Entertainment (Spain) UC6.1-3 - Test Case 3

Test Case 3	
Test Name:	End User UDP Video Upload tests
Target KPI:	Speed - sustained UL, Broadband connectivity (peak) UL, Speed - sustained demand
Measurement Method:	The speeds will be measured in the vMEC, the traffic will be simulated in a component installed in the UE device to simulate the traffic source.
Parameters:	UE IP, UE Name, sockets, Mbps, test seconds
Validation Conditions:	A complete set of short and long duration tests will be required, also with some variation in the number of parallel sockets in order to observe potential service performance degradation due to concurrency. The UE type will be key to validate the results in a particular device.

Table 76: Media & Entertainment (Spain) UC6.1-3 - Test Case 4

Test Case 4	
Test Name:	End User Video Download tests in single UE
Target KPI:	Speed - sustained demand DL, Broadband connectivity (peak demand) DL, Speed - sustained demand
Measurement Method:	The speeds will be measured in the vMEC, the traffic will be simulated in a component installed in the UE device to simulate the traffic source.
Parameters:	UE IP, UE Name, parallel sockets, test seconds
Validation Conditions:	A complete set of short and long duration tests will be required, also with some variation in the number of parallel sockets in order to observe potential service performance degradation due to concurrency. The UE type will be key to validate the results in a particular device.

Table 77: Media & Entertainment (Spain) UC6.1-3 - Mapping of Tests Cases to sub-Use Cases

Test Case id	Ultra High-Fidelity media	On-site Live event experience	Immerse and Integrated media
Test Case 1	Yes	Yes	Yes
Test Case 2	Yes	Yes	Yes
Test Case 3	Yes	No	No
Test Case 4	Yes	Yes	Yes

The list of KPIs per sub-Use Case is resumed in Table 78

Table 78: Media & Entertainment (Spain) UC6.1-3 - Mapping of sub-Use Cases to generated KPIs

Test Case id	KPIs
Test Case 1	Speed – sustained demand DL, Speed – sustained demand UL, Broadband connectivity (peak demand) DL, Broadband connectivity (peak demand) UL, Speed – sustained demand
Test Case 2	Speed – sustained demand DL, Broadband connectivity (peak demand) DL, Speed – sustained demand
Test Case 3	Speed – sustained demand UL, Broadband connectivity (peak demand) UL, Speed – sustained demand
Test Case 4	Speed – sustained demand DL, Broadband connectivity (peak demand) DL, Speed – sustained demand

4.13.3 Test Case Blueprint & Execution results

Table 79: Media & Entertainment (Spain) UC6.1-3 - Low Level Test Case 1

Test Case 1	
Test Name:	End User Video UDP TCP tests in single UE
Test Objective:	For different types or UE types and client's concurrency, observe the peak and sustained performance supported by the video service. Application metrics: Traffic DL and UL for different concurrency Target KPI: "Speed - sustained demand" and "Broadband connectivity (peak demand)" In this case we want to understand the sustained and peak concurrency for several terminals.
Test Prerequisites:	One or more 5G Smartphones and one 5G FastMile Gateway 5G radio coverage in optimal laboratory conditions The measures are stored in the vMEC KPI Application, and a mechanism will have to be implemented to propagate this metric to the Kafka bus. The measures will be then published in Kaftka from the application.

Required Capabilities:	In the hosting site we will need:
	• Compute capacity at MEC to host the two applications
	  ○ KPI & Measurements.
	  ○ Application Video Ingestion
	• Full 5G network: access + EPC

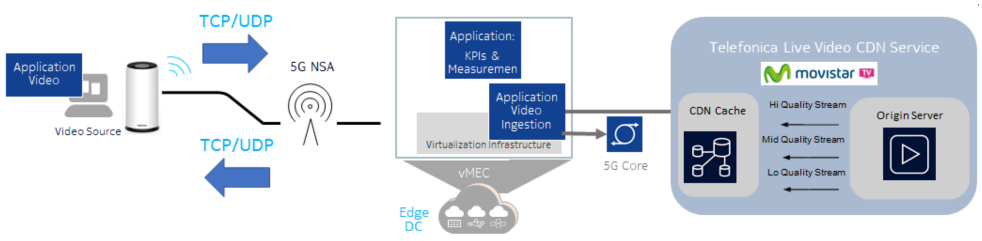
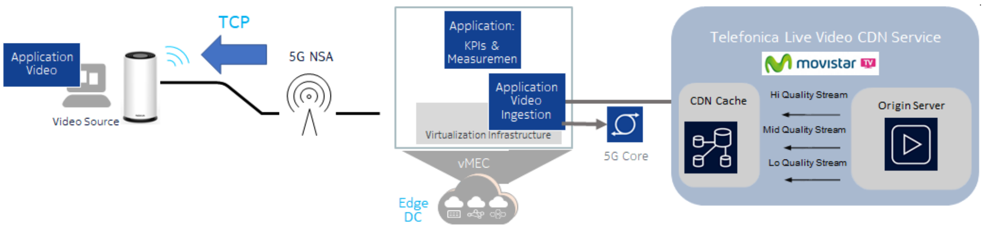
	Test Topology:	 End User Video UDP TCP tests in single UE The selected UE, in this case maybe the Nokia FastMile 5G Gateway, is connected to the 5G network. The KPI and Application Video Ingestion are deployed at vMEC, so several tests could be executed.
	Test Variables:	The following could be changed during the test executions: • UE IP: To launch the test against several terminals • UE Name: To identify the terminal tested • Sockets: To define the concurrency level of the sockets • Seconds: To define the duration of the test, that can be different for peak and for sustained tests.
Sub-Case 1	**Test Procedure:**	**Deployment**: virtualized applications should be deployed real time as part of this phase. **Procedure**: after deployment, the test phase should start running Initial test duration “Seconds” = 60 seconds, initial “Sockets” = 1 socket Loop*: run experiment for sockets: 5, 10, 15, 20, 40 Loop*: Run experiment for duration 300 seconds and 3600 seconds Loop*: run experiment for all the terminals: UE IP, UE Name **Monitoring**: real time data results will be sent to the Kafka bus in order to have real-time results during the tests runs.
	Expected results:	Once all the loops are finalized, all the measurements and results will be available in the system and then can be identified the specified threshold for each test environment. If all the values are lower than the threshold, the result will be PASS, if at least one value is higher, the result will be FAIL. The test report should include the graphics “Speed - sustained demand” and “Broadband connectivity (peak demand)” plus the result (PASS/FAIL), and the concurrency and KPIs values and the thresholds.

Table 80: Media & Entertainment (Spain) UC6.1-3 - Low Level Test Case 2

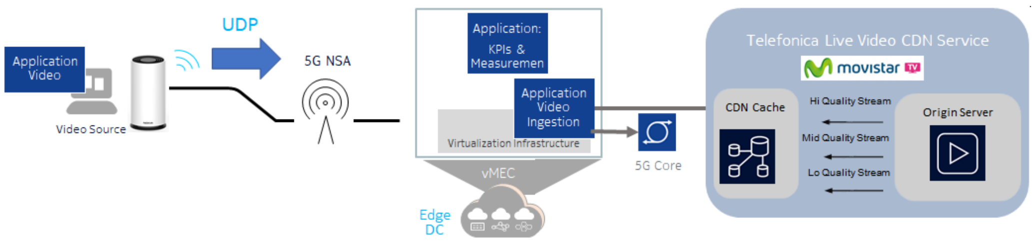
Test Case 2	
Test Name:	End User TCP Download tests in single UE
Test Objective:	For different types or UE types and client’s concurrency, observe the peak and sustained performance supported by the video service. Application metrics: Traffic TCP DL for different concurrency

<table>
<tr><td colspan="2"></td><td>Target KPI: “Speed - sustained demand” and “Broadband connectivity (peak demand)”
In this case we want to understand the sustained and peak concurrency for several terminals.</td></tr>
<tr><td colspan="2">Test Prerequisites:</td><td>One or more 5G Smartphones and one 5G FastMile Gateway
5G radio coverage in optimal laboratory conditions
The measures are stored in the vMEC KPI Application, and a mechanism will have to be implemented to propagate this metric to the Kafka bus. The measures will be then published in Kaftka from the application.</td></tr>
<tr><td colspan="2">Required Capabilities:</td><td>In the hosting site we will need:
Compute capacity at MEC to host the two applications
KPI & Measurements.
Application Video Ingestion
Full 5G network: access + EPC</td></tr>
<tr><td rowspan="3">Sub-Case 1</td><td>Test Topology:</td><td>

End User TCP Download tests in single UE
The selected UE, in this case maybe the Nokia FastMile 5G Gateway, is connected to the 5G network. The KPI and Application Video Ingestion are deployed at vMEC, so several tests could be executed.</td></tr>
<tr><td>Test Variables:</td><td>The following could be changed during the test executions:
UE IP: To launch the test against several terminals
UE Name: To identify the terminal tested
Sockets: To define the concurrency level of the sockets
Seconds: To define the duration of the test, that can be different for peak and for sustained tests.</td></tr>
<tr><td>Test Procedure:</td><td>Deployment: virtualized applications should be deployed real time as part of this phase.
Procedure: after deployment, the test phase should start running
Initial test duration “Seconds” = 600 seconds, initial “Sockets” = 10 socket
Loop*:
run experiment for sockets: 10, 20, 40
Loop*:
Run experiment for duration 3600 seconds and 36000 seconds
Loop*:
run experiment for all the terminals: UE IP, UE Name
Monitoring: real time data results will be sent to the Kafka bus in order to have real-time results during the tests runs.</td></tr>
</table>

<table>
<tr><td></td><td>Expected results:</td><td>Once all the loops are finalized, all the measurements and results will be available in the system and then can be identified the specified threshold for each test environment. If all the values are lower than the threshold, the result will be PASS, if at least one value is higher, the result will be FAIL.
The test report should include the graphics “Speed - sustained demand” and “Broadband connectivity (peak demand)” plus the final result (PASS/FAIL), and the concurrency and KPIs values and the thresholds.</td></tr>
</table>

Table 81: Media & Entertainment (Spain) UC6.1-3 - Low Level Test Case 3

<table>
<tr><th colspan="3">Test Case 3</th></tr>
<tr><td colspan="2">Test Name:</td><td>End User UDP Video Upload tests</td></tr>
<tr><td colspan="2">Test Objective:</td><td>For different types or UE types and client’s concurrency, observe the peak and sustained performance supported by the video service.
Application metrics: Traffic UDP UL for different concurrency
Target KPI: “Speed - sustained demand” and “Broadband connectivity (peak demand)”
In this case we want to understand the sustained and peak concurrency for several terminals.</td></tr>
<tr><td colspan="2">Test Prerequisites:</td><td>One or more 5G Smartphones and one 5G FastMile Gateway
5G radio coverage in optimal laboratory conditions
The measures are stored in the vMEC KPI Application, and a mechanism will have to be implemented to propagate this metric to the Kafka bus. The measures will be then published in Kaftka from the application.</td></tr>
<tr><td colspan="2">Required Capabilities:</td><td>In the hosting site we will need:
Compute capacity at MEC to host the two applications
KPI & Measurements.
Application Video Ingestion
Full 5G network: access + EPC</td></tr>
<tr><td rowspan="2">Sub-Case 1</td><td>Test Topology:</td><td>

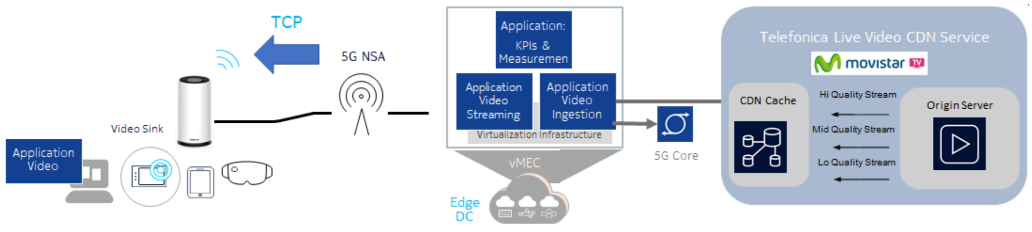
End User UDP Video Upload tests
The selected UE, in this case maybe the Nokia FastMile 5G Gateway, is connected to the 5G network. The KPI and Application Video Ingestion are deployed at vMEC, so several tests could be executed.</td></tr>
<tr><td>Test Variables:</td><td>The following could be changed during the test executions:
UE IP: To launch the test against several terminals
UE Name: To identify the terminal tested
Sockets: To define the concurrency level of the sockets</td></tr>
</table>

		• Seconds: To define the duration of the test, that can be different for peak and for sustained tests.
	Test Procedure:	**Deployment**: virtualized applications should be deployed real time as part of this phase. **Procedure**: after deployment, the test phase should start running Initial test duration "Seconds" = 600 seconds, initial "Sockets" = 10 socket Loop*: run experiment for sockets: 10, 20, 40 Loop*: Run experiment for duration 3600 seconds and 36000 seconds Loop*: run experiment for all the terminals: UE IP, UE Name **Monitoring**: real time data results will be sent to the Kafka bus in order to have real-time results during the tests runs.
	Expected results:	Once all the loops are finalized, all the measurements and results will be available in the system and then can be identified the specified threshold for each test environment. If all the values are lower than the threshold, the result will be PASS, if at least one value is higher, the result will be FAIL. The test report should include the graphics "Speed - sustained demand" and "Broadband connectivity (peak demand)" plus the final result (PASS/FAIL), and the concurrency and KPIs values and the thresholds.

Table 82: Media & Entertainment (Spain) UC6.1-3 - Low Level Test Case 4

Test Case 4	
Test Name:	End User Video Download tests in single UE
Test Objective:	For different types or UE types and client's concurrency, observe the peak and sustained performance supported by the video service. Application metrics: Traffic Video DL for different concurrency Target KPI: "Speed - sustained demand" and "Broadband connectivity (peak demand)" In this case we want to understand the sustained and peak concurrency for several terminals.
Test Prerequisites:	One or more 5G Smartphones and one 5G FastMile Gateway 5G radio coverage in optimal laboratory conditions The measures are stored in the vMEC KPI Application, and a mechanism will have to be implemented to propagate this metric to the Kafka bus. The measures will be then published in Kaftka from the application.

Required Capabilities:	In the hosting site we will need:
	• Compute capacity at MEC to host the two applications
	  ○ KPI & Measurements.
	  ○ Application Video Ingestion
	• Full 5G network: access + EPC

<table>
<tr>
<td rowspan="4">Sub-Case 1</td>
<td>Test Topology:</td>
<td>


End User Video Download tests in single UE

The selected UE, in this case maybe the Nokia FastMile 5G Gateway, is connected to the 5G network. The KPI and Application Video Ingestion are deployed at vMEC, so several tests could be executed.
</td>
</tr>
<tr>
<td>Test Variables:</td>
<td>
The following could be changed during the test executions:

UE IP: To launch the test against several terminals
UE Name: To identify the terminal tested
Sockets: To define the concurrency level of the sockets
Seconds: To define the duration of the test, that can be different for peak and for sustained tests.

</td>
</tr>
<tr>
<td>Test Procedure:</td>
<td>
Deployment: virtualized applications should be deployed real time as part of this phase.
Procedure: after deployment, the test phase should start running
Initial test duration “Seconds” = 600 seconds, initial “Sockets” = 10 socket
Loop*:
run experiment for sockets: 10, 20, 40
Loop*:
Run experiment for duration 3600 seconds and 36000 seconds
Loop*:
run experiment for all the terminals: UE IP, UE Name
Monitoring: real time data results will be sent to the Kafka bus in order to have real-time results during the tests runs.
</td>
</tr>
<tr>
<td>Expected results:</td>
<td>
Once all the loops are finalized, all the measurements and results will be available in the system and then can be identified the specified threshold for each test environment. If all the values are lower than the threshold, the result will be PASS, if at least one value is higher, the result will be FAIL.
The test report should include the graphics “Speed - sustained demand” and “Broadband connectivity (peak demand)” plus the final result (PASS/FAIL), and the concurrency and KPIs values and the thresholds.
Other measures that will be generated during the test and that will be available for Vertical analysis will be the following:
<table>
<tr><th>Measurement File</th><th>Type</th><th>Measures</th></tr>
<tr><td>http.log</td><td>Real time per request</td><td>End User Application information for Multimedia</td></tr>
<tr><td>MeasureIngressSpeed.log</td><td>Real time period 10 seconds</td><td>Multimedia Live Video Channels ingress in MEC</td></tr>
<tr><td>hostname.dat, net.csv, disk.csv, cpu.csv</td><td>Real time period 10 seconds</td><td>MEC 5G VNF information</td></tr>
<tr><td>procs.csv</td><td>Real time period 10 seconds</td><td>MEC 5G VNF Application information</td></tr>
<tr><td>UDP_Latency.csv</td><td>Real time period 1 seconds</td><td>UDP Latency</td></tr>
<tr><td>TCP_Latency.csv</td><td>Real time period 1 seconds</td><td>TCP Latency</td></tr>
</table>
</td>
</tr>
</table>

4.13.4 Pilot Initial validation status

As already stated, the first validation phase for this UC will be done at 5TONIC, not integrated with the platform. These initial validation activities have not been executed yet, due to the situation caused by COVID19. These will be included in future WP2 Deliverables, together with the integration activities (in particular, the descriptors resulting from the required blueprints).

4.13.5 Summary & next steps

We are proceeding in our work for the Use Case integration in 5G EVE and 5TONIC [30]. Currently, the plan is divided in three main testing cycles:

- By M24: make sure we have everything ready to deploy an experiment related to the test of the four test cases, defining its blueprints, descriptors and other required information. Follow the complete 5G EVE workflow for completing the experiment, probably in an off-line basis, using the components already integrated in the project.
- Between M24 and M30: after validating the execution of one test case, replicate the 5G EVE workflow for the rest of test cases, using the 5G EVE tools available for automating the process as much as possible.
- Between M30 and M36: repeat the test with the last version of the 5G EVE platform. Final validation and report in D2.5.

4.14 Use Case 6.4 - Media & Entertainment: Virtual visit over 5G

Some physical places, such as houses and popular touristic places, provide limited access to potential visitors. In this scenario a virtual visit is proposed to relax this limitation.

Buying or renting houses or apartment is not immediate and visiting many of them is usually required before finding the lovely one. A very good experience of 360° video with a virtual reality headset could be the starting point for deploying this service at large scale. Moreover, virtual visitors (i.e., potential buyers) do not have time to waste waiting for the download of large 360° video content to finish. Therefore, we advocate the use of video streaming to quickly start a virtual visit and to quickly swap from one virtual visit to another. This use-case, showing this service, should then rely on a very high performing physical network.

4.14.1 Pilot execution context

The video 360° Use Case promotes eMBB and URLLC scenario with high data rates and low latency requirements. The main objective is to contribute to the identification of application-layer performance metrics relevant to a 360° video streaming service as well as to the identification of 5G performance metrics that are expected to be the key drivers for the performance 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 as depicted in Figure 81.

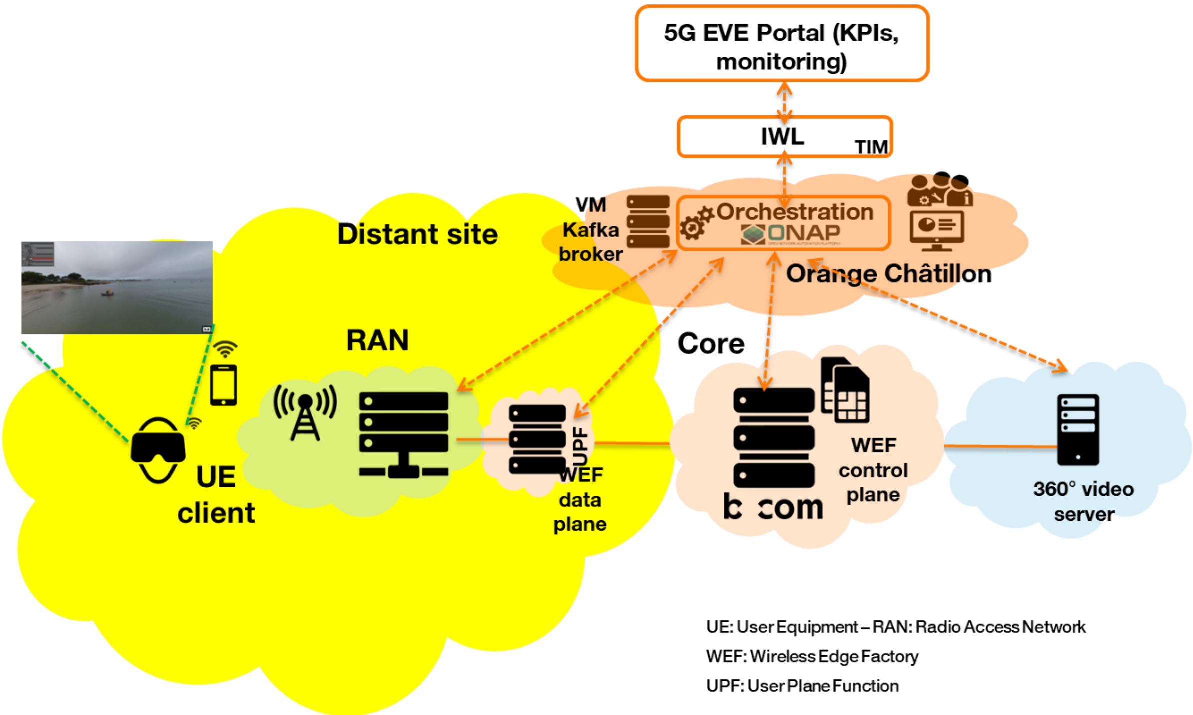


Figure 81: Media & Entertainment (France) UC6.4 - Architecture overview

The E2E video 360° Use Case follows the general workflow process that has been specified in the 5G EVE project, starting from the portal, where the vertical defines his experiment and the tests he wants to execute. The video server can be deployed close or far from the UE. We made the choice to deploy it first at the same place of the Wireless Edge Factory (WEF) control plane whereas the data plane is close to the RAN. Figure 82 describes the UE equipment (Head Mounted Display + graphical card) and the components constituting the video server VNF.

The video service is integrated within the network infrastructure composed of the CORE and RAN parts. The CORE is implemented via the WEF [59] instance**,** composed of its control plane that could be distant from its data plane, which in turn is locally instantiated close to the UE. The RAN part is based on open source OAI [59] code, which is currently based on LTE but will move on 5G NR very soon. The video server and the CORE components are available as VNF and on boarded in ONAP [49] for their automatic deployment. In the first experimentation, the RAN is manually deployed but will be very soon available as PNF/CNF.

The objective of the experimentation is to evaluate the impact of the delay and the bandwidth on the video quality. The main KPIs are directly measured at the application layer. Their monitoring will be correlated with the QoE of the user carrying the HMD.

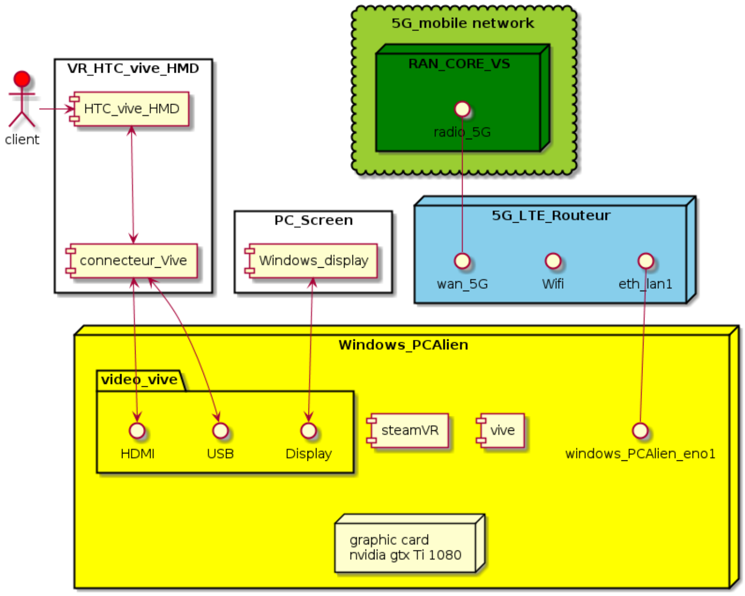


Figure 82: Media & Entertainment (France) UC6.4 - UE definition

Figure 82 illustrates the UE terminal that is composed of:

- The HTC Vive HMD client that is connected to one gamer PC integrating one graphical card. The HMD is plugged to the PC via its HDMI port (for the video streaming content) and to the USB port (for the feedback on positioning information of the user in the room). We can also visualize the video content on a PC screen that is the same content of the scene shown in the HMD (Right and left eyes).
- The PC alien is connected to the Ethernet port 4G/5G router via its Ethernet connector making the "bridge" with the radio 4G/5G.
- The LTE/5G router receives via radio the video content transmitted from the RAN gNodeB, itself connected to the WEF control plane and the Video Server (VS).
- The PC alien is also used to measurement metrics at the UE side, like throughput, delay, buffer occupancy, etc. The measurements are pulled-up to the Kafka broker, located in Orange Châtillon in a specific VM, via the video server using the radio UL transmission.

4.14.1.1 Actors

Vertical

The video 360° Use Case is proposed by ORA-FR, who provides all the different video content, the video server as well as the UE equipment.

VNF provider(s)

The VNF of the video server is provided by ORA-FR. It has been on boarded on the ONAP orchestrator with the help of ORA-PL.

The WEF VNFs have been provided by B-COM and on boarded by ORA-FR and ORA-PL.

The OAI vEPC and RAN VNFs have been provided by ORA-RO.

Experiment developer(s)

ORA-FR is the experiment developer who is in charge of providing all the VSD and NSD files.

Experimenter(s)

ORA-FR is the experimenter too. He is in charge of providing the test case execution context and the analysis of the performance results.

Site Manager(s)

ORA-FR is the site manager of the French site. It will manage the network infrastructure availability and the VNF components deployment with the support of the distant French site. In our video 360° Use Case deployment, the B-COM site is hosting the experiment.

4.14.1.2 Planning & Status

Compared to what was planned in D2.6 [6], the objectives of the experiment were not significantly changed. The impact of the delay and the bandwidth (data throughput) on the video 360° service are the two main KPIs we want to analyse on the user's experience. For achieving that objective, the parameters variations are directly applied at the application video server and the measured metrics are pushed to the Kafka broker via the Ansible playbooks integrated in the video server VNF.

Our first deployment is carried out in the B-COM site facility, by deploying the RAN, CORE (WEF data plane) and the video server in B-COM site, whereas the WEF control part will be deployed in a distant site. We have upgraded the WEF release in V1.3 that allows us to improve the management between the data and control planes. After having validated the E2E process in the B-COM site, we plan to iterate the deployment in the Nokia and Eurécom sites.

CORE and Video Server VNFs are on boarded on ONAP [49] and can be deployed/managed from the ONAP Orange Châtillon orchestrator. CNF/PNF RAN will follow very soon.

Of course, for the success of the E2E integration, the interconnection between the IWL and the ONAP orchestrator located in Orange Châtillon has been implemented and the VPN tunnel between the two sites is up and operational. We succeed to reach around 100 Mbps in UDP traffic transmission and less than 35 ms as ping delay.

In order to be able to manage the deployment in the French cluster, we have implemented in our French site facility one supervision tool that allows us to give the status of the reachability of the different French sites facilities (B-COM, Eurécom and Nokia) from Orange Châtillon as well as the network status with the IWL. Some periodic tests are carried out informing us about network infrastructure availability.

Our plans are totally in phase with what has been depicted in Fig.56 in D2.6 [6].

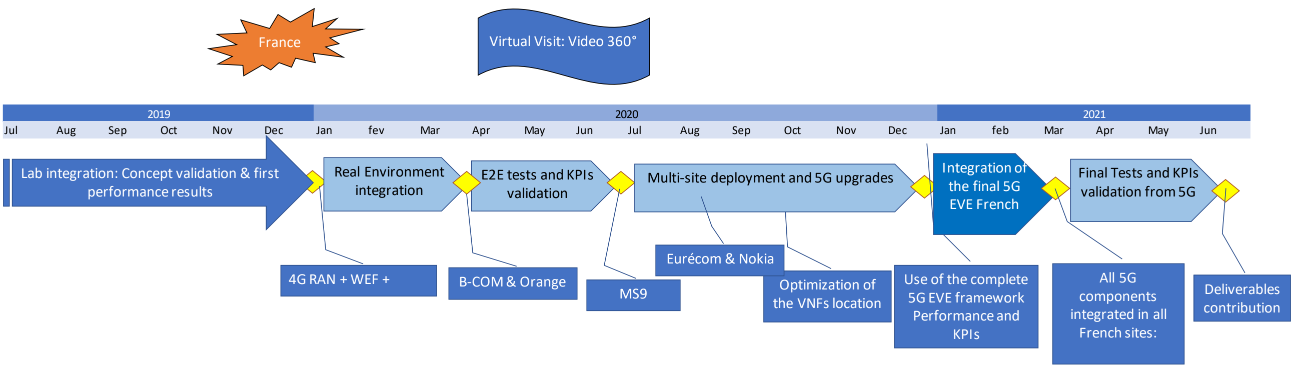


Figure 83: Media & Entertainment (France) UC6.4 - Roadmap

4.14.2 Pilot architecture

The two sub-Use Cases defined will run on top of a 4G/5G network, executing a virtual video service that can be deployed in MEC or cloud environment. In that case, the video server is deployed within the 5G EVE French site facility that provides the network infrastructure and the connectivity. In the first experiment only one end-user device (HMD composed of a PC alien) is considered.

According to this, the following diagram shows the infrastructure implemented in French 5G EVE facility.

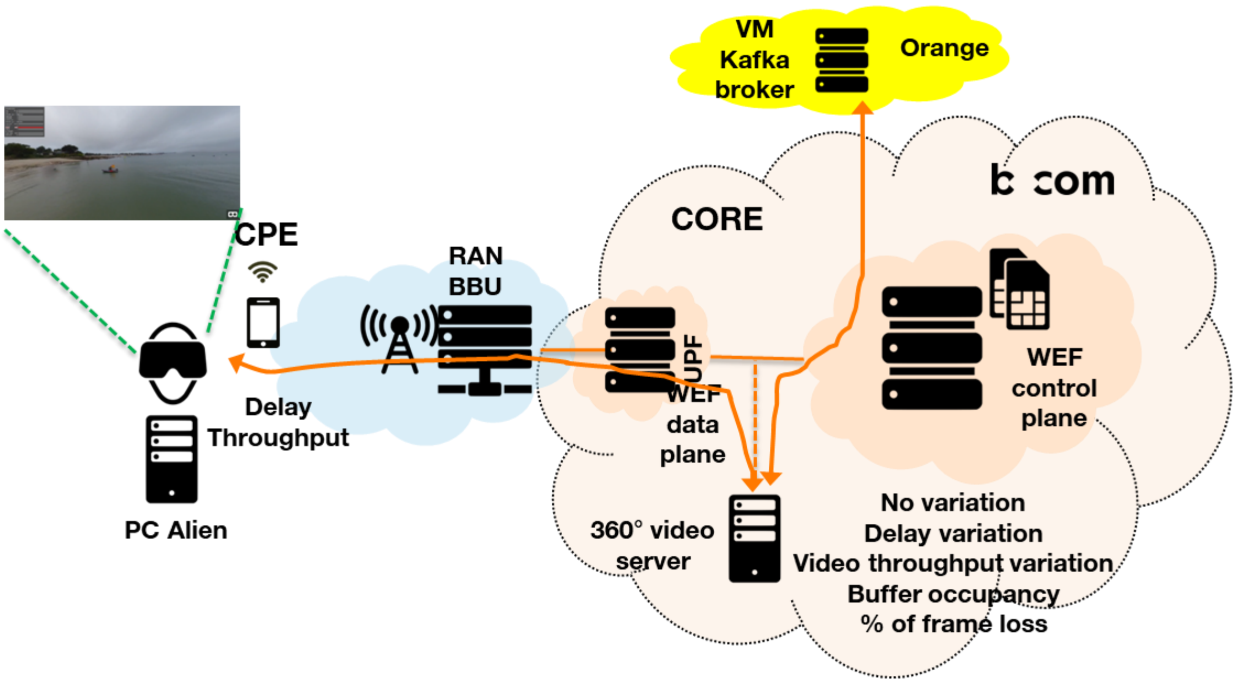


Figure 84: Media & Entertainment (France) UC6.4 - Implemented network architecture

The device (HMD) is connected to the CPE (or router) via Ethernet connection. The CPE is 5G/4G capable and can connect to the LTE RAN solution. Once the connection is established, data is sent through Radio and the RAN is connected to the CORE network based on the WEF solution. The video server is connected to the WEF on its GWu interface (Gi interface).

Metrics are measured at the device side, such as the data throughput and the delay (between the device and the video server). At the video server side, we plan to adjust/parametrize the video stream in delay and throughput to show the impact of the video service. The performance will be compared to "no variation" parameters adding. We plan also to monitor the buffer occupancy at the video server side that allows us to compare the transmitted video stream data throughput with the received one. The percentage frame loss is also evaluated to inform about the video quality of transmission that will be correlated to the user's experience. All these metrics (at UE and video server sides) are forwarded from the video server towards the Kafka broker to be monitored by the portal. The Ansible playbook is implemented in the video server for sharing all these parameters.

In deliverable D5.2 [15], the 3 main video 360° test plans have been presented and are summarized in the following tables. More technical details are given in Section 4.14.3by the Low Level Test Cases defined for each test case.

Table 83: Media & Entertainment (France) UC6.4 - Test Case 1 – without perturbation

Test Case 1	
Test Name:	Video service without any perturbation
Target KPI:	Reference delay between the video server and the UE

	Reference throughput measured at the UE side
Measurement Method:	Delay measurement (ping) between the video server and the UE (client). Video throughput measured at UE side
Parameters:	Video server at the same location as the GWu
Validation Conditions:	Good video quality, no frame retransmission, video buffer occupancy empty (radio transmission at the same scheduling as the video server transmission)

Table 84: Media & Entertainment (France) UC6.4 - Test Case 2 - delay variation

Test Case 2	
Test Name:	Effect of delay in video service quality (Nausea Level or operational video service)
Target KPI:	Max time delay of supporting the video scene (without nauseaor operational video service)
Measurement Method:	Delay measurement (ping) between the video server and the UE (client). Video server to be deported in different locations (same place as UE or MEC)
Parameters:	Variation of the delay applied at the video server side
Validation Conditions:	Delay value will be considered acceptable until the Nausea Level appears or bad video service quality

Table 85: Media & Entertainment (France) UC6.4 - Test Case 3 - Throughput variation

Test Case 3	
Test Name:	Effect of the throughput in video service quality (Nausea Level)
Target KPI:	Min throughput for supporting VR video 360° (without nausea or operational video service)
Measurement Method:	Measurement of the data throughput at the UE side and comparison with the video throughput at the video server side
Parameters:	Variation of the data throughput applied at the video server side
Validation Conditions:	Data throughput value will be considered acceptable until the Nausea Level appears or bad video service quality % of lost frames Video buffer occupancy monitoring

The list of 4G/5G KPIs to be covered in the different test cases are the following:

Table 86: Media & Entertainment (France) UC6.4 - meaningful KPIs

5G related KPIs	**Is it measurable during experimentation?**	**Validation Condition**
E2E Latency	*Yes*	*Vertical specification*
E2E Jitter	*Optional*	*Vertical specification*
Download data rate	*Yes*	*At least, consistent 20Mbps per user are expected*

Download peak data rate	*Optional*	*Vertical specification*
Vertical KPIs	**Is it measurable during experimentation?**	**Can it be mathematically derived from 5G related KPIs?**
Video transmission delay	*Yes*	*No mathematical formula known*
Video data throughput	*Yes*	*No mathematical formula known*
Video buffer occupancy	*Yes*	*No mathematical formula known*

VSB, CB and ExpB

VSB: the Vertical Service Blueprint is a description of the architecture components, with the identification of the different endpoints (reference points) between the components. The VSB of the French video 360° Use Case is available at [57].

In Figure 85, as you may notice, the video server in the architecture is described in the VSB as atomic component.

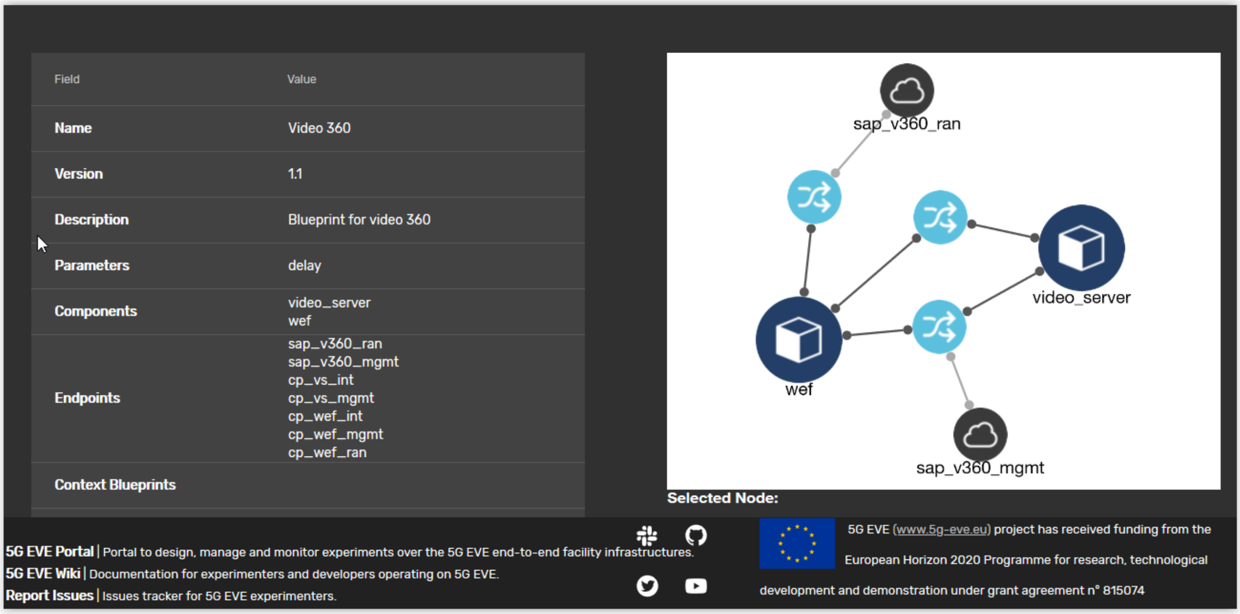


Figure 85: Media & Entertainment (France) UC6.4 - VSB

CB: The context blueprint of the virtual visit over 5G Use Case corresponds to the component concerned by an experiment, in this first CB of this Use Case the experiment is, for instance, adding a video delay variation. The CB is available at [58], the experiments by defining the amount of throughput, the unit (in ms), the endpoints and the sites where this experiment is available (in this case France Rennes and France_Lannion). Delay is one of the parameters.

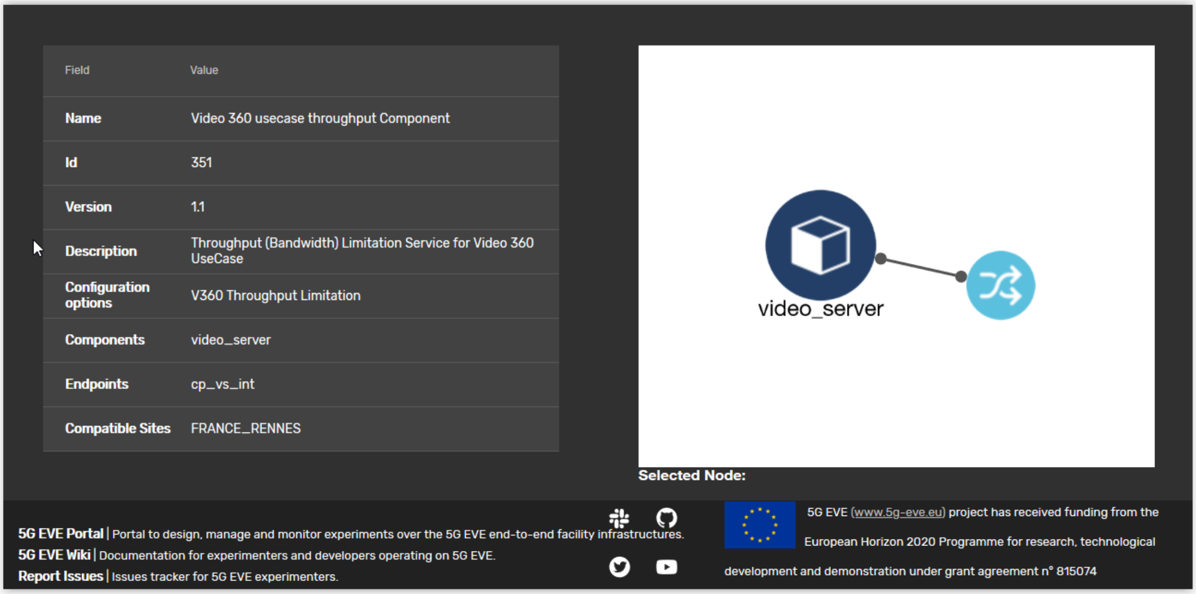


Figure 86: Media & Entertainment (France) UC6.4 – CB

ExpB: the Experiment Blueprint is a high level representation of an experiment. As already mentioned, we plan to make some variations of the delay and bandwidth in some specific ranges. When configuring the variation of the delay, the ExpB also contains the metric involved, which is the measurement of the latency and the related VSB, CB and TCB. Our set-up considers only one single user.

The ExpB file is show in Figure 87.

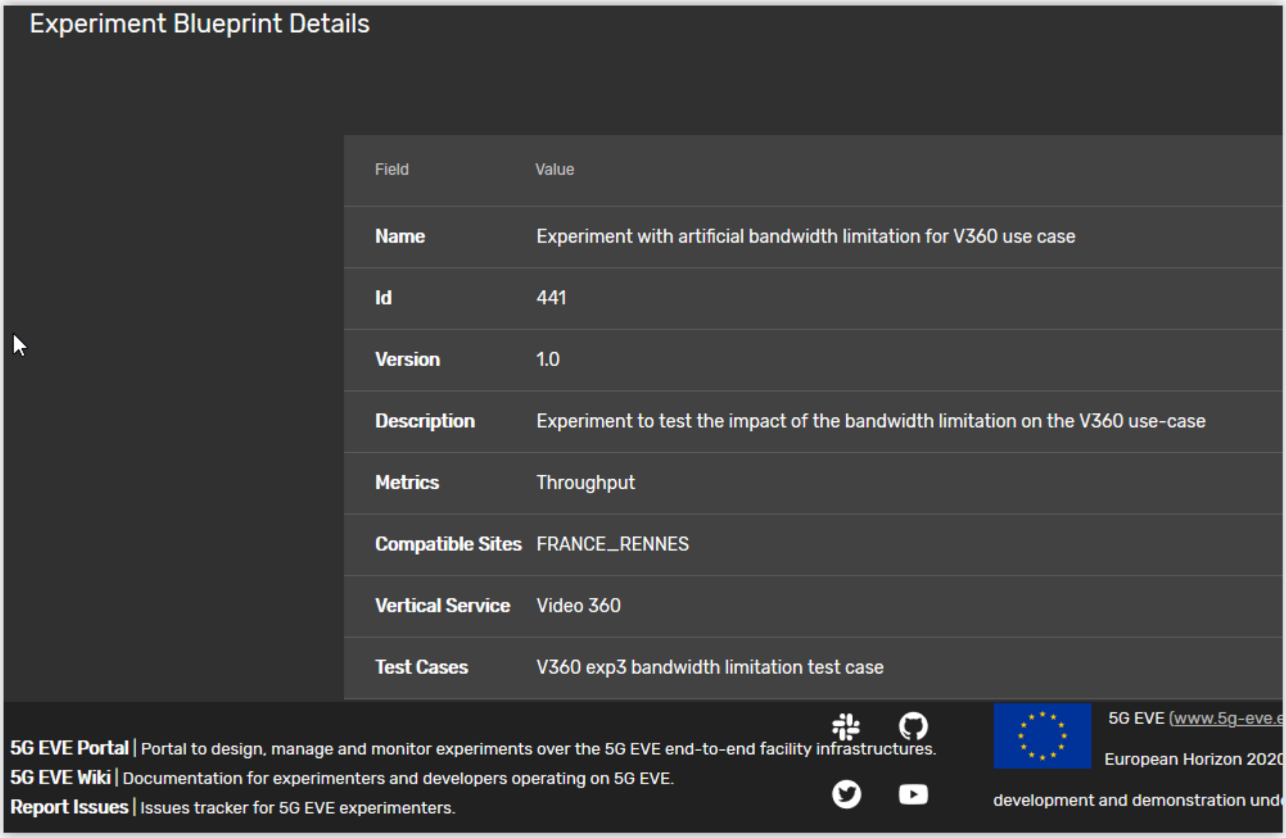


Figure 87: Media & Entertainment (France) UC6.4 - ExpB

Some VNFs are especially used in this architecture design. We propose to describe them in a technical way (see Annex C).

4.14.3 Test Case Blueprint & Execution results

Table 87: Media & Entertainment (France) UC6.4 - Low Level Test Case 1

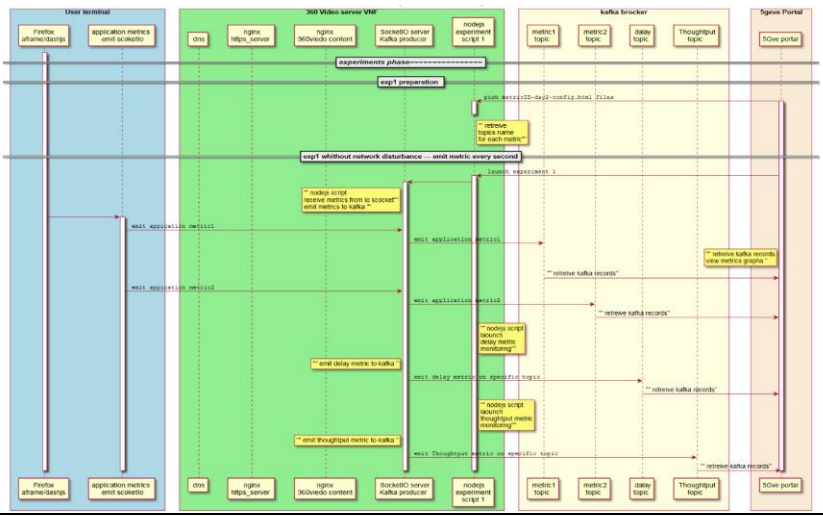
Test Case 1		
Test Name:		Video service without any perturbation
Test Objective:		Measure the network latency and data throughput without any perturbation applied at the video server side.
Test Prerequisites:		-
Required Capabilities:		Video server at the same location as the UE, VR device, 4G/5G network infrastructure.
Sub-Case 1	**Test Topology:**	The callflow (especially for the KPIs collection in Kafka broker) is illustrated in the following diagram. 
	Test Variables:	None.
	Test Procedure:	To launch the video transmission without applying any disturbance. Measure at the UE the data throughput and latency (via ping from the UE to the video server). Send the KPIs back to the video server (in radio UL) that will publish the metrics to the Kafka broker via Ansible playbook
	Expected results:	At least data throughput at the same schedule as the transmitted video stream with latency compatible with no nausea phenomena

Table 88: Media & Entertainment (France) UC6.4 - Low Level Test Case 2

Test Case 2	
Test Name:	Video service with delay variation
Test Objective:	Measure the network latency and data throughput with appliance of delay perturbation applied at the video server side.
Test Prerequisites:	-

<table>
<tr><td colspan="2">Required Capabilities:</td><td>Video server at the same location as the UE, VR device, 4G/5G network infrastructure.</td></tr>
<tr><td rowspan="4">Sub-Case 1</td><td>Test Topology:</td><td>The callflow with delay variation (especially for the KPIs collection in Kafka broker) is illustrated in the following diagram.

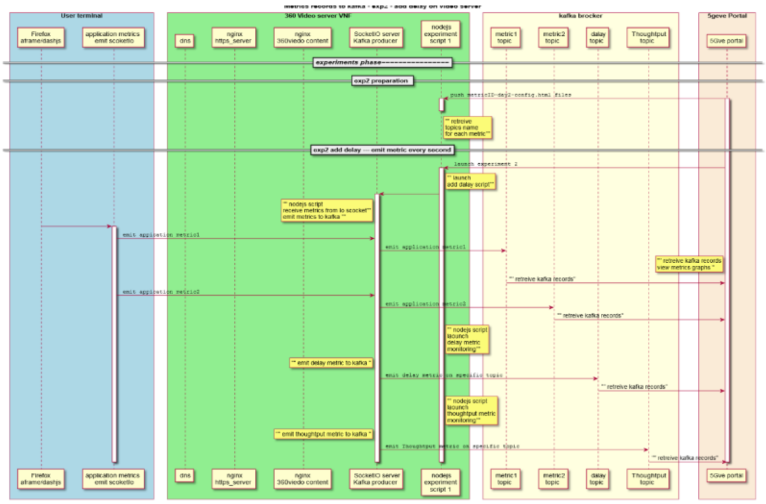
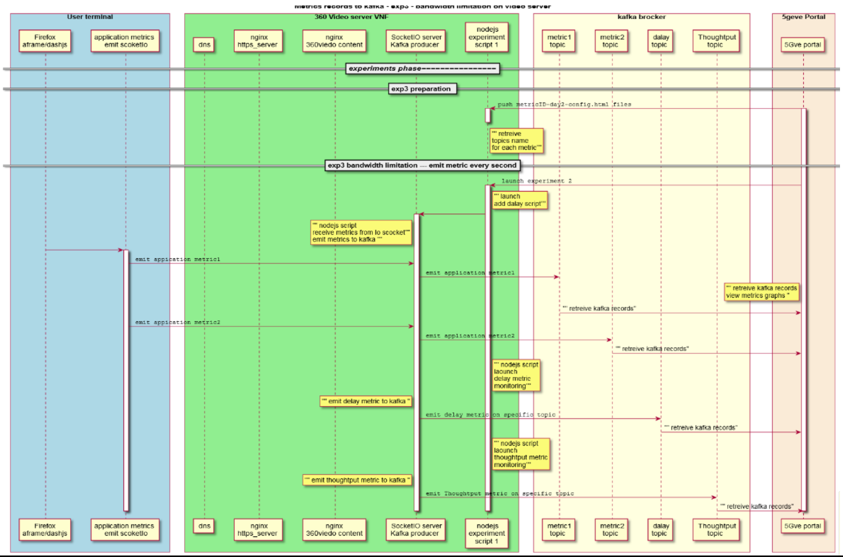

</td></tr>
<tr><td>Test Variables:</td><td>Delay at video server.</td></tr>
<tr><td>Test Procedure:</td><td>To launch the video transmission with applying different delay values. Measure at the UE the data throughput and latency (via ping from the UE to the video server). Send the KPIs back to the video server (in radio UL) that will publish the metrics to the Kafka broker via Ansible playbook</td></tr>
<tr><td>Expected results:</td><td>Good video QoS and QoE. Determine the threshold of delay that is acceptable at the UE side (quality of the video stream, number of frames lossed, nausea phenomena apparition, jerky images …).</td></tr>
</table>

Table 89: Media & Entertainment (France) UC6.4 - Low Level Test Case 3

<table>
<tr><th colspan="3">Test Case 3</th></tr>
<tr><td colspan="2">Test Name:</td><td>Video service with throughput variation</td></tr>
<tr><td colspan="2">Test Objective:</td><td>Measure the network latency and data throughput with appliance of data throughput perturbation applied at the video server side.</td></tr>
<tr><td colspan="2">Test Prerequisites:</td><td>-</td></tr>
<tr><td colspan="2">Required Capabilities:</td><td>Video server at the same location as the UE, VR device, 4G/5G network infrastructure.</td></tr>
<tr><td>Sub-Case 1</td><td>Test Topology:</td><td>The callflow with video throughput variation (especially for the KPIs collection in Kafka broker) is illustrated in the following diagram.</td></tr>
</table>

		
	Test Variables:	Video throughput variation at the video server.
	Test Procedure:	To launch the video transmission with applying different video throughput values. Measure at the UE the data throughput and latency (via ping from the UE to the video server). Send the KPIs back to the video server (in radio UL) that will publish the metrics to the Kafka broker via Ansible playbook
	Expected results:	Good video QoS and QoE. Determine the threshold of throughput that is acceptable at the UE side (quality of the video stream, number of frames lossed, nausea phenomena apparition, jerky images …).

4.14.4 Pilot Initial validation status

As already described above, all the test case execution blueprints have been on boarded in the 5G EVE portal. All the VNF are ready and can be deployed automatically (except the PF RAN) from ONAP. Currently we are making the initial tests for VNF deployment from the multi-orchestrator part located at the IWL to ONAP Châtillon.

The different scripts that aim at being launched from the portal are also ready to run the experiment. However, the link validation between the portal (in operational mode installed in Turin at the IWL) and the multi-orchestrator is ongoing. This what does not allow us to fully validate the E2E framework and report it in this document.

However, the video server VNF is managing the KPIs collection and can forward the metrics to the Kafka [56] broker implemented in Châtillon. This has been validated as depicted in Figure 88 in a light example of data collection. Among the infrastructure metrics, we can measure the delay and data throughput video transmission. For the UC KPIs, delay, data throughput, frames loss, video buffer occupancy can be monitored too.

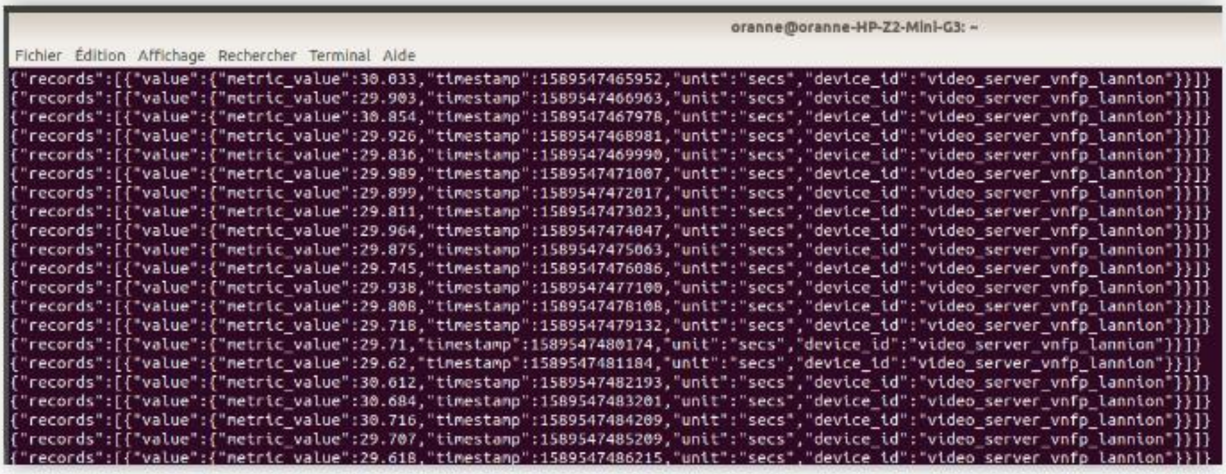


Figure 88: Media & Entertainment (France) UC6.4 – Recorded Kafka measurement values.

The Use Case has been locally tested in the French site facility by deploying and testing it. So, it is ready to be integrated and operated in the whole 5G EVE E2E infrastructure. We plan to make the first performance evaluations beginning of July 2020.

4.14.5 Summary & next steps

The E2E video service integration is operational and ready for testing. As next steps, we plan to deploy the video server in a distributed cloud that is reached by the different French site facilities independently and evaluate the impact regarding its location and then establishing a distributed service where the video server could be shared between sites and/or installed locally as MEC. Also, we propose to test the service using 5G RAN and CORE, with more than 1 user. 5G Nokia is available in Paris Saclay (as deployed for the EDF UC) and the deployment automation in their site is ongoing (first tests are successful). The Open Source 5G NR OAI-RAN is planned to be integrated before the end of this year by using Eurecom Openshift framework (automatic deployment of CNF/VNF from ONAP to Openshift [63]).

Another point could be also to deploy the video service in outdoor environment in all the 3 different French sites (B-COM, Nokia and/or Eurécom)

4.15 Use Case 6.5 - Media & Entertainment: High-quality multi-site gaming experience

The gaming scenario of UC6.5 was introduced in the project at the beginning of 2020. This means that the scenario has not been described in previous project Deliverables. Maintaining the structure of other Deliverables in WP2, the following introductory paragraphs present initial considerations regarding this experiment.

Within 5G EVE, the gaming Use Case utilizes the 5G EVE infrastructures to deliver a next-generation volumetric media streaming service. The goal is to exploit the advances in the 5G network's softwarization and virtualization to deploy an efficient, effective and self-managing media streaming service for emerging types of media that will leverage novel network service deployment, management, and operational paradigms.

Storyline

In summary, the UC context is a new generation gaming experience that places playing users (denoted as players for the rest of this document) within the game virtual environment through a synthetic virtual representation. This is achieved through the generation of a live 3D media stream for each player.

This Use Case demonstrates a real-time interactive media application where the two players are interacting with each other in a common virtual gaming environment through a digitized virtual representation (i.e. textured 3D shapes). In addition, this gaming application allows for the live spectating of each gaming session by remote third-party users (denoted as spectators for the rest of this document). Given the nature of the media streams (i.e. full 3D), spectating heterogeneity is large, as it can comprise both 2D view or Virtual Reality (VR) spectators, with spectators that use mobile phones, head-mounted displays and headsets, and even traditional desktop PCs. This type of next-generation media applications comes with new varying consumer requirements that, in turn, necessitate new functionalities and capabilities when being deployed.

Purely from a media perspective, the volumetric appearance representation of live performances comprises a diverse multimedia stream. On one end, the 3D geometry needs to be streamed. This is usually represented in the form of a 3D triangle mesh, which as a result of modern real-time 3D capturing and reconstruction technologies is of time-varying nature. Further, the 3D media stream is accompanied by a multi-view video stream which is used to reconstruct the colored appearance of the users through multi-view mesh texturing.

Finally, it is important to clarify that while the UC involves both players and spectators as end-users, in the scope of 5G EVE, we assume a fixed quality of experience and service cost for the players, while we try to optimize the experience for the spectators under cost constraints, by making proper 5G EVE platform design decisions and taking advantage of them.

Requirements

The limited progress in efficient and effective inter-frame coding of the 3D time-varying meshes, in addition to the increased payload of the color multi-view stream used to texture the 3D mesh, realizes the first requirement of the UC, which is high bandwidth due to the large volume of data to be transmitted. Additionally, to support live broadcasting of the session to spectators, there is a need that the streaming pipeline exhibits low latency timings. Further, supporting heterogeneous spectator clients (i.e. clients of varying processing power, screen resolution, and network conditions) is an additional challenge, as the service needs to support a variety of heterogeneous spectating users simultaneously. The aforementioned requirements for high bandwidth, low latency and heterogeneity in network conditions, processing power and screen resolution at the consumer’s side, imply that there is no one-size-fits-all encoding profile for the immersive media streams. Thus, with current technology and in 5G EVE, fulfilling these demands can only be achieved through an efficient implementation of adaptive streaming.

Based on statistics, in the UC, the interactive sessions between the participants are expected to be short in duration, in the order of minutes. Additionally, a small but respectable number of spectators (in the order of 10 – 50) are expected to join each session to watch the live session. As described in the previous paragraph, to tackle the heterogeneity of the spectators we would need to have varying simultaneous transcoding functions that would transcode the immersive media streams to various qualities. Different encodings require different processing power and different network conditions for optimal end-to-end pipeline performance, in terms of visual quality and latency.

Given the fact that the sessions are expected to be short in duration, it is implied that the transcoding functions are of short duration. Thus, the first requirement that the UC imposes to the 5G EVE platform is to support the dynamic on-demand onboarding and instantiation of the transcoding function during the session.

Further, synchronizing the media streams with the game state metadata requires an increased amount of memory which does not scale well when many gaming sessions are expected to run in parallel. Thus, the architecture with on-demand function instantiation during a game session (apart from session start) can be easily identified as a cost-effective and scalable solution to this specific problem as well. The table Table 90 resumes the identified KPIs for this Use Case.

Table 90: Media & Entertainment (Spain) UC6.5 - meaningful KPIs

5G-EVE KPI	Definition	Specific Targets	Measurement/Assessment
Quality of Experience (QoE)	Metric to trace the perceived quality by the users.	Understand how network congestion affects QoE	Deployment of virtual Probes on strategic sites, where players and spectators exist
Service Monitoring	Ability to define service metrics to monitor performances	Full traceability of the microservice components throughout their lifecycle.	Monitoring offered by the VIM.

4.15.1 Pilot execution context

As already described in section 4.15, the UC service's backbone is the real-time transcoding of the media streams. To realize this, the UC combines the efficient transcoding of the media stream with the dynamic instantiation paradigm to run transcoding (i.e. stateless) functions on the 5G edge for maximum cost savings without compromising quality and scalability. Moreover, the UC utilizes the Service-Specific Cognitive Network Optimizer (SS-CNO) to offer network-centric adaptive streaming to spectators, which is a global optimization method in contrast to traditional and more common, client-based adaptive streaming.

In the following subsections, we describe the service components, application components, workflows, and UC's SS-CNO.

Service Components

The UC comprises a set of VNFs that facilitate its operation. All VNFs in the UC follow the server-less paradigm, with some of them marked as "regular", meaning that they are spawned as server-less functions on session start, while others are marked as "on-demand", implying that they can be instantiated at any point in time during the session.

A summary of the UC VNFs is given below:

- **vTranscoder** (on-demand): This VNF live re-encodes incoming media traffic. The profiles have been solidified to be two produced on CPU that encode textures as still jpeg images. Geometry coding's fidelity also varies with different profiles. The output of vTranscoder VNFs is published in specific topics on vBroker to be consumed by other components.
- **vBroker** (regular): A message broker VNF that is used to facilitate inter-component communication in the UC.
- **vProbe** (regular): This tool provides a QoE metric for the media that is passing through it. It is packaged into a Docker container in order to be deployed into any placement of the workflow.

<u>Application Components</u>

As the UC revolves around a Virtual Reality (VR) game, the game application comprises of three types of components:

Game Server: The Game Server acts as the central managing node of the application responsible for instantiating and controlling the required features, such as automating service deployment. Upon launching, the Game Server handles the service deployment by instantiating the network service in the MANO and configures the VNF instances when the required parameters become available. It is the main module communicating with the MANO and passing generated parameters between the MANO, the instantiated VNFs, and Player Clients and Spectator Clients.

Player Clients: The player client is the application component used by the players in order to join a game hosted by the game server. They are responsible for handling the players' movements, producing 3D media streams and visualizing the game state in order for the players to be able to play.

Spectator Clients: The spectator clients are the application components used by spectators to spectate a game session. Spectator clients can support heterogeneous running conditions such as different types of devices (mobile, desktop, Virtual Reality), consuming transcoded 3D media streams of different qualities and consuming the media streams both live or on-demand, in case of a replay clip. Live spectating is implemented in the same manner implemented for the player clients, consuming the produced media streams via the vBroker in real-time.

Service Optimisation Component

Two variants of the UC service optimization have been developed. The first focuses on optimizing the original version of the UC service that comprises two multi-profile producing transcoding functions and focuses on fine-tuning their resource consumption in terms of profile selection.

However, current billing practices would not allow for finer-grained service cost optimization using this multi-responsibility-based service design. Further, the design itself detracts away from the service development best practices that rely on modular functions under the single responsibility principle. Consequently, the UC transitioned to a design where each transcoding function is responsible for the production of a single profile. This opened up new opportunities for service optimization, and more specifically a cost-oriented approach.

Thus, an updated variant of the UC optimization was developed as an SS-CNO and was designed to fulfil a three-fold role. First, to collect application-specific metrics from spectator clients. Second, to process those metrics globally for each standalone session, spawn new transcoder function instances and terminate existing ones, based on a pre-specified Quality-of-Experience (QoE) – cost trade-off policy. Third, the UC SS-CNO will assign transcoding profiles to spectators, realizing real-time network-centric adaptive streaming.

In summary, the objective of the UC service-specific CNO is to optimize the cost efficiency of each session to eventually maximize profits, while also retaining the serviced QoE levels. To this end, we need to consider revenues and costs. Costs are comprised of fixed production costs and variable costs. Variable costs in our case involve the deployment cost of the transcoders. The revenues can be considered an indirect function of the user QoE through the reasonable assumption that (more) satisfied users will in-turn provide (more) revenue to the service provider.

For the UC SS-CNO to be able to balance costs and QoE, it has to know certain system parameters in addition to media session-specific parameters, like the production framerate, and service-specific parameters like the function that connects revenue and QoE and the parameters that describe each of the delivered profiles/qualities that can be produced by the transcoders. These include the bitrate, processing time (average encoding time per frame), visual quality (i.e. average texture PSNR) and qualitative/categorical characteristics like inter- or intra-frame coding.

Given all the above data, the UC SS-CNO will be able to select which profiles will be transcoded on a per-session basis. In this way, the SS-CNO will mandate to each spectator which profile they will be consuming while also taking into account the cost optimization of the service itself. Thus, the SS-CNO will initially consider the resulting QoE each spectator would experience if he was to transition to any of the possible profiles/qualities. For the profile to QoE mapping, we leverage recent work on the literature ([64],[65]) that describes the QoE as a function of the received Peak Signal-to-Noise Ratio (PSNR) and framerate for gaming scenarios.

Subsequently, the SS-CNO solves an integer programming problem in order to select which qualities will be produced by also taking into account that session's service costs. Under the server-less paradigm, each produced quality requires a dedicated transcoder. Each quality can be considered on or off and this way allows us to model hardware resource constraints as well. The incoming stream profile is always available since it does not require any transcoding and thus no cost is associated with it. Then each combination is scored in terms of the average QoE it would offer to the spectators and its transcoding cost. The combination that best balances these two factors are chosen by the CNO.

Following that, the UC SS-CNO communicates with the overarching CNO to request resources and then acts to either spawn new transcoding functions, destroy existing ones or re-direct spectators to consume other profiles given its selected combination. In this way, the service seeks to achieve minimal costs while preserving certain QoE levels, aiming for maximal QoE to all spectators. This is controlled by a (service-specific) ratio factor between QoE and costs under a linear modelling assumption. The aforementioned profile selection process is repeated at regular intervals to take into networking conditions variations, changes in resource availability and the varying nature of the spectator population.

4.15.1.1 Actors

Vertical: Telefonica I+D (TID)

TID will provide to the experiment the telecom operator view, i.e., the requirements needed to be taken into account to make sure that the conclusions of the experiment are meaningful for future deployment of gaming-related services.

VNF provider(s): Universidad Politécnica de Madrid (UPM)

As stated in the description above, three VNFs are expected to be provided by UPM as part of this Use Case: the vTranscoder, the vBroker and the vProbe. UPM will also provide the Game Server engine, which will act as a PNF since it is not virtualized.

Experiment developer(s): UPM & TID

Both UPM and TID will jointly elaborate the required blueprints, descriptors and configuration/execution scripts in order to be integrated with the 5G EVE platform.

Experimenter(s): UPM & TID

Again, both UPM and TID will jointly execute the experiments and participate in the evaluation of the obtained results, starting from the KPI validation and visualization procedures supported by the 5G EVE platform.

Site Manager(s): IMDEA Networks and Universidad Carlos III de Madrid (UC3M)

The site managers of 5TONIC will perform the monitoring and scheduling tasks for the Gaming Use Case.

4.15.1.2 Planning & Status

The Gaming pilot under UC6.5 started its activity in January, suffering a delay with respect to the other pilots since it was not originally included in the project. The roadmap of this pilot is presented in Figure 89.

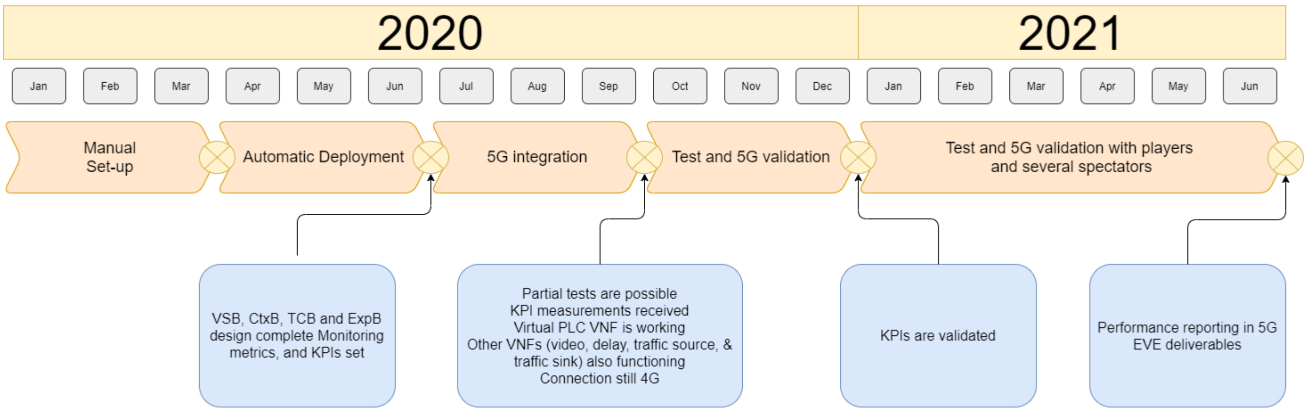


Figure 89: Media & Entertainment (Spain) UC6.5 - Roadmap and current status

As of today, and after having finished the first stage of the integration process (the "experiment design", resulting in the high-level test plan template), we are working in parallel in the next two phases:

- Integration of VNFs in the catalogue and on-boarding of their associated descriptors

- Creation of the required blueprints

The first process is being executed taking advantage of the replication of the 5TONIC orchestration environment that is available at TID's lab. With this, we can locally try to on-board and deploy the associated VNFs, starting from the VNF images and descriptors provided by UPM. This approach shall accelerate the process, since we can work without impacting the rest of the Use Cases at 5TONIC, and only interact with the production environment once we have ensured that the descriptors are correct and work well.

4.15.2 Pilot architecture

Since this Use Case has been recently included in the 5G EVE project, previous Deliverables of WP5 do not include its high-level test plan template. The pilot's architecture is depicted in Figure 90.

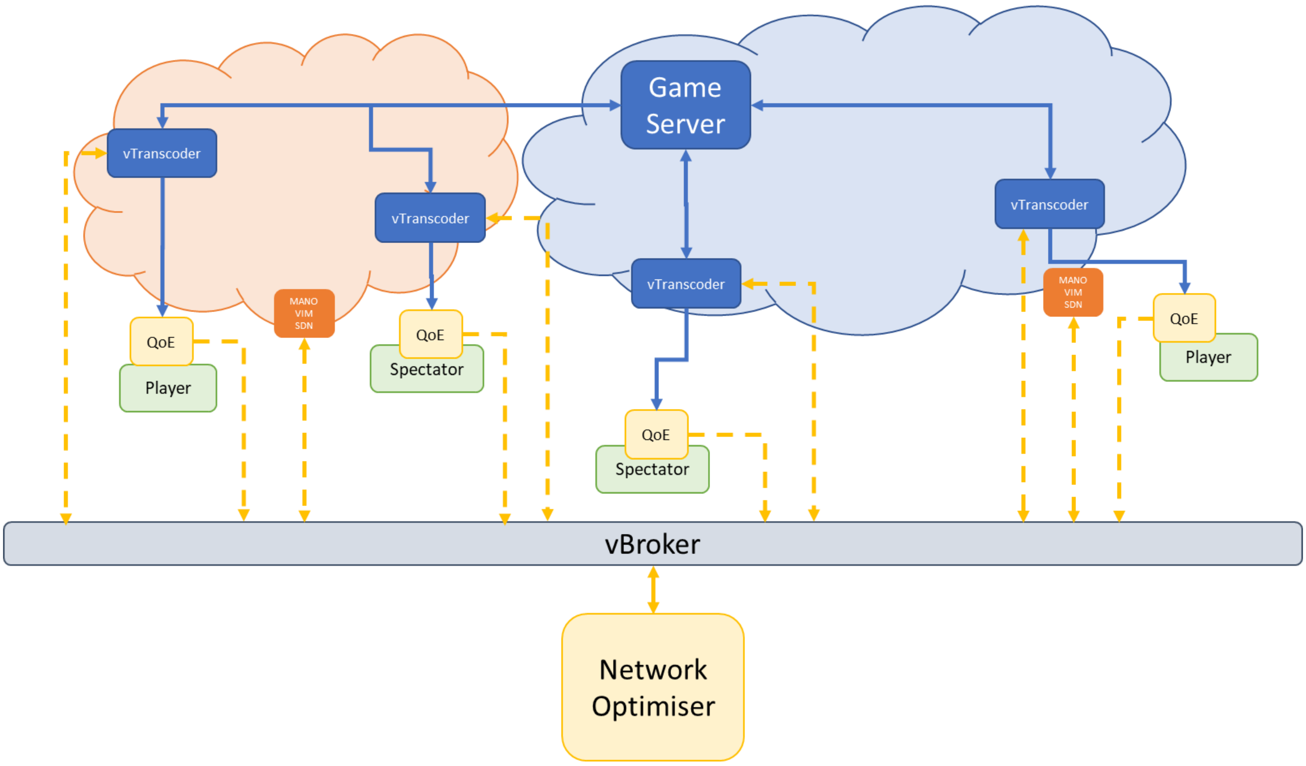


Figure 90: Media & Entertainment (Spain) UC6.5 – Pilot architecture

As seen, and due to the multi-site nature of the experiment, it is expected that the game server is located in one site (maybe together with some players and/or spectators), and that other players and/or spectators are located on other sites. QoE will be measured on all client devices, and will provide measurements that will be consumed by the Service Optimisation component, which will in turn execute corrective actions either over the Game Server itself, or over the network (via the Multi-site Network Orchestrator, developed in WP3).

There are two test cases for this experiment described in Table 91 and Table 92.

Table 91: Media & Entertainment (Spain) UC6.5 – Test Case 1

Test Case 1	
Test Name:	Monitoring module connection
Target KPI:	Service Monitoring
Measurement Method:	The Network Optimiser module will try to model the status of the service.

Parameters:	The workflow will be created with different configurations of transcoders, players and spectators. For each configuration the Network Optimiser module will need: • Used codec • vProbe measured QoE • Bitrate • CPU usage • RAM usage
Validation Conditions:	The needed parameters for optimisation are continuously available for the CNO. Error will be thrown if a parameter is missing.

Table 92: Media & Entertainment (Spain) UC6.5 – Test Case 2

Test Case 2	
Test Name:	Optimised QoE
Target KPI:	QoE
Measurement Method:	A vProbe will be deployed in all clients (players and spectators) and will return the measured QoE.
Parameters:	Congestion problems will be created in different parts of the workflow. QoE should always be acceptable.
Validation Conditions:	QoE will be considered acceptable until its MOS value goes beyond 3. (Final value still to be defined).

Currently, we are working in the UC to define the different blueprints (VSB, CB and ExpB). These will be included in future Deliverable D2.5.

4.15.3 Test Case Blueprint & Execution results

The Low Level Test Cases used to define the Test Case Blueprint are not yet available for this Use Case.

4.15.4 Pilot Initial validation status

This UC still has not generated any descriptor (VSD, CD or ExpD), nor executed initial validation activities. These will be included in future Deliverable D2.5.

4.15.5 Summary & next steps

As seen in the previous sections, this Use Case started late in the project, but is doing a strong effort to catch up with the rest of the Use Cases. The most important item is that we have a realistic roadmap that shall ensure the appropriate integration of the Use Case with the 5G EVE platform, and thus the execution of the required experiments and the extraction of the desired results.

As stated in the planning section, the next step for this Use Case is to continue with the integration with the platform, in two directions: creation of the different blueprints (starting from the high-level test plan summarized in Section 4.15.2) and on-boarding of the different VNFs and VNFDs/NSDs.

5 Conclusions and Future work

The document has presented the current status of the 5G EVE E2E site facility project MS8 and MS9. This deliverable points out the main infrastructure KPIs that can be currently achieved in each site facility. As it was identified in the 5G EVE DoW, the 5G EVE framework is now ready to “Start the Pilots”, by means, start the experiment instantiation, execution and data analysis from the 5G EVE Portal. This has been proven by the Instantiation, Execution and data collection for one pilot Experiment issued from the internal UC2.2 (see Section 4.4), for which the evidences from this process have been included in the Use Case description. Based on the internal UCs available for instantiation, a training session has been performed and two webinars will take place in the near future (expected July 2020). They aim at helping the 5G EVE framework adoption for future partners from ICT-19/22 projects.

Furthermore, Chapter 4 provides the current integration status for all the internal Use Cases, including their implemented Vertical Service architecture, their execution context(s), and their Test Cases definition. Few Use Cases provided some preliminary execution results. When possible the source code of the corresponding blueprints have also been referenced. This information, together with the Use Case management methodology described in Chapter 3, should provide futures Use Cases with implementation examples and the methodology to integrate them into the 5G EVE framework.

This document will be enhanced by a final version, D2.5 *Final pilot test and validation*, which is due at the end of the project (M36). This final document will provide the final status of the 5G EVE E2E site facility and the complete description of the internal Use Cases, including their Experiment Execution results and Analysis. It will also provide the Use Case management methodology, if any. In this D2.4 deliverable, we only focus on the 5G EVE internal Use Cases. In the D2.5 it is planned to include some pointers to the deliverables containing the Use Cases description, architecture and execution results from the ICT-19/22 projects that have selected 5G EVE as reference platform to implement some of their Use Cases. By doing so, it will be possible to give the full picture of experimentation activities carried out inside 5G EVE during the project duration, while letting each project the freedom to manage their milestones (ICT-19/22 projects go beyond 5G EVE) and the way to document their Use Cases.

Acknowledgment

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Annex A: Use Case integration calendar template

The following table provides a template to build a Use Case integration calendar. The goal is to schedule the actions of each of the activities included in the Experimentation workflow.

Table 93: Use Case integration calendar form

Deadline	Phase (D1.3)	Task	Responsible(s)
<date>	<id>	<action summary>	<Partner>

Annex B: Experimentation template

This annex contains the contents of the Experimentation template document allowing to map the experiment definition and high-level test cases description provided by the vertical, into the architecture and the low-level test cases implementation by the Experiment developer. The content in the following sub-sections correspond to the v4 of the test plan template.

Annex B.1: Experiment Description

TO BE FILLED BY THE VERTICAL: please, include a brief description of the experiment to be executed, including what are your expected capabilities from the 5G EVE infrastructure (3-5 lines).

Experiment Description: Expected Capabilities:

TO BE FILLED BY THE VERTICAL: please, include a brief description of your own components that you will be deploying on top of 5G EVE infrastructure as part of this experiment. Please, include also the deployment requirements for these components. For virtual elements, these requirements may include RAM, disk, vCPUs, etc.; for physical ones, information about size, power requirements, etc. will be required.

Main objective of this section is to help determining the required hosting capabilities on the destination sites. Therefore, it is not required to include components which will not be provided by you, even if you envision they will be required for the experiment (e.g. traffic generators). 5G EVE will determine these for you.

Table 94: Test plan template - Experiment components form

Component Name	Description	Deployment requirements

TO BE FILLED BY THE VERTICAL: please, include a brief description or figure on how the previous components interact with each other. This way we can derive the connectivity requirements for your experiment.

Experiment architecture:

TO BE FILLED BY THE VERTICAL: please, include a list of all the KPIs (5G network related or internal to your application) that are of interest for you during experimentation. Some of these KPIs will be used to determine the validation conditions (PASS/FAIL) of the experiment; some others will be used as variable parameters during execution. Please, list them all so it is clear which KPIs should be included in your test reports.

5G EVE will be able to measure and present as part of the test report your required 5G network related KPIs.

However, for KPIs internal to your application, please determine if they can be empirically measured during experimentation (either by your own components or by external ones), or if they can be mathematically derived from 5G network related KPIs. If there is such a known mathematical relationship with network parameters like latency, jitter, throughput, etc., please include it in the table below.

For experiments with KPIs that cannot be empirically measured, or with not known relationships with network parameters, it may still be possible to execute them on 5G EVE. The Vertical, however, should only expect validation of these KPIs based on its own local human analysis.

Table 95: Test plan template - meaningful KPIs form

5G related KPIs	**Comments**	
Vertical KPIs	**Is it measureable during experimentation?**	**Can it be mathematically derived from 5G related KPIs?**

Annex B.2: Test plan

TO BE FILLED BY THE VERTICAL. INSTRUCTIONS:

- There should be (ideally one and only) one test case for each high-level KPI which is meaningful for the Vertical running the experiment.
- The required information implies the minimum required for 5G EVE partners to derive the low-level test plan, meaningful from an infrastructure point of view. Fields include:
    - Target KPI: should include which KPI will be used to validate the experiment (PASS/FAIL) (one per test case)
    - Measurement method: should include the procedure the vertical uses to measure the target KPI in its own tests. E.g. component A is measuring KPI A, putting results in a database in component B, from where they can be accessed.
    - Parameters: should include which variables (external conditions) the vertical uses to ensure the experiment conditions match those of the production environment. E.g. number of users, background traffic, etc. It must be noted that, if the Target KPI can be measured or mathematically derived, the Vertical will by default get the relationship of the Target KPI with the variable parameter(s) as part of the test report.

- Validation conditions: should include the conditions the target KPI should meet to consider the test as passed. E.g. KPI A should be below a certain threshold during the whole experiment. If the test is failed, the test report will give back the value of the parameter at which the Target KPI surpassed the threshold.
  If the objective of the test is actually to measure the KPI under different conditions, this field may just include "To measure the KPI". That type of tests will not generate a pass/not passed result in the test report, but will just provide the measurements.

Table 96: Test plan template - High Level Test Case form

Test Case 1	
Test Name:	
Target KPI:	
Measurement Method:	
Parameters:	
Validation Conditions:	

Annex B.3: Low level test plan

TO BE FILLED BY THE 5G EVE CONSORTIUM. INSTRUCTIONS:

- There should be (ideally one and only) one test case for each high-level KPI which is meaningful for the Vertical running the experiment.
- If derived from the external conditions, the "expected results" change, then this can be reflected in different Test Sub-cases. Ideally, the Test Objective, Prerequisites, and Required Capabilities will be common, while the rest of the fields will be completed on a per sub-case basis.
- The fields on each Test Case are:
  - Test Objective, to be derived mainly from "Target KPI" in Vertical Test Plan
  - Test Prerequisites, to be derived mainly from "Experiment Description" and/or "Measurement Method" in Vertical Test Plan. This reflects if any initial conditions are to be met before launching the test
  - Required Capabilities, to be derived mainly from "Experiment Description" and/or "Measurement Method" in Vertical Test Plan. This reflects the requirements imposed to the potential hosting sites, to make sure they can support the experiment.
- The fields associated with each Test Sub-case are:
  - Test Topology, to be derived mainly from "Experiment Description"
  - Test Variables, to be derived mainly from "Parameters" in Vertical Test Plan
  - Test Procedure, to be derived mainly from "Experiment Description" and "Measurement Method" in Vertical Test Plan
  - Expected Results, to be derived mainly from "Expected Results" in Vertical Test Plan

Table 97: Test plan template - Low Level Test Case form

Test Case 1	
Test Name:	
Test Objective:	
Test Prerequisites:	
Required Capabilities:	

Sub-Case 1	**Test Topology:**	
	Test Variables:	
	Test Procedure:	
	Expected results:	
Sub-Case 2	**Test Topology:**	
	Test Variables:	
	Test Procedure:	
	Expected results:	

Annex C: Use case 6.4 - Media & Entertainment: Virtual visit over 5G – Network Services and VNFs

Annex C.1: 360video_server VNF (nginx, nodejs, experiment, dns)

How the ClientVR works?

The user launches Firefox with the 360 video streaming https URL page on claq.5geve.com domain. Firefox retrieves Aframe.js (with three.js embedded), dash.js and socketIO from the video server VNF. The video content mpd file is retrieved from the video server and 360 video chunks are streamed (thanks to dashjs) and seen in the Head Mountain Display (HMD).

The socketIO connects to the https server on port 3000 and application specific metrics (e.g. delay, BufferLevel, etc.) are emitted every seconds.

The video server VNF is composed of the following components:

1. Nginx

Figure 91 gives the Nginx architecture. It is the https server listening on port 443 with self-certificated and self-signed certificates for claq.5geve.com domain where the video are located. For VR services, https is required by Firefox. This https server is in charge of serving the 360video HTML page with aframe, dashjs, socketIO and the video content.

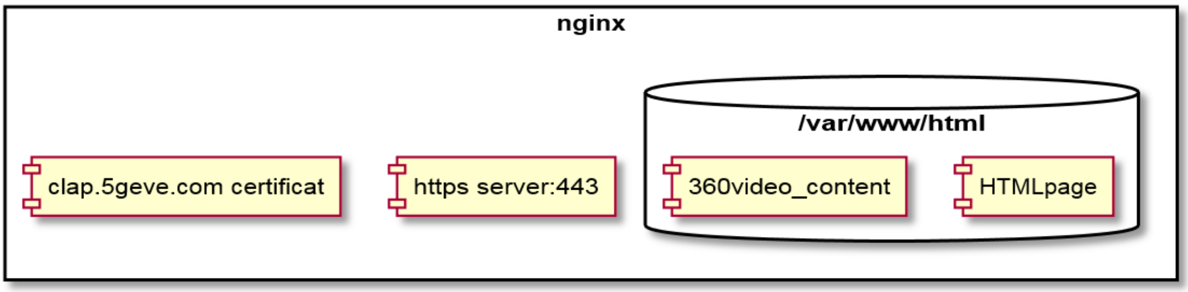

Figure 91: Media & Entertainment (France) UC6.4 - nginx description

2. Nodejs

Figure 92 represents the Node.js that is an open-source, cross-platform, JavaScript runtime environment that executes JavaScript code outside a web browser. Nodejs is used to launch the https server on port 3000 and link the socketIO to the 360 video HTML webpage. It is also used to launch the Kafka producer.

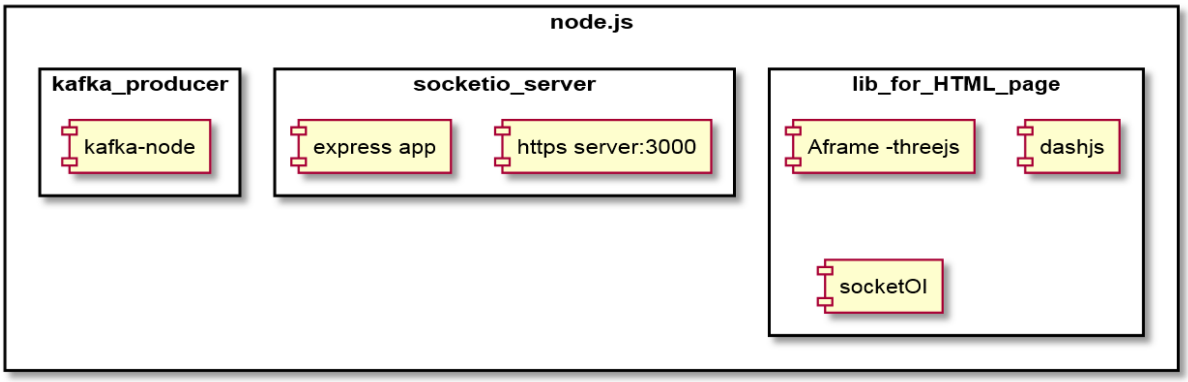

Figure 92: Media & Entertainment (France) UC6.4 - node.js description

3. Experiment- Metric to kafka

As described in more details in Section 4.14.3, there are three experiment scripts, one per experiment, which will be launched by the experiment blueprint from the portal.

The Figure 93 gives the main functionalities of metrics collection according to the experiment. At the begging of one experiment, the experiment scripts, embedded in the test case execution, are in charge of launching:

1. The nodejs script (the data shipper) which is in charge of:
   - Extract metric specific topic name from {metricID}-day2-config.yaml files
   - launch Kafka producer and emit every second server video metrics (delay and throughput) to Kafka broker on their specific topic
   - listening to socketIO on https port 3000 and as soon as it receives a metric record from the HTML page (every second), emit application metrics to Kafka brocker on their specific topic
2. For experiment 2, a specific bash script “add_delay” which will add delay values on the video server egress interface. This added delay will vary automatically during the time of the experimentation.
3. For experiment 3, a specific bash script “bandwidth_ limitation” which will limit the bandwidth on the video server egress interface. This bandwidth limitation will vary automatically during the time of the experimentation.

At the end of the experimentation (after a few minutes), these experiment scripts are in charge of stopping the nodejs script (data shipper) and, if needed, bash script “add_delay” or “bandwidth_limitation”.

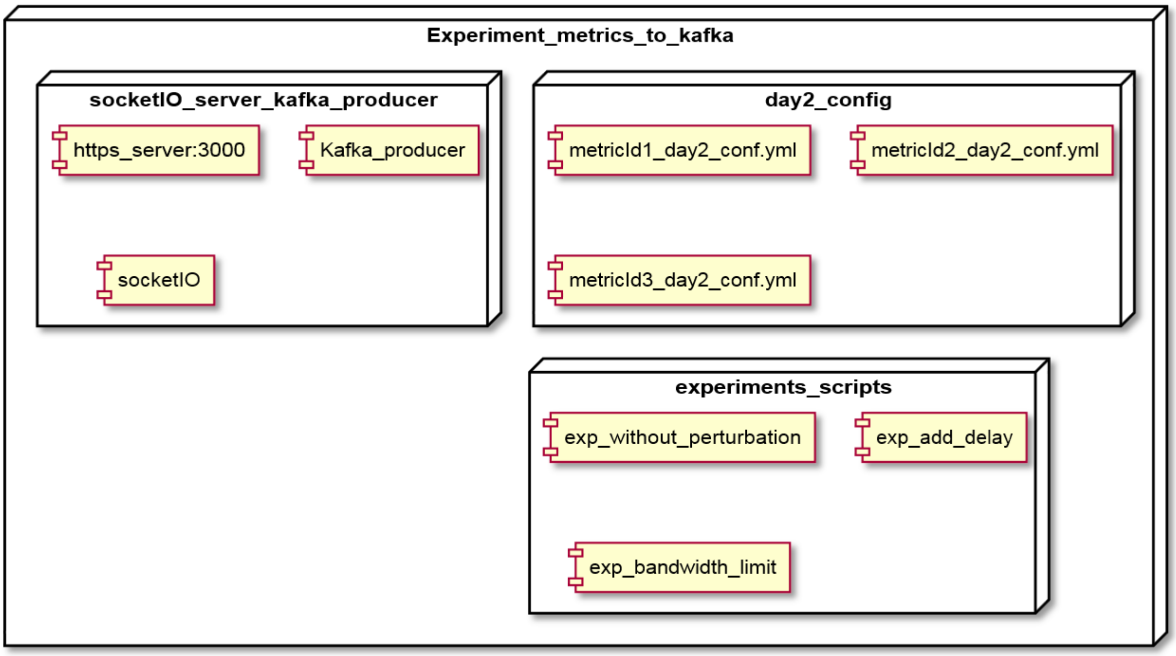

Figure 93: Media & Entertainment (France) UC6.4 - Experiment metrics collection representation

We are using one DNS server that is in charge of resolving the claq.5geve.com domain with its own IP address, which is the IP address of the VNF. This resolution is needed in order to use the self-signed certificate for the claq.5Geve.com domain.

Annex C.2: Wireless Edge Factory (WEF) V1.3 VNF

The new V1.3 WEF [59] release has been developed and is now used in 5G EVE French site facility. Its general architecture is depicted in Figure 94.
The internal functional split of WEF core functions is not exposed outside of the WEF, which allows supporting legacy UEs, eNodeBs, Wi-Fi Access Points and external IP networks interconnection. Most of the core components are also compliant with the 3GPP standards.

Separating control plane from user plane allows to deploy the WEF to geographically remote sites (Campus, events places, etc.). The control plane is centralized (either on external public or private cloud), hosted on a cloud environment whereas user plane is distributed over various locations.

The user plane is routed through the GW-U, whatever the access technology (Wi-Fi, LTE…). Several GW-Us are distributed on different locations. Each GW-U gathers the traffic to/from the access network and the external packet data network. Service Function Chaining is supported to handle data packets redirection through a given and ordered set of VNFs in the user plane.

The S/PGW-C application interacts with the MME as if it was a legacy S/PGW. Following 3GPP standards, the MME is also interacting directly with the HSS for subscriber's authentication as well as, on the access side, with eNodeBs and UEs.

Monitoring and customer care dashboards are added to provide user friendly monitoring and management features.

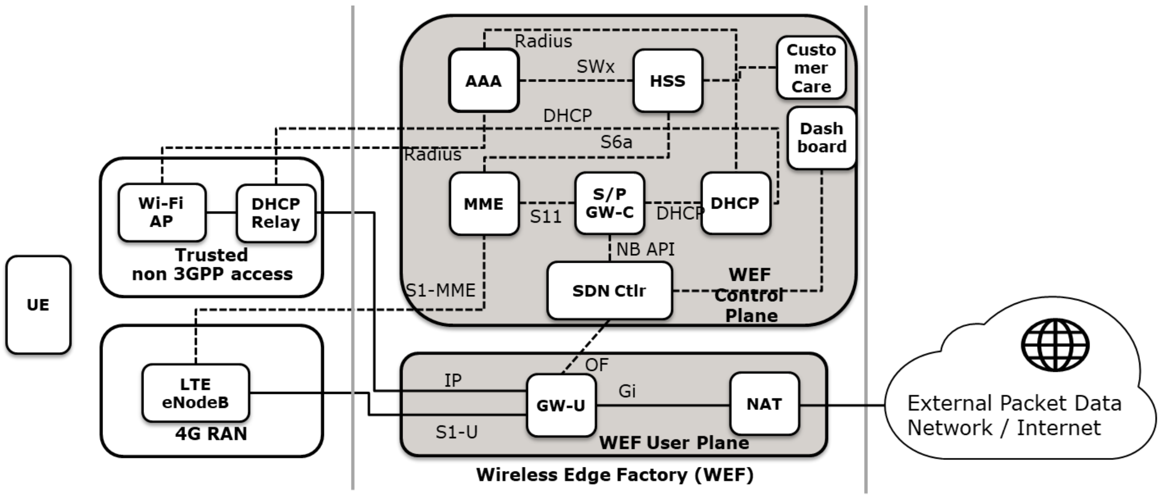

Figure 94: Media & Entertainment (France) UC6.4 - WEF v1.3 Functional Architecture

On Figure 95, the Control plane VNFs are kept as VM deployed in a Openstack [62] tenant, while User plane VNFs are hosted on another Openstack tenant, that could be in the same or another Openstack tenant.

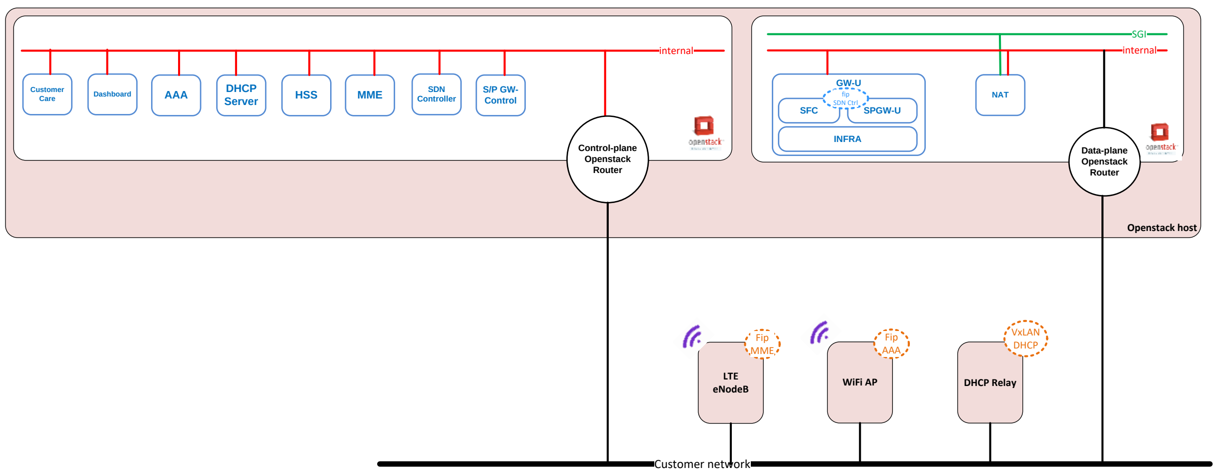

Figure 95: Media & Entertainment (France) UC6.4 - WEF 1.3 hosted on Openstack

For example when orchestrating the WEF deployment via a network orchestrator like ONAP (that is our case), it is preferable that all VNFs be deployed on the same VIM (Virtualized Infrastructure Manager), i.e. on Openstack tenants.

The WEF is currently upgraded to be able to support 5G. It will be integrated to our facility beginning of next year (2021).

Annex C.3: OAI RAN VNF and PNF

OAI [60] RAN component can be instantiated as physical component or as a virtual component. Both physical and virtual needs to be based on Ubuntu 16.04 LTS 64-bits as operating system and it is a must to have kernel version greater than 4.10.x. As resources requirements, the flavor should consist of:

- 2-4 cores Intel i5/i7 or Xeon (2/3/4) – equivalent of these types/characteristics of CPUs as vCPUs + special CPU flags enabled
- 8/16 GB of RAM

- 1/2 ethernet ports (1Gb S1, 1/10Gb)

After all these requirements are in place, a snap of OAI can be downloaded from Eurecom mosaic5g Gitlab [61] and then start to configure the component. Update the configuration file: oai-ran.enb-conf-get and modify MCC, MNC and mme_ip_address and network interfaces sections in /var/snap/oai-cn/current/enb.band7.tm1.50PRB.usrpb210.conf, and then start the service: sudo oai-ran.enb-start.

In order to prepare and install OAI RAN on a virtual machine, some modifications of Openstack configurations and flavor needs to be done in prior.

- *This instantiation was made on Ubuntu 16.04 (as host OS), Openstack Ocata and KVM hypervisor.*