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**5G European Validation platform for Extensive trials**

# Deliverable D1.4
# KPI collection Framework

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# Table of Contents

# List of Acronyms and Abbreviations

| Acronym | Description |
|---|---|
| 3GPP | Third Generation Partnership Project |
| 5G PPP | 5G Public Private Partnership |
| AGV | Automated Guided Vehicle |
| CAPEX | Capital Expenditure |
| OPEX | Operative Expenditure |
| CDN | Content Delivery Network |
| EPC | Evolved Packet Core |
| ETSI | European Telecommunications Standards Institute |
| eMBB | enhanced Mobile Broadband |
| HMI | Human Machine Interface |
| ICT | Information and Communication Technology |
| IEEE | Institute of Electronics and Electrical Engineering |
| IETF | Internet Engineering Task Force |
| IMT | International Mobile Telecommunications |
| IoT | Internet of Things |
| IP | Internet Protocol |
| IPR | Intellectual Property Rights |
| ISG | Industry Specification Group (ETSI) |
| IT | Information Technology |
| ITU-T | International Telecommunications Union – Telecommunications standardization sector |
| GMS | Game Management System |
| KPI | Key Performance Indicator |
| LTE / -A | Long Term Evolution / -Advanced (3GPP) |
| MCPTT | Mission Critical Push To Talk |
| MEC | Multi-Access Edge Computing |
| MME | Mobility Management Entity |
| mMTC | massive Machine Type Communications |
| MNO | Mobile Network Operator |
| MTP | Mobile Transport and Computing Platform |

| | |
|---|---|
| NFV | Network Functions Virtualization |
| NGMN | Next Generation Mobile Networks |
| NOP | Network Operator |
| OF | Open-Flow (ONF) |
| ONF | Open Networking Foundation |
| OPNFV | Open Platform for NFV |
| PMC | Probability of Missing Command |
| PoP | Points of Presence |
| PTP | Precision Time Protocol |
| PUC | Probability of Unwanted Command |
| QoE | Quality of Experience |
| QoS | Quality of Service |
| RAN | Radio Access Network |
| SDN | Software Defined Networks |
| SO | Service Orchestrator |
| S-/P-GW | Serving / Packet Gateway |
| SLA | Service Level Agreement |
| SME | Small Medium Enterprise |
| URLLC | Ultra-Reliable Low-Latency Communications |
| vEPC | virtual EPC |
| VISP | Virtualization Infrastructure Service Provider |
| VNF | Virtual Network Function |
| VRU | Vulnerable Road User |

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# Executive Summary

This document describes how the Key Performance Indicators (KPIs) are collected and integrated in the project and how this information can be used for different vertical and architecture validations. The document details: 1) the framework and methodology that facilitates collecting all data set from sites and verticals and, 2) the experiments that are planned for the generation and correlation of the experimentation tests.

KPIs are critical measures that indicate to what extent a targeted outcome has been fulfilled. KPIs are essential to measure improvements on implementations or on data communication networks, and this information is critical to build a virtuous loop of continuous improvement.

The good KPIs must create objective evidence of progress towards a result, measuring parameters valid for decision making, should be used to keep progress over time and keep track of quality, compliance and resources utilization.

Initially, ITU created the ITU-R M.2083 Recommendation that defines eight key "Capabilities for IMT-2020", which form a basis for the13 technical performance requirements released by ITU WP 5D back in February 2017 in their DRAFT NEW REPORT ITU-RM. [IMT-2020.TECH PERF REQ] [1].

Moreover, 5G-PPP has conducted several studies about requirements of 5G services. This document is focused on the innovative vertical use case requirements that will be validated in the scope of this 5G-EVE project.

The 5G Architecture Working Group as part of the 5G PPP Initiative is looking at capturing novel trends and key technological enablers for the realization of the 5G architecture. The work has generated a new version of the Architecture, document "5G PPP 5G Architecture White Paper Revision 3.0" [2], with the 5G PPP Phase II and Phase III projects with special focus on understanding the requirements from vertical industries involved in the projects and then driving the required enhancements of the 5G Architecture able to meet their requirements. The results of the Working Group are now captured in this Version 3.0, which presents the consolidated European view on the architecture design.

Remembering the famous anonymous quote: *"Experimental confirmation of a prediction is merely a measurement. An experiment disproving a prediction is a discovery"*, we expect in the project to generate many measurements and some discoveries. The spirit of the KPI collection framework is to be able to reach the maximum result from the new 5G networks and see the evolution of the improvement as we progress in the new 5G standard implementation and in the new vertical services deployed on these new networks.

The main inputs for this document are:

- From Task 1.1, the requirement definition and analysis from vertical industries and the deliverable "Requirements definition and analysis from participant vertical industries" D1.1 [3], and
- From Task 1.2 "5G-EVE end to end facility reference architecture for vertical industries"

Other deliverables in the project will use and further evolve the architecture and guidelines outlined in this document, as well as the recommendations issued by 5GPPP TMV Working Group.

# 1 Introduction

This document, the Deliverable D1.4, describes how KPIs are collected and integrated into the project and how those KPIs can be used for different verticals and architecture validations. This document describes the KPI Collection Framework that will be available in the 5G-EVE project. In particular, it describes how KPIs are collected and integrated into the project and how those KPIs can be used for different vertical and architecture validations.

The document is structured as follows:

- Chapter two describes the framework expectation.
- Chapter three identifies a high-level view of the key components for the KPI collection framework. First, we introduce the different usability of the KPIs information during the industries services validation, following with an introduction to the KPI architecture. Then we describe several mechanisms for the recollection of data and how the MEC, as standardized by ETSI, can be used for KPI generation. Finally, we will evaluate the performance architecture and the simulation tools to support the proposed Use Cases. In the last subchapter we analyze the aggregation and correlation of the generated information.
- Chapter four details the KPI information sources from the 5G Infrastructure, including the activity log files, the configuration data, active and passive probes and monitoring devices that will be used in the network validation.
- Chapter five details the KPIs sources from the several vertical service applications, including the activity log files, the configuration data, the active probes and the monitoring devices that will be used in the services validation.
- Chapter six describes the different uses of KPIs information in terms of different use cases, where we have included a description of the six use cases supported initially in the project, and also in terms of architecture including the NSA/SA deployments, the targeted coverage area and the new 5G radio environmental factors.
- Chapter seven concludes the document giving some remarks and future line of work.

# 2 Expectation of KPI collection Framework

A 5G end-to-end facility for vertical industries requires a meticulous analysis of the needs defined by these companies to achieve their objectives, so a dialogue must be established between industries and communication infrastructure providers to guarantee that these objectives can be met and verified in a simple and fast way. In 5G-EVE we have conducted an interactive dialogue with companies representing various industrial sectors in order to identify their business requirements and to determine the 5G network requirements, which have finally been translated into a requirements document for vertical industries.

To ease the generation of relevant information that verify the correct network operation devoted to the verticals, a KPI Collection Framework has been defined supporting all standard KPIs of the 5G networks and some of the specific industry KPIs that participate in the first phase of the project. The tests environment of the proposed KPIs will include the description of the following blocks:

1. **Mechanisms for collecting key information for estimating KPIs,** correlation strategies for different experiments and measurements, architectures of the supported performance simulators, information aggregation strategies and proposals for result visualization.
2. **Information sources for the generation of 5G KPIs and KPIs of services of vertical industries**, including description of the activity files from network elements and servers, information of both active and passive probes as well as information from specialized monitoring elements.
3. **Description of the possible uses of the KPIs to different vertical industries or with different deployment architectures**. It is important to bear in mind that not all vertical industries can have all the ideal resources of a brand-new network, and therefore, different deployment architecture solutions must be supported to cover a wide range of deployment possibilities, even when the requirements of the industries can be the same.

Requirement validation is critical for this project. The requirement validation should be documented, actionable, measurable, testable, traceable, related to identified business needs or opportunities, and defined to a level of enough detail for implementation. As specified in the ISO 9241-210 standard[1], user-centered design begins with a thorough understanding of the user requirements and needs

The benefits of the requirements validation can include increased productivity, enhanced quality of work, reductions in support and training costs and improved user satisfaction. With the advent of 5G technologies, new networking experiences are added such as Internet-of-Things (IoT), virtual and augmented reality (VR and AR), mission critical applications, massive machine-type communication, Gigabit mobile connectivity (on the go) and others, which promise to offer new services and facilities to people's daily lives by creating "smart" homes and cities as well as vertical synergies between different markets. 5G services promise to implement new visions and deliver novel solutions within the framework of this demanding and competitive environment.

[1] ISO, 2010, Ergonomics of human-system interaction -- Part 210: Human-centered design for interactive systems (ISO 9241-210:2010) provides requirements and recommendations for human-centred design principles and activities throughout the life cycle of computer-based interactive systems. It is intended to be used by those managing design processes, and is concerned with ways in which both hardware and software components of interactive systems can enhance human–system interaction. It is published by the Technical Committee ISO/TC 159/SC 4

# 3 High-level view of key components for the KPI Collection Framework

In this chapter we will identify the framework for the KPI collection. First, we will explain the reasons why KPIs from new vertical use cases are needed, describing their usability in each of the main deployment phases. Secondly, the KPI Collection Framework High-level architecture is described providing also one implementation example deployed in a virtualized Multi-Access Edge Computing node inside the 5G network. Then, we describe several mechanisms for measurement generation and transmission. Later, the ETSI-MEC specification is described, including how the 5G Network can show some capabilities that can be used for KPI generation like the monitoring or handling of QoS to external entities. KPIs are usually generated by performance measurement systems and tools that are shortly described in the Section 3.5 and also by simulation tools that are listed in Section 3.6. Section 3.7 includes the methodology description the flow of information and how the tester interact with the 5G EVE Portal GUI. Also, the most relevant 5G KPIs information sources are described, including a brief proposal of implementation. Finally, one reference example of KPIs recollection and aggregation method is described in Section 3.7.2.

## 3.1 KPIs Usability

KPIs are generated to monitor the quality of services, applications or network services to which we must guarantee enough quality so that they can offer or deploy their services, see [13] for more information about services and service capabilities. However, it is necessary to classify the type of deployment where those KPIs are generated depending on the state of deployment. We can establish a first high level classification in three levels:

- **Phase 1: Interoperability** of elements and adaptation to standards. In this phase, the main objective is to verify that the different devices interact in the expected way and conform to established standards. Normally here the UEs are validated and the elements are configured to eliminate any interoperability problem. In this phase, the use of instrumental equipment is usually required to perform low-level interoperability reports and exhaustive compatibility validations of different measures.
- **Phase 2: Proof of concept and scalability** preceding a real deployment. This phase is prior to the deployment of real networks and services, and the main objective is to prove that the service and objective applications of the service can be functionally provided. We also want to check to what extent the system is scalable and can support load tests. Equipment with load simulators or automatic equipment to perform functional tests are the ones that are most commonly used in this phase.
- **Phase 3: Monitoring service** once deployed. This phase allows to monitor the quality of services once they have been deployed in the real network, and they require periodic reports that allow to take preventive measures and control the quality that is really being delivered to the end users. In this phase, many data is integrated in the most efficient way possible, and usually require the deployment of components in the applications that generate part of the information used to monitor the quality of service in the users. This phase generates a lot of information, and it is critical to provide efficient data aggregation mechanisms.

When we talk about KPIs it is good to have as reference what is the expected outcome for the particular generation context, since that allows us to use in the most efficient way instrumental equipment, load simulation equipment or possible applications development.

In Phase 1, interoperability tests of the UEs with the 5G networks and with the services applications will be executed. Depending on the features and frequencies of the 5G network that is being deployed, it is required to repeat these tests to ensure that we are within the acceptance parameters and the network is compliant with the required standards.

In Phase 2, load and simulation tests will be performed in laboratory environments. Before deploying a commercial service, we must optimize the resources to use efficiently the allocated networks resources. In this phase, we will verify that we can reach our coverage, concurrency and load that was defined for the commercial launch.

Phase 3 is the most critical as the service is in operation and users are continuously evaluating the perceived quality. This phase requires a continuous and periodic monitoring. Having the quality of the provided service well controlled will allow us to anticipate any service degradation and problem.

Any Vertical Industry will have to go through these three phases, and therefore the KPIs that will be implemented, tested and measured, should be applied in the most efficient way to each of these three phases.

## 3.2 Introduction to KPI High-level architecture

The 5G-EVE Project must support various use cases for very diverse companies, deployed in physically dispersed locations and with different network providers. On the other hand, the project must generate information on service KPIs and 5G network KPIs that allow companies to verify that their functional and business requirements are within their expected ranges of operation, and therefore can guarantee the quality of services to its customers.

In the following Figure 1 we can see a high-level view of the functional blocks, the information flow and the APIs that will be implemented in the project. In the lower layer we can see the 5G network components, in the mid layer the different KPI Collection Modules that will be implemented to support the flow of information, and in the upper layer the KPI storage and generation components.

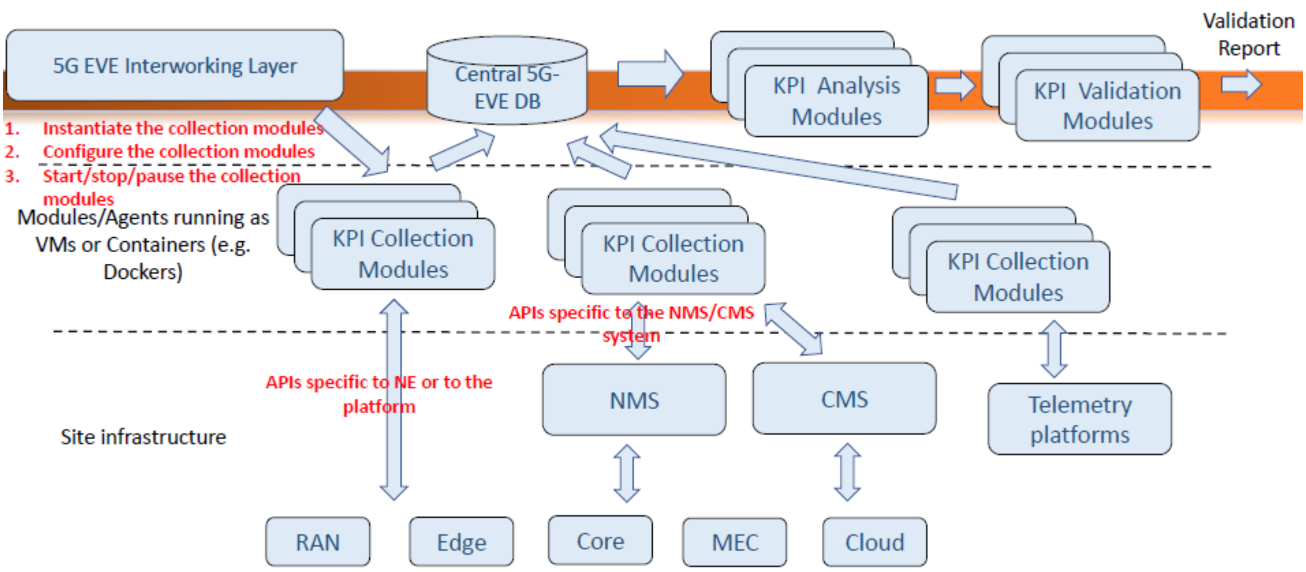


**Figure 1: 5G-EVE KPI framework – high level architecture**

The 5G-EVE KPI Collection architecture will support the information flow necessary to generate the quality of service information to the industry. The proposed architecture must support a prominent level of heterogeneity including SA or NSA networks. We will also support diverse levels of heterogeneous networks, where some network elements could not be included in 5G architectures (although the reference will be that the entire system must be able to be deployed in a 5G network).

In Figure 2, we see one example of KPI Collection Modules implemented in virtualized Multi-Access Edge Computing nodes of the 5G network. In this proposed implementation, there will be a catalog of KPIs Collectors that will provide a set of KPIs generation capabilities. Depending on the site needs, in other words depending on the required vertical industries that must be supported in a particular site, a combination of these Virtual Network Functions (VNF) can be deployed as needed. In case a new set of KPIs must be supported for a new vertical company, it is required to create a new block with the required functionality.

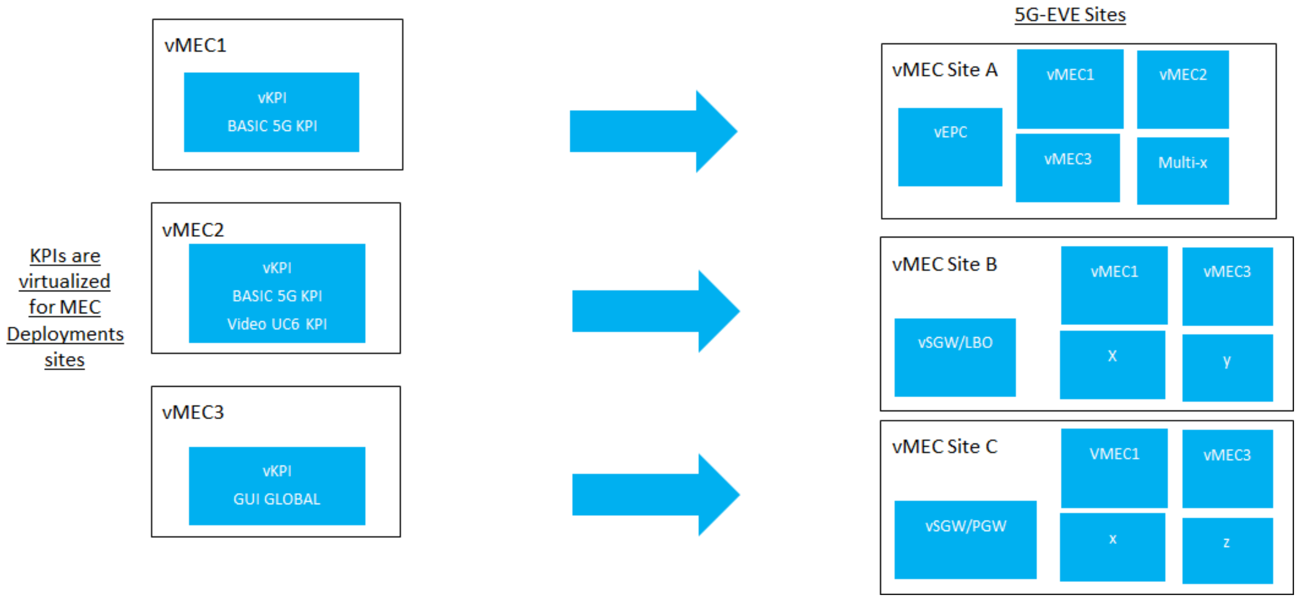


**Figure 2: Example of KPIs virtualized deployment for measurements**

Ideally, these KPIs collectors must be implementing the Network Functions Virtualization Release 2; Protocols and Data Models; NFV descriptors based on TOSCA specification and the VNF Package specifications, defined in ETSI GS NFV-SOL 001 [5] and in ETSI GS NFV-SOL 004 [6].

This TOSCA Simple Profile in YAML, fulfilling the requirements specified in ETSI GS NFV-IFA 011 [8] and ETSI GS NFV-IFA 014 [9] for a Virtualized Network Function Descriptor (VNFD), a Network Service Descriptor (NSD) and a Physical Network Function Descriptor (PNFD). The present document also specifies VNFM requirements and NFVO specific to handle NFV descriptors based on the TOSCA.

The TOSCA YAML CSAR file is an archive file using the ZIP file format whose structure complies with the TOSCA Simple Profile YAML v1.1 Specification [7]. The CSAR file may have one of the two following structures:

- CSAR containing a TOSCA-Metadata directory, which includes the TOSCA.meta metadata file providing an entry information for processing a CSAR file as defined in TOSCA v1.0 Specification [10].
- CSAR containing a single yaml (.yml or .yaml) file at the root of the archive. The yaml file is a TOSCA definition template that contains a metadata section with template name and template version metadata. This file is the CSAR Entry-Definitions file.

## 3.3 Gathering of data

We must establish different mechanisms for collecting information from various sources, supporting both aggregation of previously generated information, and ingestion of real time information. In both cases, the information can be either sent by the source, or collected by different information collectors.

Table 1 describes some of the mechanisms that can be supported, depending on the type of data source.

**Table 1 Different types of source measurements**

| Source of information | Pluging to be provided |
|---|---|
| elasticsearch | Reads query results from an Elasticsearch cluster |
| exec | Captures the output of a shell command as an event |
| file | Streams events from files |
| http | Receives events over HTTP or HTTPS |
| snmp | Polls network devices using Simple Network Management Protocol (SNMP) |
| snmptrap | Creates events based on SNMP trap messages |
| syslog | Reads syslog messages as events |
| tcp | Reads events from a TCP socket |
| udp | Reads events over UDP |
| WebSocket | Reads events from a WebSocket |
| ftp file | Files transmitted in FTP server |

In case it was necessary to integrate new kind of information from a new source, a new plug-in that can select and transport the information from its origin to one of the information collection systems must be created.

## 3.4 ETSI-MEC

A significant part of the services and applications of new generation mobile networks will be deployed close to the end users, mainly due to services that are localized in certain geographical areas, or services that require very low latency. Such applications will be deployed in Multi-Access Edge Computing (MEC) architectures that will guarantee the required quality, and therefore they must guarantee the services and quality of service demanded. ETSI has identified a migration architecture for MEC services from 4G to 5G and has also defined several deployment modes for those new components.

As per the ETSI GS MEC 011 [11] specification, a key baseline functionality of the MEC platform is to route IP packets to MEC applications which are meant to handle the traffic in different ways:

- **In Breakout mode**, the session connection is redirected to a MEC application which is either hosted locally on the MEC platform or on a remote server. Typical breakout applications include local CDN, gaming and media content services, and enterprise LAN.
- **In In-line mode**, the session connectivity is maintained with the original (Internet) server, while all traffic traverses the MEC application. In-line MEC applications include transparent content caching and security applications.
- **In Tap mode**, specified traffic is duplicated and forwarded to the tap MEC application, for example, when deploying virtual network probes or security applications.
- **In Independent mode**, no traffic offloading function is needed, but still the MEC application is registered in the MEC platform and will receive other MEC services, such as DNS, Radio Network Information Service (RNIS), etc.

Initially, in most of the operators MEC deployments, MEC will be based in 4G networks, and then as the new 5G networks are available, MEC will be shifted to 5G networks. These two models will coexist and probably the most probable scenario will be hybrid 4G and 5G. Figure 3 depicts a possible migration scenario:

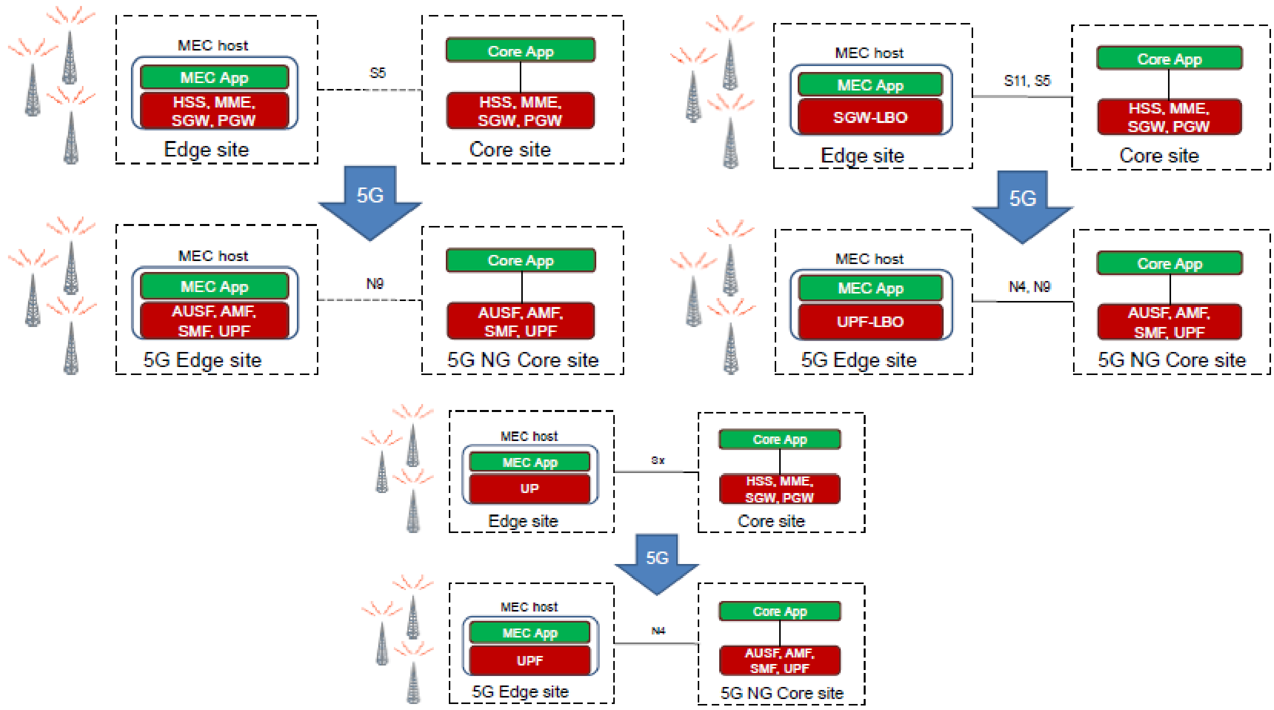


**Figure 3: MEC deployments in 5G and 4G networks. Migration patterns for MEC deployments from 4G to 5G, from ETSI MEC Deployments in 4G and Evolution Towards 5G**

MEC is useful for KPIs generation and correlation with the expected capabilities exposure and by the aggregation capacity, allowing an easy migration from 4G to 5G networks (see Figure 3). The Network Exposure Function has appeared in 5G as a service-aware "border gateway" that enables the external Application Functions (AFs) to communicate with the 5G Network Functions. In ETSI-MEC architecture, the Network Exposure Function (NEF) is delivering capability information of the 5G Network to external entities, in some cases these services and capabilities can be used for KPI related tasks, like the following:

- **Monitoring**: allows an external entity to request or subscribe to UE related events of interest. The monitored events include a UE's roaming status, UE connectivity loss, UE reachability and location related events (e.g. location of a specific UE, or identification of UEs within a geographical area). The Access Management Function and the Unified Data Management (AMF & UDM) are the key entities in providing access to such event information.
- **Provisioning**: allows an external entity to provision expected UE behavior to the 5G system, for instance predicted UE movement, or communication characteristics.
- **Policy and Charging**: handles QoS and charging policy for UE based requests made by an external party, which also facilitates sponsored data services. The PCF is the key entity about Policy and Charging Control (PCC), although most NFs are involved to some degree in supporting the PCC framework.

## 3.5 Performance architecture

Performance conditions must be guaranteed in real deployments to vertical industries with enough quality at peak hours, in extreme conditions, and to optimize the allocated network resources. In normal conditions, the network is in use with less load than in performance conditions, but the different service operators need to guarantee a minimum set of service KPIs to their users to provide the compromised services.

As already defined in "5G PPP use cases and performance evaluation models" v1.0 [16] in Section 3, the 5G main characteristics, KPIs (similar to the ones defined in "IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond"), and basic information on how to evaluate them through inspection, analysis or simulation (see Figure 4) are:

1. In case of evaluation through inspection, the evaluation is based on statements.
2. In case of analytical procedure, the evaluation will be based on calculations using the technical information provided by the technology component owner, which are related to methodology, algorithm, module or protocol that enables features of the 5G system is a technology component or enabler.
3. Evaluations through simulations contain both system level and link level simulations although it is expected that most solutions will be assessed using system level evaluation.

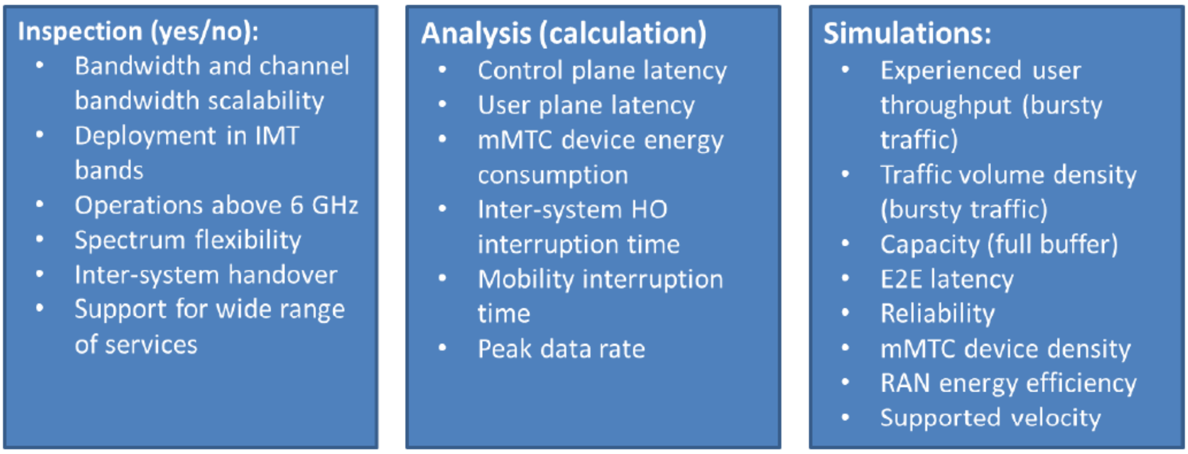


**Figure 4: 5G KPIs and their assessment method as defined in 5G PPP**

The performance system architecture must include some simulation elements required to create the environmental conditions that can be used to simulate user, network and server traffic or transmission conditions. In each use case, different elements will be emulated in order to check whether certain KPIs can be provided for the end users.

| Requirements | UC-1-IT-TRENITALIA | UC-3a-AV-ASTI | UC-3b-AV-GR-ERICSON | UC4-WINGS-EDF | UC-5a-SmartTurin | UC-5b-Nokia-GR |
|---|---|---|---|---|---|---|
| **Performance: Tools, systems or equipments used to simulate a group of real client to check system load capacity (i.e.: in video services a system that simulates a hundreds of real players)** | Stress-test tools for mobile apps on commercial smartphones and application backend systems- Tools like iPerf, PacketGen | Yes, traffic simulator to simulate traffic load and latency simulator to evaluate latency requirements | not necessary | Mainly real sensors, energy sources and energy consumers. Simulation to be investigated to increase the scale but is not decided yet. | not necessary | Real sensors/devices |

| UC-5c-WINGS | UC-6a-TELEFONICA-UHFM | UC-6-TELEFONICA-OLEE | UC-6-TELEFONICA-IIM | UC-6-VV-ORANGE-FR |
|---|---|---|---|---|
| Stress-test tools for mobile apps and real smartphone devices | Yes, Spirent Avalanche & real devices | Yes, Spirent Avalanche & real devices | Yes, Spirent Avalanche & real devices | |

**Figure 5: Performance tools, systems or equipment's**

The tools listed in the Figure 5 can be used to create the performance conditions under which tests will be executed. In the case of multimedia use case, the instrumental Spirent Avalanche [18] equipment will be used to create the traffic directly inside the 5G network while executing the test. Some real devices can be simultaneously used to validate that the test is also running as expected for some real users, even making possible some parallel visual validations for the multimedia content at the same time. In other use cases, some traffic simulators will be used to load the 5G platform as expected. These tests will be executed with the tools and equipment described in Figure 5

## 3.6 Simulations tools

A simulation is something that tries to imitate the behavior/state of something else, but it is not exactly the thing itself. Simulations are generally used to simulate practical situations that can happen in reality, but for various reasons such as cost, risk, effort or wear, it is better to perform them with a representation.

Therefore, on each simulation exercise, a component or components of the 5G system can be replaced by a simulated element, see Figure 6. The objective is to evaluate the behavior of those elements when the simulation conditions and the executed test are produced.

In this section and in the context of the use cases of interest, we will review which elements will be used to substitute real elements in the tests and allow us to validate the requirements identified by the vertical partners companies.

| UC-1-IT-TRENITALIA | UC-3a-AV-ASTI | UC-3b-AV-GR-ERICSON | UC4-WINGS-EDF | UC-5a-SmartTurin | UC-5b-Nokia-GR |
|---|---|---|---|---|---|
| Android smartphones for collecting raw data from sensors and linux servers and analysizing mobility patterns, simulations and tests being performed by technical people involved in the project | Yes, traffic simulator to simulate AGV traffic. | not necessary | Mainly real sensors, energy sources and energy consumers. Simulation to be investigated to increase the scale but is not decided yet. | not necessary | Real sensors/devices |

| UC-5c-WINGS | UC-6a-TELEFONICA-UHFM | UC-6-TELEFONICA-OLEE | UC-6-TELEFONICA-IIM | UC-6-VV-ORANGE-FR |
|---|---|---|---|---|
| Smartphone simulator and real smartphone devices. | Yes, Spirent Avalanche & real devices | Yes, Spirent Avalanche & real devices | Yes, Spirent Avalanche & real devices | simulation of VRplayer : Avaratar recorder/replayer & real VR devices (HMD) |

**Figure 6: Simulation tools**

Depending of the main target of the use case, a different simulation approach has been selected for the initial phase of the project. For instance, in the case of the Multimedia UC-6a-TELEFONICA-UHFM, the selected proposed tool is Spirent Avalanche and also real devices. In this case, part of the clients will be implemented with an automatic video player emulated by Spirent (see Figure 7), in charge of tests configuration of HLS server contents for live events. The Spirent Avalanche can be used to emulate several video streaming protocols for live and for Video. The emulation tool can configure different TCP buffering sizes and congestion protocols accordingly to targeted clients.

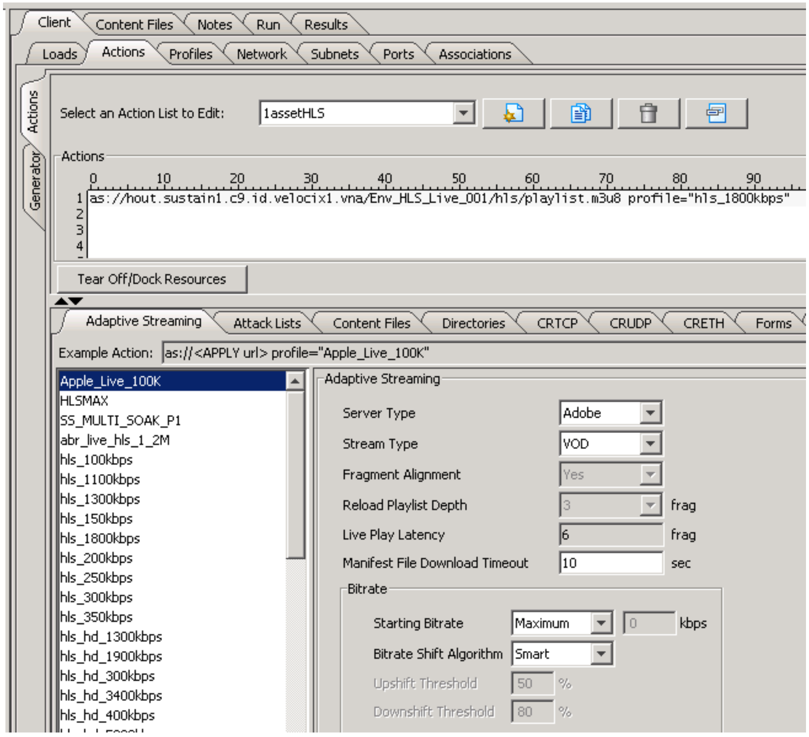


**Figure 7: Adaptive Video Streaming configuration with Spirent Avalanche for Simulations**

## 3.7 Methodology for the Aggregation and correlation of information

Each Vertical Use Case have identified network requirements that need to be fulfilled to provide expected QoS. These network requirements have been mapped for each individual Vertical Use Case into eight High Level KPIs (5G EVE KPIs) that will support Verticals to validate their UCs. Full details are included in “5G EVE Deliverable D1.1 Requirements Definition & Analysis from Participant Vertical-Industries.”

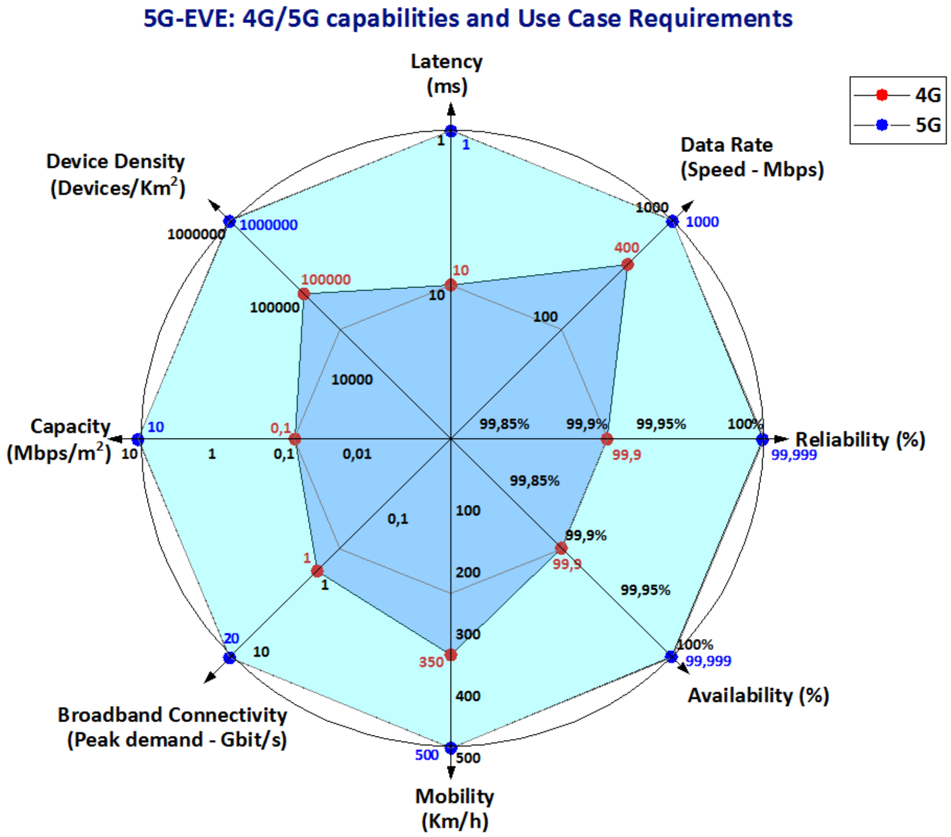


**Figure 8: 5G-EVE: 4G/5G capabilities**

Throughout the Test Design Phase (Note: For further details, refers to MS6 - 5GEVE Architecture_v2.0), an analysis is done to cross-check Vertical Use Case network requirements with 5G EVE platform offered capabilities. As a result of this activity, one or more 5G EVE platform sites are identified as potential candidates to run Vertical Use Case Experiments.

Once the site has been selected, Test Preparation Phase starts and at the completion of this phase, Vertical Devices / elements are integrated into 5G EVE platform. Then, this platform is configured and ready for defining the test cases of the experiment. 5G EVE platform configuration to support the UC experiment execution includes among other items:

- **Subset of KPIs** that will be used to monitor the experiment test cases.
- **Identification and configuration of simulation tools** required by test experiment to simulate: real clients (i.e.: UE application to simulate real player used by a user), foreground traffic to simulate air interface load caused by additional traffic of similar or different characteristics (i.e. UE application + application server injecting traffic into 5G cell) and background traffic to simulate transport network load (e.g. via servers and rate limits to artificially increase transport network load or reduce available capacity)
- **Network Configuration** including 5G System network functions instantiation.
- **Manual actions** like subscriber provisioning in the network [UDM (5GCN - SA) / HSS (5G EPC - NSA)]

The aforementioned items are executed either by the Vertical tester using tools available in the 5G EVE Portal GUI, automatically by the system or manually by 5G EVE technical support staff. For further details on 5G EVE platform architecture and tools, refers to MS6 - 5GEVE Architecture_v2.0.

After the Test Preparation Phase, Test Execution and Monitoring Phase is initiated by the Vertical Tester generating 5G EVE Platform the Test Cases that will be executed to validate the experiment. Test Cases are generated using "Advanced 5G Testing Tool - Module" of Run Experiment Tool available in 5G EVE Portal GUI. For each Experiment/Vertical Service several parameters (e.g. traffic profile to be simulated, number of simultaneous traffic generators, time sequence for traffic generated by application servers...) will be available for the Tester to compose the Test Cases to be executed.

During TC execution, selected 5G EVE KPIs included in the TC will be monitored using "Experiment Monitoring & Data Collection Module" of “Run Experiment Tool” available in 5G EVE Portal GUI for the Vertical to monitor TC execution. Additionally, Experiment logs can be collected using the same tool.

Finally, the Tester will be able to export from the 5G EVE platform a file which includes information of system configuration used during TC execution.

The aggregation of information for the different experiments under different configurations or simulation conditions will be critical to understand the role of each sub-component on the overall test result.

The experimentation KPIs results should be grouped according to specific characteristics, like the following:

- Physical location of the experiment
- Test Configuration
- Time Period of the experimentation
- Type of end device
- Frequency of RF experimentation
- Type or model of end device
- 5G Service Type
    - xMBB, where extreme Mobile Broadband is the key service requirement.
    - uMTC, where the reliability is the key service requirement of the UC.
    - mMTC, where the massive connectivity is the key service requirement of the UC.

Ideally any combination of the available filters grouping will be valid to check the impact of variations of some KPIs correlated by all these filters. This type of data aggregation can be critical to optimize the desired end configuration for the final vertical industries massive deployments.

The data maybe generated in different experiments or in different places being the same experiment. Also changing the environmental conditions can be interesting to correlate or compare results in order to make later operational or design decisions that allow optimizing the network or see the impact of some of the events experienced.

Therefore, the system must allow to store the results of all the experimental executions that have been executed, being always executed with a methodology correctly implemented and documented that allows its replication over time and from which similar results are expected in any execution If the latter is not guaranteed, the experiment data will not be considered valid for the generation of valid KPIs.

### 3.7.1 KPIs information

5G EVE KPIs can be calculated using the following performance information / data:

- **5G EVE KPI - User Data Rate or Speed**: is set as the minimum user experienced data rate required for the user to get a quality experience of the targeted application/use case (it is also the required sustainable date rate).

- Measurement object: To measure this KPI, for each individual UE and end-user application, the application throughput across time must be measured and recorded. For the sake of that, UE device application (for DL traffic) and Application Server for each individual UE (for UL traffic) must be able to measure and expose this information at UE level + Application level granularity.

  For DL, UE device application must be able to provide this info in some format (e.g. Built-in KPI log file managed by android smartphones).

  For UL, several alternatives exist like a PC equipped with Wireshark sniffing traffic from a mirrored port in a switch or Wireshark on a Linux machine involved with connectivity to Application server.

- Measurement time granularity: Time granularity depends on Vertical / UC requirement and application measurement capabilities in both the UE and the application server. This information should be exposed by the Application Server and UE application to Data Collection Manager module in the Interworking Layer.

- **5G EVE KPI - Peak Data Rate - Broadband connectivity**: is the high data rate provision during high traffic demand periods (It is also a measure of the peak data rate required).

  The measurement procedure for Peak Data Rate is the same as User data Rate or Speed measurement procedure described above.

- **5G EVE KPI - Capacity**: is measured in bit/s/m2 is defined as the total amount of traffic exchanged by all devices over the considered area. The KPI requirement on the minimum Traffic Volume Density / Areal Capacity for a given use case is given by the product: [required user experienced data rate] x [required connection density].
  - Measurement object: To measure this KPI, the following PIs will be used:
    - "Number of 5G System Connected Users": Counter available in NG-RAN node [gNB – ("5G base station", providing NR access) or ng-eNB ("enhanced 4G base station", providing E-UTRA access)]. Counter reports average number of connected users in the cell in the reporting period.
    - User Data Rate or speed: described above.
  - Measurement time granularity:
    - "Number of 5G System Connected Users": Counters is reported with a minimum granularity of 15 minutes (reporting period).
    - User Data Rate: described above.
- **5G EVE KPI - Latency (end-to-end or E2E Latency)**: Measures the duration between the transmission of a small data packet from the application layer at the source node and the successful reception at the application layer at the destination node plus the equivalent time needed to carry the response back.
  - Measurement object: To measure this KPI, for each individual UE and end-user application, the application latency across time must be measured and recorded. For the sake of that, UE device application or Application Server for each individual UE must be able to measure and expose this information at UE level + Application level granularity.

    In case there are limitations to measure Latency as described above, and since Latency is measured aggregating elapsed time in both directions (UL+DL), an alternative way is to deploy an application that can send ping commands to a UE (RTT is measured). This application could be deployed as a VNF close to Application Server.

Note: The following picture shows an implementation design for a traffic generator application implemented as a VNF. Similar concept could be used to ping application.

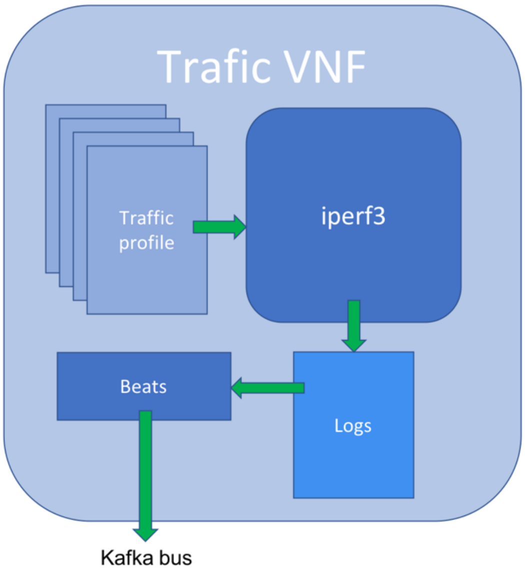


**Figure 9: Example of traffic VNF with iperf3**

- Measurement time granularity: Time granularity depends on application measurement capabilities used. In case of ping application used, this time is configurable.

- **5G EVE KPI - Device Density**: is the number of simultaneous active connections per square kilometer supported for massive sensor deployments. Here, active means the devices are exchanging data with the network.
    - Measurement object: "Number of 5G System Connected Users": Counter available in NG-RAN node [gNB – ("5G base station", providing NR access) or ng-eNB ("enhanced 4G base station", providing E-UTRA access)]. Counter reports average number of connected users in the cell in the reporting period.
    - Measurement time granularity: "Number of 5G System Connected Users": Counters is reported with a minimum granularity of 15 minutes (reporting period).

- **5G EVE KPI - Reliability**: is 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: the reliability rate is evaluated only when the network is available.

  Reliability refers to the continuity in the time domain of correct service and is associated with a maximum latency requirement. It can be measured as the maximum tolerable packet loss rate at the application layer within the maximum tolerable end-to-end latency for that application.
    - Measurement object: To measure this KPI, for each individual UE and end-user application, the packet loss rate across time must be measured and recorded. For the sake of that, UE device application (for UL traffic) and Application Server for each individual UE (for DL traffic) must be able to measure and expose this information at UE level + Application level granularity.

      For UL, UE device application must be able to provide this info in some format (e.g. Built-in KPI log file managed by android smartphones).

For DL, several alternatives exist like a PC equipped with Wireshark sniffing traffic from a mirrored port in a switch or Wireshark on a Linux machine involved with connectivity to Application server. A post processing tool could calculate packet loss rate for the corresponding application data traffic.

- Measurement time granularity: Time granularity depends on Vertical / UC requirement and application measurement capabilities in both the UE and the application server. This information should be exposed by the Application Server and UE application to Data Collection Manager module in the Interworking Layer.

- **5G EVE KPI - Availability**: is the network availability characterized by its availability rate X, defined as follows: the network is available for the targeted communication in X% of the locations where the network is deployed and X% of the time.

  Service availability can be measured by evaluating service operational state of NG-RAN node cells providing service (coverage) to UE.

  - Measurement object: "Cell Availability": Counter available in NG-RAN node [gNB – ("5G base station", providing NR access) or ng-eNB ("enhanced 4G base station", providing E-UTRA access)]. Counter reports the length of time that a cell is available for service.
  - Measurement time granularity: "Cell Availability": Counter is reported with a minimum granularity of 15 minutes (reporting period).

- **5G EVE KPI - Mobility**: refers to the system's ability to provide seamless service experience to users that are moving. In addition to mobile users, the identified 5G use cases show that 5G networks will have to support an increasingly large segment of static and nomadic users/devices.

  Seamless service experience means that UE achieves QoS required by the service / application, see [1] for ITU-R M.2410-0 and [12] for 3GPP TS 22.261 and [14] for 5G-PPP evaluation modelling. Therefore, in this context, it can be defined as the system's ability to reach Vertical / UC requirements of 5G EVE KPI - Latency (also end-to-end or E2E Latency), 5G EVE KPI – Availability, 5G EVE KPI – Reliability, 5G EVE KPI - User Data Rate or Speed, 5G EVE KPI – Capacity and 5G EVE KPI - Device Density to users that are moving.

  Seamless service experience should also be understood in the sense that the Vertical / UC performance requirements are fulfilled, and this is directly mapped to target included 5G EVE KPIs.

  "3GPP TS 22.261 V16.0.0 - Service requirements for the 5G system" describe the system Performance requirements for different scenarios classified in: high data rate and traffic density scenarios, Low latency and high reliability and Higher-accuracy positioning.

  - Measurement object: To measure this KPI, the following PIs will be used:
    - 5G EVE KPI - Latency (also end-to-end or E2E Latency), 5G EVE KPI – Availability, 5G EVE KPI – Reliability, 5G EVE KPI - User Data Rate or Speed, 5G EVE KPI – Capacity and 5G EVE KPI - Device Density
    - "UE speed" that will be provided by UE application or measured through alternative means.
  - Measurement time granularity:
    - 5G EVE KPI - Latency (also end-to-end or E2E Latency), 5G EVE KPI – Availability, 5G EVE KPI – Reliability, 5G EVE KPI - User Data Rate or Speed, 5G EVE KPI – Capacity and 5G EVE KPI - Device Density: refer to 5G EVE KPIs measurement time described in previously in this section.

- "UE speed": Time granularity depends on application measurement capabilities in both the UE or alternative tool.

### 3.7.2 KPIs recollection and aggregation example

In this reference example, the 5G EVE KPI source data is collected and stored by Data Collection Manager module in the Interworking Layer. The 5G KPIs information is exposed in the 5G EVE Portal GUI for the Vertical Tester to monitor 5G EVE KPIs during the experiment execution but also to collect logs later.

Data Collection Manager coordinates the collection and persistence of all performance metrics that are required to be monitored during the execution of experiments for testing and validation of the targeted KPIs.

Data collection Manager maps 5G EVE KPI monitoring and collection requested by Vertical tester into a request for selective collection of network and service-related metrics to the involved 5G EVE sites. In this way, only the metrics needed to validate the KPIs required by the vertical will be monitored in each of the involved site facilities and collected by the Data Collection Manager (either with explicit queries or through publish/subscribe mechanisms) for their storage in a common database shared with the 5G EVE experiment portal.

The following picture Figure 10 shows the Experiment monitoring and data result collection architecture elements. Interworking Layer is responsible of aggregating KPI sources from different network elements and 5G EVE sites. Kafka distributed streaming platform (https://kafka.apache.org/) could be used to transform proprietary from different network / system elements in 5G EVE sites into 5G EVE standard logs that can be aggregated by Data collection Manager in the Interworking layer.

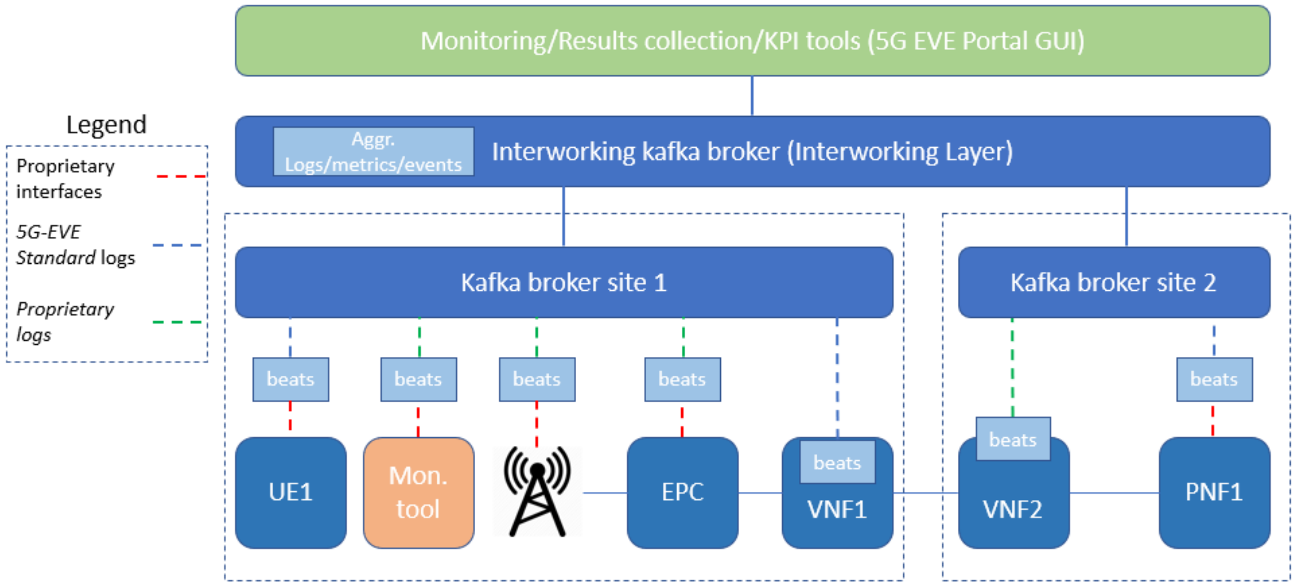


**Figure 10: Example of the experiment monitoring and data result collection architecture elements**

# 4 KPIs Data Sources from 5G infrastructure and Services Applications

Key Performance Indicators are built with measurements, logs and information from the test environment, in this chapter we are detailing the sources of the information required for the generation of these KPIs for the supported Use Cases.

In the first subchapter we will identify the information that is generated or configured with information from within the 5G Infrastructure network. The source of the information is related to 5G network elements, from the User Entities to the MEC servers or the 5G core components.

In the second subchapter we are listing the data sources generated by the service applications deployed for the vertical use cases, where the network or the services applications and not components of the 5G network infrastructure. These components are usually deployed to guarantee that the service is delivering the required Service Level Agreement to the targeted audience.

The information from the Services Applications together with the information from the 5G Infrastructure will be used to validate the 5G KPIs in the different executions of the tests on the Use Cases.

## 4.1 Data Sources from 5G Infrastructure

In this first subchapter we are identifying and describing the sources of information for KPIs generation, including the 5G network infrastructure in the different Use Cases supported in the 5G-EVE project, see the next Figure 11.

| 5G Network KPI Sources | Vertical | Site | Simulations: Tools, systems or equipments used to simulate a real client | Performance: Tools, systems or equipments used to simulate a group of real clients | Log Files | Traffic emulators. Tools or devices used to generate traffic in the 5G Network | Passive probes generation | Monitoring devices |
|---|---|---|---|---|---|---|---|---|
| UC-1 | Transport: Trains | Italy | Android smartphones for collecting raw data from sensors and linux servers and analysizing mobility patterns, simulations and tests being performed by technical people involved in the project | Stress-test tools for mobile apps on commercial smartphones and application backend systems- Tools like iPerf, PacketGen | Built-in KPI log file managed by android smartphones (front-end side) and linux servers (back-end side)+ PC equipped with wireshark | Mobile devices (smartphone) and sensors | External sensors available in the Italian site (e.g., Libellium sensors)+ PC equipped with wireshark | PC equipped with wireshark |
| UC-2 | Turism: Augmented Fair Experience | Spain | | | | | | |
| UC-3a | Industry 4.0: Factory | Spain | Traffic simulator to simulate AGV traffic. | Traffic simulator to simulate traffic load and latency simulator to evaluate latency requirements | | Traffic simulator to simulate AGV traffic. | | |
| UC-3b | Industry 4.0: Factory | Greece | | | Embedded PC wireshark capture files | Tools like Iperf | Switches with mirroring ports connected to a PC for sniffing traffic | PCs with wireshark to monitor DL/UL traffic parameters |
| UC4 | Utilities: Smart Energy | Greece | Mainly real sensors, energy sources and energy consumers. Simulation to be investigated to increase the scale but is not decided yet. | Mainly real sensors, energy sources and energy consumers. Simulation to be investigated to increase the scale but is not decided yet. | Instrumented embedded device/PC connected to sensors and actuators | | | Sensors connected to energy sources and energy consumers and corresponding real-time monitoring service. |
| UC-5a | Smart City: Safety & Environment | France | | | PC equipped with wireshark used in parallel with WiFiscanners to validate logs | Tools like iPerf, PacketGen | | |
| UC-5b | Smart City: Safety & Environment | Greece | Real sensors/devices | Real sensors/devices | Instrumented Gateway device | Real devices/sensors | Traffic sniffer | Integgrated instrumentation and PCs with wireshark |
| UC-5c | Smart City: Safety & Environment | Greece | Smartphone simulator and real smartphone devices. | Stress-test tools for mobile apps and real smartphone devices | Instrumented smartphone device | Tools like iPerf, PacketGen | VirtualBox metrics monitoring: network, CPU, memory | STARLIT's real-time monitoring system |
| UC-6a | Media & Entertainment: UHFM | Spain | Yes, Spirent Avalanche & real devices | Yes, Spirent Avalanche & real devices | Instrumented Smart Phone device | SmartPhone as modem, real video devices connected: SmartTVs, Tablets | vMEC Linux monitoring: network, CPU, memory | Real Time Monitoring system and Localization system @vMEC |
| UC-6b | Media & Entertainment: On Site Event | Spain | Yes, Spirent Avalanche & real devices | Yes, Spirent Avalanche & real devices | Instrumented Smart Phone device | SmartPhone as modem, real video devices connected: SmartTVs, Tablets | vMEC Linux monitoring: network, CPU, memory | Real Time Monitoring system and Localization system @vMEC |
| UC-6c | Media & Entertainment: Immersive & Integrated | Spain | Yes, Spirent Avalanche & real devices | Yes, Spirent Avalanche & real devices | Instrumented Smart Phone device | SmartPhone as modem, real video devices connected: SmartTVs, Tablets | vMEC Linux monitoring: network, CPU, memory | Real Time Monitoring system and Localization system @vMEC |
| UC-6d | Media & Entertainment: Immersive & Integrated | France | Simulation of VRplayer : Avaratar recorder/replayer & real VR devices (HMD) | | Wireshark (on the pc linked with the video device) | Real VR devices (HMD) | Wireshark to capture pcapng traces on different Linux machine involved in the end to end architecture | |

**Figure 11: Summary of 5G Network KPI sources**

First a list of different 5G network elements activity log files is described, following the 5G network configuration data that describes the experiment configuration or the network settings.

### 4.1.1 Activity log files

For some 5G measures each Use Case is planning to use different network elements, and some of these elements will generate activity information stored in logs that will be ingested and processed for KPIs generation.

The following File logs will be ingested by the KPI Collection Modules:

- Android Smartphones: these commercial devices are the first 5G market devices and provides some information logs that will be ingested in the project. Format for this log files will be preferably of plain text such as CSV or JSON.
- Linux Servers from the Back-end: some of the virtualized 5G network elements are built on top of Linux operating system, the performance logs generated by the operating system will be used as source of information.
- PC Servers with Wireshark capture software: Wireshark capture software installed in some Computers and connected to the 5G network infrastructure are being used to generate performance information evidences
- Instrumented embedded devices connected to sensors and actuators: some embedded IoT sensors and actuators will be used to generate logs files
- Instrumented Gateway devices: some 5G gateways with instrumental support functionality will be
- Instrumented smartphone devices: some 5G smartphone devices with instrumental support functionality will be used

### 4.1.2 Configuration data

The test configuration data will be ingested in the 5G-EVE KPI framework, data information sources will be in parameter-value files.

Information stored in these files will be 5G settings of the 5G Network. This information could change from one experiment configuration to another and can include UE capabilities supported in a given terminal firmware, 5G radio configuration or environmental test conditions.

1. Some of the UE capabilities can include the configuration of operating bands and channel bandwidths. The throughput of the RF specifications is in many cases defined separately for different frequency ranges. The frequency ranges in which 5G NR can operate are basically corresponding the frequency range 450 MHz – 6000 MHz, or to the frequency range 24250 MHz – 52600 MHz
2. The use of some Carrier Aggregation features including several frequencies in the same frequency range or even in several ranges will be included.
3. The site test environmental description including simulation scenarios, distances, geometries, etc.
4. Sources of information not included in the automatic information collection system could be included in a first approach as experiment file configuration
5. GPS information or positioning information of the UE and the radio elements used in the test

This file format will be agreed in all the sites for all the experiments.

### 4.1.3 Active Probes information

Active probes, or traffic generators, are network elements that can simulate clients that produce traffic sent to the applications or received from the servers for client emulations. These probes are producing logs information with the measurements of some parameters of the traffic sent and received to the 5G Network.

In the 5G-EVE Use Cases the following active probes will be used:

- User Entities:
    - Mobile devices and sensors: these devices will generate 5G network traffic with automatic tests measurements
    - Smartphones: these devices will be used to simulate real user traffic inside the 5G network

- Traffic simulator:
    - Iperf traffic emulator: iperf or iperf3 based software will be used to generate 5G network traffic inside the 5G network infrastructure to stress the use cases executed tests cases
    - PacketGen traffic emulator: this traffic generator will be used in some Use Cases with specific performance profile tests.

### 4.1.4 Passive Probes information

Passive probes are network elements that can sniff network traffic generated in the network during the experiments. These probes produce logs information with the measurements of some parameters of the sniffed traffic sent and received to the 5G Network. These probes are not generating traffic and are not disturbing the real 5G network load in any way.

In the 5G-EVE Use Cases the following passive probes will be used:

- Software:
    - Wireshark PC: this network capture software will be used with specific filters to store information related to some 5G network traffic. The capture logs will be ingested by the 5G-EVE collector and will be associate to some Use Cases results.
    - VirtualBox software: the VirtualBox includes some metrics like network activity, CPU loads, memory allocation, etc, that will be ingested by the system
    - Virtual Multi-access Edge Computing: this particular 5G network element will be based on Linux Operating System and the standard Linux logging capabilities including network activity, CPU loads, memory allocation, etc, will be ingested
    - Pcapng traces: this experimental version of the pcap software will be used to generate some 5G network measures supported in some Use Cases.
- Hardware:
    - Switches with ports mirroring connected to a PC: these switches will be interconnecting some 5G network interfaces, allowing the replication of real bi-directional network traffic in other ports that will be analysed with other capture devices or with the switch traffic statistics couter.

### 4.1.5 Monitoring devices

Several monitoring devices will be used in the network in the experiments. These devices are producing logs data information with the measurements of some parameters of the 5G Network traffic. These devices are installed inside the 5G network.

In the 5G-EVE Use Cases the following monitoring devices will be used:

- Wireshark PC: this network capture software will be used with specific filters to store information related to some 5G network traffic. The capture logs will be ingested by the 5G-EVE collector and will be associate to some Use Cases results.
- Sensor connected to energy sources and consumers: these monitoring devices will be part of the 5G network monitoring
- STARLIT real-time monitoring system: this monitoring system will be deployed to monitor the 5G network
- Real Time Monitoring system and Localization system @vMEC: the system will be able to monitor the User Entity localization and some real-time data during the experiment execution. The information will be later ingested by the 5G-EVE common collector.

## 4.2 Data sources from vertical services applications

In this second subchapter we are identifying and describing the sources of information in Figure 12 for the KPIs generation, including the vertical service applications deployed for the vertical use cases, where the network or the services applications and not components of the 5G network infrastructure. These components are usually deployed to guarantee that the service is compliant with the required Service Level Agreement to the targeted audience.

| Services KPI Sources | Vertical | Site | Log Files | Configuration Files | Active Probes |
|---|---|---|---|---|---|
| UC-1 | Transport: Trains | Italy | Application log files managed by android smartphones (front-end) and linux servers (back-end) | Configuration file | Traffic generator iperf |
| UC-2 | Turism: Augmented Fair Experience | Spain | | | |
| UC-3a | Industry 4.0: Factory | Spain | Platform log files | configuration files | Yes, traffic simulator to simulate AGV traffic. |
| UC-3b | Industry 4.0: Factory | Greece | Platform log files | configuration files | |
| UC4 | Utilities: Smart Energy | Greece | Platform log files. | Configuration files | |
| UC-5a | Smart City: Safety & Environment | France | Platform log files. | Configuration files | |
| UC-5b | Smart City: Safety & Environment | Greece | Platform log files | configuration files | |
| UC-5c | Smart City: Safety & Environment | Greece | Platform log files, Mobile application log files | Configuration files | Mock clients |
| UC-6a | Media & Entertainment: UHFM | Spain | Video Servers, Application Servers | Configuration test file | Players with Applications |
| UC-6b | Media & Entertainment: On Site Event | Spain | Video Servers, Application Servers | Configuration test file | Players with Applications |
| UC-6c | Media & Entertainment: Immersive & Integrated | Spain | Video Servers, Application Servers | Configuration test file | Players with Applications |
| UC-6d | Media & Entertainment: Immersive & Integrated | France | Video Servers | Configuration test file | simulation of VRplayer : Avaratar recorder/replayer |

**Figure 12: Summary of Services Validation KPI sources**

### 4.2.1 Activity log files

Some of the KPIs can be validated with data from specific Use Cases applications. The logs of activity of the Applications may be parsed by 5G-EVE system to extract some relevant parameters valid to generate KPIs related to the end user performance. The information will be critical to check whether the different use cases are delivering traffic with enough quality to the final users.

Some of the applications that will produce this information are the following:

- Application log files managed by android smartphones: the front-end applications installed outside the 5G network infrastructure, in android smartphones will be used to generate some KPIs information.
- Linux server: the back-end application servers installed outside the 5G network infrastructure will be used to generate KPIs information.
- Platform log files: the AGVs platform will generate some log files with information that will be ingested by the 5G-EVE collectors.
- Mobile application: the AGVs mobile applications will generate some log files with information that will be ingested by the 5G-EVE collectors.
- Video Servers: the video streaming servers are delivering TCP video to the end video players and will generate aggregated video session statistics for any end-device from the server side. This information will be ingested by the KPI collectors.
- Application Servers: the video application servers will be configured to support several kind of video stress-tests and video streaming configuration, generating information of the test experiment environment that will be ingested in the 5G-EVE framework.

### 4.2.2 Configuration data

The configuration data of the Services Validation Sources is represented by a text file with description of the Services capabilities used in the tests (i.e.: channels bitrates, video format, streaming format, etc). The file format must be agreed by all the sites for all the experiments.

The test configuration data for the application services will be ingested in the 5G-EVE KPI framework, data information sources will be in parameter-value files. Information stored in these files will be application services settings of the non 5G Network. This information could change from one experiment configuration to another and can include:

1. Video channel bitrates: for some video delivery services the same channel can be delivered with several video bitrates, potentially delivering different video service levels that will be perceived by the end users with different levels of quality.
2. Video streaming format: video can be delivered in several adaptive streaming formats like HLS, Smooth Streaming, MPEG-DASH that will generate different distribution platforms
3. Video encoding format: videos will be delivered with several resolutions, including SD, HD or 4K video, with different video compression codecs like h264 or h265.

This file format will be agreed in all the sites for all the experiments.

### 4.2.3 Active Probes information

Active probes are service elements that can simulate clients that produce traffic sent to the servers for client emulations. These probes are producing logs information with the measurements of some parameters of the traffic sent and received to the 5G Network. These active probes are installed outside the 5G network and usually are deployed by the services operators to guarantee the committed Service Level Agreements.

In the 5G-EVE Use Cases the following active probes will be used:

- Traffic generator: the iperf or iperf3 software tool will be used with several profiles to generate simulation of user traffic
- Traffic simulator with profile to simulate AGV traffic: this specific traffic simulator profile will simulate several profiles the AGV traffic for some end-to-end simulation tests
- Mock clients: some specific applications will implement very specific traffic profiles for some clients
- Players with Applications: for video services tests a complete system of automatic video players with application servers that include a set for video files with a library of different bitrates, codecs and streaming formats will be used for automatic traffic generation.
- Simulation of VRplayer: one specific application, the Avaratar recorder and replayer will be used for immersive video automation tests

# 5 Use of KPIs information

In this chapter we will review the classification of Vertical Industries to identify the main target of the generated KPIs for each use case, and we are also analysing the deployment architecture that can be applied for the supported Use Cases in different scenarios, deployment areas or technological options.

## 5.1 Different verticals

In this first subchapter we will review the classification of Vertical Industries and the diversity of coverage areas of the participating vertical industries in the 5G-EVE projects.

In the first phase of the project the targeted Use Cases will support the industries in Figure 13.

| Requirements | UC-1-IT-TRENITALIA | UC-3a-AV-ASTI | UC-3b-AV-GR-ERICSON | UC4-WINGS-EDF | UC-5a-SmartTurin | UC-5b-Nokia-GR |
|---|---|---|---|---|---|---|
| **Verticals: Different verticals that can run the use case and that can influence in the validation requirements capabilities.** | Transport | Logistics companies, industry automation, self-driving car | Telcos, logistics companies, industries | Utilities, Consumers, Telcos. | Municipalities, Operators, City planners | eHealth providers/Hospitals/Telecom providers |

| UC-5c-WINGS | UC-6a-TELEFONICA-UHFM | UC-6-TELEFONICA-OLEE | UC-6-TELEFONICA-IIM |
|---|---|---|---|
| Municipalities, Hospitals, Telcos | Big Telco Operator | Big Telco Operator | Big Telco Operator |

**Figure 13: Vertical Industries**

### 5.1.1 Use case 1 - Smart Transport: Intelligent railway for smart mobility

Intelligent transportation paradigms are one of the main vertical industries targeted by 5G, since the wide applicability of the sector as well as the stringent requirements on latency, reliability, mobility and BW, provide a challenging use case. Trenitalia (TRIT) will lead the experimentation in this area.

This Figure 14 is the high-level description of the two supported scenarios:

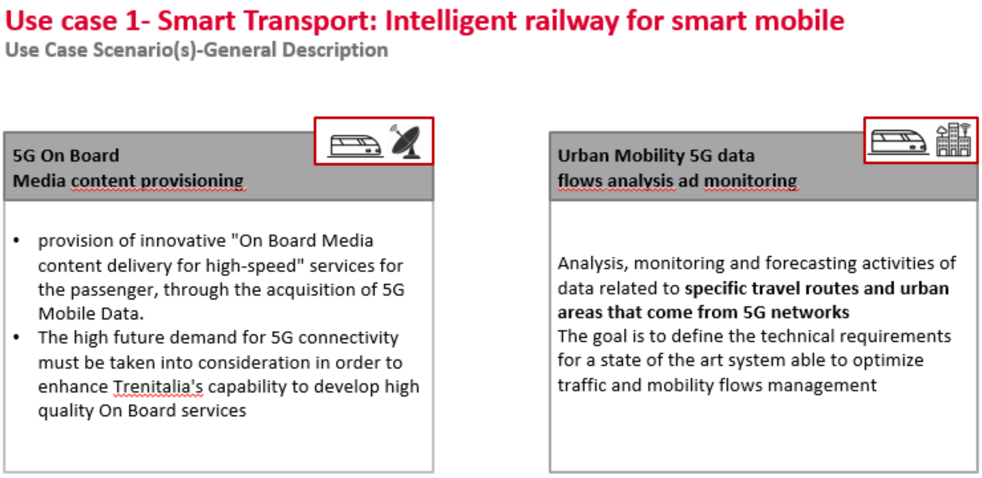


**Figure 14: Smart Transport for intelligent railway scenarios summary**

The considered use of intelligent railway mobility will set in an On-Board demo environment framed on two main general requirements related to:

- Number of users: potential number of users of On-Board 5G related services is set up to 300 per each daily train transport offering

- Mobility: an achievable value for a mobility of up to 300 km/h is considered to guaran-tee 5G collecting end-user position and contextual data

In the next Figure 15 we can see some datils of on the included scenarios, the Urban Mobility 5G data flows for traffic management for public transport.

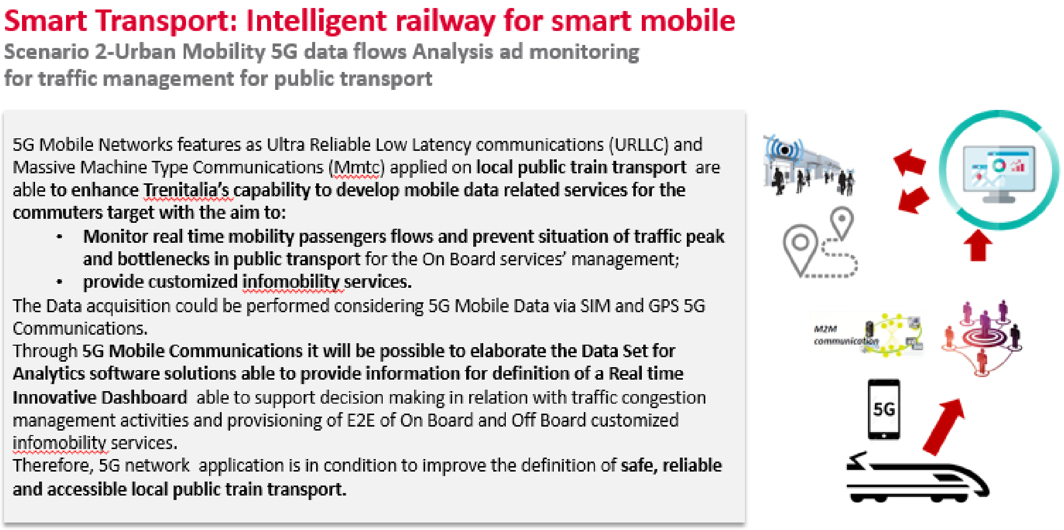


**Figure 15: Scenario for Smart Transport data flows Analysis and monitoring**

From these demo framework requirements, a set of target KPIs has been identified regarding the URLLC and mMTC aspects to ensure Service continuity related to the On-Board connectivity and high level of throughput provisioning level per passenger for the experimentation of the 5G End to End ser-vices.

### 5.1.1 Use case 2 - Smart Tourism: "Experiential tourism through 360 de-grees video and VR"

Tourism activity must be considered a vast transversal industry involving a wide range of multiple providers and users which configure and determine its unique idiosyncrasies. This diversity obliges to conscientiously concrete the potential use cases participating in 5G-EVE projects so as to obtain real validation resulting from access to early state-of-the-art 5G features that can transform and improve the tourism sector.

The efforts in these sub-uses cases are concentrated in the overall use case "Experiential tourism through 360 degree video and VR", in order to transform the experience of participants in events, conventions, presentations and meetings (professionals and general public), by amplifying their participation and improving their interac-tions, taking advantage of VR technology and the immersive qualities of 360 degree video.

Therefore, the preliminary analysis requires placing the user at the center of our efforts to:

- Guarantee personalized attention by providing high quality content that will consume on demand, taking advantage of the high speed provided by 5G.
- Provide an enriched experience to the users, thanks to the 360 degrees video immersion in combination with VR technology.
- Encourage the digital transformation of the tourism industry, transforming any event into an immersive space of work and knowledge.
- Promote new revenue sources, thanks to the interaction possibilities offered by the combination of 5G and VR.

Based on these general premises designed to provide the "new user experience" and taking into account the potential offered by the tourism industry for the validation of 5G connectivity, the following sub-use cases have been selected:

**Immersive events in** Figure 17: participation in events is a constant in the tourism industry and to improve the visibility of professional events while providing a differential experience of the product to attendees is possible by combining VR technology with 360 degrees video. This technological combination will take experimentation and immersion to the next level, facilitating the organization and assistance to events that take place simultaneously and providing them with an immersive experience thanks to the 360 degrees video.

High definition contents (4K/8K) can be consumed with 360º video from different angles and it is here where 5G connectivity will play a fundamental role, because:

- a greater bandwidth will be necessary so as to enable visualizing this content with the proper quality and avoiding pauses;
- an improvement in latency should be required in order to improve user's experience with content reception.

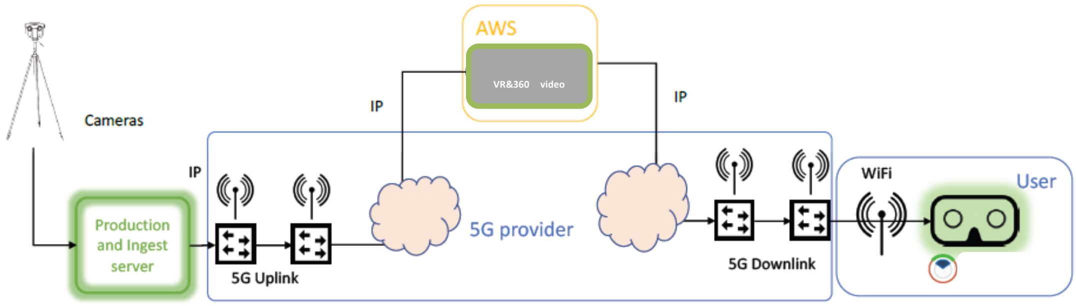


**Figure 17: Immersive events**

**Virtual tickets in** Figure 18: 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 MICE sector. The 5G technology will facilitate the reception of content via streaming with respect to any event thanks to the improvement in connectivity and bandwidth. In the case of the organizers, the sale of virtual tickets will allow the packaging of contents according to multiple market segments, creating on-demand contents that are of the full interest of the target audience.

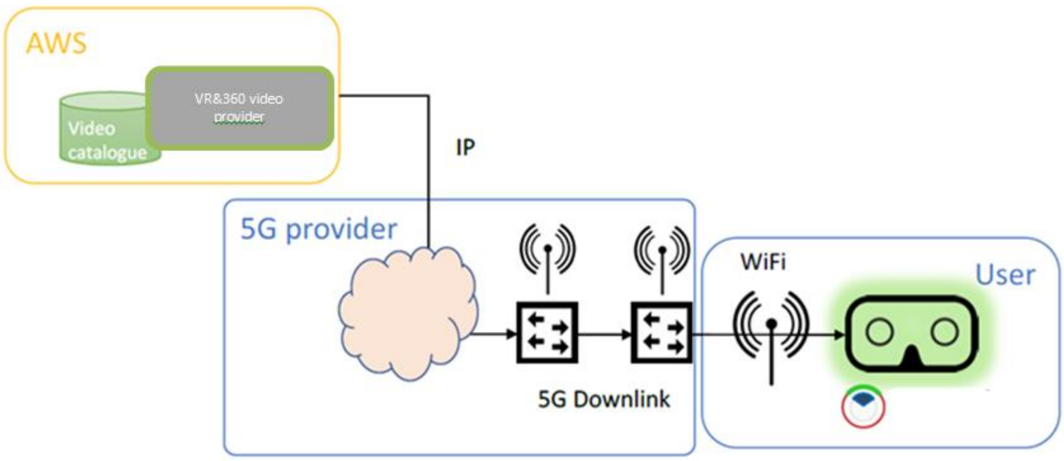


**Figure 18: Virtual tickets**

The targeted KPIs in these sub use cases are related to the VR streaming demands at a sustained bit rate of 200 Mbps (Uplink) and 50 Mbps (downlink) in specific locations. VR headsets should be used for tests. E2E latency must be lower than 1 ms for sub-use case 1 and 100 ms for sub-use case 2.

### 5.1.1 Use case 3 – Industry 4.0: AGVs

This use case intends to demonstrate the feasibility of centralizing the control of automated guided vehicles (AGVs) operating in complex manufacturing environments and relying on wireless connections between the vehicles and a centralized control unit close to the network edge.

The use case requirements demand some functionalities which are provided or only supported by 5G, like reduced latency, network slicing to support different processes that may present different requirements, and high bit rate to support the use of inputs to the guidance process like high definition video and/or LIDAR sensors.

There are two sites scenarios for tests, one in Greece and a second in Spain. In Figure 19 we see an overview of the UC3 scenario for Greece:

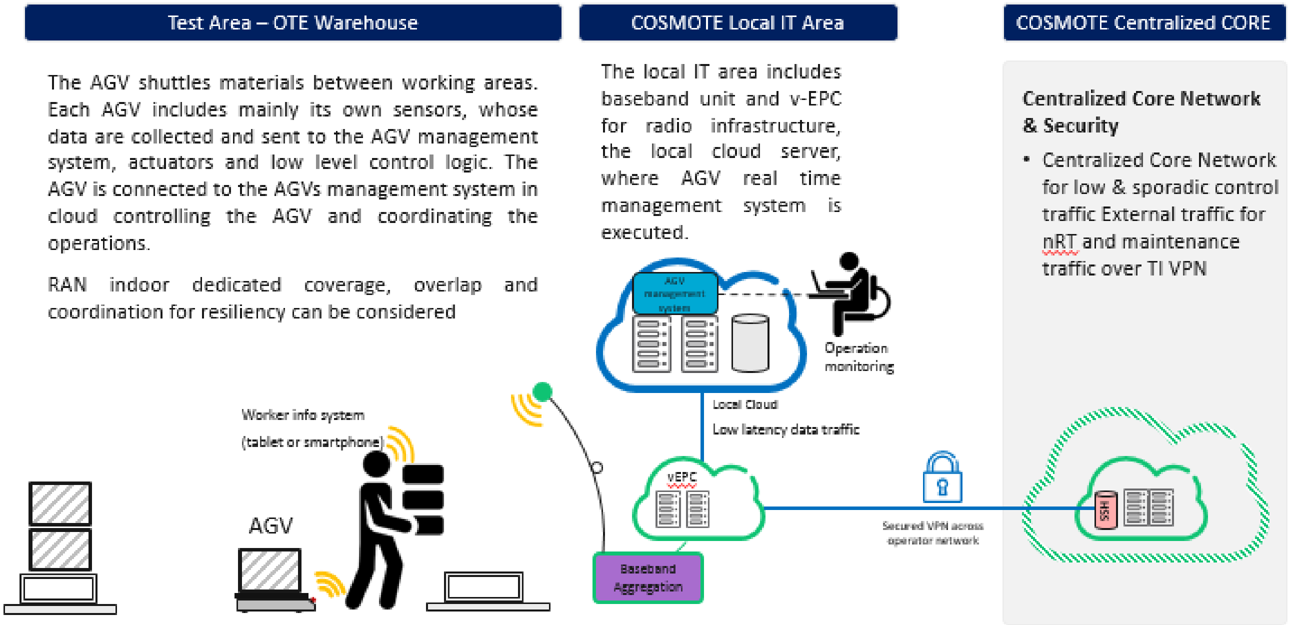


**Figure 19: Industry 4.0 AGVs overview**

Mobile robots will be used to transport goods between various stations in a process or to and from de-pots. Deploying mobile robots in logistics improves 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 or dirt, robots can carry out any sequence of events to ensure that materials arrive at the right place just in time.

A high-performance mobile network connecting the robotic vehicles to the cloud-based control system is required. For example, an UL speed of 80 Mbps or higher, maximum acceptable jitter of less than 5 ms, no data buffering and end-to-end latency of less than 10 milliseconds is required to ensure seamless and safe operation.

The Figure 20 is the high-level description of the UC3 scenario for Spain:

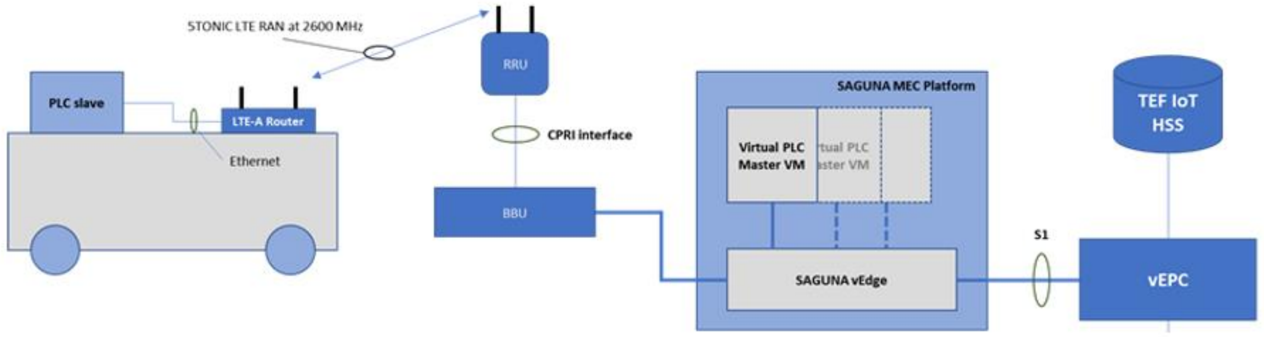


**Figure 20: Industry 4.0 components for ASTI AGV**

The AGV will have a Slave PLC on board. This PLC will collect the information from the sensors and physical inputs, this will be sent to the Virtual PLC. The Virtual PLC will process all this information, then it will take the appropriate control decisions and it will generate the right signals to control the motors of the AGV. This control signals will be sent by 5G communication to the Slave PLC, who will process them translating to real physical signals to command the motors.

The most challenging requirements to ensure the deployment of the solution in the future factories is the high reliability and the low latency and jitter.

### 5.1.1 Use case 4 – Utilities

The integration of an ever-increasing number of distributed generators (renewable energy, farms, households, etc.) into the electricity grid also introduces greater unpredictability of energy production and an increased risk of failures and section isolations. Currently, fault detection and management in energy grids, takes place through fibre connectivity among the centralized electricity generation points (e.g. power plants).

The move towards Distributed Generators (DG) offers great potential but also makes a fibre-communication monitoring solution prohibitive due to its deployment cost. 5G can enable ultra-fast and ultra-reliable fault detection and management among an extensive number of DGs, with decreased CAPEX and OPEX.

Such a fault management system is essential for modern smart grids, enabling immediate reaction to change in the network thus avoiding unwanted islanding, providing dynamic stability and protection to the network and eventually allowing the integration of an even greater number of DGs. The use of smart metering and fault detection mechanisms in combination with MEC functionality for ultra-fast processing, could even lead towards a centralized grid protection system, elevating the level of control over the energy grid.

There are two sites for this Use Case, one in France and the other in Greece, this Figure 22 is the high-level description of the Greek site:

- Network of energy sources, comprising batteries but also panels combined with sensors to measure the energy level. Panels are the prosumers.
- Network of energy consumers, comprising some actuators, like lamps, fans etc. combined with sensors to measure the energy consumption
- Distribution network, comprising cables connecting sources with consumers

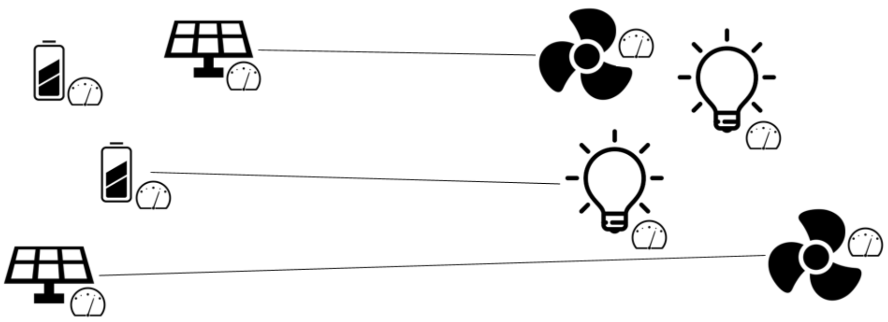

**Figure 21: Utilities for electricity sensors and distribution network**

The use case considers the small/medium scale representation of distributed electricity generation in smart grids. The use case will target as first step a demonstration system with actual distributed energy generation and consumption points as well as smart meters, and potentially at a second stage a scaled-up demonstration taking place in a specially equipped room.

The targeted KPIs include fault detection lower than 5 milliseconds with a 99.999% network availability and 99.999% network reliability. In case of message delivery failure, a notification should be issued to lead to the deployment of a fallback solution. Device density and data rate requirements are lower than 2000 devices/km2 and lower than 50 Mbps.

This Figure 22 is the high-level description of the French site:

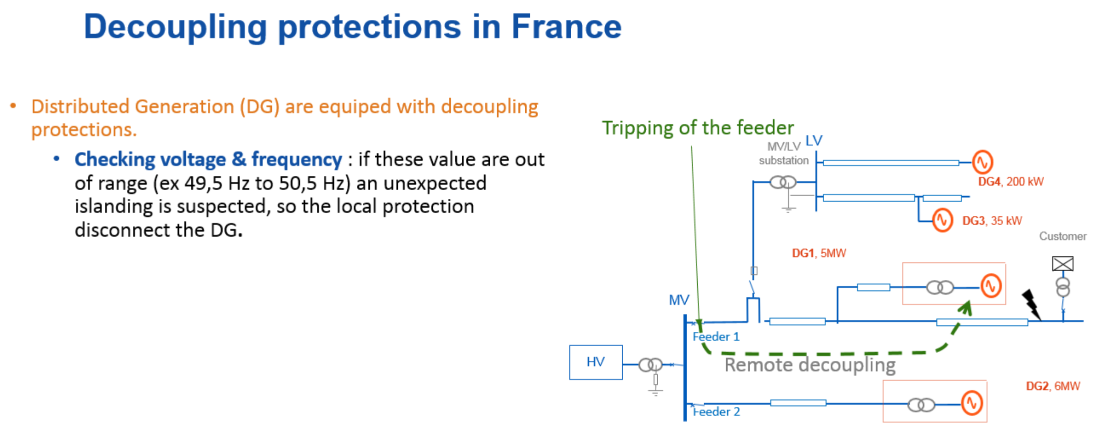


**Figure 22: Utilities for electricity distributed generation with decoupling protection**

This French scenario supports remote decoupling protections for DGs in the electric grid and considers two electric feeders in a primary substation and all the Distributed Generation (DGs) connected to these feeders. The Use Case scenario implements a demonstration mockup with actual distributed energy generation protection and feeder protections.

The targeted KPIs for the fault detection includes a latency lower than 30 milliseconds with a 99.999% network availability and 99.999% network reliability. In case that the latency cannot be obtained, a notification should be issued to switch to the deployment of a fallback configuration of the DGs protections. Device density and data rate requirements are lower than 2000 devices/km2 and lower than 1 Mbps.

### 5.1.1 Use case 5 – Smart City

The smart city concept integrates information and communication technology (ICT), and various physical devices connected to the network (the Internet of things or IoT) to optimize the efficiency of city operations and services and connect to citizens.

Smart city technology allows city officials to interact directly with both the community and city infrastructure; and to monitor what is happening in the city and how the city is evolving.

There are two sites for this Use Case, one in Italy and the other in Greece, this Figure 23 is a description of the Italian site:

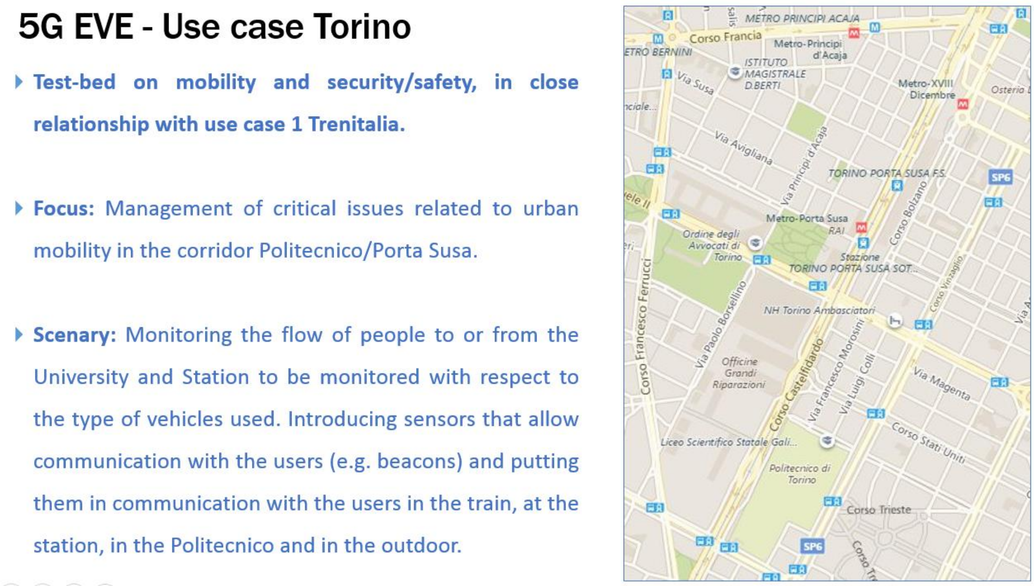


**Figure 23: Smart City of Torino overview**

Within the framework of the collaboration between TIM and Comune di Torino for the 5G deployment in the city of Turin, managed under the “5G Memorandum of Understanding” signed on May 2017, the partners involved in this “Safety and Environment - Smart Turin” testbed will work towards the implementation of the well-known set of 5G services under the areas of URLLC and mMTC. A set of significant number of sensors will be deployed and connected to the Italian 5G site, acquiring ultra-low latencies in the overall communication. In particular, the object of the experimental activities will be focused on the “Urban Safety” scenario.

This Figure 25 is the high-level description of the Greek site for the connected ambulance:

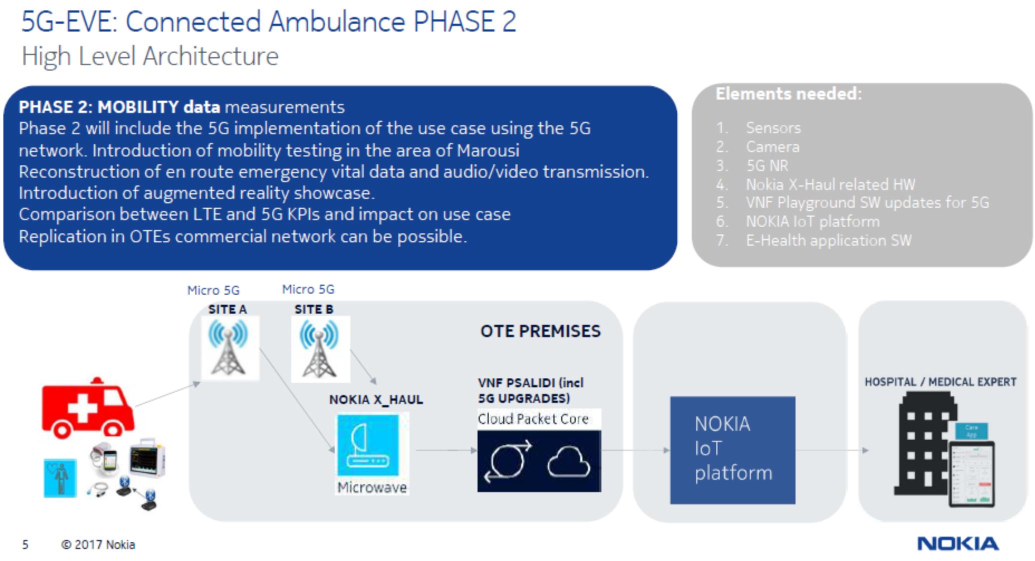


**Figure 24: Smart City for Connected Ambulance overview**

The 5G "Connected Ambulance" concept will advance the emergency ambulance services with their healthcare stakeholders to help create improved experiences and outcomes for patients in their care. The vision of the Connected Ambulance combines many advanced technologies that come together to enable the delivery of better life enhancing outcomes for patients. The continuous collection and streaming of patient data will begin when the emergency ambulance paramedics arrive at the incident scene right before the delivery of the patient to the emergency department at the destination hospital.

There are more scenarios in the Greek site including:

- Automated indoor environment adaptation with functionality for learning user patterns to forecast the preferences of the user regarding indoor environment/home appliances configuration and proactively take actions/offer recommendations.
- Remote health monitoring and forecasting comprising functionality for learning patterns in the user's physical status so as to be able to identify abnormalities. Family members and/or professional caretakers can be informed, and appropriate alarms may be raised if necessary.
- Smart mobility providing navigation instructions, information on dangerous locations in the proximity, public transportation help considering user preferences and health/wellbeing status.

The network requirements of the services envisaged in this use case are shaped as follows:

- mMTC slices for aggregating various kinds of information as described above in the context of continuously monitoring the users and the city. KPIs: latency ~20 ms; mobility spanning 0-200 km/sec; device density around 60K devices/km2.
- uRLLC slice for disseminating critical information, such as in the case of re-routing due to urgent city incidents. KPIs: latency <5 ms; speed up to 1Mbps; reliability ~99,99%; availability ~99,99%; mobility spanning 0-200 km/sec; broadband connectivity ~25Mbps; capacity up to 0,2Mbps/m2.
- eMBB slice for providing support to caregivers through live streaming of the user's status while on route to the hospital. KPIs: latency ~ 20 ms; speed spanning 25Mbps-400Mbps; mobility up to 200km/h; broadband connectivity at 400Mbps.

### 5.1.1 Use case 6 – Media & Entertainment

Media will play a critical role in the future communications in a myriad of new 5G vertical applications, we have selected the most critical use cases including Ultra High-Fidelity (UHF), On-site Live Event and Immersive media in order to be able to customize and enhance the quality of the Vertical user's experience. To this

end, eMBB scenario will be used to guarantee maximum coverage, mMTC for machine media creation and URLLC to guarantee live events coverage will be supported.
This use case includes four (adaptable) multimedia scenarios:

- *Ultra-High-Fidelity* Media experience with highly immersive viewing experience and ultra-crisp, wide-view pictures will be made possible through the use of both linear (e.g. live programming, streaming) and non-linear (e.g. on-demand) content. To guarantee this high quality of experience, the future 5G network should be able to support efficient network management high speed transport capabilities and strategies, e.g. by means of local and network caching of content.
- *On-site Live Event Experience* will be made possible in large scale event sites, such as cinemas, stadiums and hall parks leading to enhanced viewing experience (replay, choose a specific camera, etc).
- *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 / hers ambient for viewing (e.g. in the car, at home etc.) New 5G capabilities will enable 360 immersive video experiences such as immersive video conferencing simulating the face to face experience that present videoconferencing systems do not allow.
- *Immersive Virtual Visitors* should benefit from 360° media delivery in a quality that may allow replacing a physical visit with a virtual one, therefore one general requirement is to support the streaming of 360° video matching the highest quality supported by high-end head mounted displays

For the Ultra High-Fidelity Media experience the current IPTV platform will be used to provide high quality video to the 5G Network new video devices, allowing the deployment of new 4K video qualities to these new devices using a mobile network. The Multi-Access Edge Computing will be used as a collector for the TV HEAD-END multicast video sources, delivering to the new 5G network access video in Adaptive Video format to the new devices.

This Figure 25 is the high-level description of the UC6 where the IPTV Platform of Telefonica will be used by the new 5G network devices:

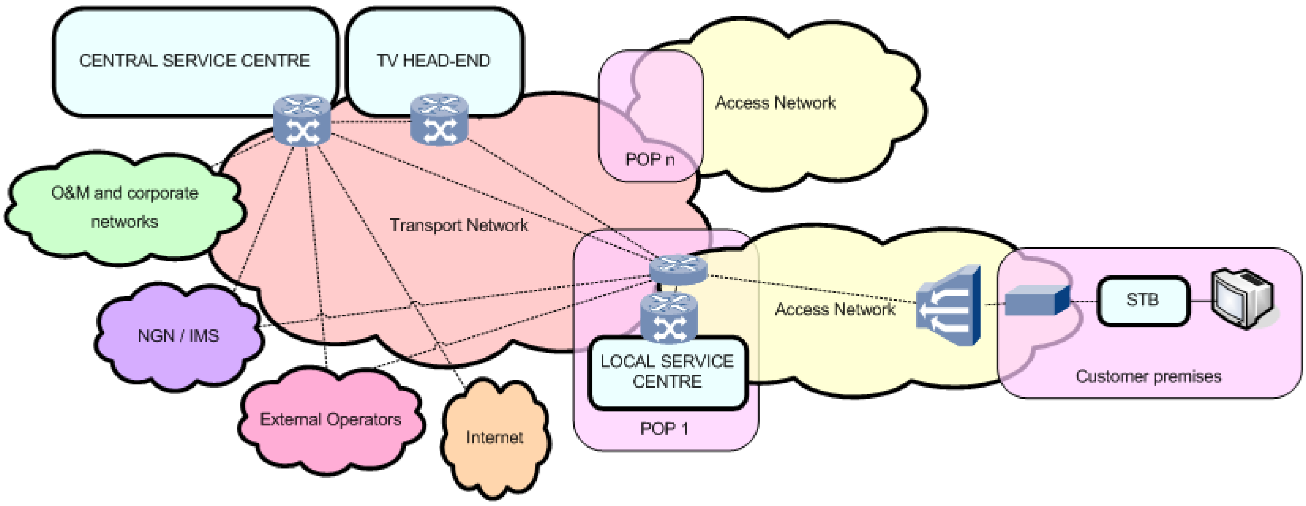


**Figure 25: Media & Entertainment: IPTV Platform for Fiber and xDSL STB clients**

The next Figure 26 presents the scenario for the On-Site Live Events Experience:


**Figure 26: On-sites event experience**

For the eMBB aspects of multimedia, up to 50 Mbps of a single video source will be generated, but many concurrent video sources will be tested including up to 20 channels at 1 Gbps total bandwidth. For mMTC and URLLC a camera car for remote driving using and control will require lower latency than 10 milliseconds and ultra-reliable capacity. The KPIs will be updated and revised during the project lifetime accordingly to the evolution of the standardization process and corresponding technology availability and actual implementation.

## 5.2 Deployment Architectures

Depending on many factors the verticals deployments are customized for different covered areas, previous infrastructure, or just adjusted to budget constraints.

In the following Figure 27 we can see the selected models adopted by the 5G-EVE participant vertical industries for the first phase of the project.

| Requirements | UC-1-IT-TRENITALIA | UC-3a-AV-ASTI | UC-3b-AV-GR-ERICSON | UC4-WINGS-EDF | UC-5a-SmartTurin | UC-5b-Nokia-GR |
|---|---|---|---|---|---|---|
| **Architectures: Short description of the Network capabilities or deployment model used in the UC** | LTE commercial following by NSA 3.x infrastructure with 5G radio band B43 | NSA 3.x for first phase with vMEC @ edge, 5G radio in 3,5 GHz | | NSA 3.x for first phase with edge devices, 5G radio in 3,5 GHz, GRPS, NB-IoT | LTE commercial following by NSA 3.x infrastructure with 5G radio band B43 | NSA 3.x for first phase with edge devices, 4G radio in Band 7 |

| UC-5c-WINGS | UC-6a-TELEFONICA-UHFM | UC-6-TELEFONICA-OLEE | UC-6-TELEFONICA-IIM | UC-6-VV-ORANGE-FR |
|---|---|---|---|---|
| NSA 3.x for first phase with edge devices, 5G radio in 3,5 GHz, GRPS, NB-IoT | NSA 3.x for first phase with vMEC @ edge, 5G radio in 3,5 GHz | NSA 3.x for first phase with vMEC @ edge, 5G radion in 3,5 GHz | NSA 3.x for first phase with vMEC @ edge, 5G radion in 3,5 GHz | First phase in 4G context to validate the end to end use case, then migration to 5g context |

**Figure 27: Architecture of the deployment network**

## 5.2.1 NSA vs SA

3GPP defined several network deployment options to expedite the roll-out of 5G. These can be categorized into two groups, as presented in Figure 28: Non-standalone (NSA) and Standalone (SA).

- In the NSA options (3, 4, 7) 5G New Radio (NR) gNB and 4G LTE eNB co-exist in the RAN and connect to either an existing EPC or a new 5G Core (5GC). Initially, most CSPs will deploy Option 3 which adds 5G NR into an existing LTE network to primarily to improve coverage and capacity for enhanced mobile broadband services (eMBB).
- In the 5G SA deployment options (2, 5), a new 5GC is connected to either new 5G NR or evolved LTE (eLTE) radio network. In addition to Option 3, many CSPs are trialing and testing SA option 2.

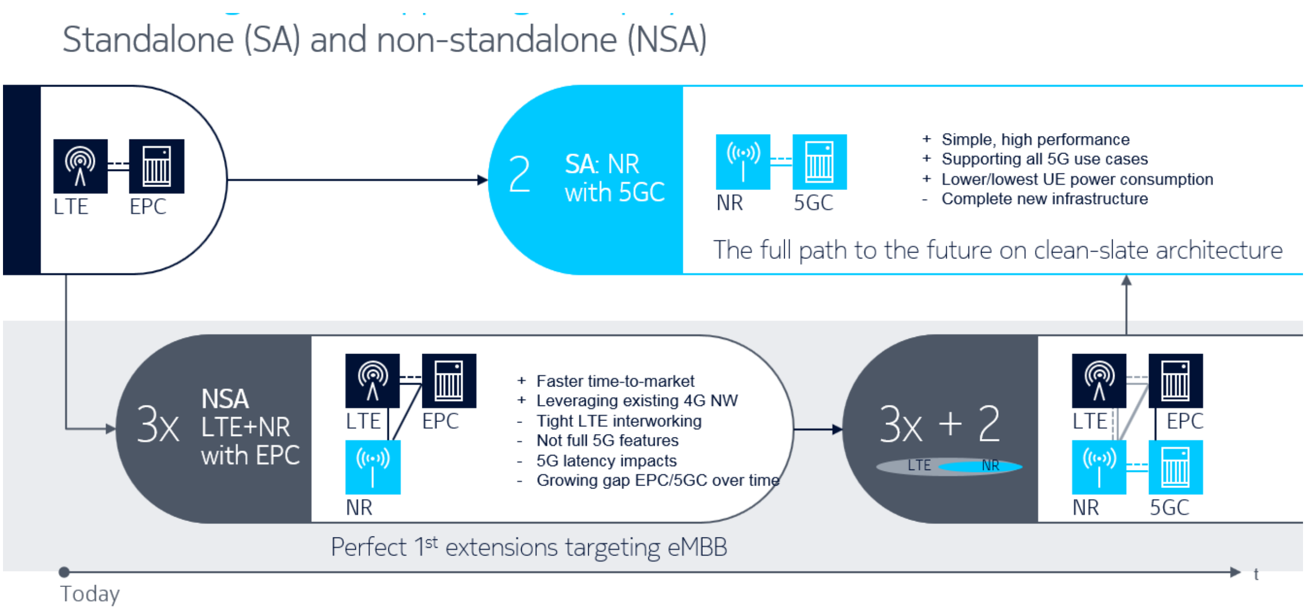


**Figure 28: Standalone and non-standalone options**

## 5.2.1 Covered Areas

Depending on each deployment scenario the different Use Cases could be deployed using several combinations of sites for the installation of the applications servers, providing different competitive advantages.

In the following Figure 29 we can classify the type of deployment:

- Far edge: providing smallest latency but requiring deploying the MEC services in many locations. Ideal for very located deployments like factories.
- Aggregated edge: providing low latency, covering several radio nodes, ideal for city size deployments
- Regional: this deployment is ideal for services that must be provided at region level, the solution is optimal for the deployment of capacity in a regional area, covered with a few MEC
- Central: massive deployment, the new applications will be available in the whole network just by deploying a few MEC servers

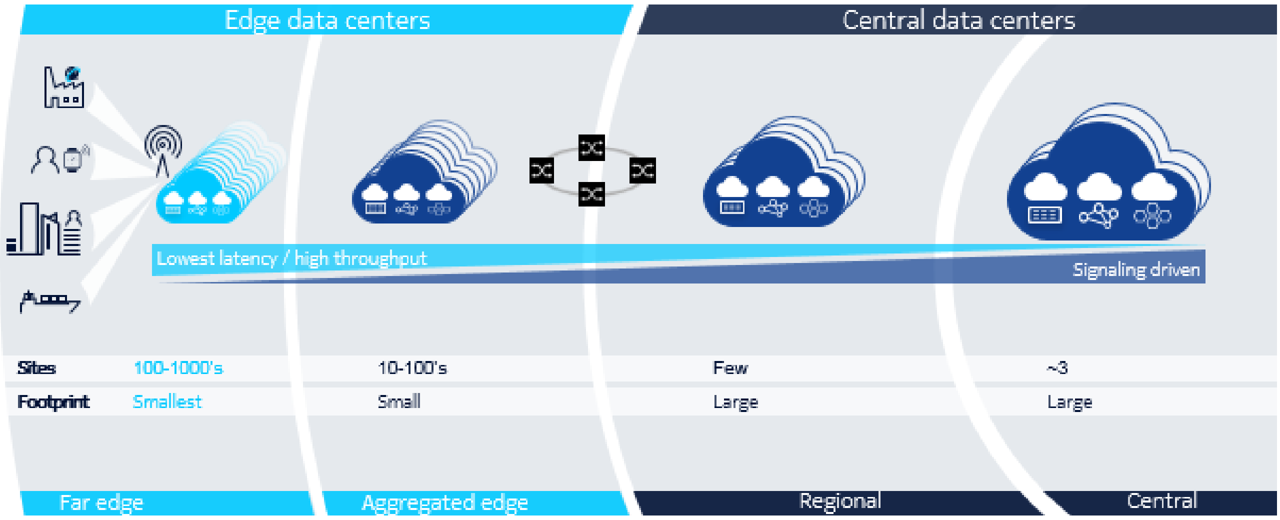


**Figure 29: Coverage areas and MEC deployment location**

### 5.2.1 Deployment of new 5G radio environmental factors

The deployment of new 5G radio capacity will rely on many practical factors that will cover the most prioritized requirements like the following:

- **Previous 4G radio infrastructure**: in case the radio operator already has some 4G deployed radio, the NSA options could be easier to introduce. The existence of previous radio infrastructure will be also critical for the location of the new sites for placing the new 5G radio antennas.
- **Covered area of the deployment**: we can classify the deployment in the following types
  - Far edge: providing smallest latency but requiring deploying the MEC services in many locations. Ideal for very located deployments like factories.
  - Aggregated edge: providing low latency, covering several radio nodes, ideal for city size deployments
  - Regional: this deployment is ideal for services that must be provided at region level, the solution is optimal for the deployment of capacity in a regional area, covered with a few MEC servers
  - Central: massive deployment, the new applications will be available in the whole network just by deploying a few MEC servers
- **Frequency availability and carrier aggregation**: the different ranges of frequencies and the availability for the operators at country levels, or at the different covered areas. The bandwidth baseband capacity for the different new 5G radio frequencies and the combinations with carrier aggregation of the several 5G frequencies or 5G/4G frequencies will create very robust deployments with extremely high users' bandwidths in some deployment scenarios. In the following Figure 29 we can see the

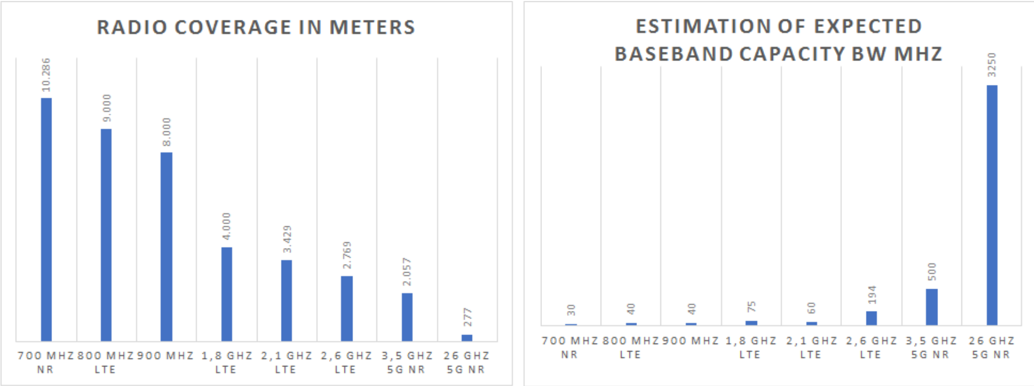


**Figure 30: Estimation of radio coverage and baseband capacity for several 5G NR frequencies**

- **MEC new applications** will support the generation of new KPIs and monitoring support by using the "Capabilities exposure" functions. In ETSI MEC, there is a specific function, namely the Network Exposure Function (NEF), to expose capability information and services of the 5G CN Network Functions to external entities, in some cases services and capabilities can be exposed over NEF, like the following:
  - Monitoring: Allows an external entity to request or subscribe to UE related events of interest. The monitored events include a UE's roaming status, UE loss of connectivity, UE reachability and location related events.
  - Provisioning: Allows an external entity to provision expected UE behaviour to the 5G system, for instance predicted UE movement, or communication characteristics.
  - Policy and Charging: Handles QoS and charging policy for UE based requests made by an external party, which also facilitates sponsored data services.

# Conclusion

This deliverable is defining the KPIs collection framework for 5G end to end facility by identifying the main sources used in the different Uses cases, indicating the log files, configuration data, probes and monitoring devices that are going to be used in the project to support the targeted KPIs for the given vertical industries requirements. The document is describing a very high-level methodology description on how to collect all the data sets from all the sites facilities in the different experiments. Other deliverables in the project will use and further evolve the architecture and guidelines outlined in this document, as well as the recommendations issued by 5GPPP TMV Working Group.

We have identified the key components for the KPI collection frame-work, where the usability of the KPIs information is the main pillar, some of the main data gathering mechanism have been identified, and we have also evaluated the performance architecture and simulation tools for the initial Use Cases.

The KPI information sources from the 5G Infrastructure and the KPIs sources for the vertical services applications for the initial 5G-EVE Use Cases have been identified. We have also detailed the uses of the KPIs information in terms of architecture and deployment options.

This document is an input for the "Experimentation tools" Task 4.1 and also for all the tasks in the Work Package 5 "Design and implementation of testing and validation methodologies and tools", where:

- the implementation details of the overall methodology framework will be defined in Task 5.1, the definition of environmental conditions and 5G scenario aspects will be defined in Task 5.2, the design, implementation and maintenance of testing, validation and technology benchmarking procedures will be defined in Task 5.3

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