



5G PPP Technology Board

On Board Procedure to 5G PPP Infrastructure Projects

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1 Introduction

5G Infrastructure PPP Phase-3 [1] includes three platforms projects (through the ICT-17 call [2]) that have started their work in July 2018. The projects, namely 5G EVE, 5GENESIS and 5G-VINNI are providing large-scale end-to-end 5G validation network infrastructures. They cover about 20 European sites and nodes on a pan-EU basis and will be operational until 2021 as shown in Figure 1. Their infrastructure provides an adequate level of openness to make it possible for vertical industries to test their innovative 5G business cases. A summary of their activities can be found in the publication “5G network support of vertical industries in the 5G Public-Private Partnership ecosystem” [3].

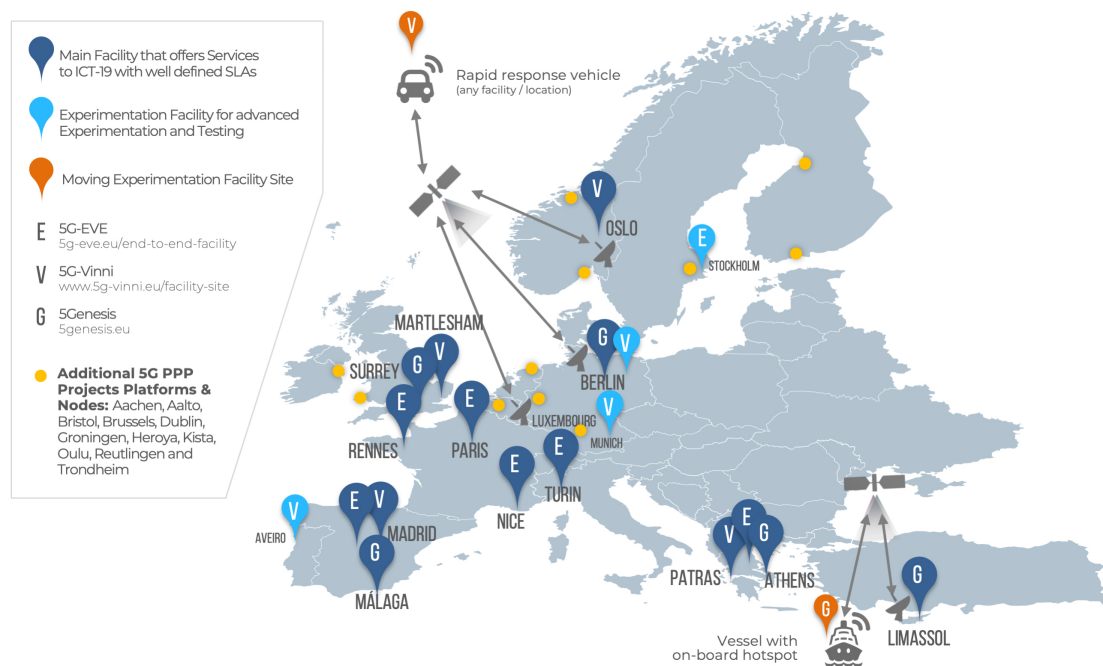


Figure 1: The three infrastructure projects.

As 5G networks aim to support the vertical industries, a set of seven Vertical Pilot projects (through the ICT-19 call [4]) have started their activities in June 2019. They demonstrate advanced 5G validation trials across multiple vertical industries. These projects take advantage of the abovementioned ICT-17 projects and interwork with them as shown in Figure 2.

	 5G EVE	 5Genesis H2020 EU PROJECT	 5G-VINCI
 5G! DRONES	✓	✓	
 5G HEART	✓	✓	✓
 5G GROWTH	✓		✓
 5G smart	✓		
 5G SOLUTIONS 5G Solutions for European Citizens	✓		✓
 5G - TOURS	✓		
 5G VICTORI	✓	✓	✓

Figure 2: Collaboration between infrastructure and vertical projects

As the vertical projects will have to rely on the infrastructure projects an on-board procedure is needed to explain how this can take place in each of the three infrastructure projects. The purpose of the current document is to provide, in a summarized form, all the information and links needed for a stakeholder to start the design of an experiment using one the infrastructure platforms.

2 Information about 5G EVE

2.1 Interacting with the infrastructure

The following “external” roles have been defined:

- **Vertical:** actor with the knowledge of the service to be tested, including SLAs and service components.
- **Verticals’ VNF Provider:** actor who provides the VNF packages for the vertical applications.
- **Experiment developer:** actor responsible for specifying the blueprints associated to an experiment, as well as the associated NFV network services descriptors. This user has the knowledge about the 5G EVE infrastructure and expertise about NFV network service modelling. Moreover, it interacts with the vertical to receive information about the details of the target service.
- **Experimenter:** actor responsible for the request of an experiment and the assessment of its results. He/she defines the characteristics of an experiment starting from its blueprint, requests the deployment of related virtual environment and experiment execution and analyses results and KPIs.

Further details about the actions that can be performed by each role are available in 5G EVE D4.1 [5], section 2.1.

2.2 Information & input needed for running an experiment

The following information is needed to run an experiment:

- Experiment blueprint, i.e. a high-level representation of an experiment template.
- Experiment descriptor, a high-level representation of a fully set-up experiment.
- Target site
- Desired time slot

An **experiment blueprint** is typically defined by an “experiment developer” and it includes information about the following:

- Vertical service blueprint, including details about the service components, their interconnectivity, service-level parameters, application metrics, configurable parameters.
- Network Service Descriptor associated to the vertical service. If needed, service-specific VNF packages can be also provided for vertical applications.
- Context blueprints describing the operation context and/or experimental conditions to run the experiment (e.g. artificial background traffic, artificial delay, etc.). Context blueprints can be selected from the 5G EVE catalogue or new ones can be defined by the experiment developer.
- Test case blueprints, with details about the scripts to run the experiment and their configuration.

- Target site(s), infrastructure metrics to be measured and KPIs to be validated.

Further details about the information model of an experiment blueprint are available in 5G EVE D4.1 [5], section 5.2. The 5G EVE portal provides a wizard tool, called Experiment Blueprint Builder, which guides experiment developers through the steps needed to define an experiment blueprint. This tool is documented in 5G EVE D4.2 [6], section 1.4.3.

The experiment blueprint is used as basis for the definition of an **experiment descriptor**, an action performed by the “experimenters” whenever they need to run a new experiment. The definition of the experiment descriptor allows to configure an instance of experiment blueprint by assigning the required values to its parameters, by customizing the tests to be performed and by specifying the criteria for the KPIs evaluation. Further details about the information model of an experiment descriptor are available in 5G EVE D4.1 [5], section 5.2.7. An experiment descriptor can be created using the 5G EVE Intent Base Networking (IBN) tool, as described in 5G EVE D4.1 [5], section 4.4.3.

2.3 Provided output: monitoring, analysis and results visualisation

The 5G EVE Testing as a Service offers four key capabilities:

- the automation of 5G experiments execution in intra- or inter-facility environments
- metrics monitoring features
- KPI validation features
- performance diagnosis features

In particular, the 5G EVE portal will allow the experimenter to (i) visualize application and infrastructure level metrics during the experiment execution, (ii) visualize final test reports with the results of the test cases and the evaluation of the KPIs declared in the experiment blueprint, (iii) in case of unsuccessful tests to use performance diagnostics to perform root cause analysis.

Further details about the 5G EVE model-based testing framework are available in 5G EVE D5.2 [10], with information about the supported network KPIs (section 2.1.2) and the high-level testing, validation and monitoring procedures (sections 2.2, 2.3 and 2.4 respectively). The performance diagnosis features is under study/development.

2.4 Potential infrastructure extension capabilities

The 5G EVE facility can be extended to orchestrate services and resources in additional sites, exploiting the 5G EVE Inter-Working Framework (IWF) capabilities. Adding a new site in the 5G EVE platform requires the following:

- Site facility extension must be validated either by sites managers and/or IWF manager. The new site facility must respect the rules in terms of interconnection by following the procedures established by each site. Typically secured VPN interconnection with current 5G EVE site facility is implemented. Details about

the interconnection approach for the different 5G EVE sites are provided in 5G EVE D2.1 [8] (section 2.9 for 5G EVE Greek site, section 3.9 for 5G EVE Italian site, section 4.8 for 5G EVE Spanish site, section 5.9 for 5G EVE French site).

- Develop a new **site-specific driver for the IWF Adaptation Layer**, to translate the IWF commands into the messages adopted by the local orchestrator deployed in the site. Further details about the IWF Adaptation Layer are available in 5G EVE D3.3 [7] section 3.6, while examples of per-site adaptations are reported in section 3.7.

2.5 On-board procedure to the 5G EVE ecosystem

5G EVE Platform will be used by different Vertical industries to run their experiments in a 5G enabled infrastructure.

Along the experiment flow process, an active dialogue between Verticals and 5G EVE Platform stakeholders make possible to come to a full reciprocal understanding of 5G EVE platform capabilities and Vertical use cases requirements and agree on the trial specifications including the use cases to be validated, scenarios covered, interfaces used, metrics and KPIs measured, etc.

That will then be materialized in experiments’ co-design and co-development activities that will provide Verticals with a tailor-made 5G virtual infrastructure to run their experiments with similar characteristics to those of real 5G standards-based commercial deployments to come. That approach will allow Verticals to collect the measurements needed to fully assess the performance of their services in scenarios replicating realistic operational environments, with the final objective of tuning the configuration of their applications to meet the conditions and characteristics of different deployment options, thus maximizing the efficiency of the service roll-out phase.

The execution of Experiments and associated test cases are structured in four main phases as shown in Figure 3 below.

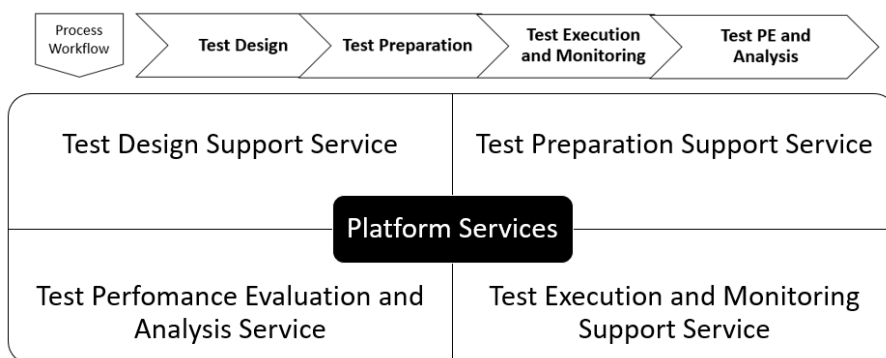


Figure 3: 5G EVE validation test process phases

- Experiment Design: In this phase, Vertical and other specialized actors, like VNF provider and Experiment developer, cooperate to identify the major characteristics, objectives and KPIs of the experiment related to a vertical service.

- b. Experiment Preparation: In this phase, the experiment environment is properly prepared and configured to enable the experiment execution in a given timeslot and for a given configuration.
- c. Experiment Execution: In this phase, the dedicated virtual environment to run the experiment (and associated test cases) is built, and finally the experiment Test Cases are executed.
- d. Experiment Results Evaluation: In this phase, the *Experimenter* analyzes the experiment / test cases results.

A detailed description of this 5G EVE standard process, along with also practical examples based on 5G EVE Use Cases, is available at 5G EVE D1.3 [9]

2.6 Important milestones

The high-level roadmap for 5G EVE facility is shown in the figure below:

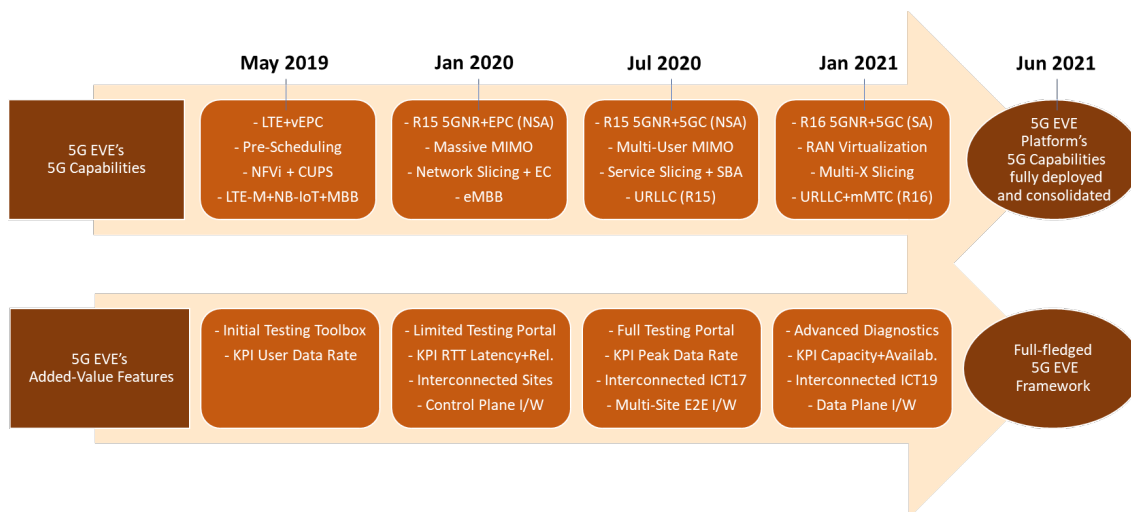


Figure 4 – 5G EVE’s roadmap

A more detailed roadmap is available in the webinar slides on “The 5G EVE End-to-End Facility for Vertical Industries” [11].

2.7 Supporting vertical projects after the completion of 5G EVE

The roadmap of 5G capabilities and 5G EVE framework described above will assist associated ICT19 projects in their detailed planning of integration and validations activities. Most of the cooperations supported by 5G EVE have been agreed for the period from July 2020 to end of June 2021, although extensions of the testing period prior to July 2020 and until the end of 2021 are also a possibility that 5G EVE is open to discuss with interested ICT19 projects.

Within the period of 5G EVE project execution the following set of rules for cooperation apply:

- Pre-conditions for cooperation:

- a. Scope, requirements, and estimated duration of the validation test activities have been discussed, specified and agreed. This type of information is available in 5G EVE [12].

Responsibility Split: Both parties commit the necessary resources for fulfilling this task, on their own respective budgets.

- b. Specific needs on additional HW/SW, due to specific capacity, scalability or technology demands of the ICT19 project use cases versus the available and road-mapped capabilities offered by 5G EVE platform, and, in particular, by the selected site facility for the validation tests, have to be carefully assessed. This type of information is to be reflected in dedicated deliverables of the ICT19 projects.

Responsibility Split: The ICT19 project leads and staffs this activity. 5G EVE will ensure timely and detailed inputs on deployments and roadmaps.

- Support level for the cooperation:
 - a. 5G EVE will support the specific integration of extra HW/SW components required to be hosted on the 5G EVE platform, as a result of the gap analysis mentioned above. These activities should be properly planned as tasks in the ICT19 project plan.

Responsibility Split: The involved HW/SW acquisition/depreciation costs are covered by the ICT19 project, as well as the cost incurred for its integration to be performed by staff of the ICT19 project partners. 5G EVE commits to support the ICT19 project in the timely deployment and integration of those new HW/SW assets in its hosting site facilities according to an agreed plan, and to also deliver a hosting service upon fees stipulated by each facility site and agreed between the two parties.

- b. The preparation and execution of the use case validation tests is a key task in the ICT19 project plan.

Responsibility split: The ICT19 project dedicates the resources for designing, preparing, executing, and analysing the results of its use case validation tests. 5G EVE in turn will provide training for those tasks, technical support for the preparation of the tests (through the Site managers) and licenses (free of charge, under otherwise stipulated by the parties in specific cases) the access to the 5G EVE platform portal for supporting those tasks and, more specifically, the availability of the involved 5G capabilities deployed in the site facility chosen by the ICT-19 project for the agreed scheduled tests.

For the period beyond 5G EVE project execution the above pre-conditions and support level conditions are affected in this way:

- Pre-conditions for cooperation:

At this stage when 5G EVE has been completed, 5G EVE cannot dedicate resources any more for supporting use case analysis or gap analysis. However, that should not create any relevant impact since most of those tasks are part of the early stages of the ICT19 project plans and cooperation with 5G EVE.

- Support level for the cooperation:
 - a. HW/SW integration activities and implicit hosting services.

At this stage the potential services for supporting extended or further use case validation tests cannot be supported any more by the 5G EVE project as such (as it has ended).

The recommendation to ICT19 projects is to initiate a negotiation directly with the owner of the site facility selected for their validation tests.

- b. 5G EVE platform services and 5G capabilities.

At this stage the legal framework for licensing the 5G EVE services and use of underlying 5G capabilities will have expired. Also, maintenance activities shall have been discontinued as the 5G EVE project has ended.

The recommendations to ICT19 projects are to:

- Initiate a discussion with the key partners of 5G EVE contributing to the development of the platform, in order to negotiate a license to use it.
- Initiate a discussion with the selected hosting site facilities, in order to negotiate a potential extension of their support with extended availability of the deployed 5G capabilities, potentially against a fee.

3 Information about 5G GENESIS

3.1 Interacting with the infrastructure

5GENESIS consortium has identified the following actors [13].

- **Experimenter:** An experimenter is an external user that want to use the 5GENESIS Facility. The experimenter can set experiments and get results through either the web interface after registration (5GENESIS portal) or through a direct use of the API for experimenters, developed in the project. For both the approaches, the functionality and the provided capabilities are the same. Typically, the experimenter is the integrator of the vertical technologies into the service to be validated on 5GENESIS;
- **Platform Operator:** Hosts, manages and operates the platform's software and infrastructure, including the interface to the experimenters, the telecommunications infrastructure, as well as, the coordination, management, orchestration and monitoring systems;
- **Platform Technology Provider:** All vendors and research institutions that provide software and hardware components to the 5GENESIS platforms;
- **Testers and End Users:** The users of the services deployed in the 5GENESIS platforms by the Experimenter. They can be either individuals or corporate end-users.

3.2 Information & input needed for running an experiment

All the information required can be provided easily through the portal. However, the 5GENESIS consortium has structured the input parameters required in a set of interlinked information fields, towards: i) facilitate the organization of experiments that target KPIs validation/measurement campaigns, and ii) enable the potential to compare results of different experiments. The information collected via the portal (see Figure 5 below)) is used to complete the experiment descriptor template defined by the project in D2.3 [14] and updated in D6.1 [15].

The following fields define the 5GENESIS Experiment Descriptor:

- Experiment description
 - Experiment ID/name
 - Type of experiment
 - User Equipment
- Test case
- Slice(s)
- Scenario

CREATE EXPERIMENT

Name

Type

Test Cases

- Round Trip Time Test
- Maximum User Data Rate Test
- MCPTT Tests
- Service Creation Time Tests
- Video Performance

UEs

- Galaxy S9
- Galaxy Note S10

Slice

Figure 5: Illustration of the 5GENESIS portal where an experiment is set

Test case. A test case includes information which is related to the configurations of the experimentation platform needed for receiving the measurement(s). The KPI definition, the measurements methodology and the information for the equipment preparation are added in this field. More precisely, a test case provides the following info:

- *Target KPI.* Each test case targets a single KPI. Secondary/complementary KPIs could also be defined as complementary measurements (see below). The definition of the main target KPI specializes the related target metric. i.e., the definition of the main KPI declares at least the reference points from which the measurement(s) will be performed, the underlay system, and the reference protocol stack level. The physical formula, the unit, and the type of the KPI as defined in 3GPP TS 28.554 are included here.
- *Complementary measurements.* A secondary list of KPIs useful to interpret the values of the target KPI. Getting these measurements is not mandatory for the test case. However, allows for test cases that, besides the target measurement, provide an additional set of results useful for analysis and interpretation of the relation between different KPIs.
- *Pre-conditions.* A list of test-specific information about equipment configuration and traffic description. Also, precise description of the initial state of the system under test, required to start executing a test case sequence.
- *Test case sequence.* It specializes the set of processes needed for executing the experiment in the selected underlay system.
- *Methodology, calculation process and expected output.* The experimenter shall provide the acceptable values for variables that affect the testing procedure, as the monitoring time, the iterations required, the monitoring frequency, etc. In addition, the units that shall be used in the measurements and, potentially, a request for first order statistics (Min, Max, etc.) of the target KPI measurement.

- *Applicability.* A list of features and capabilities which are required by the system in order to guarantee the feasibility of the test.

The list of test cases that have been defined by the 5GENESIS project are available in D6.1 [15]. Each platform is in the process of realizing the test cases already defined. Those test cases are the *standard ones* defined by the consortium in the project framework; however, it is also possible the experimenter to define and implement new test cases to cover specific measurements or applications requested by the verticals.

Slice(s). Each 5GENESIS platform will also provide a predefined list of end-to-end slices covering radio resources configuration, mobile core network, transport network and resources allocated in the virtualized infrastructures offered by the platforms. This list will be available for setting up an experiment.

Scenario. The scenario includes information which is related to network, service and environment configurations and it is specific to the selected technologies and the target system. From the performance perspective the scenario reproduces network conditions that affect the values of the KPIs to be measured. More precisely, a test case that targets a specific measurement can be set for different scenarios that declare parameters such as the level of the transmission power in a base station, the mobility of the end devices, the traffic load in the system etc.

3.3 Provided output: monitoring, analysis and results visualisation

The 5GENESIS consortium targets the realization of a full-chain Monitoring and Analytics (M&A) framework, for a complete collection and analysis of the heterogeneous data produced during the usage of the 5GENESIS Facility. The framework ultimately aims to the verification of the infrastructure status during the experiments for the validation of 5G KPIs.

The “Release A” of the 5GENESIS M&A framework has been thus designed and developed, as documented in the project Deliverable D3.5 [16]. It includes advanced Monitoring tools and Machine Learning (ML)-based Analytics, divided in three main functional blocks, that is, Infrastructure Monitoring (IM), Performance Monitoring (PM), and Storage/Analytics.

In light of state-of-the-art network monitoring and analytics functionalities, the 5GENESIS M&A framework positions itself as a key enabler for a complete validation of 5G KPIs. Its design, which takes roots from former EU H2020 Projects TRIANGLE [17] and MONROE [18], along with its development, which is based on widespread programming languages (e.g., Python and ML libraries for the Analytics component) and results in open-access software components, allow a lightweight integration, use, and exploitation within heterogeneous hardware/software platforms.

3.4 Potential infrastructure extension capabilities

Details to be included in WP5 deliverables of 5GENESIS [19].

- *Vertical Industry - specific VNFs.* 5GENESIS platforms are in principle open to host VNFs and servers to be installed in the core and/or edge parts of the network. The procedure for doing that is under discussion and it will be resolved based on the decided capabilities of the final API and the specific characteristics (and resources) of each platform.
- *End devices from verticals/ICT19.* 5GENESIS platforms are open to support end devices, brought by verticals/ICT19 projects. Currently, 5GENESIS platforms support 4G and 5G-NSA devices, as well as IoT and loRa Devices.
- *RAN and Core components from verticals/ICT19.* This potential should be discussed in a per platform basis (a per platform agreement is required). Deliverables D5.3 (M24) and D5.4 (M32) will include the details of the interfaces that verticals/ICT19 should support.

3.5 On-board procedure to the 5GENESIS ecosystem

The required steps for the full onboard and experimentation procedure on a 5GENESIS platform are listed below:

1. The experimentation procedure requires a close interaction between the experimenter and the platform operator. The initial stage of the experiment includes a consulting work of the platform operator that will enable to collect and understand the requirements of the experimenter.
2. During the consultancy phase the platform operator will identify the measurements needed to validate the system under test. Those measurements that are internal to the system under test have to be provided by the experimenter. The platform operator will instruct the experimenter about the existing mechanisms to expose these measurements, so the probes available in the platform can collect them and integrate into the general measurement collection process of the platform.
3. The experimenter needs to introduce the changes into the VNFs, application or any other component which is part of the solution under test.
4. The experimenter needs to provide all the components of the solution under test to the platform operator, for example, a mobile device, a mobile app, a network service, etc. The platform operator will deploy the solution in the platform and will produce, if needed, new test cases to cover the experimentation features requested by the experimenter.
5. The platform operator will provide to the experimenter the credentials to access to the platform Web portal (Figure 6).
6. The experimenter can check in the info page of the Web portal the details of the network scenarios available in the platform.
7. The experimenter can create a new experiment. By default, the experimenter will have a list of standard test cases that cover technologic KPIs such as throughput and round-trip time, the list of NS previously provided to the platform operator, a list of user equipment which will be connected to different scenarios as explained in the info page, and a list of predefined slices that can be selected. If the

experimenter has requested custom test cases the list of custom test cases will be enabled.

8. The experiment can execute and track the status of the execution. Execution logs are also available after the execution of the experiment.
9. Once the experiment has finished the measurements are available in raw format and can be also visualized in Grafana.

The screenshot displays the 5GENESIS web portal interface for the onboard procedure. It is organized into four main sections:

- Basic Information:** Contains a 'Name' field with the value '1', a 'Visibility' dropdown menu set to 'Public', a 'Description' text area with the value '1', and an 'Update' button.
- VNFD Packages:** Lists two packages: 'vnfd2.txt' with ID 'placeholder' and 'vnfd1.txt' with ID 'None'. It includes 'Delete' buttons for each, an 'Onboard' button, a 'Pre-load' button, and an 'Add VNFD package' section with a 'Browse' button.
- Virtualized Infrastructure Manager:** Features a 'VIM Location' dropdown menu set to 'Main DC' with an 'Update' button, and a 'vimImage.txt' field with 'Onboard' and 'Delete' buttons.
- Network Service Descriptor:** Includes an 'Add NSD file' section with a 'Browse' button and a 'Pre-load' button.

Figure 6 The 5GENESIS web portal used for the onboard procedure

3.6 Important milestones

Comprehensive descriptions of all the capabilities and the integrated components of the 5GENESIS platforms, are ready¹. Comprehensive descriptions of the 5GENESIS Experimentation Facility (portal, management, slice managers) are expected by mid of April 2020

The cartographies, prepared in 5G PPP TB level, include all the important milestones for the 5GENESIS trials (Phase 3 verticals cartography) as well as the expected dates for

¹ Please check D4.2, D4.5, D4.8, D4.11, D4.14, and D4.17 in <https://5genesis.eu/deliverables/>

providing technology-related capabilities (Platform Capabilities Table). Here we summarize the list of available capabilities in February 2020, as well as the dates for the planned trials from each one of the 5GENESIS platforms

Technologies/capabilities available in February 2020

- 5G NSA
- Network Slicing
- Hosting of 3rd party VNFs
- Edge Computing
- Automatic testing framework

Milestones of the 5GENESIS trials per platform

- Athens platform: Initial Q2-2020, and Full-scale deployment Q1-2021
- Malaga platform: Q2-2020
- Berlin Platform: Q3-2020
- Limassol Platform: Q1-2020
- Surrey Platform: Initial Q2-2020, Full-scale deployment Q4-2020

3.7 Supporting vertical projects after the completion of 5GENESIS

The ICT-19 projects that have expressed their interest to use 5GENESIS platforms are represented by partners that are also part of the 5GENESIS consortium. This will facilitate the procedures. Overall, the approach will be defined at a platform-level.

4 Information about 5G-VINNI

4.1 Interacting with the infrastructure

5G-VINNI has defined an actor role model in alignment with the 3GPP model defined in TR28.801 [20] and the model described in the 5G PPP Architecture white paper V3.0 [21]. In the 5G-VINNI model, the following roles are defined for the customer level:

- Communication Service Provider (CSP) Customer
- Digital Service Provider (DSP) Customer
- Network Slice as a Service (NSaaS) Customer

For the sake of simplicity, all above customer roles may use the 5G-VINNI facility services as experimenters, whereas the main customer role considered by 5G-VINNI is the NSaaS customer and the CSP customer.

However, 5G-VINNI has defined four exposure levels [22] [23] that allow additional roles such as DSPs, CSPs and other Network Operators to interact with a 5G-VINNI facility site. The default exposure level 1 allows a Communication Service Customer to access service application layer configuration and management operations.

The interaction at exposure levels other than level 1 has to be discussed and negotiated with the affected 5G-VINNI facility site.

4.2 Information & input needed for running an experiment

5G-VINNI has defined two structures to allow verticals to quickly bring their use cases into 5G-VINNI facility, being:

- the 5G-VINNI Service Blueprint (5G-VINNI-SB), and
- the 5G-VINNI Service Catalogue (5G-VINNI-SC).

The 5G-VINNI Service Catalogue contains pre-defined 5G-VINNI-SBs which have either been pre-configured in the 5G-VINNI-SC or have been defined by previous verticals when they have conducted their tests. Over time, the number of 5G-VINNI-SBs in the 5G-VINNI-SCs will increase, as more verticals test their use cases on 5G-VINNI facilities.

When a vertical cannot use a pre-existing 5G-VINNI-SB for their test purposes, they are able to create a new 5G-VINNI-SB that can be based on a previous one. This allows rapid definition of the specific 5G-VINNI-SB which might be required for their specific Service Level Agreements (SLAs).

The 5G-VINNI Service Blueprint model

A 5G-VINNI-SB is a baseline, model-based service template describing a given network slice to be provisioned using NSaaS. This service template is a structured document that provides a complete description of a given network slice, including information on service topology and expected behaviour. It is used by the Communication Services Provider

(CSP) as a reference to conduct service management procedures, both at instantiation time (deployment procedures) and at run-time (operational procedures).

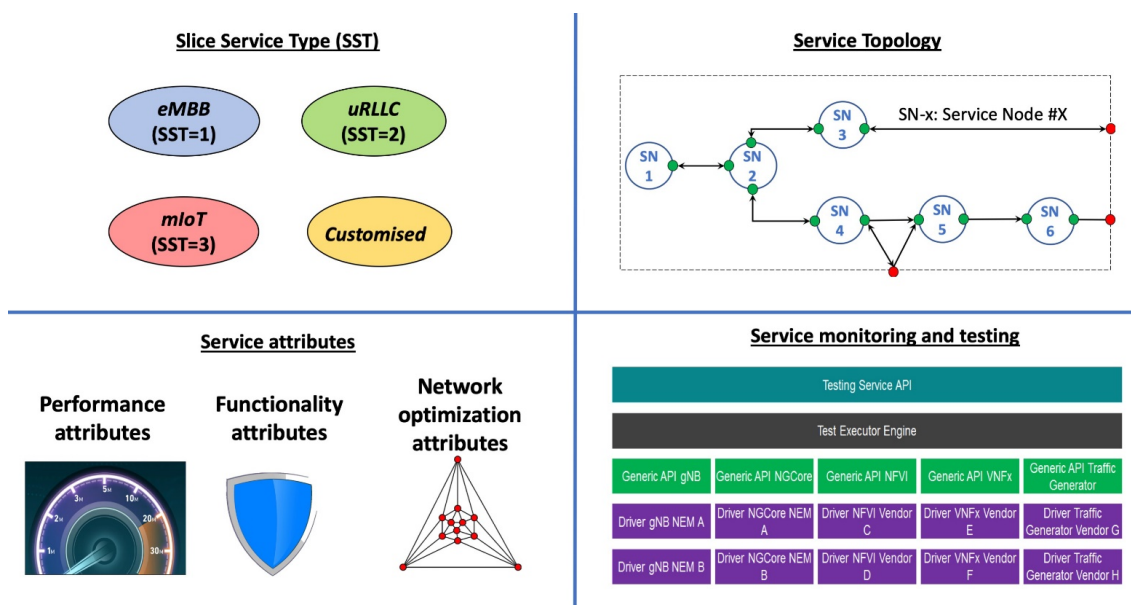


Figure 7 5G-VINNI Service Blueprint (SB) structure to be used by the CSPs

The 5G-VINNI-SB structure is arranged into four main parts as illustrated in Figure 7. These are:

Slice Service Type (SST) is a 3GPP parameter [24] that specifies the 5G service category the slice is meant to support. The following SST values are defined: “1” (eMBB), “2” (uRLLC) and “3” (mMTC). There is also a custom slice type SST>3 which allows for the definition of other slice types for example “SST=4” for Vehicle to everything (V2X) service.

Service topology which represents the default topology of the slice defines how the slice is constructed from a logical viewpoint by identifying i) the nodes which constitute a slice, including information on their individual functionality; and ii) how these nodes are connected with each other, including information on their connectivity type. A node can be mapped to a Network Service or a VNF depending on selected NFV criteria design. Examples of these nodes include 3GPP components (e.g. gNodeB, 5G core network functions (NFs)), value-added service functions (e.g. firewalls, NAT) and edge applications (e.g. virtual reality server, Cloud RAN).

The slice default topology can be flexibly extended thus offering the verticals the opportunity to bring their own NFs and applications into slice definition by simply attaching them to define slice access points (red connection points in Figure 7).

Service attributes correspond to generic network slice template (GST) attributes as defined in GSMA NG 116 [25]. The specification of values for these attributes allows the vertical to provide the service requirements the slice must satisfy, based on SLAs that the vertical requires the facility to provide.

4.3 Provided output: monitoring, analysis and results visualisation

During VNFD and NSD development the vertical customer may optionally incorporate testing and monitoring services. Such services can be consumed both as a human-driven or an automated interaction. Such services require actions from the vertical customer in order to be properly consumed such as the VNF exposing its functionality to a monitoring system. Testing and Monitoring are offered as a service.

Testing as a Service (TaaS) is a set of testing tools and automation frameworks that allow the vertical customer to either execute standard verification of the Network Service or create and execute customized suites of tests that can be integrated into the life cycle of the NSD. Such tests can also include the vertical customer's application, since the TaaS system is capable of onboarding specific drivers.

Monitoring as a Service (MaaS) is providing an overview of the health and performance of the system. MaaS includes Network Monitoring services and Telemetry services. The first provides an overview of the traffic flowing across the network. The second provides insight about the health and performance of the individual Network Service or VNFs/application components.

While TaaS is devoted to the active verification of the system or Network Service, the MaaS is intended for observation and maintenance of the Network Service. MaaS can be combined with TaaS for improving the understanding of the performance and working principles of the network, but it has relevant value also as a standalone service.

The testing phase takes place, either through automated scripts or via user interactions. Test automation is preferred, in order to ensure consistency and repeatability of the results.

The results of testing (and the MaaS output) will be stored in heterogeneous data stores. These data stores cannot be defined at the present moment and will be strongly dependent on the use cases and tools used.

4.4 Potential infrastructure extension capabilities

Interconnection and hence extension with non-5G-VINNI facility sites is subject to agreement between the stakeholders, i.e. the 5G-VINNI facility site operator in question, and the stakeholder that wishes to extend the 5G-VINNI facility site by adding own capabilities.

An interconnection through the 5G-VINNI service portal – as described in the onboarding vertical application on 5G-VINNI facility white paper [22] – is possible, however this option has not been discussed in detail.

Potential extensions are related to the 5G-VINNI exposure levels that are detailed in deliverable D3.1 [23].

4.5 On-board procedure to the 5G-VINNI ecosystem

In 5G-VINNI the different stakeholders of a 5G system co-design and co-develop different parts of the onboarding process. The process consists of the following phases:

- i) **The co-design period** involves stakeholders such as vertical customers, 5G-VINNI facility providers and developers of customer facing services and resource facing services to understand the vertical needs and how to enable them.
- ii) **The iterative co-development period** involves the vertical customer and the 5G facility provider to jointly develop the final service to be ordered including the development of any VNFs, test scripts and monitoring services. Testing as a Service (TaaS) and Monitoring as a Service (MaaS) can be integrated during the preparation of the VNFs and development of service templates, subject to availability of TaaS and/or MaaS in the 5G-VINNI facility site.
- iii) **The operational and KPI testing KPI period.** In this phase the vertical customer can make repeatable and scheduled service orders of the developed service blueprint via the portal and perform KPI testing, monitoring and assessment.

4.6 Important milestones

5G-VINNI defined releases of the infrastructure (R0-R3 and final release) as well as four maturity levels as follows (Figure 8):

ML1 – validation tests – covers R0 and R1 that have been defined as internal milestones for performing validation tests and performance measurements of the 5G-VINNI infrastructure.

ML2 – co-funded trials – covers R2 and R3 in which the infrastructure is stable and available for experimentation and testing by verticals applications of 5G PPP ICT-19 projects and possibly external verticals applications subject to negotiation. In this phase certain upgrades are planned and documented in Deliverable D2.1 [26].

ML3 – cost-based trials – covers the period after the end of the project. For a period of one year after the end of the project, 5G-VINNI has committed to keep the infrastructure available for ICT-19 vertical customers but expects a compensation of the incurred additional costs.

ML4 – Any experiment (market-priced) – covers the long term perspective of establishing commercial testing services base on the possible evolution of the infrastructure for this purpose.

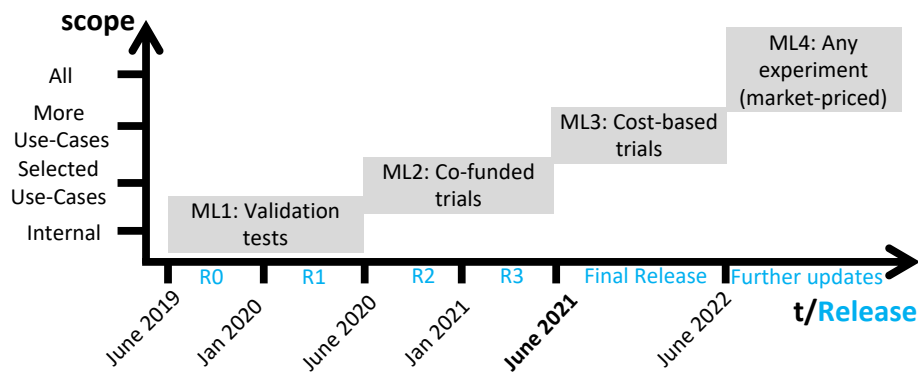


Figure 8 5G-VINNI Key milestones

4.7 Supporting vertical projects after the completion of 5G-VINNI

As indicated in the previous section, 5G-VINNI has defined maturity level 3 (ML3) of its infrastructure. In this period ICT-19 vertical customers can be supported on a cost recovery basis. During the proposal phase for ICT-19 project, 5G-VINNI has published requirements and expectations from 5G-VINNI by ICT-19 projects. In summary ICT-19 projects are expected to:

- provision resources and effort for integration of use cases
- provide funding in case additional gNB is required, including transmission cost if not present
- provide funding in case additional MEC site shall be integrated
- provide funding in case a customized slice template is required
- provide funding in case of use of capacity beyond basic offering (to be defined)
- provide funding for own experiment execution (5G-VINNI will provide field support for test implementation)
- budget and provide high capacity interconnection if needed (to be defined)
- provision budget after 3rd year of 5G-VINNI (i.e. from 1.July 2021 – 1.July 2022) for cost recovery of 5G-VINNI resources

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6 List of Contributors

Name	Company / Institute / University	Project	Country
Almudena Diaz Zayas	University of Malaga	5GENESIS	Spain
Jaime García Reinoso	Universidad Carlos III de Madrid (UC3M)	5G EVE	Spain
Anastasius Gavras	Eurescom GmbH	5G-VINNI	Germany
Alexandros Kaloxylou	The 5G Infrastructure Association	Technology Board Chairman	Belgium
Giada Landi	Nextworks	5G EVE	Italy
Manuel Lorenzo	Ericsson España	5G EVE	Spain
Kashif Mahmood	Telenor ASA	5G-VINNI	Norway
Pedro Merino Gomez	University of Malaga	5GENESIS	Spain
Jose Antonio Ordonez Lucena	Telefónica Investigación y Desarrollo	5G-VINNI	Spain
Christos Tranoris	University of Patras	5G-VINNI	Greece
Dimitris Tsolkas	Fogus Innovations & Services	5GENESIS	Greece