VertIcal demos over Common large scale field Trials fOr Rail, energy and media Industries

D4.1 Field trials methodology and guidelines

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Responsible:	Fraunhofer Fokus (**FhG**)
Editor(s):	Eric Troudt (**FhG**)
Authors:	Eric Troudt (**FhG**) Ioanna Mesogiti (**COSM**) Tanya Politi (**UoP**) Christos Tranoris (**UoP**) Spyros Denazis (**UoP**) Panagiotis Papaioannou (**UoP**) Shadi Moazzeni (**UNIVBRIS**) Amin Emami (**UNIVBRIS**) Constantinos Vrontos (**UNIVBRIS**) Hamid Falaki (**UNIVBRIS**) Anna Tzanakaki (**UNIVBRIS**) Kostas Katsaros (**DCAT**) Charles Turyagyenda (**DCAT**) Miguel Catalán (**I2CAT**) Adriana Fernández (**I2CAT**) Luke Kazanis (**MATI**) Anthony Karydis (**MATI**) Athina Metridou (**MATI**) Joanna Tzima (**MATI**) Marius Iordache (**ORO**) Carmen Patrascu (**ORO**) Drissa Houatra (**Orange**) Navid Nikaein (**EUR**) Peter Lundh (**BT**) Miggi Zwicklbauer (**RBB**) Martin Piovarci (**KCC**) Jesús Gutiérrez (**IHP**)
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Executive Summary

ICT-19 projects plan to leverage ICT-17 projects' infrastructures to accommodate vertical industries, with the goal of testing and evaluating the performance of their vertical services/ applications on the basis of service level Key Performance Indicators (KPIs). For this purpose, ICT-17 actions are jointly making an effort to establish a harmonized view of their developments towards the definition of the experimentation methodology, and the definition of the on-board procedure for accommodating external experimenters and Verticals. Along these lines, 5G-VICTORI will perform field trials of various scales focusing on a set of specific use cases (UCs) associated with several vertical industries, deployed over the four 5G facility platforms 5G-VINNI, 5G-EVE, 5GENESIS, (ICT-17 facilities) and the 5GUK Bristol testbed, as well as on cross-facility field trials enabled by the 5G-VICTORI Infrastructure Operation System (5G-VIOS). In this context, an active dialogue between 5G-VICTORI Verticals (and external Verticals) and the 5G-VICTORI facility representatives and technology providers would allow reducing the time to refine the proposed trials, and to assure the accomplishment of the Vertical services requirements.

In the context of 5G-VICTORI's WP4, the vertical specific KPIs will be validated against specific performance targets, through well-defined experimentation procedures, so that results retrieved are: specific, meaningful, reproducible, and achievable in similar contexts. For this purpose, effort has been put in the definition of 5G-VICTORI common methodology and the guidelines to be followed by each facility site for preparing and executing the facility and cross-facilities field trials. All four facilities have very similar testing procedures/workflows that are supported by their specific (diverse) technologies. However, to facilitate the accommodation and testing of 5G-VICTORI vertical UCs across the different ICT-17 platforms and to enable productive interactions between the verticals and the facilities, it is of high importance to align these testing procedures adopting initially a common methodology that addresses the following aspects:

- Formalization of concepts and adoption of a common language between stakeholders and facilities.
- Classification of stakeholders. 5G-VICTORI platform ecosystem, comprises the following roles: 5G-VICTORI Facility Operator, 5G-VICTORI Platform, 5G-VICTORI Technology Provider, Testers and End Users, General users, Experimenter, Vertical (industry), Vertical VNF provider.
- Procedures/ Operations to be performed before, after and at the time of execution of field trials.
- Identification of measurements/metrics to be retrieved, mapping/relating those to vertical UC KPIs and evaluation of results.
- Testing/ Experimentation unit's definition/description (in a common way), adhering to the previous aspects.
- Cross-facility experimentation capabilities (through 5G-VIOS).

Concerning the procedures/ operations to be performed, the 5G-VICTORI high-level methodology comprises the following three main stages, which are also reflected in the project description of work:

1. Experimentation Design, including the procedural steps starting from the definition of the UCs to the network infrastructure deployment, and to the high-level definition of the experiments.
2. Experimentation Development, constituting the workflow of following 3 steps / procedures:
   - Definition of Experiment Descriptors, including the roles involved in the trial, specific end-user / service / network functionalities, and test cases, in the form of specific templates common for all UCs and all facilities, the Scenarios and Network Slice(s).
   - Creation of Experiment, by translating the Experiment Descriptors to specific test scripts, in ways understandable for each facility (their specific User / Experimentation interfaces).
   - Test Scenario & Network Slice Selection.
3. Operations / Experimentation Execution, which focuses on the:

- Execution of Experiment, as detailed in the Descriptors, by performing human and / or facility interactions / operations including the collection of measurements and monitoring of metrics.
- Analysis and Reporting, at which point the results are exposed to the experimenters or authorised users through Analytics and Performance tools.

5G-VICTORI goes beyond the initial harmonisation of procedures at logical level, to the implementation of a common framework to materialise this alignment, namely the 5G-VIOS. The latter aims to provide an additional level of orchestration framework on top of the facilities individual orchestrators, which allows either brokering of experimentation procedures to the facilities or even direct orchestration of them such as in the case of the 5GUK testbed.

Besides the technology specifics of each 5G facility (e.g. in terms of service deployment, experiment creation and measurements collection) and their individual methodological approach to testing through iterative steps, the 5G-VICTORI experimentation methodology goes one step further to the capability of the facilities to utilize service blueprints developed at platform level or even facilitate co-design and co-development of experiments over the interconnected facilities. Regarding the cross facility / cross vertical experimentation, methodology it is assumed that several service blueprints will be developed within each facility and all such services will be exposed to the 5G-VICTORI ecosystem as ready to be scheduled through a common 5G-VICTORI framework (implemented by 5G-VIOS.

The 5G-VICTORI methodology and guidelines along the aforementioned lines, are described in detail in this document.

1 Introduction

In the overall 5G vision, defined by the 5G-PPP Architecture Work Group (WG), there is an immediate need to design and deploy future proof End-to-End (E2E) 5G infrastructures that serve to address a wide range of vertical applications. These must fulfil a set of requirements, such as featuring a flexible architecture, and the possibility to offer converged services across heterogeneous technology domains deploying unified software control. Despite the significant progress in 5G technologies witnessed in Europe stemming from current and previous 5G-PPP Actions, the validation of 5G solutions in large scale trials involving multiple vertical industries is still at its infancy.

The availability of such infrastructures stem from efforts such as ICT-17 and some other European and national initiatives. Their characteristics facilitate the extension of such infrastructures towards those owned by Vertical industries and support a plethora of services that can be offered to these verticals using different network slices. These slices could then concurrently offer services such Enhanced Mobile Broadband (eMBB), Ultra-reliable Low Latency (uRLL) and Massive Machine–to-Machine (mMTC).

To date, these 5G infrastructures focused on the evaluation of network-level Key Performance Indicators (KPIs) [1]. Unlike ICT-17 actions, ICT-19 projects accommodate vertical industries requiring additional tests and measurements. Vertical specific applications are composed of services that are configured to offer such applications. The test and evaluation of these services are accounted as service level KPIs.

5G-VICTORI will perform trials of various scales focusing on a set of specific UCs associated with several vertical industries. The aim of these trials will be to validate a set of KPIs as they are dictated by the specific vertical UCs developed by the project and the conformance of the achieved 5G-PPP KPIs to these, given the project technical implementations.

Technology and architecture validation in 5G-VICTORI will be carried out considering the most critical parameters of each vertical sector under real life conditions. For the architecture validation we not only consider the stringent requirements of the vertical applications but also the introduction of new business models. This validation will therefore take both a technology and a business perspective.

In 5G-VICTORI, the experimentation methodology revolves around the profiling of experiments, including specific configurations and conditions. This methodology is aligned with the 5G-PPP Test, Measurement and KPIs Validation (TMV) Work Group (WG). Concepts here referred to are also recurrent concepts promoted by the TMV WG [1]. The TMV's priority is to provide methodologies and Test Cases for the validation of the End-to-End (E2E) services delivered to the verticals. It defines:

This deliverable outlines the methodology and guidelines for the preparation and execution of field trials in 5G-VICTORI. This entails the formalization of key concepts and establishing of templates for testing and experimentation descriptions. Because the 5G-VICTORI is built upon four facilities—5G-VINNI, 5GENESIS, 5G-EVE and 5GUK—each with existing platforms and experimentation methodologies, this deliverable describes each facility's background and explains how each will be aligned with the common 5G-VICTORI framework. In addition to the methodological unification across facilities, a way towards technical unification is proposed, enabled by 5G-VIOS, an orchestration brokering platform.

1.1 Purpose of the document

This document is the first deliverable of 5G-VICTORI's Work Package 4 (WP4), being the first report stemming from Tasks 4.1, 4.2, 4.3 and 4.4.

The purpose of this deliverable is to meet the following WP4 objectives:

- Intra-, and Inter-field trial preparation and execution methodology. Initial high-level definition of the (inter) field trials enabled by 5G-VIOS.
- Initial timeline of the planned work.

Table 1-1 Dependencies with previous 5G-VICTORI Documents

id	Document Title	Relevance
D2.1 [2]	5G VICTORI Use case and requirements definition and reference architecture for vertical services	This document presents the 5G-VICTORI UCs and their specific requirements (UC requirements, network performance requirements and functional requirements), as they are dictated by the associated vertical industries.
D2.2 [3]	Preliminary individual site facility planning	This document defined the Hardware and Software belonging to the different facilities, and refers to the experimentation main aspects of the network deployment.
D2.5 [4]	5G-VICTORI Infrastructure Operating System – Initial Design Specification	This document presents the 5G-VIOS, the 5G-VICTORI E2E platform that spans across multiple facilities and provides interconnection and interworking. This way creating a common infrastructure of integrated network and compute/storage resources.

1.2 Document structure

This document comprises five sections. Following the Executive Summary and Introduction sections:

Section 2 establishes the field trial methodology and guidelines in 5G-VICTORI to be employed across all facilities.

Section 3 describes the experimentation methodologies employed by existing platforms at each of the facilities and how they are to be aligned with the 5G-VICTORI methodology.

Section 4 outlines the implementation 5G-VIOS, a platform with the purpose of technically unifying experimentation across facilities in 5G-VICTORI methodology.

Finally, section 5 presents the concluding remarks.

2 Common methodology and guidelines

5G-VICTORI relies on the already running ICT-17 infrastructure 5G-PPP projects 5G-VINNI (Patras, Greece facility), 5GENESIS (Berlin, Germany facility), 5G-EVE (France-Romania facility) and the 5GUK testbed (Bristol, UK). These 5G infrastructures developed across Europe provide the capability to vertical industries to test their innovative services and to enable novel 5G business cases. ICT-17 actions are jointly making an effort to establish a harmonized view towards the definition of experimentation methodologies and on-boarding procedures in order to accommodate external experimenters and Verticals [5].

ICT-19 projects exploit these diverse 5G infrastructures, available through the ICT-17 projects, and as such they require intensive coordination in order to define a commonly acceptable viewpoint for running trials over these infrastructures that are also being purposely upgraded. Taking this into consideration, in 5G-VICTORI there is an ongoing active dialogue between Verticals (and external Verticals), the 5G-VICTORI facility representatives and technology providers to enable the establishment of optimised experimentation process, in order to reduce the time to refine the proposed trials, and to ensure the accomplishment of the Vertical services requirements.

It should be noted that all four facilities have very similar testing procedures/workflows that are supported by their specific (diverse) technologies. However, in order to facilitate accommodation and testing of the 5G-VICTORI vertical UCs across the different ICT-17 platforms and to enable productive interactions between the verticals and the facilities, it is of high importance to align these testing procedures adopting initially a common methodology that addresses the following aspects:

a. Formalization of concepts and adoption of a common language and terminology (i.e. testing procedures, metrics/measurements/ KPIs, etc.).
b. Formalization of types of stakeholders and involved parties.
c. Procedures to be followed/ Operations to be performed (also those involving pure human interactions/ communications) before, after and at the time of the execution of experiments/trials.
d. Identification of measurements/metrics to be retrieved, mapping/relating them to vertical UC KPIs and evaluation of results.
e. Testing/ Experimentation unit's definition/description (in a common way), relating to the previous aspects.

This section summarises the common 5G-VICTORI understanding of the concepts defining the trials, the involved stakeholders, as well the common methodology for measuring specific KPIs.

2.1 Formalization of concepts

The first step before defining the 5G-VICTORI common methodology would be to formalise, in a common way, the concepts that are already used in the various ICT-17 projects adopting different terminologies. To this end, the following concepts and terminology will be used throughout this document and in the upcoming technical documents of the project:

- **Domain**

A group of entities that belong to a certain infrastructure that follow common rules and procedures. Examples are network, administrative or technology domains.

- **Platform vs Facility**

5G-VICTORI is built on the concept of a common (single E2E) inter-facility orchestration platform that is able to broker network services across multiple domains and facilities that comprise the 5G-VICTORI Platform [4]. In 5G-VICTORI, facilities refer to the different test environments associated with the ICT-17 projects 5GENESIS, 5G-VINNI,5G-EVE and the 5GUK, comprising each facility one or multiple sites.

- **Measurement system**

One or more measurement devices plus any other elements / components interconnected to perform a complete measurement from the first experiment operation to the end result [5] [6].

- **Device under test (DUT)**

The device or component to be placed in a test fixture (measurement system) and tested [5]. Usually, a single device being tested [6].

- **System under test (SUT)**

A system of devices / components, i.e., a specific combination of DUTs, being tested at the same time [6]. A SUT may – especially for virtualized network environments or software – include the computer system hardware and software on top of which the implementation under test operates [5].

- **Metric**

A generic high-level definition of a target quality factor (attribute) to be evaluated, i.e., a definition independent of the underlying system, the reference protocol layer, or the tool used for the measurement. Examples are capacity, latency, reliability, etc.

- **Test case**

A test case sets the basis to run experiments in an organised and structured way and defines the information needed regarding the configurations of the facility where the measurement activities are carried out. Each test case includes, apart from the description of the experiment and its measurable objectives, information about on configuration specifying: i) the configuration of the environment (for all RATs and network); ii) the set of procedures; iii) the monitored metrics, and iv) formulas required to (analytically) calculate the KPIs, and so on.

The main target of the test cases in the context of 5G-VICTORI is to test and validate 5G KPIs, whether these stem from the assessment of 5G network infrastructures or are related to evaluation of vertical services' KPIs.

More precisely, a test case provides the following information (More details and an example template is shown in section 2.5 and in [7]):

- Description: provides, a high level description of the test case scope, objectives, and/or rationale behind the need for this test case.
- Key UC Requirements and Target KPI(s): Each test case targets a single (or very few) main target KPIs and addresses a number of requirements. Secondary/complementary KPIs could also be defined as complementary measurements. The definition of the main target KPI needs to be specialized to related target metrics, 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.
- Components and Configuration: includes a list of particular SW/ HW components and a A list of features and capabilities that are required to be supported by the SUT in order to execute the test case steps.
- Test Procedure: It provides information necessary for correct conduction of the test case so that it can be repeatable in the same or different setups. In particular this field may include (where necessary) the following information:
    - Pre-Conditions: Any requirement that needs to be done before execution of the test case. A list of test specific pre-conditions that need to be met by the SUT including information about equipment configuration, traffic descriptor, i.e., precise description of the initial state of the SUT required to start executing the test steps.
    - Test case steps: A number of steps (actions/ procedures) that need to be performed during the execution of the test.
- Measurements:

- Methodology: Acceptable values for the monitoring time, the iterations required, the monitoring frequency, etc.
- Complementary measurements: A secondary list of metrics/KPIs useful to interpret the values of the target metric/KPI. Getting these measurements is not mandatory for the test case.
- Calculation process: If needed, any information related to the required calculation process. This information may include details related to the underlay measurements/ monitoring system.

- Expected Result: Brief description of the expected results and, where necessary, their representation. These can be: specific KPI target values, specific QoS profiles for the vertical services, etc., required in the form of single values, graphs, spider diagrams, etc.

- **Scenario**

The scenario includes information that is related to the E2E conditions for running the experiments in the network. It depends on the 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, such as the mobility, signal strength, interference, UE mobility and the UE location.

- **Traffic descriptor**

The description of the traffic sources that emulate the traffic from real applications or reproduce background traffic conditions

- **Experiment**

A 5G-VICTORI experiment is the execution of one of more test cases in different scenarios and using different slicing configurations.

- **Experiment descriptor**

It is assumed that each experiment is associated with an Experiment Descriptor. This descriptor includes a list of performance targets – or even Service Level Agreements (SLAs) – relevant profiling and experiment parameters, as well as Network Functions and Network Service Descriptors (NSDs). The Experiment parameters consist of all possible test scenarios and network slices.

The performance targets list specifies the resources that should be measured throughout the profiling process the minimum and maximum values for each resource, the performance metrics that should be collected and the methodology to analyse these. In addition, the performance targets are evaluated via KPIs that can be used to asses if the virtual components, e.g. Virtual Network Functions (VNFs), are successfully handling the workload or not.

- **Slice / Slice configuration**

In general, slice is defined as the set of specific E2E resources allocated in each component for the execution of the experiments. E2E slice configuration includes radio resources configuration, mobile core network (CN), transport network and resources allocated to the virtualised infrastructures offered by the platforms, etc.

2.2 Stakeholders and roles in 5G-VICTORI

The 5G-VICTORI 5G facilities play an instrumental role in bringing together technology players, vendors, operators and verticals. The facilities orchestrate individually the interaction of these stakeholders targeting new business models and opportunities for the ICT and vertical industries. Moreover, this environment allows establishing cross-vertical collaborations and synergies offering further enhancement in value propositions.

Below we present the different roles considered in the 5G-VICTORI ecosystem, involving both internal and external stakeholders:

- **5G-VICTORI Facility Operator**: any entity that has the 5G competence to operate an E2E 5G-VICTORI infrastructure. While traditionally the role is assumed by Telecommunication Operators, other business opportunities seem to emerge and this role is adopted by some of the 5G-VICTORI partners that own the 5G infrastructure and (possibly) any associated edge deployment. The Facility operator hosts, manages and operates the facility's SW and infrastructure, including the network infrastructure and main/edge data centres, as well as the associated experimentation framework for coordination, management, orchestration and monitoring assets.
- **5G-VICTORI Platform**: the 5G-VICTORI platform encompasses the different 5G-VICTORI facilities. Each 5G-VICTORI facility comprises one or more interconnected sites. The 5G-VICTORI Platform includes the cross-domain orchestration platform (5G-VIOS) [4] that will be adopted by each of the 5G-VICTORI facilities.
- **5G-VICTORI Technology Provider**: any vendors of system and software that build products around the 5G ecosystem and need to have early validation results using E2E 5G deployment setups. They are certainly bringing in their products for integration, still they must also follow the experimentation life cycle to get measurable validation results.
- **Testers and End Users**: a user that makes use of a 5G-VICTORI facility (or facilities) by setting up experiments and obtain results through either the web interface after registration or through a direct use of the Application Programming Interface (API) for Experimenters developed in the project.

  5G-VICTORI technology providers or external technology providers need to know the ecosystem for integrating their third party systems and SW in the 5G-VICTORI facilities. The project has to make available documentation about interfaces and APIs to interconnect their systems with the control, configuration and monitoring planes available in a 5G-VICTORI facility.
- **General users**: users of the services deployed at the 5G-VICTORI facilities to support the execution of experiments, carrying out specific interactions and utilising specific equipment as necessary per case. They can be either individuals or corporate end users.
- **Experimenter**: actor responsible for the request of an experiment, the definition of the characteristics of the experiment (starting from its blueprint), the request of virtual environment to follow, analyse and the assessment of its results.
- **Vertical (industry)**: stakeholders with activities focused in the area of specific end-user services with specific requirements from the underlying network infrastructure -usually not met with current network technologies. Verticals have knowledge of the service to be tested, including SLAs and service components. An Experimenter may himself/herself belong to a Vertical Industry. Verticals are keen to test a 5G infrastructure and experience promised services and KPIs. These verticals may optionally bring their industry specific systems and SW to be integrated with the 5G-VICTORI facility(ies), which can be equipment or appliances using SIM cards, applications either physical or virtual. Within 5G-VICTORI the Vertical industries can request measuring specific KPIs (by defining additional test cases) either standard and predetermined per platform, or especially described (through a custom test case) in well-defined network setups (scenarios).
- **Vertical VNF provider**: who provides the VNF packages for the vertical applications.
- **Field trial**: activities that aim to validate and demonstrate the functionality of a system or parts of it in relevant, pre-production / pre-operational or production /operational (though pre-commercial) environment, in the case of 5G-VICTORI being the vertical industries' sites.

2.3 5G-VICTORI methodology for the execution of field trials

This section presents the high-level methodology for the execution of the field trials, starting from the definition of the steps prior to the experimentation (some of them already detailed in deliverables D2.1 and D2.2), to the ones related to the preparation of the SUT and the execution of the experiments. Figure 2-1 provides a graphical representation of this methodology.

Figure 2-1 High-level Methodology for the execution of field trials

In general terms, adjusting the common approach of "Design - Implementation – Testing" to the development of the setup and the execution of field trials in 5G-VICTORI, the high level methodology comprises the following three main stages, which are also reflected in the project description of work (5G-VICTORI proposal):

4. Experimentation Design.
5. Experimentation Development.
6. Operations / Experimentation Execution.

ICT-17 projects are currently promoting a harmonized view towards the definition of the experimentation methodology in terms of logical steps, procedures and operations to be followed [5].

This previous work has motivated the harmonisation of the experimentation procedures and operations in all 5G-VICTORI facilities (ICT-17 and 5GUK). This harmonisation has led to the definition of the steps described below.

2.3.1 Facility / vertical experimentation methodology

Experimentation Design

The "Experimentation Design" includes a number of steps, which are performed via direct communication between the verticals and general users, with the 5G-VICTORI facility operator, 5G-VICTORI technology providers, Vertical VNF providers etc.; which mainly include system / network / experimentation design work; and define the technical work to be carried out, related to technology deployment, etc. It shall be noted that these methodological steps reflect the way that 5G-VICTORI work is structured and are followed at project level.

In particular, these steps are the following:

a. **Definition of UCs;**
   This step includes iterative discussions between stakeholders aiming to achieve a coherent definition of the UCs in terms of services to be provided, at specific sites / locations, over specific network deployments. This exercise that was part of deliverable D2.1 [1] and will be further elaborated in the context of WP2.
b. **Identification of requirements**;
   This step includes the identification of the requirements associated with each use case in terms of network system functionality and network performance (exercise that was part of deliverable D2.1 [1]).
c. **Definition of infrastructure and components**;
   This step includes the definition of the Hardware and Software components and functionalities that need to be deployed for the support of the UCs extracted from the requirements (exercise that was part of deliverable D2.2 [3], and of the upcoming deliverable D2.3).
d. **Deployment of upgrades to existing platforms**;

including additional hardware installation, software components deployment, upgrade of facilities' functionalities etc. (that will be captured in deliverable D4.2).

e. **High-level definition of the experiments;**
to evaluate the delivery of the defined UCs;
At this step the experiment is defined to the level of detail including the identification of roles involved in the trial, and specific end-user / service / network functionalities. This definition of the experiments includes descriptive information subject to further elaboration in the next step.

Experimentation Development

At this stage, having the required experimentation facility setup deployed, the experimentation design work is fused to the facilities to develop the experimentation. At this point, differences between facilities may exist, related to their underlying technologies and deployment specificities. However, as aforementioned, ICT-17 projects are currently promoting a harmonized view towards the definition of the experimentation methodology [5], and this work has motivated the harmonisation of the methodological/ logical experimentation development procedures and operations in all 5G-VICTORI facilities (ICT-17 and 5GUK). As a result, the following workflow of three steps / procedures has been identified as a common methodology for this stage:

1. **Definition of Experiment Descriptors**
At this step the Experiment Design work is nailed down to specific flows of end-user / service / network functionalities, and to specific facility configuration following the same general procedure below. To allow reproduction of experiments across facilities the necessary information is captured in a common way for all facilities, however different facilities may have their own specific ways of interpreting these Descriptors to facility- understandable information, and materializing them.
   - **Elaboration of the Definition of the experiment**;
     At this point the experiment is defined to the level of detail including the identification of roles involved in the trial, and specific end-user / service / network functionalities.
   - **Definition of test cases**
     At this point, the experiment is further elaborated to the level of test cases including the identification of target requirements' testing and/or the identification and secondary vertical services and/or network KPIs, where necessary the methodology to extract KPI evaluation results from obtained measurements/metrics, the general configuration or else the pre-conditions, and finally to the level of flows of specific end-user interactions, service/ application operations, and network functionalities triggering/usage etc. in the form of specific templates common for all UCs and all facilities (section 2.5).
     - At this point it shall be noted that the latter flows can take the form of test scripts– to be run in a specific facility.
   - **Definition of scenarios**
     At this point, the network configuration and deployment specifications that are required for test cases are defined, including the radio access network (RAN) configuration, the computational resources, the network conditions that can be emulated or imposed by the use case applications, mobility, etc. The definition of the scenarios depends on the facilities capabilities. However, in terms of high level definitions, common templates are defined for all 5G-VICTORI facilities (section 2.5).
   - **Definition of the Network Slice(s)**
     Along with the network configuration, the network slice characteristics associated with specific test cases and scenarios are defined as next step. Network Slice definitions will include details of the E2E resources allocated and Quality of Service (QoS) guarantees for the execution of the experiments.
2. **Creation of Experiment**

At this step, the Experiment Descriptors are translated to specific test scripts, in ways understandable for each facility as required by their specific User / Experimentation interfaces.

3. **Test Scenario & Network Slice Selection**
   As next step, the test scenario and the network slice(s) associated with the test case are selected by the facility following their specific implementations.

Operations / Experimentation Execution:

This stage includes the execution of the experiment, the collection of the measurements and the analysis and evaluation of results. From the methodology point of view, this stage comprises the next two steps:

4. **Execution of Experiment**
   At this point, the experiments are executed as detailed in the Descriptors, by performing human and / or facility interactions / operations including the collection of measurements and monitoring of metrics. The technology specifics of each facility are taken into consideration. These specifics have been elaborated in WP2 deliverables while some hints are also provided in Section 3.

5. **Analysis and Report**
   At this point, the monitored experiment results are exposed to the experimenters or authorised users through Analytics and Performance tools. This process includes the collection of measurements and analysed metrics from the facility, and the extraction of KPIs measurements from this information. “Performance Profiles” can be defined at this process which can be used to evaluate KPIs against the respective performance targets and SLAs.

2.3.2 Cross facility/cross vertical experimentation methodology

5G-VICTORI goes beyond the initial harmonisation of procedures at logical level, to the implementation of a common framework to materialise this alignment. Even, the project goes even beyond the initial harmonisation of procedures at the facilities, independently, as the project aims to build and operate an open, and extensible reference ecosystem that will integrate verticals into existing interconnected 5G-PPP Platforms. Besides the technology specifics of each 5G facility (e.g. in terms of service deployment, experiment creation and measurements collection) and their individual methodological approach to testing through iterative steps, 5G-VICTORI experimentation methodology goes one step further to the capability of the facilities to utilize service blueprints developed at platform level or even facilitate co-design and development of experiments over the interconnected facilities.

Regarding the cross facility / cross vertical experimentation, methodology it is assumed that several service blueprints will be developed within each facility and all such services will be exposed to the 5G-VICTORI ecosystem as ready to be scheduled through a common 5G-VICTORI framework (implemented by 5G-VIOS, see Section 4). Hence the different stakeholders of 5G-VICTORI cross-facility system will be able to design and develop different parts of the experimentation process (e.g. comprising elements of already developed experiments), which then, during the Operations / Experimentation Execution phase, will be available to the vertical customer across facilities to make repeatable and scheduled experiments (through service orders to specific facilities) of the developed services blueprints via 5G-VICTORI common framework. Latter capability will allow for instance, KPI testing, monitoring and even benchmarking over the interconnected testing facilities. At the same time, the main advantages of this part of the methodology is that allows fast vertical deployment times, and improved business and technology KPIs. At logical level, the methodology is presented in Figure 2-2.

To that respect, in the context of the project, the 5G-VICTORI state-of-the-art ecosystem design will be driven by the requirements of the *Transportation, Energy, Media, Factory of the Future* verticals deployed across the various extended infrastructures.

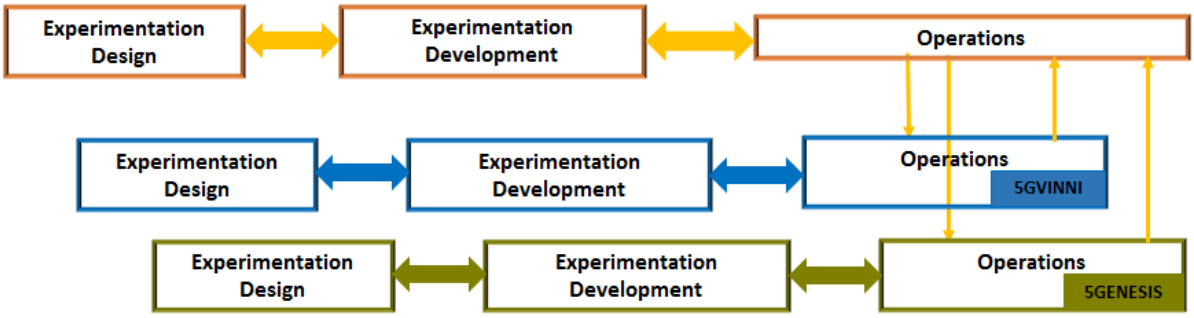

Figure 2-2 Cross facility/cross vertical experimentation methodology

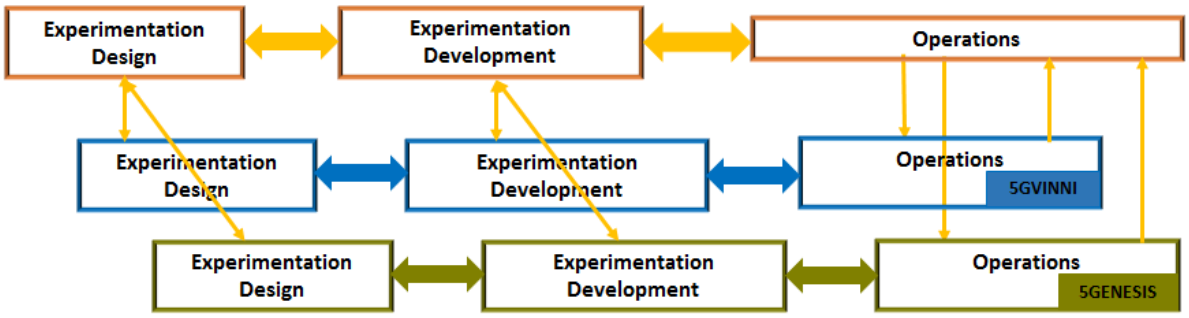

Figure 2-3 Cross facility/cross vertical co-design and co-development of experiments methodology

2.3.3 Cross facility/cross vertical co-design and co-development of experiments

Further extending the cross facility experimentation capabilities, the 5G-VICTORI methodology allows for cross facility/cross vertical co-design and co-development of experiments. This implies that the experimentation design phase may involve stakeholders such as vertical customers, 5G-VICTORI facility providers and developers to comprehend vertical requirements, propose solutions, and jointly develop the final services (to be developed and deployed), the test scripts and the monitoring services. Latter (experimentation development) phase enables the design of the 5G-VICTORI services over ready to deploy components or purpose built ones available in various facilities, and aims at providing flexible ways for building complex constellations of virtual network and vertical functions, all running over a combination of elements that can be efficiently shared and deployed. This aspect of 5G-VICTORI methodology is presented in Figure 2-3.

The main advantages of this part of the methodology is that allows increased sustainability, resource sharing, lower vertical deployment times – of course related to the level of maturity that each deployed component at the various 5G test facilities.

2.4 5G-VICTORI methodology for the measurement of KPIs

Forthcoming 5G network deployments aim to cope with the explosive growth of mobile internet traffic and to meet the future services' QoS targets in terms of bandwidth per service, latency, number of device connections, traffic density, mobility, etc., which are far beyond the existing (4G/4G+) technologies' capabilities.

To this end, the whole ICT ecosystem moves from technology-driven approaches to service-driven ones. In practice, this means that, unlike current network deployments, which are based on the satisfaction of service-agnostic, abstract and (network-wide) cumulative requirements; 5G network deployments will satisfy more flexible and varied requirements which will be dictated by the specific stakeholders/applications/services. Therefore, the evaluation methodologies of the 5G networks have

shifted the orientation from network infrastructure and platforms evaluation to vertical services' performance evaluation over these infrastructures; as an indirect mean also of platforms evaluation. This shift is reflected in the EU research activities and projects and at second stage in the work of 5G-PPP.

In this respect, efforts focus on addressing initially the following aspects:

- Find mechanisms to derive a service / application performance from a given network performance
- Identify the measurement qualities and points for meaningful network performance assessment.

To this end, main logical steps of the various methodologies followed in 5G deployments performance evaluations are the following:

1. Identification of key reference UCs, namely network deployment and services to be studied.
2. Research and identification of key 5G network and network services KPIs as defined in various standardization bodies, 5G research and industry partnerships and projects (e.g. 5G-PPP, NGMN, ITU, Projects, etc.).
3. Research and identification of key 5G and (in general) future services/applications KPIs as defined by various stakeholders, mainly service providers, vertical industries, application developers and end users.
4. Mapping between the 5G/future services/applications KPIs and the network/network services KPIs, focusing on the criticality, importance and influence of 5G network performance KPIs on services/applications KPIs.
5. Identification of interfaces and respective architecture elements including both network and end devices/applications, from where evaluation measurements / insights can be obtained.

In the context of the 5G-VICTORI project, the key reference UCs (step 1) have been defined in the project proposal and have been refined along with initial KPIs in 5G-VICTORI deliverable D2.1 [1], while the main aspects of the network deployment (step 1) have been presented in 5G-VICTORI deliverable D2.2 [3] and will be presented in the context of 5G-VICTORI deliverable D2.4.

2.4.1 5G Network and Network Services Evaluation

The evaluation of the 5G networks and network services requires monitoring of the work performed by Standardisation Development Organisations (SDOs), mainly 3GPP, the European Telecommunications Standards Institute (ETSI) and ITU, as well as industry alliances and fora on KPIs. As widely known, ITU initially provided the applications and network services generic target KPIs illustrated in Figure 2-4.

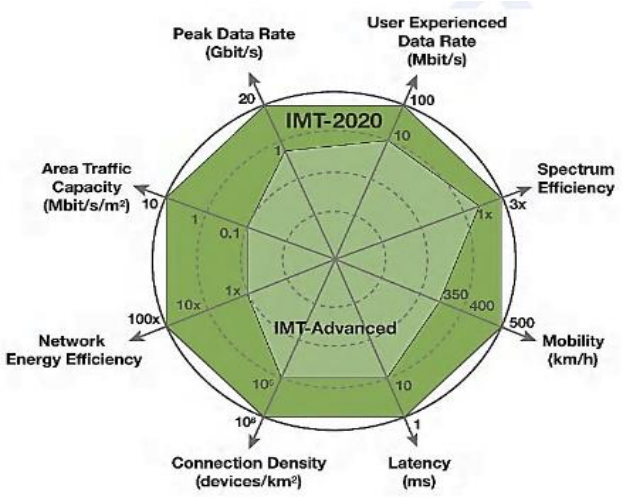

Figure 2-4 IMT 2020 Targets by ITU [18]

Refining further these generic targets, ITU and 3GPP distinguished generic Service Classes to be used for mapping applications/services to network service classes (also identified by 3GPP/NGMN [19]/etc.), namely: enhanced Mobile BroadBand (eMBB), massive/enhanced Machine Type Communications (m/eMTC) or massive Internet of Things (mIoT) and Ultra-Reliable Low Latency Communications (URLLC).

While adhering to these classes, 3GPP defined various KPIs on a per service category/ deployment/ etc. basis along with target values in [9], [10], [11], [12], [13], [14]. More specifically:

- In TR 22.861 [10], the mIoT Service Class is associated with massive IoT deployments e.g. for utilities, factories of the future, industry 4.0 and automotive vertical UCs.
- In TR 22.862 [11], the URLLC Service Class is associated with mission critical communications e.g. in industry automation, health, Public Protection and Disaster Relief (PPDR), etc. vertical UCs, requiring high reliability, high availability and low latency (e.g. < 1 ms in control plane and < 10 ms in user plane).
- In TR 22.863 [12], the eMBB Service Class is associated with high data rate services (multimedia services, broadband data services) reflecting the ITU targets of 100 Mbit/s user data rate, and 3GPP's targets at areas/hotspots of high traffic density reaching 3.75 Mbit/s DL/m^2 and 7.5 Mbit/s/m^2 UL.

At the same time, in the context of 5G-PPP activities, the aforementioned KPIs defined by SDOs have been compiled, resulting in 5G network-related KPIs that encompass both 5G equipment capabilities and network deployment specificities. With the progress of work on 5G in various bodies and projects, all these KPIs have been overloaded with definitions and target values, later stages of 5G-PPP work focused on the refinement of these KPIs, and their decomposition to specific, measurable, and relevant KPIs. Initially Latency and Service Deployment Time have been refined [15]. In particular:

- The E2E latency KPI has been decomposed into a number of delay contributions associated with the network segments, the processing at the various network components and application layer delays.
- The Service Deployment Time KPI has been decomposed into timing KPIs related to the following distinctive operations: Platform Provisioning, Service/Application Onboarding, Service Instantiation/Configuration and Activation, Service Modification and Service Termination.

An overview of the various networks and network service KPIs defined by the various SDOs is provided in Table 2-1.

Table 2-1 Key 5G networks and network services KPIs by ITU, NGMN, 3GPP and 5G-PPP

KPIs		Source
Multitenancy support		3GPP, NGMN, & 5G-PPP
Scalability		5G-PPP, NGMN/ Telcos
CAPEX/OPEX efficiency		5G-PPP, NGMN
Energy Efficiency		5G-PPP, NGMN
Radio Network node capacity		5G-PPP
Latency ("T_": transmission time over the specified network segment) ("P_": processing time introduced by the component / function)	**T_RAN Latency**	5G-PPP
	T_Backhaul	5G-PPP
	T_Core	5G-PPP
	P_UE	5G-PPP
	P_RAN	5G-PPP
	P_UPF_Edge	5G-PPP
	P_UPF_Core	5G-PPP

("R_": Application component Response time)	R_Client	5G-PPP
	R_Server_Edge	5G-PPP
	R_Server_Core	5G-PPP
User data rate		ITU, 3GPP
Reliability		ITU, 3GPP
Availability		ITU, 3GPP
Connection Density		ITU, 3GPP
Traffic Density		ITU, 3GPP
Ubiquitous access		5G-PPP
Mobility		3GPP, 5G-PPP
Positioning Accuracy		ITU, 3GPP
Service Deployment Time		
Phase 0. Platform Provision	Platform configuration	5G-PPP
	Platform deployment	5G-PPP
Phase 1. Onboard-ing	Network Slice Template	5G-PPP
	Network Service Descriptor	5G-PPP
	VNF package	5G-PPP
	MEC App Descriptor	5G-PPP
	Other applications	5G-PPP
Phase 2. Instantiate Configure & Activate	Instantiate Network Slice (NSI)	5G-PPP
	Instantiate & Activate Network Service (NS)	5G-PPP
	Instantiate & Configure VNFs in service chain (VNF)	5G-PPP
	Instantiate & Configure MEC App	5G-PPP
	Instantiate & Configure other applications	5G-PPP
	Configure other NFVI[1] elements	5G-PPP
	Configure SDN infrastructure	5G-PPP
	Configure Optical WAN	5G-PPP
	Configure satellite backhaul	5G-PPP
Phase 3. Modify	Modify Network Slice configuration	5G-PPP
	Modify Network Service configuration	5G-PPP
	Detect scale out/in decision	5G-PPP
	Implement manual scale out/in	5G-PPP
	Implement autoscale out/in	5G-PPP
	Modify VNF configuration in service chain	5G-PPP
	Modify MEC App configuration	5G-PPP
	Modify configuration of other applications	5G-PPP
	Modify configuration of other NFVI elements	5G-PPP
	Modify configuration of SDN infrastructure	5G-PPP
	Modify Optical WAN circuit	5G-PPP
	Modify satellite backhaul configuration	5G-PPP
Phase 4. Terminate	Terminate Network Slice	5G-PPP
	Terminate Network Service	5G-PPP

[1] Network Function Virtualisation Infrastructure

	Terminate VNFs in service chain	5G-PPP
	Terminate MEC App	5G-PPP
	Terminate other applications	5G-PPP
	Remove configuration of other NFVI elements	5G-PPP
	Remove configuration from SDN	5G-PPP
	Terminate Optical WAN circuit	5G-PPP
	Terminate satellite backhaul circuit	5G-PPP

2.4.2 5G-VICTORI Vertical Services Evaluation

As aforementioned, in parallel to the identification of the network and network services KPIs for each deployment, the identification of key vertical services/applications KPIs is needed. The latter will be defined by various stakeholders, mainly service providers, vertical industries, application developers and end users. For the UCs of 5G-VICTORI and the applications/services that will be deployed and demonstrated over the project facilities, the detailed identification of these KPIs is performed in the context of WP3 deliverables along with the testing and performance evaluation details.

2.4.3 Mapping between Network and Vertical Services KPIs and KPIs refinement

Next step would be the combination of the specific, measurable, and relevant KPIs of the 5G network deployment, with the measurable qualities of the vertical services/applications KPIs. The result of this work would be the identification of the critical network KPIs that influence the vertical services/applications KPIs aiming at extracting insights and derive conclusions regarding the application performance based on network performance information. For the KPI's analysis, the 5G-VICTORI facilities' deployments, and the facilities' separate monitoring capabilities at specific probing points will be taken into consideration together with the general 5G component level architecture approaches summarized in [16].

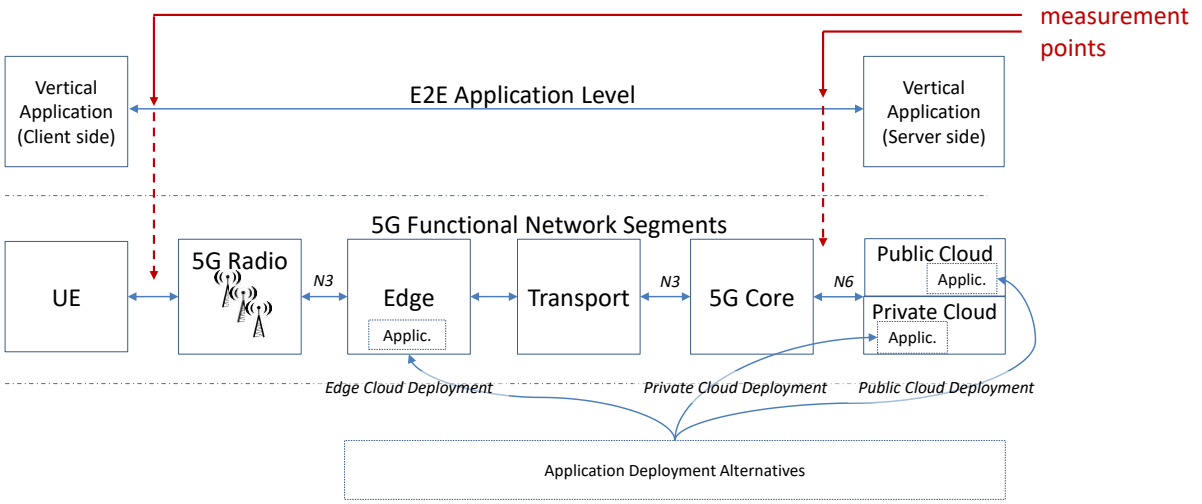

Figure 2-5: Identification of measurement points and mapping of network to vertical service KPIs based on [16].

To this end, also the work performed currently in the 5G-PPP Vertical Task Force (TF) of the Test, measurement and KPI Validation (TMV) Work Group (WG) is tightly monitored and extended in the context of 5G-VICTORI. In practice this includes the identification of interfaces and respective architecture elements involving both network and end devices/applications, from where evaluation measurements / insights can be obtained and the refinement of key technical 5G network KPIs namely –initial list to be extended as project work progresses:

- Latency.
- User Data Rate.

- Traffic density.
- Connection density.
- Location Accuracy.

Indicatively, in general terms, and depending on the network deployment and vertical services/ applications specificities and the measurement capabilities of the facilities:

- The evaluation of vertical application delays between two application components placed at specific network segments (e.g. MEC/core/ public internet, etc.) will be based on the 5G network latency contributions analysis of [15], along with an association between the critical measurable quantities and the facilities capabilities to measure these quantities.
- The evaluation of (user) data rate between two application components placed at specific network segments (e.g. MEC/core/ public internet, etc.) will be based on a similar analysis of data rate retrieved at various network measurement points, and a similar mapping between the critical measurable quantities and the facilities capabilities to measure these quantities. For instance a "Service data rate" will be determined by the minimum of "user data rates" achieved through the various network segments between these two components.
- The evaluation of achievable traffic density or area traffic capacity[2] [3], at vertical services level, which can be defined as the total traffic throughput per specific geographical area of interest for a number of (media) services/connections (with specific QoS) defined (by the vertical), an be based on network measurable quantities such as:
  - Area Traffic Capacity / Traffic throughput at 5G-Radio_Network part, measured for the specific geographical area
  - Capacity of various 5G Transport Network segments from the 5G Radio Network part to the Edge or Core Network
  - Capacity at Edge and/or Core Network parts.

[2] *ITU-R M.2410-0 Report (2017) Definition (https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2410-2017-MSW-E.docx):* Area traffic capacity is the total traffic throughput served per geographic area (in Mbit/s/m^2). The throughput is the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time.

This can be derived for a particular use case (or deployment scenario) of one frequency band and one TRxP layer, based on the achievable average spectral efficiency, network deployment (e.g. TRxP (site) density) and bandwidth.

[3] *NGMN Recommendations (2016) Definition (*https://www.ngmn.org/wp-content/uploads/Publications/2016/160603_Annex_NGMN_Liaison_to_3GPP_RAN_72_v1_0.pdf*):*

Full buffer: Total traffic throughput served per geographic area (in Mbit/s/m2). The computation of this metric is based on full buffer traffic.

Non full buffer: Total traffic throughput served per geographic area (in Mbit/s/m2). Both the user experienced data rate and the area traffic capacity need to be evaluated at the same time using the same traffic model

- Similarly, the evaluation of achievable connection density[4] [5] [6], at vertical services level, which can be defined as:
  - Connection Density per specific geographical area (not necessarily km^2 as reference) per vertical for a number of (media) services (with specific QoS) defined by the vertical.
  - Connection Density per specific geographical area (not necessarily km^2 as reference) per vertical per specific (media) service (with specific QoS) defined by the vertical.
  - Device Density per specific geographical area (not necessarily km^2 as reference) per vertical per UE state (e.g. idle, inactive, connected), and so on;

  directly corresponding to some/ any of the following potential measurement qualities:
  - Connection/Device Density at 5G-Radio_Network part, measured for the specific geographical area, for UEs at various states
  - Connection Density at 5G Radio Network part, measured for the specific geographical area, for a specific number of (media) services (with specific QoS) defined by the vertical; and as a subset for a specific media service defined by the vertical
  - Connection Density at 5G Edge Network part, measured for the specific geographical area, for a specific number of (media) services (with specific QoS) defined by the vertical; and as a subset for a specific media service defined by the vertical
  - Device Density at Edge and/or Core N& services (e.g. idle, inactive, connected).

2.5 Testing/ Experimentation units definition/ templates

In alignment with the previously discussed approach, the Testing/ Experimentation units definition / description is performed in a common way for all 5G-VICTORI UCs and facilities.

As mentioned in section 2.1, this document provides the initial specifications in the form of templates of the following key concepts in the 5G-VICTORI common methodology:

- the experimentation scenarios that describe the E2E conditions to run experiments (see Section 2.5.1).
- the test cases, which define the targets of the experiment, the procedure and the measurements that have to be collected in order to validate the targeted KPIs.
- the Experiment Descriptors, which contain all the information required by the platforms to run the experiments.

2.5.1 Scenario template

The scenario template will be as shown in Table 2-2:

Table 2-2 Scenario description template

Scenario Description Template

[4] *ITU-R M.2410-0 Report (2017) Definition (https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2410-2017-MSW-E.docx):* Connection density is the total number of devices fulfilling a specific quality of service (QoS) per unit area (per km2). Target QoS to be defined as delivery of a message of a certain size within a certain time and with a certain success probability. The target value of this KPI for 5G networks is 1 000 000 devices per km^2.

[5] *NGMN Recommendations (2016) Definition (https://www.ngmn.org/wp-content/uploads/Publications/2016/160603_Annex_NGMN_Liaison_to_3GPP_RAN_72_v1_0.pdf):* Same definition as ITU. Remarks of NGMN: Foreseen as most relevant for mMTC. QoS definition should take into account the amount of data generated within a time t_gen that can be sent or received within a given time, t_sendrx, with x% probability.

[6] *Typical KPI measured: Number of Devices at Radio Access Network that are capable of receiving specific network service with specific QoS characteristics.*

Radio access technology (RAT)	*4G, 5G, Sub-6, mmWave*
Standalone / Non-Standalone (if applicable)	*(5G equipment)*
Cell Power	*in dBm*
Frequency band:	*Sub-6, mmWave*
Maximum bandwidth per component carrier	*50 MHz, 100 MHz, 200 MHz, 400 MHz,* *800 MHz, 1 GHz, 2 GHz*
Sub-carrier spacing	*Sub 6 GHz: 15 kHz, 30 kHz, 60 kHz* *mmWave: 60 kHz, 120 kHz, 240 kHz, 480 kHz*
Number of component carriers	*Maximum number of CC = 16 (5G)* *Maximum number of CC = 5 (4G)*
Cyclic Prefix	*Cyclic Prefix: normal, extended*
Massive MIMO	*Number of antennas on xnB*
Multiple-Input Multiple-Output (MIMO) schemes (codeword and number of layers)	*The number of codewords per Physical Downlink Shared Channel (PDSCH) assignment per UE* - *1 codeword for 1 to 4-layer transmission* - *2 codewords for 5 to 8-layer transmission.*
Modulation schemes	*Downlink: QPSK, 16 QAM, 64 QAM, 256 QAM* *UplinK: QPSK, 16 QAM, 64 QAM, 256 QAM*
Duplex mode	*FDD, TDD*
TDD uplink/downlink pattern	*(if applicable)* *e.g. 0.5 ms, 0.625 ms, 1 ms, 1.25 ms, 2 ms, 2.5 ms, 5 ms, 10 ms*
Contention based random access procedure/contention free	*(if applicable)*
User location and speed	*Coordinates, in km/h*
Background traffic	*(if applicable)*
Computational resources available	*e.g. RAM, storage*

2.5.2 Test Case template

Each test case is then homogenously through 5G-VICTORI facilities and use case described in the template shown in Table 2-3. More information on these test descriptions will be provided in WP3 deliverables.

Table 2-3 Test Case template

Test Case Template	
<Test Case ID>	*<Test Case Title>*
Description	*Description of the test case, and high level purpose*
Key UC requirements and KPIs	*Definition of the UC requirements and targeted KPIs*
Network performance requirements and KPIs	*Definition of Network performance requirements and KPIs. The definition of the main metric/KPI declares at least the reference points from which*

	the measurement(s) will be performed, the underlay system, the reference protocol stack level, etc.	
Network Functional requirements and KPIs	*Definition of Network functional requirements*	
Components and Configuration	*Components*	*A list of HW/SW components (for example, components that may be needed when testing alternative network deployments/ technologies) that are necessary for the test case*
	Configuration	*A list of features, capabilities, how components are interconnected, required by the SUT in order to execute the test*
Test procedure	*Pre-conditions*	*Any pre-condition that needs to be done before execution of the test case. A list of test specific pre-conditions that need to be met by the SUT including information about equipment configuration, traffic descriptor, i.e., precise description of the initial state of the SUT required to start executing the test steps*
	Test Case steps	*A number of steps (actions/ procedures) that need to be performed during the execution of the test. Depending on the test case nature / deployment / scope, this field can also specialise the test and measurement process (methodology) of the metric for the selected underlay system.*
Measurements	*Methodology*	*Acceptable values for the monitoring time, the iterations required, the monitoring frequency, etc.*
	Complementary measurements	*A secondary list of metrics/KPIs useful to interpret the values of the target metric/KPI. Getting these measurements is not mandatory for the test case.*
	Calculation process	*If needed, any information related to the required calculation process. This information may include details related to the underlay measurements/ monitoring system. The Units of the metric and, potentially, a request for first order statistics (Min, Max, etc.) can be also included*
Expected Result	*Brief description of the expected results and, where necessary, their representation. These can be: specific KPI target values, specific QoS profiles for the vertical services, etc., required in the form of single values, graphs, spider diagrams, etc.*	

The report after the execution of a test case should be as shown in Table 2-4:

Table 2-4 Test report

Field	Description	
Test Case ID	*< test case ID>*	
Facility, Site	*Name of the facility, or facilities involved; Site involved*	
Description	*What is going to be measured, what is that the test assesses, whether the test lacks part of the components or procedures that should be normally part of it*	
Executed by	Partner: *5G-VICTORI Partner*	Date: *YYYY-MM-DD*
Purpose	*Goals of the test*	
Scenario	*Refer to the right scenario template used for the test*	
Slice Configuration	*Configuration of the slices (if any) and details about them*	
Components involved	*HW and SW components involved, name them*	
KPIs collected (Metrics collected)	*Detail the particular metric or KPI of interest (definitions of these metrics and KPIs are part of D3.X deliverables)*	
Tools involved	*General available tools not specifically developed in the project, e.g. ping, Iperf, etc.*	

Results and KPIs Primary Complementary	*List both the main result of the test and additional measurements that are outcomes from the tests*
Target metric/KPI and verification (pass/fail)	*Check whether the test has satisfied the requirements set as target*

2.5.3 Experiment Descriptor template

In particular, an Experiment is defined by the **Experiment Descriptor**, containing all the information required by the facilities to run the experiments. The Experiment descriptor template consists of the fields indicated in Table 2-5:

Table 2-5 Experiment Descriptor template

	Type	Description
ExperimentType	Standard/Custom	*type of Experiment*
Automated	<bool>	whether it is manual or automated
TestCases	<List [str]>	*test cases to execute*
UEs	<List [str]> UEs IDs	*UEs to use*
Network Slice	<str>	*Definition of the slice, including both the virtual network functions (VNFs) and the 3GPP features of the slice*
Network Services	<List [Tuple [str, str]]> (NSD Id, Location)	*definition of the network services Catalogues*
Network Scenario	<str>	*scenario to configure and deploy out of those defined*
Exclusive Execution	<bool>	*whether it runs at the same time as other experiments or not*
ReservationTime	(Minutes)	*define the duration of the experiment when automation is not enabled*
Application	<str>	
Performance targets & SLAs	JSON	*Description of the target KPIs (network, vertical), methodology to measure them, Performance metrics and the thresholds.*
Experiment Parameters	<Dict [str,obj]>	
Edges	<registration_info>	*{VLANs, Edge_IDs}*
Remote	<str>	*Remote platform Id, to identify the secondary platform that will be part of the distributed experiment*
Remote Descriptor	<Experiment Descriptor>	*contains a JSON object in the same format as the main descriptor, but excluding the 'Remote' and 'RemoteDescriptor' fields*
Version	<str>	
Extra	<Dict [str,obj]>	

It should be noted, that –at the time of writing this document– the definition of these templates (of sections 2.5.1, 2.5.2, 2.5.3) are subject to an iterative process of feedback exchanged between the verticals and the platform operators. This process will be finalized with the completion of the initial set of deliverables of WP3 tasks, i.e. 5G-VICTORI deliverables D3.1, D3.2 and D3.3, in order to accommodate any specificities related to the UCs and, at the same time, to be concrete, lean and clean to the expected experimenters.

3 Facility-specific approach to field trials

This section captures the specific guidelines and methodologies the ICT-17 projects (5GENESIS, 5G-VINNI and 5G-EVE) and the 5GUK testbed set up prior to implement any demonstration or trial using the 5G platforms. This section also reports on the timelines and dependencies of each facility to be prepared for and execute field trials.

3.1 5G-VINNI Facility

5G-VINNI Facility sites are intended to provide a platform for external parties, be that ICT-19 project participants or others, to test their proposed 5G UCs in an environment that is expected to be operational and stable for the delivery of good quality, 5G service. Within 5G-VINNI, the Patras 5G facility is based mostly on open source components and it is designed and built to provide the capability for experimenters to test and demonstrate UCs that will advance the industries appreciation of what 5G networks can enable. To that respect, the Patras 5G facility is an exemplary Open Source 5G and IoT facility. Numerous partners have deployed their technologies in the Patras 5G /Greece facility, thus creating a unique 5G playground for KPI validation and support on future verticals. For more information please check http://wiki.patras5g [17].

3.1.1 Concepts and architecture

With Patras 5G Operation Support Systems (OSS), Network Function Virtualization (NFV) and experimentation enabled services, like Openslice and Open Source MANO (OSM), the Patras5G facility enables end-to-end (E2E) automated deployment of multiple customized-slices over the whole network – access, transport and core. This further includes the slicing of the IoT devices at the edge of the network. The Patras 5G facility is equipped with a cloud platform, able to host core network components, as well as NFV and Multi-access Edge Computing (MEC) deployments.

Vertical applications can access the Patras 5G Service Catalogue through the Patras Facility site portal: https://patras5g.eu. Vertical applications can self-manage and onboard their artifacts through the Patras 5G Portal or access programmatically available services. Various artifacts can be managed through the facility portal https://patras5g.eu via standardized TMForum OpenAPIs: Service Catalog, Service Order and Service Inventory, Partner Management and Users, Service Orchestration, VNFs/NSDs catalogue, network function orchestrator (NFVO) endpoints via OSM North Bound Interface (NBI), Service and NFV Deployment requests.

The Patras 5G facility adopts the Network Slice as a Service (NSaaS) delivery model, whereby the Patras5G facility provisions tailored network slices to verticals upon request. Each vertical uses the slice that has been provided to meet their requirements for trialing activities, setting up different UCs and assessing their Key Performance Indicators (KPIs) under different network conditions.

3.1.2 Experimentation Workflow

The Patras5G facility is based on Openslice (http://openslice.io), which allows NSaaS delivery model as shown in Figure 3-1, where the Patras5G portal and service catalogue expose TM Forum Open APIs towards verticals to allow them to directly trigger necessary operations for service ordering. The Patras5G Service Catalogue derives content from Patras5G Facility Service Catalogue offerings. The vertical's service order is then passed to the Service Orchestrator (SO), which in turn instantiates the network slice by subsequent calls to the respective NFVO. The NFVO implements the northbound interface using ETSI SOL 005.

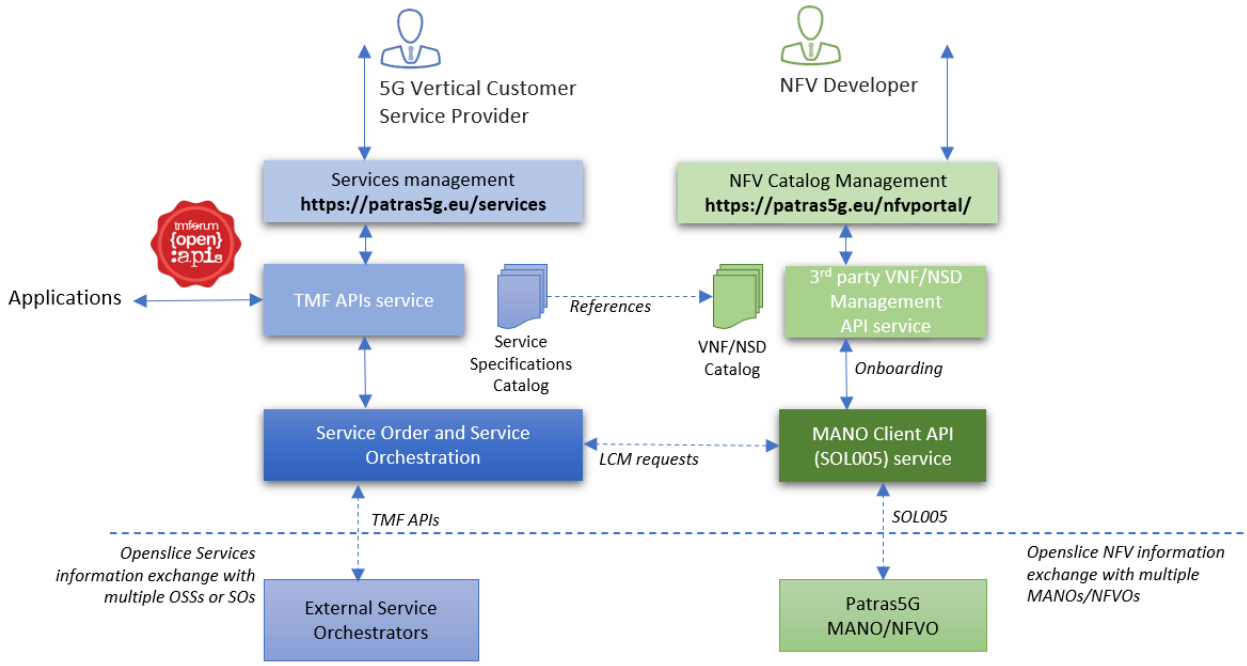

Figure 3-1 University of Patras Openslice

The Patras Facility site portal is based on Openslice (http://openslice.io), a prototype open source, operations support system. UoP is the main contributor of OpenSlice. It supports VNF/NSD onboarding to OSM and NSD deployment management. It also supports TMFORUM OpenAPIs regarding Service Catalog Management, Ordering, Resource, etc. Openslice offers the following main functionalities:

- Service Catalog Management: A Communication Service Provider (CSP) will have the ability to manage the Service Catalog Items, their attributes, organize in categories and decide what to make available to Customers.
- Services Specifications: A CSP will be able to manage Service Specifications.
- Service Catalog Exposure: A CSP will be able to expose catalog to customers and related parties.
- Service Catalog to Service Catalog: Openslice able to consume and provide Service Catalog items to other catalogs.
- Service Order: The Communication Service Customer will be able to place a Service Order.
- Service Inventory: The Communication Service and Provider will be able to view deployed Services status.

Openslice thus support both APIs for programmable access to the infrastructure as well as a web portal for user friendly access.

3.1.2.1 Service Exposure Levels of Patras5G

The Patras5G exposes four Levels of services shown below under different circumstances and requirements. This depends on the customer UCs and needs.

Level 1 Access: Exposed entity and access: 5G-VINNI Portal (WEB UI and REST API) https://patras5g.eu, VPN access to deployed NS

Description: Service Catalog exposure (TMForum), Service Ordering Support (TMForum), scheduled orchestration, and VPN access to deployed NS. Access to monitoring data of various points

Level 2 Access: Exposed entity and access: 5G-VINNI Portal (WEB UI and REST API) https://patras5g.eu NFVO onboarding. Will be available at the level of 5G-RAN, 5G-CORE and Transport Controllers

Description: Upload/manage 3rd party VNFs/NSDs to facility NFVO (via web UI and REST API). scheduled NSD orchestration, Depending on the capabilities and if the underlying technologies allow this.

Level 3 Access: Exposed entity and access: Access to facility OSM (web and NBI SOL005)

Description: This will be available in special cases where the portal access is not enough. In most cases a separate tenant will be created (OSM SIX).

Level 4 Access: Exposed entity and access: Access to facility NFVI

Description: Use of OpenStack (Rocky) APIs and HORIZON UI. Tenant will not have administrative privileges. Allowed to install Virtual Machines (VMs) on subnets accessible by the 5G core. In certain cases will be allowed to view VNFs deployed by the OSM tenant project.

See also (https://wiki.patras5g.eu/support-and-lcm) about the Exposure Level definition.

3.1.3 Vertical onboarding at 5G-VINNI

5G VINNI and especially 5G Patras facility recognizes the challenges that involve vertical onboarding on Patras5G facility. The problem is compounded by the introduction of experimentation aspects as it involves monitoring and testing of KPIs when the network slice is in operation. As discussed in [20] the different stakeholders of 5G system co-design and co-develop different parts of the onboarding process for a successful service operation and KPI testing. The 5G VINNI white paper adapted by the Patras 5G facility discusses the challenges and the iterative procedure for this co-design, as shown in Figure 3-2. The process consists of several phases, the details of which are discussed in the whitepaper:

i. The co-design period, which involves stakeholders such as vertical customers, Patras5G facility providers and CFS/RFS developers to understand the vertical needs and how to enable them.

ii. The iterative co-development period which involves the vertical customer and the Patras5G 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. This is subject to availability of TaaS and/or MaaS in the Patras5G 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.

During this period an official Testing period can start according to the Patras5G facility. The final developed Service Specification is launched in the Patras5G facility catalogue and ready for service orders which, in turn, are instantiated.

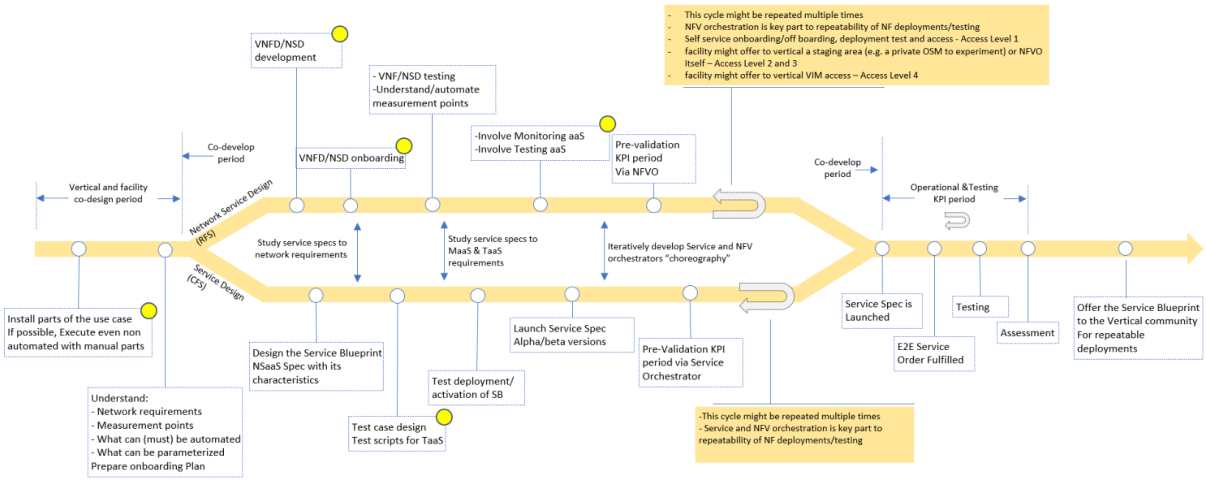

Figure 3-2 Patras5G vertical onboarding process after 5G VINNI

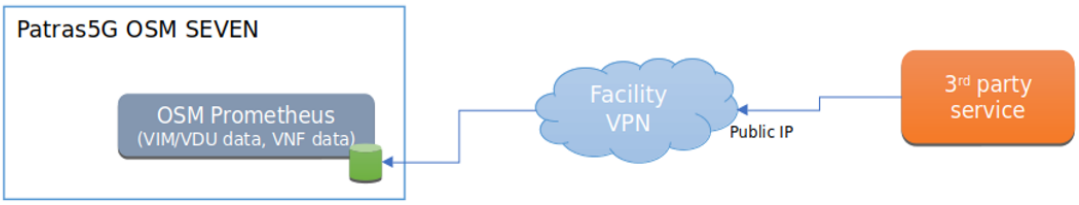

Figure 3-3 Current Monitoring Infrastructure at Patras5G

3.1.4 Testing and assessment

In the final phase, the actual testing takes place, either through automated scripts or via user interactions. It is strongly suggested to use test automation in order to ensure consistency and repeatability of the results. Testing consulting services will be provided in order to facilitate the testing and experimentation operations. The results of the testing (or the MaaS aspects) will be stored in heterogeneous data stores. Monitoring data is available to the vertical customer for any assessment.

3.1.5 Telemetry and Monitoring

The Patras5G facility in University of Patras, provides remote access to its monitoring infrastructure via a VPN to involved partners. Currently the infrastructure provides monitoring data and metrics related to the Cloud infrastructure itself and also for all the VNF health, as seen in Figure 3-3:

This architecture is being expanded to collect monitoring data directly from the VNFs and Physical Network Functions (PNFs). Another instance of Prometheus will be provisioned inside the cloud, which will establish a new channel of communication between the VNF's which will be used only for monitoring and management purposes. Over this network Prometheus will collect data from the VNFs that will contain and run an instance of NETDATA software. NETDATA will provide a REST API that will be accessible from the management network [20] [21]. NETDATA will also collect data from RAN via a custom plugin that UoP will develop. This information will be used to evaluate KPI's according to the methodology developed within 5G-VICTORI.

3.1.1 5G-VINNI Alignment with 5G-VICTORI Experimentation methodology

Within 5G-VINNI, the Patras5G facility is based mostly on open source technologies and components and it is designed and built to provide the capability for experimenters to test and demonstrate use cases that will showcase and even extend the 5G network capabilities. 5G-VINNI has developed a methodology and supporting services for vertical onboarding but even for innovative technology onboarding and experimentation that allows access at various levels of the 5G-VINNI infrastructure as this is facilitated by the VNF paradigm. To that respect the alignment of 5G-VINNI to the 5G-VICTORI methodology relies heavily on architectural and technology elements but also on the openness of the

facility to development of new services. Here the 5G-VINNI facility providers at Patras facility are working together with 5G-VICTORI verticals prior to experimentation, in order to understand requirements and design the network extensions and monitoring points. As for the development of the experiments, 5G-VINNI facility providers facilitate the service and network element exposure that is required. This iterative development and testing phase will lead to the successful operation and experimentation of new services.

3.2 5GENESIS Facility

The 5GENESIS Berlin Platform is currently building a distributed facility to support E2E experimentation over 5G networks in a controlled environment [22]. 5GENESIS has proposed a 5G experimentation blueprint to serve as a common reference implementation architecture, including an openness framework, with APIs for exposing the 5GENESIS Facility to verticals for experimentation [23].

A key aspect prior to the instantiation of the reference 5GENESIS architecture is the detailed design of the workflow needed to run the experiments in the platforms and in the global facility. The **5GENESIS experimentation methodology** [23] has been designed to facilitate the execution of a series of tests and to allow computation and validation of the KPIs. The 5GENESIS Experimentation Framework is built to offer sufficient level of openness, in terms of specification and implementation, to orchestrate the on-boarding of industry specific systems and software, and to manage third parties' interactions effectively during the experimentation life-cycle [24].

5GENESIS deliverable D5.3 [24] collects in a single, self-contained document, all necessary information, conceptual and technical, to effectively support the 5G stakeholders that wish to engage with the 5GENESIS platforms. It summarises the basic definitions and design principles of the 5GENESIS Experimentation Framework, and sets out to practically describe – in the narrative of user support documentation (manual) – the technical interactions and parameters that need to be exchanged when interacting with the 5GENESIS Facility.

3.2.1 Concepts and architecture

The 5GENESIS Berlin Platform, as other 5GENESIS platforms, follows a common reference implementation architecture, which exposes an open Application Programming Interface (API) for offering the experimenters an open and common method to interface with the Facility. The experimenters leverage this API to define and execute their experiments. Moreover, a Portal is as well available to ease the process by using a friendly Web User Interface (UI) [25].

To ensure experiment repeatability, regardless of the test equipment and the entity performing the certification, the 5GENESIS experimentation methodology is based on the profiling of experiments including specific configurations and conditions. This is referred to in 5GENESIS as test case, term that will be inherited in 5G-VICTORI. Each test case describes the experiment to be carried out and its measurable objectives, and it includes a configuration file that specifies: i) the configuration of the environment (for all RATs and network); ii) the set of procedures; iii) the monitored metrics, and iv) the formulas needed to calculate the KPIs. A test case provides uniformity and organization to run an experiment in a programmatic and structured way [23]. A testing framework has been implemented in the 5GENESIS Berlin Platform to automate the testing process, and it is based on TAP, which provides: 1) a well-defined format to specify inputs/test conditions and expected outputs, 2) an interface to plug in a scenario or experiment that is to be executed, 3) the actual test execution environment, and 4) a mechanism to report results.

The validation of 5G KPIs also involves carrying out the tests under different network conditions, operation modes, etc. A **scenario** is defined to ensure the repeatability and coverage of all relevant conditions that can impact the performance results of the experiment. The scenarios define the conditions of the experiments (signal strength, interference, UE mobility, etc.).

The 5GENESIS testing methodology takes also into account the 5G concept of the **E2E slice**. While the scenarios define the conditions of the experiment, the E2E slices define the specific resources allocated in each component of the E2E network for running an experiment.

3.2.2 5GENESIS Experimentation Workflow

Depending on the nature of the experiment, a close cooperation between the Experimenters and the platform operators may be necessary. As graphically depicted in Figure 3-4 and explained below, the following phases are considered as part of the experimentation workflow:

- Experiment Consultation Phase.
- Experiment Provisioning Phase, where the necessary adaptations into the systems to be on boarded are defined, followed to the deployment of the solution by the platform operator.
    - Experiment Execution Phase, where the following processes be defined: a) Create the experiment – fill in the test case; b) Test scenario; c) Network slice.
- Experiment Decommissioning Phase.

The workflow in Figure 3-5 shows how the different elements in the platform interact during the testing and validation of the KPIs. More information is available in the 5GENESIS deliverable D2.3 [23].

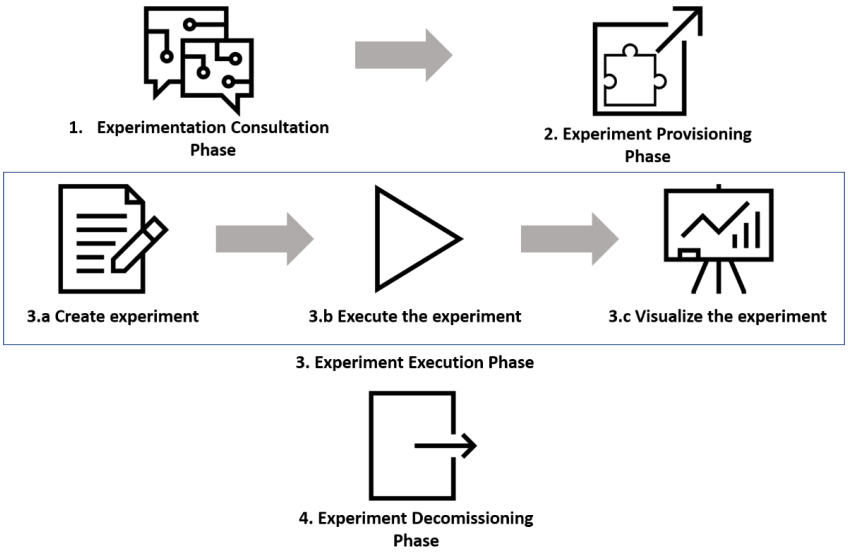

Figure 3-4 The 5GENESIS Experimentation Workflow

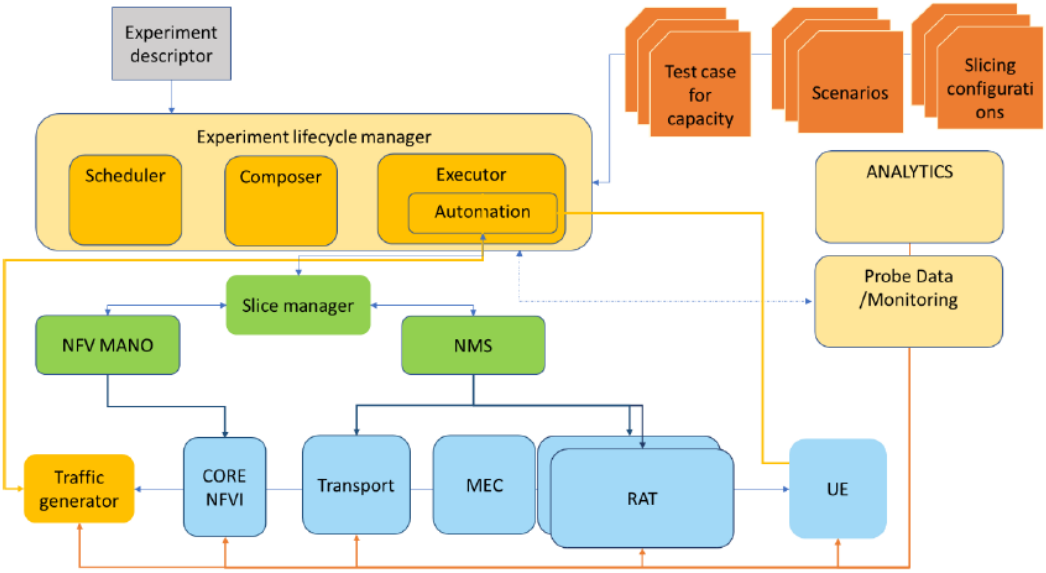

Figure 3-5 5GENESIS Experimentation workflow

3.2.3 Experimentation methodology

A test case includes information 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 information:

- 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 underlying system, and the reference protocol stack level.
- Complementary measurements. A secondary list of useful KPIs to interpret the values of the target KPI. Getting these measurements is not mandatory for the test case. However, they allow to provide additional set of results besides the target measurement, an additional and useful context data for the analysis, and an interpretation of the obtained KPIs.
- Applicability. A list of features and capabilities that are required by the system in order to guarantee the feasibility of the test.

The Berlin Platform will provide a predefined list of E2E slices covering, which will be available in the Portal for setting up an experiment:

- radio resources configuration,
- mobile core network,
- transport network, and
- resources allocated in the virtualized infrastructures offered by the platforms.

The Berlin Platform will also offer a list of scenarios that will depend on the technologies and supported releases. Each scenario includes information 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 impact 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. The two different ways of carrying out experiments are listed below:

- Experimentation via the Portal (Figure 3-6)
- Experimentation via the Open APIs (Figure 3-7)

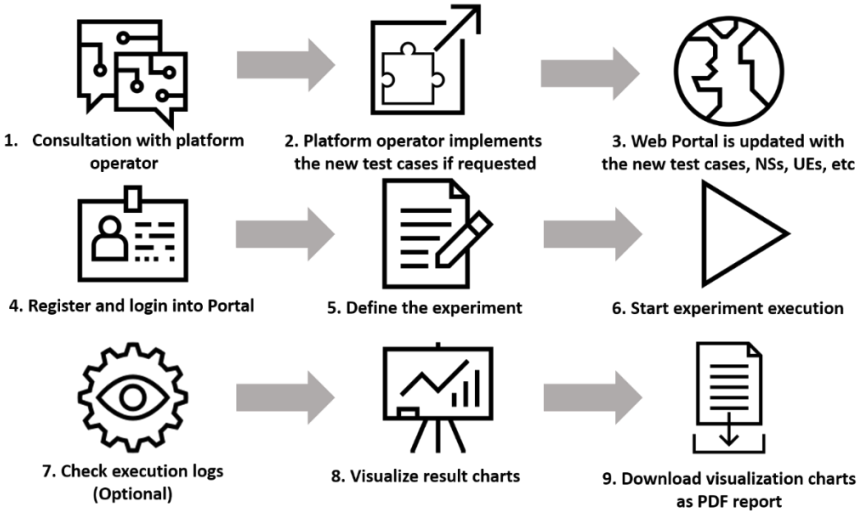

Figure 3-6 Experimentation via the Portal

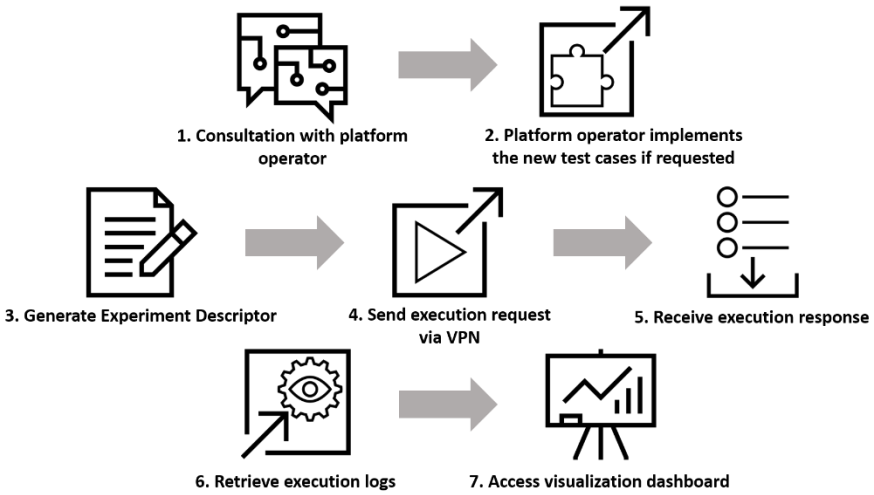

Figure 3-7 Experimentation via the Open APIs

For additional information the reader can read the 5GENESIS deliverable D5.3 [24].

3.2.4 5GENESIS Alignment with 5G-VICTORI Experimentation methodology

The existing 5GENESIS methodology for the measurement of E2E application-layer network KPIs—particularly latency and user data rate—remains relevant for any analogous vertical service KPIs in 5G-VICTORI and may only need to be refined as described in Section 2.4.3. For less directly translatable vertical service KPIs, additional measurement points will be introduced, which would require integration with the application enabling the vertical service. To conduct field trials of vertical services at the facility sites, some scenarios may require experimenter presence or interaction. These experiments would be coordinated with the site managers and would be run manually.

3.3 5G-EVE Facility

The 5G-EVE platform is the E2E European 5G validation facility consisting in the interaction of four 5G-sites from France, Spain, Italy and Greece, enabling 5G experiments for different industrial verticals, 3GPP Release 15 and later Release 16 compliant.

5G-VICTORI is supported by the 5G-EVE French cluster (Paris, Châtillon and Nice sites), referenced by the cluster high level architecture through a set of technical features [26], as the 5G-EVE French cluster is managed by Orange France (**Orange**) and supported by Eurecom (**EUR**).

The overall layered architecture is composed by the upper end-to-end service layer based on the Plug'in platform, the framework of development innovative 5G components, the 5G platform based on OpenAirInterface (OAI) and the E2E open tool orchestration component Open Network Automation Platform (ONAP), described in [26].

The 5G-EVE Orange France site in Paris (Orange Labs Châtillon) is used in 5G-VICTORI mainly for setting up VPNs (IPSec, MPLS) connections between this 5G-EVE site and the 5G-VICTORI site in Bucharest, and to enable the 5G-VICTORI services to access and use the ONAP platform running on the 5G-EVE site, for VNF orchestration and possibly other operations to be identified. ONAP is implemented within the Plug'in platform, to simplify the design, creation, orchestration, monitoring, and life cycle management of VNFs, SDN controllers and other higher-level services. The Plug'in platform relies on open source software, DevOps and CI/CD concepts, and cloud native software. It is based on a certain number of concepts such as Atom (any software component) and its derivatives, which are used for managing the lifecycle of software components. More information on the Plug'in platform and its orchestration capabilities can be found in [26].

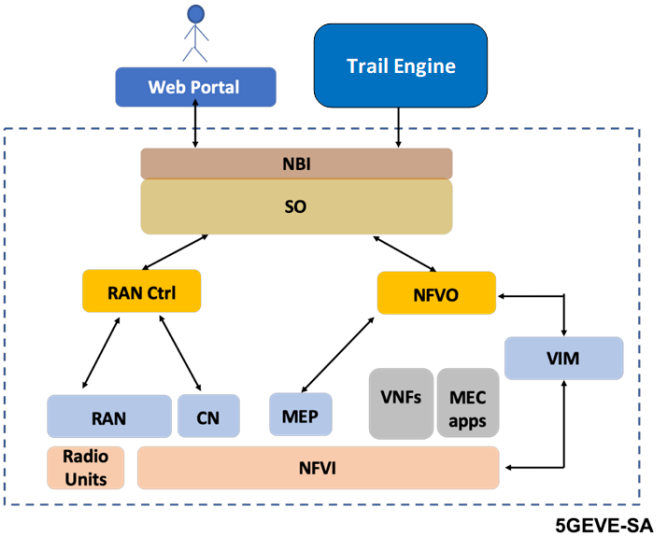

Figure 3-8 Figure 5 5GEVE-SA Architecture

Within 5G-EVE, IPSec VPN tunnels are planned between the Paris sites and three other French 5G-EVE facility sites: Eurecom site in Sophia, BCOM site in Rennes, and Nokia site in Paris/Saclay. These IPSec settings can be replicated between Paris and Bucharest, with the adequate service levels (bandwidth…) to be specified by 5G-VICTORI UCs. The Paris platform also provides an interfacing mechanism to access its ONAP orchestrator via VPNs. Orchestration services can be used to orchestrate VNFs arising from the UCs **ORO** want to run in trials in Bucharest, and with other partners in Romania. There are servers (hardware) dedicated to running the ONAP services, and two extra-servers are planned to be dedicated to 5G-VICTORI trials, but the required configuration (hardware + software) for trials need to be specified before any extension. The service capabilities dedicated to ONAP and 5G-VICTORI can be used to satisfy a certain level of performance requirements arising from UCs and trial scenarios. The Paris platform is designed to be generic and flexible enough to take into account various kinds of (programmable) service quality and performance requirements. The application (use case) can design and implement various trials scenarios, running experiments with different KPI or service qualities

3.3.1 Concepts and Architecture

The 5G-EVE platform nodes located in France operated by Orange FR and Eurecom (Paris and Nice) are extended for integration in Bucharest, operated by Orange RO and leverage mainly in OAI and Mosaic5G modules, including 5G NR, 5G CN, 4G LTE-A, 4G LTE-M, using different spectrum bands. In the first stage of implementation it will be provided a 4G EPC Core, 3GPP Release 14 compliant, with several NF implemented, as HSS, MME, S-GW and P-GW, migrating so to the 5G NSA option 3x implementation.

The 5G orchestration facility will be provided through ONAP Plug'in platform the framework to orchestrate the site facility by using the Heat templates. The 5G-EVE architecture and components are illustrated in Figure 3-8 and can be viewed in details described in 5G-EVE deliverables [27] and [28].

3.3.2 Mobile Network Infrastructure

5G RAN

As described in 5G-EVE's deliverable D2.2 [27], the RAN components are based mainly on OAI, 5GEVE-SA (Sophia-Antipolis) provides a 5G Non Stand Alone (NSA) mode; one eNodeB (4G) and one geNodeB (5G) that are deployed in the facility. RAN features that are expected to be experimented by in 5G-VICTORI Romanian cluster using Orange available licensed spectrum.

5G CN

5GEVE-SA supports only NSA 5G mode and the CN is based on 4G EPC, as described by 5G-EVE D1.3 [29]. OAI-CN implements the Control/User Plane Separation (CUPS) architecture (Release 15),

where the SPGW is separated into two entities SPGW-C (Control Plane) and SPGW-U (User Plane). The SPGW-C controls the SPGW-U via the Packet Forwarding Control Protocol (PFCP). All the components of the OAI-CN are virtualised and run in Docker containers, described by 5G-EVE D2.2 [27] Cloud-Native implementation of OAI RAN and Core is described in 5G-EVE deliverable D4.4 [30].

3.3.3 Deployment of a Trial

All the trials are deployed as a Network Slice in 5GEVE-SA. This means that the trial needs to be described in form of a Network Service Template (NST). To do so, two options are possible: through the web portal or use the SO NBI.

3.3.3.1 5G-EVE Web portal

5G-EVE-SA has its own web portal, which is different from the one used by 5G-EVE central site. The Web portal proposes to fill a form to describe a trial.

Figure 3-9 details the architecture of the Web portal, which is composed by a front-end, where the trial owner fills a form describing the scenario, and specify the KPI to be measured.

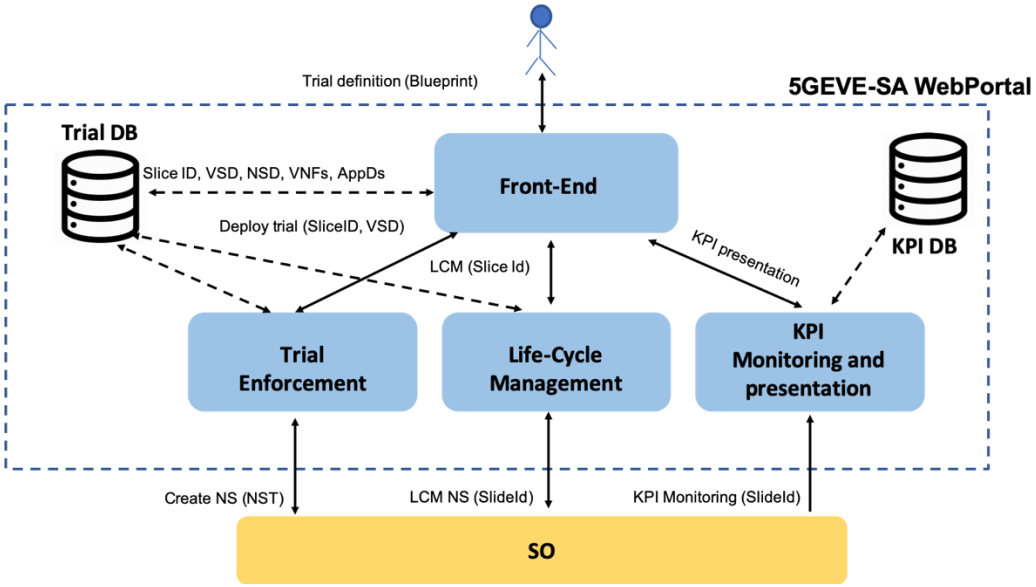

Figure 3-9 5GEVE-SA Web portal architecture

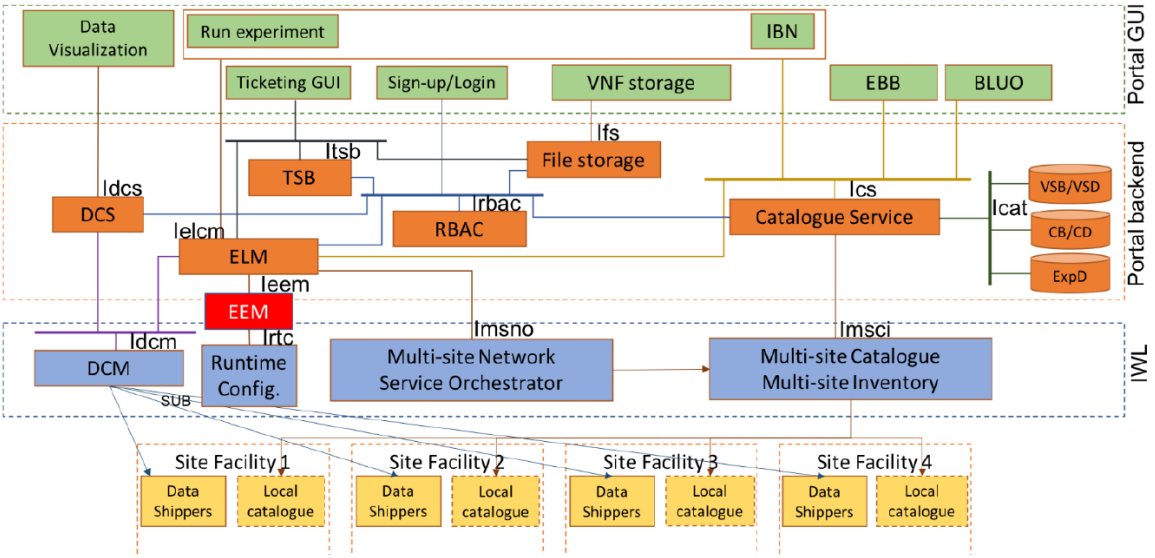

Figure 3-10 5G-EVE portal architecture

The front-end produces a Vertical Service Descriptor (VSD) that contains all the information entered by the trial owner. The VSD is stored, along with other information in a data-base, and passed to the Trial enforcement, which translates it to a NST, and via a NBI call, it is passed to the SO to request the creation of a network slice to run the trial. Other components compose the Web portal, such as Life-cycle Management, KPI monitoring and results presentation.

3.3.4 5G-EVE Experiment Workflow

5G-EVE released an experimental portal for the design process, resulting the architecture and implementation experimentation steps described in 5G-EVE deliverable D4.2 [28].

For the "official" 5G-EVE portal and corresponding workflows, there are now webinar/tutorials available with links on the main 5G-EVE website. At present SophiaTech/Eurecom infrastructure is not interconnected yet, as the ONAP integration with Orange in still on-going, and then Orange will have to do the work necessary to allow experimenters to access our site via the 5G-EVE portal, presented in details in Figure 3-10. Due to the complexity of the portals integration, the 5G-VICTORI Romanian cluster experimenters will use 5GEVE-SA portal.

The main experimentation portal components are:

- the Role-Based Access Control (RBAC), in charge of providing users management and authentication/authorization functionality,
- the Experiment Lifecycle Manager (ELM), the Portal component in charge of processing the requests to create new experiment instances offering a REST-based north-bound interface (NBI) that can be invoked by external REST clients to manage experiments,
- the Data Collection and Storage component (DCS) represented in Elastic Stack tool
- the Portal Catalogue is used to store all the blueprints and descriptors associated to the definition of a 5G EVE experiment.
- the backend northbound interface and the ELM interface
- portal Southbound Interface (SBI) responsible of the communication between the different components of the Interworking framework.
- Data Collection Manager (DCM), Runtime Configurator, Multi-site Network Service Orchestrator, Multi-site Catalogue/Inventory.
- the portal graphical user interface (GUI) layer.
- the Experiment Blueprint Builder, component of the Portal web GUI, that provides simple wizard to guide the experiment developer in the definition of an Experiment Blueprint

5G-EVE French cluster delivers a Testing-As-A-Service (TaaS) concept (see Figure 3-11) to provide an unified functional and operational infrastructure, structured in three stages, (1) Configured Stage for monitoring goals, (2) Deploy stage for list of metrics mapped to the set of probes and (3) Operate stage the dashboard providing different visualization, described in Figure 3-12.

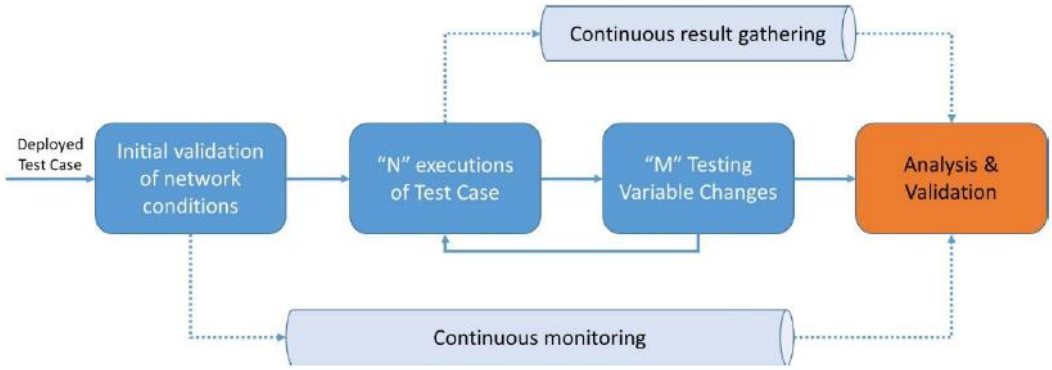

Figure 3-11 5G-EVE testing procedure

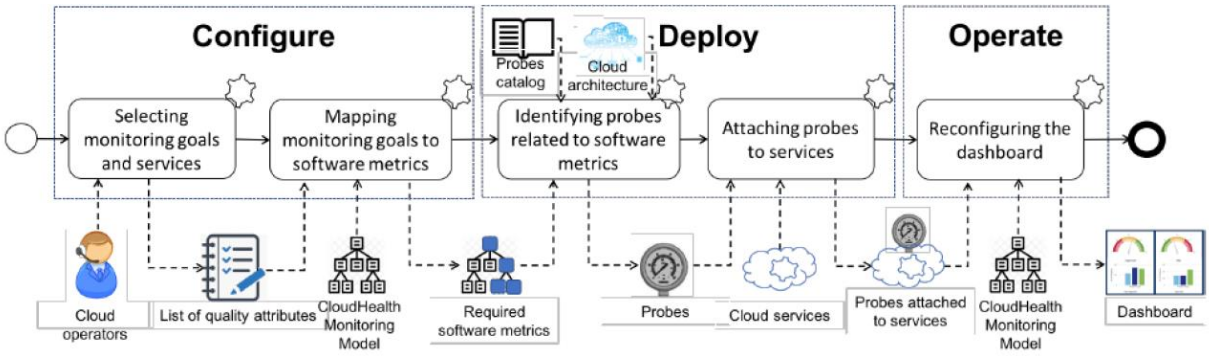

Figure 3-12 5G-EVE monitoring process framework

Figure 3-13 5G-EVE validation process workflow

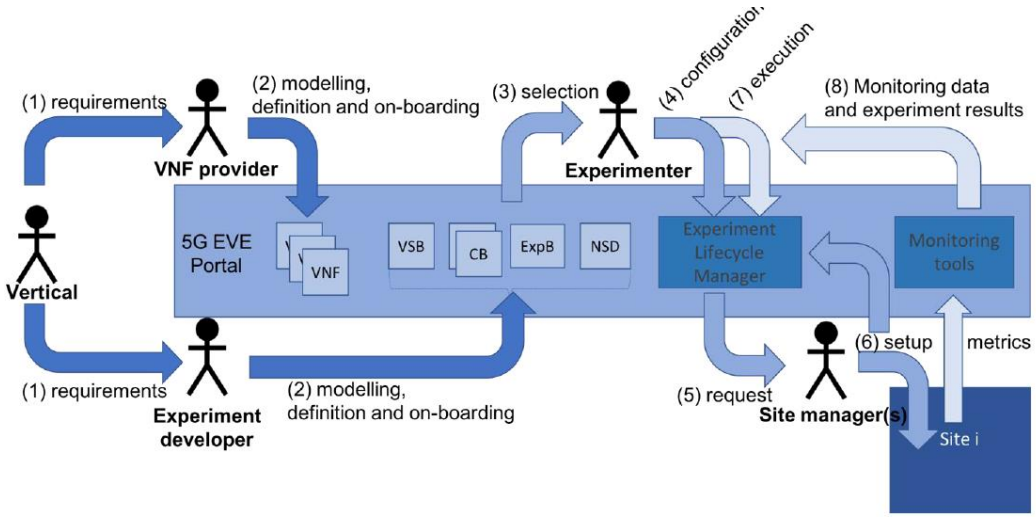

Figure 3-14 5G-EVE experimentation phases

3.3.5 5G-EVE Experimentation methodology

5G-EVE experimentation methodology for 5G testing and validation platform purpose for external experiments (5G-VICTORI UCs) is described in 5G-EVE's deliverable D5.1 [31], and consist of a process of four phases, presented in Figure 3-13. If passed, the experiment will be translated into a technical execution (network and vertical related KPIs).

5G-EVE defines vertical test plan, including the experiment template for verticals, low level test plan and the testing procedures for the UCs, the framework architecture described in 5G-EVE deliverable D5.2 [32], and it is summarized as:

- **Test Design**, permit 5G EVE Experiment Developers to understand the objectives of the different experiments, how they can be executed and what KPIs are critical for the experimenters.
- **Test Preparation**, the objective is to get everything ready to run the desired experiment
- **Test Execution and Monitoring**, once the entire infrastructure is ready, the virtual environment to run the experiment is built and configured
- **Test Performance Evaluation and Analysis:** based on the gathered results, it is checked that the values of the KPIs are consistently inside the correct performance threshold, providing a PASS or FAIL test.

The experiment design and experiment definition provides the iteration between verticals and VNFs providers, resulting a set of VNFs generated by the providers for on-boarding process on site facility (step 2 on the diagram), including also the related BluePrints and NSDs.

Further details related to 5G-EVE test and validation framework architecture are presented in 5G-EVE deliverable D5.2 [32], in deep highlighting the components involved in testing and validation.

3.3.6 5G-EVE Alignment with 5G-VICTORI Experimentation methodology

The proposed 5G-EVE methodology for E2E UCs measurements and experimentation for proposed UCs applications and related network KPIs are similar with the vertical services KPIs described in 5G-VICTORI deliverable D2.1 [1] and could be refined in section 2.4.3. The 5G-EVE experimentation methodology is based mainly on 5G-EVE-SA web portal architecture and additional activities may be introduced, as the specific applications integration will be performed and tested for further service vertical service enabling. The field trials and vertical services experimentation scenarios will be performed at the site facility premises, requiring experimenter presence and they will be run manually.

3.4 5GUK Facility

The purpose of the 5GUK test network is to demonstrate various telecommunication services required by the Bristol Cluster- Digital Mobility UC and its comprising applications, namely: App1 (Immersive media services), App2 (VR Live streaming application) and App3 (Future Mobility application). The proposed demonstration and experimentation are currently planned to take place at various locations within Bristol city centre. In the case of applications App1 and App3, users will follow a route that will allow their devices to utilise various Radio Access Technologies (RATs) while moving around either on foot or on a boat. The demonstration consists of four key locations:

1. SS G. Britain Steam Ship Museum (outside the museum area),
2. MShed Museum (outside and if needed inside the Museum),
3. Millennium Square (M.Sq.) & We The Curious (WTC) (outside area), and
4. Merchant Venturers Building (MVB) (Smart Internet Lab, inside area).

The 5GUK test network (**UNIVBRIS**) will be used to carry out the tests under various network and resource configurations to measure the metrics and evaluate the KPIs specified in the test cases. A detailed description of the test cases will be provided in **WP3** deliverables. Additionally, the performance results of the experiments, referred to as “Performance Profiles”, shall be stored utilising the Elasticsearch, Logstash, and Kibana (the Elastic stack) data repository. Based on SLA policies and business models, the “Performance profiles” can be partially or completely exposed to the experimenters and the various stakeholders described in Section 2.2.

3.4.1 Concepts and Architecture

The APs at MShed Museum, M.Sq. and MVB are supported by MEC facilities which are connected together via fibre and a millimetre wave (mmWave) mesh network. Connectivity to the MVB cloud network is realized with multiple dark fibre links. The services will be provided to 5G-VICTORI-Digital Mobility users through 5GNR (band n78), 4G LTE/A (bands 7/38) and/or Wi-Fi (IEEE 802.11ac) connectivity.

A wireless access Nomadic Node will be deployed on a boat during a boat-ride demonstration in order to fulfil the requirements of the 5G-VICTORI Digital Mobility UC. The 5G Nomadic Node will provide the required mobility services and seamless 5G connectivity within the surrounding area of SS Great Britain and at other locations where the 5G UK test network’s coverage is not sufficient to meet the UC requirements. MEC services will be provided through the compute resources available at the M.Sq, WTC and MShed network edges. Additional compute resources will be also deployed on board the Nomadic node.

The main services offered by the Bristol facility to run the test-cases in order to deploy Digital Mobility UC and validate the KPIs are outlined below:

- Access – Urban Environment:

A network of Access Points extends between hosted locations (mentioned above) within Bristol city centre including 5GNR, Wi-Fi, LTE, and other access technologies can also be integrated at available locations on project demands upon feasibility studies.

- Compute resources:

The cloud infrastructure allows for the deployment of VMs on virtualisation platforms which are hosted on Bare-metal / Dedicated Servers distributed across the network to guarantee access with high throughput and minimum latency. The Core servers are equipped with high performance CPU/GPU resources which support the **UHA** and **MATI** applications' extreme processing demand e.g. AR or VR applications.

- Equipment Hosting

BYOD (Bring Your Own Device) model allows for other Bristol cluster partners to integrate their own equipment in the test network, e.g. hosting partner's 5GNR or Wi-Fi access technologies as part of the main infrastructure or nomadic node.

- Connectivity across the network

The private fibre deployment meets the connectivity requirements of the experiment across different sites. Typical available options are dark fibre, L2 switched connectivity and mmWave full meshed backhaul.

- Remote access to deployed experiment

The test network provides dedicated VPN access for remote management and operation of deployed experiments including:

  - 5G-VIOS platform developed in collaboration with rest of the partners to offer multi-edge/domain service orchestration and management.
  - 5G-VIOS Edge Proxy, Orchestrator, Virtualised Infrastructure Management (VIM), and WAN Infrastructure Manager (WIM) at the Edges such as (OSM, OpenStack, Zeetta Automate (previously known as NetOS) and ONOS).

- End-user devices:

  5G enabled phones (Samsung) to support larger scale trials. SIM cards would be provided by DCAT/UNIVBRIS and will be registered with the Amarisoft and UNIVBRIS 5G core networks.

- Nomadic Node:

  The Nomadic Node will provide the required mobility services on a boat, supporting seamless 5GNR/LTE (NSA) and Wi-Fi connectivity at the surrounding area of the SS Great Britain, and at locations where the 5GUK test network's coverage is not sufficient for the requirements of the UCs.

The Nomadic Node will consist of backhaul connectivity, edge computing and access network resources as shown in **Figure 3-15**.

The architecture for the backhaul and fronthaul (X-haul) includes network resources such as the 4G/5G CPE Modems that provide the backhaul network connectivity through secure VPN tunnels for both data and control plane purposes. Layer-2 (L2) switches can also provide multiple E2E slices within the nomadic node.

The compute resources will host a virtualisation platform for both Application and MEC services. These services will be managed by 5G-VIOS. An orchestration brokering platform that enables management of slices, resources and orchestration of E2E network services deployed across the multiple 5GUK test network edges. The MANO node will host the 5G-VIOS Edge Proxy, Edge Mano, and other VNFs. The Edge Proxy will act as the anchor point for the secured inter-connection between this nomadic node (as an edge) and the 5G-VIOS via a secure Gateway. Other VNFs comprise a DHCP server to provide IP addresses to the UEs, DNS to resolve App hostnames, vEPCs in case they are needed and an Edge Monitoring which gathers RAN and App metrics. These could be federated to an external monitoring server.

The RAN resources will provide multiple RATs such as 4G/5G and Wi-Fi for the UEs detailed as follows.

- Amarisoft Callbox ; 5G-NSA network-in-a-box with low power output which will be provided by **DCAT** on spectrum that UNIVBRIS will provide. This would offer coverage in areas where currently UNIVBRIS test network does not provide. *The platform includes a EPC/5G Core, although it also can be connected to external cores.* Amarisoft Callbox (Figure 3-16 a)) is the solution for testing 5G NSA and SA, LTE, LTE-M and NB-IoT devices as all in a box. The box contains gNB, eNB, MME , SGW and PGW, i.e. 4G and 5G-NR NSA version compliant with 3GPP. The Callbox is powered by a deployment quality software suite and It works as an SDR that supports all LTE and 5G bands up to 3.6 GHz frequency bands.
- Wi-Fi: APs with 802.11ac capabilities (DL up to 400 Mbps, 80 MHz) based on a custom virtualization solution. Each SBC will be packaged in an outdoor enclosure with external omnidirectional antennas (Figure 3-16 b)).

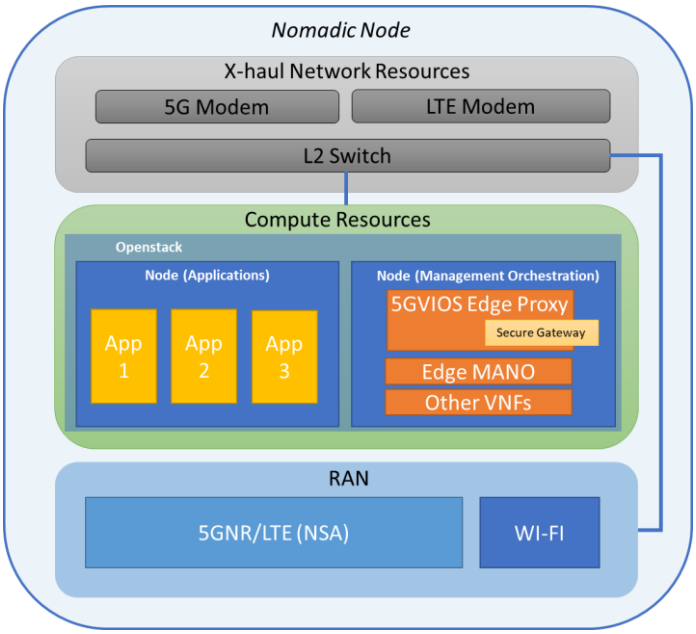

Figure 3-15 5G Nomadic Node Architecture

Figure 3-16 a) Amarisoft Callbox, b) Wi-Fi AP

3.4.1.1 Monitoring and Measurement Tools

University of Bristol's Smart Internet Lab Test Network has developed the following monitoring and measuring tool to evaluate selected KPIs. The tools are designed to measure the objective network performance experience by end-users between UE (on various air interfaces, such as Wi-Fi, LTE, 5G) and remote hosting locations. The network command and control centre tool collects data such as

Latency - the roundtrip delay taken for E2E communication; Jitters - the variation in the latency between two points; Throughput - the rate in which data can be delivered between the two points; Bandwidth and GPS location. The dataset can be fed to a Machine Learning (ML) system that draws inferences on which ancillary datapoints may be linked to KPI achievements. Measuring parameters from the device may include Link speed, Network ID, SSID, Frequency channel for Wi-Fi test and Device IMEI, Operator name and RSRP for LTE and 5G.

Figure 3-17 illustrates E2E network measurement from device position to compute location. Figure 3-18 shows results and outputs for collected measurements based on various network parameters.

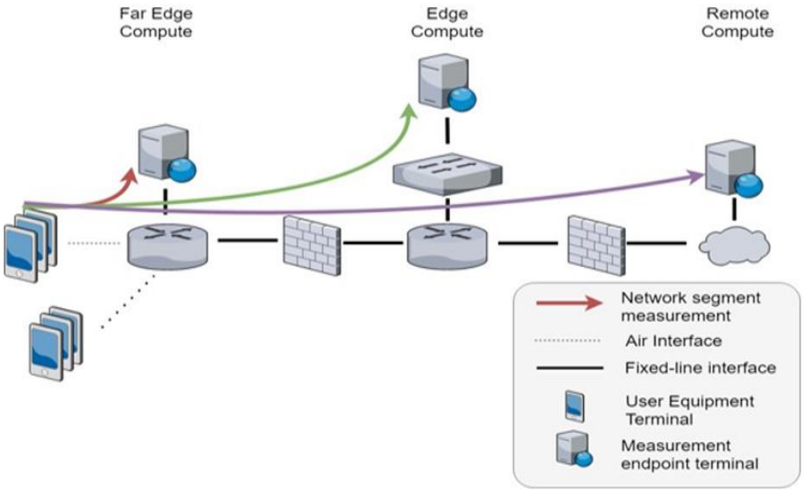

Figure 3-17 Network Architecture for E2E measurement elements

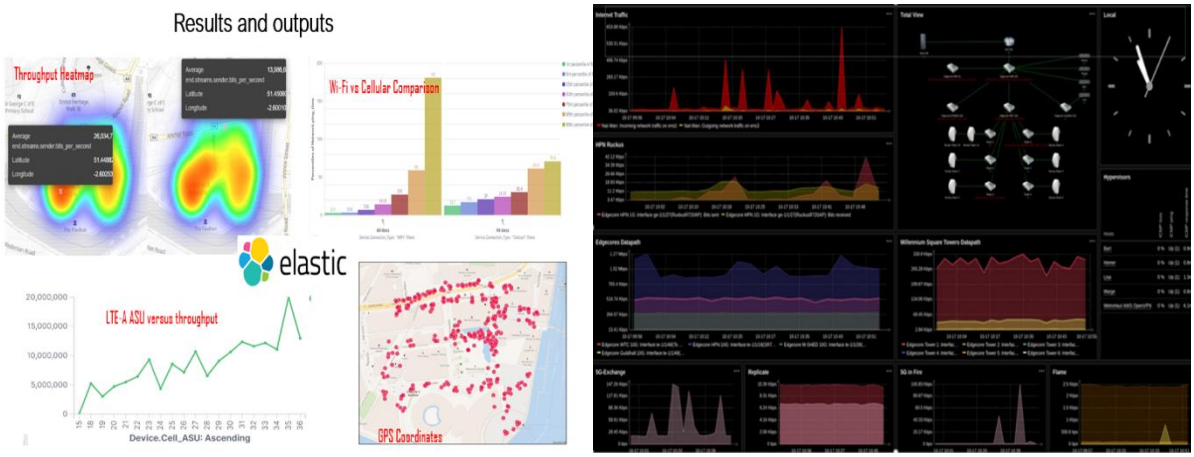

Figure 3-18 Visualising the various measurement results

Figure 3-19 Visualization of Wi-Fi metrics using Prometheus and Grafana

I2CAT's Wi-Fi Access Networks is monitored using Prometheus[7], an open-source monitoring system based on key-value time series. We have implemented a specific Prometheus exporter for our custom Wi-Fi Access Points, called Hostapd Exporter, which is available in the public list of exporters and integrations of Prometheus (Apache-2 license)[8]. This exporter gets wireless metrics from the APs, converts them to Prometheus gauges or counters, and exposes them in an HTTP endpoint. Exported metrics include global statistics of the APs (e.g. number of users) but also individual statistics of the connected users (e.g. link rates, airtime consumption, tx/rx bytes, signal power, etc.), which can be aggregated by using Prometheus built-in operators and labels. This way, we can monitor, for instance, the aggregated throughput of all users of a slice in a specific AP or in all the deployed APs of the infrastructure. Prometheus implements and HTTP API enabling a simple integration with visualization tools like Grafana[9], but also with custom applications or APIs. Figure 3-19 shows an example of a Grafana Dashboard while monitoring some Wi-Fi APs.

3.4.1.2 5G-VIOS within the 5GUK Facility

The 5GUK facility will utilise 5G-VIOS to onboard the Digital Mobility UC applications and run the corresponding experiments. Through the 5G-VIOS web-portal (GUI), the main edges, as well as the experimental users shall register to the 5G-VIOS. (Ref: D2.5 [4]). The applications' (App1, App1 and App3) inter-edge network services (iNS) and VNFs will be on boarded into 5G-VIOS and subsequently be utilised by the experimenters to define and execute their experiments. Additional APIs to interact with the applications (for instance in the case of the mobility of the users and the need to migrate specific network services from one edge to the other) and infrastructure for monitoring and visualising the performance profiles will be defined. These APIs will be utilised to monitor, report and analyse the experiments' life cycle and outcomes (i.e. pass/fail). Section 4 provides a detailed description of the experimentation methodology.

[7] https://prometheus.io/

[8] https://prometheus.io/docs/instrumenting/exporters/

[9] https://grafana.com/

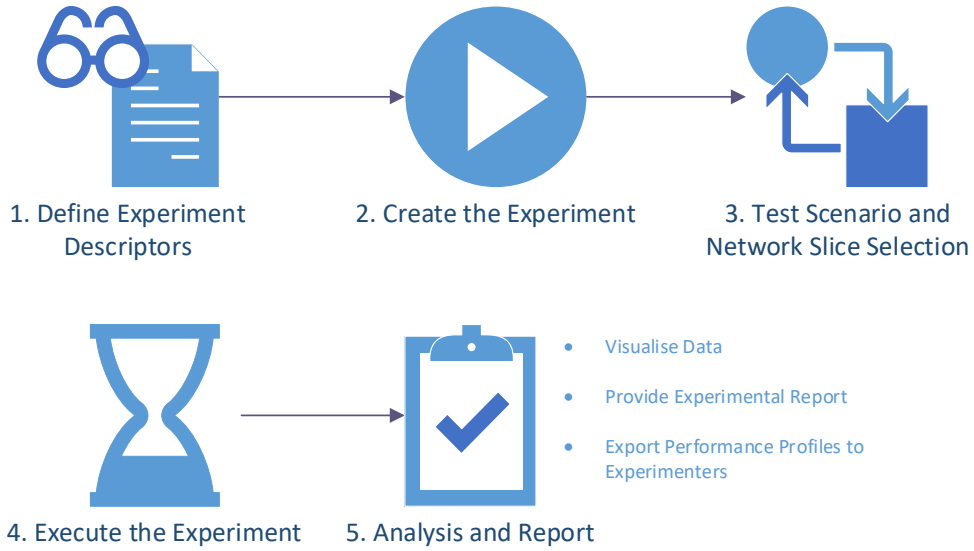

Figure 3-20 Experimentation Workflow at 5GUK facility

3.4.2 Experimentation Workflow

Five main steps were identified before successfully completing the experimentation of a test-case, as shown in Figure 3-20. The methodology in each step will be explained in detail on the following chapter as 5G-UK adopts 5G-VIOS and directly complies with its workflow implementation.

3.5 Overview of Alignment of ICT-17 & 5GUK facility procedures in 5G-VICTORI

The 5G-VICTORI experiment workflow consists of five key steps utilizing the 5G-VIOS platform as will be described in next section:

1. Define Experiment Descriptors.
2. Create Experiment.
3. Test Scenario & Network Slice Selection.
4. Execute the Experiment (incl. monitoring metrics).
5. Analysis and Report (incl. collecting analysed metrics and measured KPIs, creation of the “Performance Profiles” by the Profiling component and recording).

These would need to be aligned for each of the platforms. Specifically, for the 5G-UK platform, the alignment is closer since parts of 5G-VIOS stem from the 5GUK Exchange project with some component modifications. In addition, some new components will be added to the 5G-VIOS to fulfil the experiment workflow requirements mentioned above. Please refer to deliverable D2.5 for the whole list of new/modified components. The infrastructure and resources of 5GUK platform would be directly connected to 5G-VIOS without the need of an additional API as an intermediate testing workflow interface following the same experimentation procedure.

With respect to ICT-17 platforms, Table 3-1 summarizes the information and actions 5G-VICTORI needs to consider in order to align all different methodologies when supporting cross facility/cross vertical experimentation.

Table 3-1 Experimentation Workflow

5G-VICTORI experiment workflow (materialised in 5G-VIOS framework)	5G- VINNI	5GENESIS	5G-EVE	5G-UK
Define Experiment Descriptors	**The co-design period** **The iterative co-development period**	**Experiment Consultation Phase**	**Test Design phase**	5G-UK will directly align processes with the 5G-VIOS ones, as its resources will be directly registered/connected to 5G-VIOS without an additional API as an intermediate testing workflow interface.
1. Create Experiment **2. Test Scenario & Network Slice Selection**	**Service Specification period** (launched in the Patras5G facility catalogue and ready for service orders, which in turn are instantiated.)	**Experiment Provisioning Phase** (the necessary adaptations into the systems to be on boarded are defined, followed to the deployment of the solution by the platform operator.)	**Test Preparation Phase** (objective: to get everything ready to run the desired experiment).	
3. Execute the Experiment (incl. monitoring metrics)	**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. (Telemetry & monitoring are involved at this stage) The results of the testing (or the MaaS aspects) will be stored in heterogeneous data stores. Monitoring data is available to the vertical customer	**Experiment Execution Phase**, where the following processes be defined: ○ Create the experiment (blueprint) – fill in the test case. ○ Create the Test scenario ○ Create the Network slice ○ Collection of telemetry & monitoring data **Experiment Decommissioning Phase**	**Test Execution and Monitoring Phase:** once the entire infrastructure is ready, the virtual environment to run the experiment is built and configured. A: Through the portal B: Through direct execution of Testing/ Scenarios workflow. **Monitoring Workflow** (Separate, parallel to Experimentation flow): (1) Configured Stage for monitoring goals, (2) Deploy stage for list of metrics mapped to the set of probes.	
Analysis and Report (incl. collecting analysed metrics and measured KPIs, creation of the "Performance Profiles" (by the Profiling component) and recording).	**Evaluation of results**	**Evaluation of Results**	**Test Performance Evaluation and Analysis:** checking that the values of the KPIs are consistently inside the correct performance threshold, providing a PASS or FAIL test. **Monitoring Workflow:** (3) Operate stage with the dashboard providing different visualization.	

…

4 Common Experimentation Methodology Implementation in 5G-VIOS

4.1 Role of 5G-VIOS in the trials

As aforementioned, a common methodology will be adopted by each facility to 5G-VICTORI experimentation procedures. 5G-VICTORI aims to further align these procedures not only at methodological level but also at technical level (where possible) and it will provide an overlay platform to interact with the platforms' APIs and to use these workflows (implemented by various technologies) in a homogeneous manner. The 5G-VIOS Platform will facilitate the interaction with the ICT-17 platforms and/or ICT-17 facilities, especially during the cross-facilities/cross-vertical scenarios.

5G-VIOS is the orchestration brokering platform that enables management of slices, resources and orchestration of E2E vertical network service deployed across the across the multiple 5G-VICTORI domains, sites and facilities. 5G-VIOS will provide network service deployment across different sites, dynamic L2 or layer-3 (L3) cross-site service interconnections, inter-site service composing and on-boarding, E2E slice monitoring and management for the deployed E2E services. 5G-VIOS provides the verticals (Energy, Transportation, Media and Smart Factories) with a common entry point into the 5G-VICTORI system analogous to the ETSI NFV Single Logical Point of Contact (SLPOC[10]). The vertical services are implemented and onboarded to the respective extended ICT-17 facilities and then these vertical services are accessible through the 5G-VIOS GUI.

4.2 5G-VIOS Operations to be triggered or brokered

The role of 5G-VIOS is to trigger for the 5GUK or trigger/ broker for interconnected platforms the actions/procedures described in sections 3.5 and 4.1 in order to fulfill the requirements of a vertical cross-facility service request; specifically Service Instantiation, Service Termination, Service Monitoring and Profiling, On-boarding Vertical Applications and Service Migration. The figures below show an example assuming that services require access to the NFVO of each 5G testing facility.

[10] A Single Logical Point of Contact (SLPOC) to an administrative domain is used for service requests. In this case the MANO systems with an administrative domain are hidden from the verticals and unified interfaces are exposed by the SLPOC and offered to the verticals.

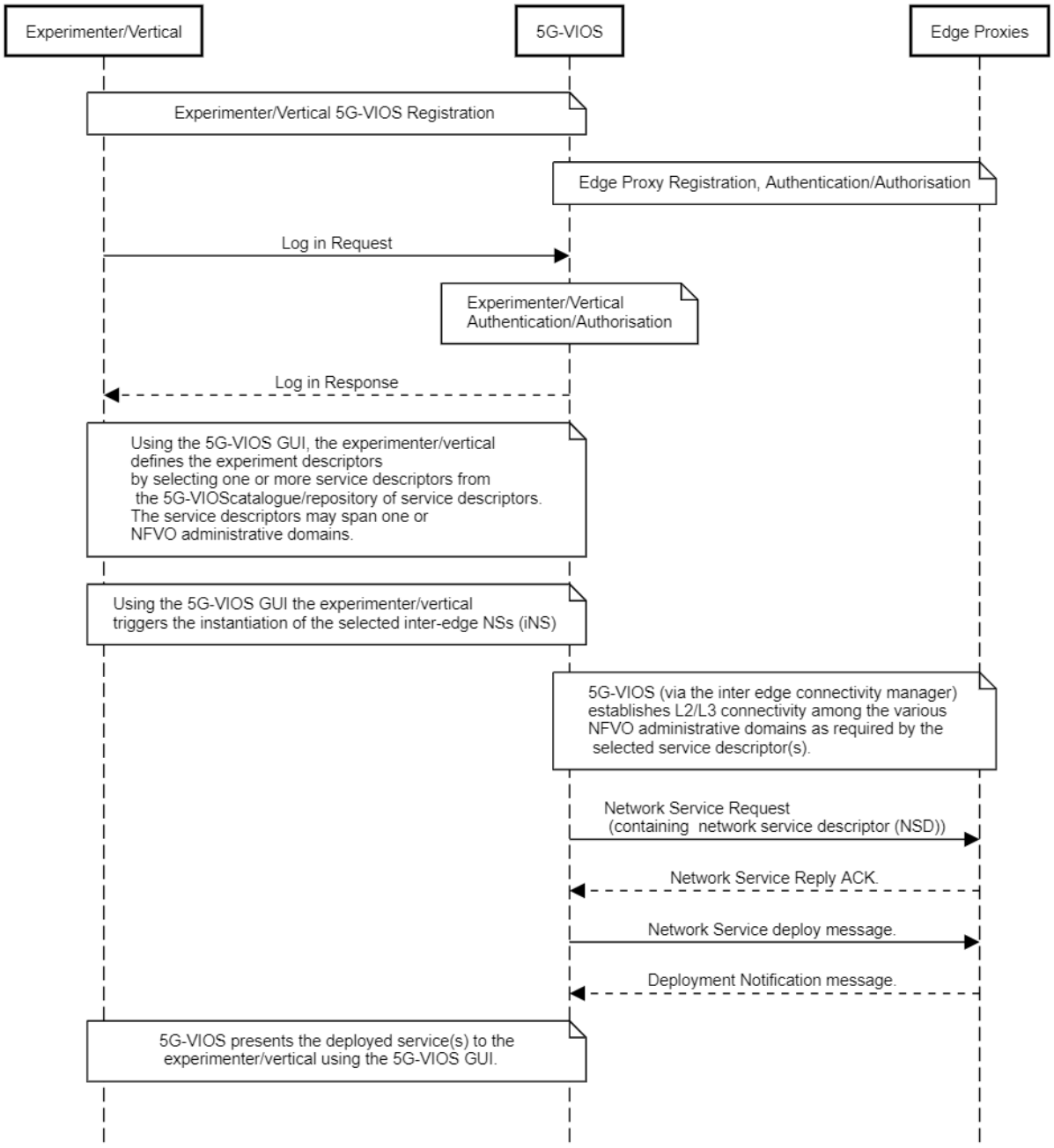

Figure 4-1 Service Instantiation

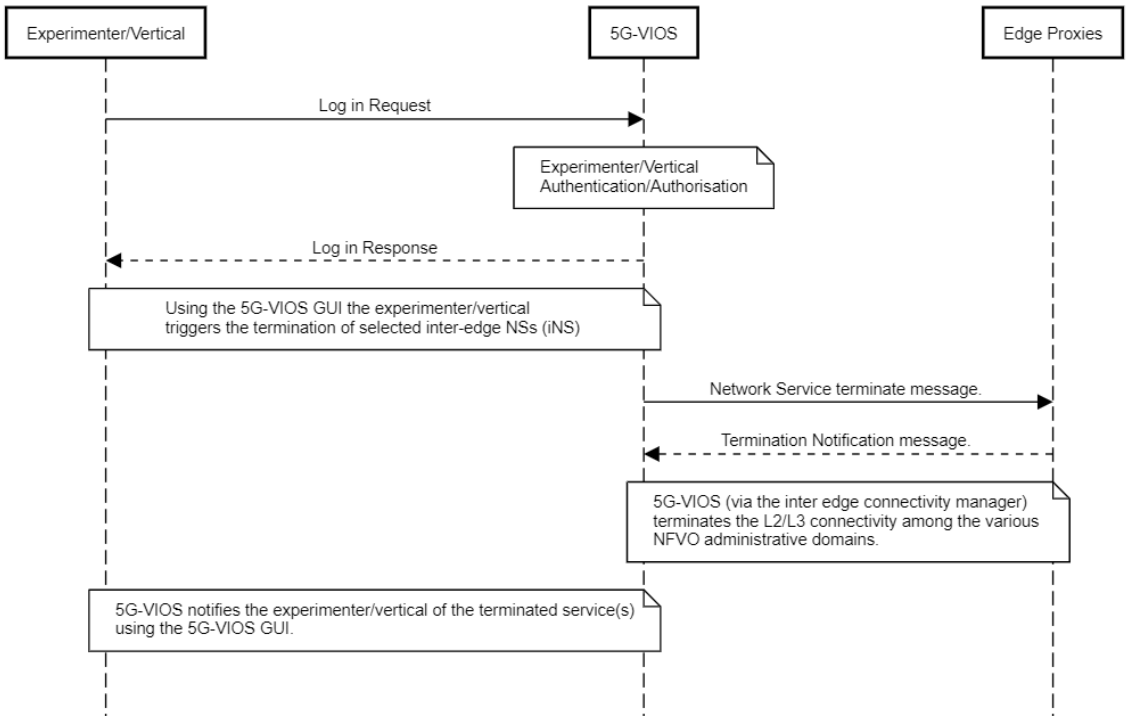

Figure 4-2 Service Termination

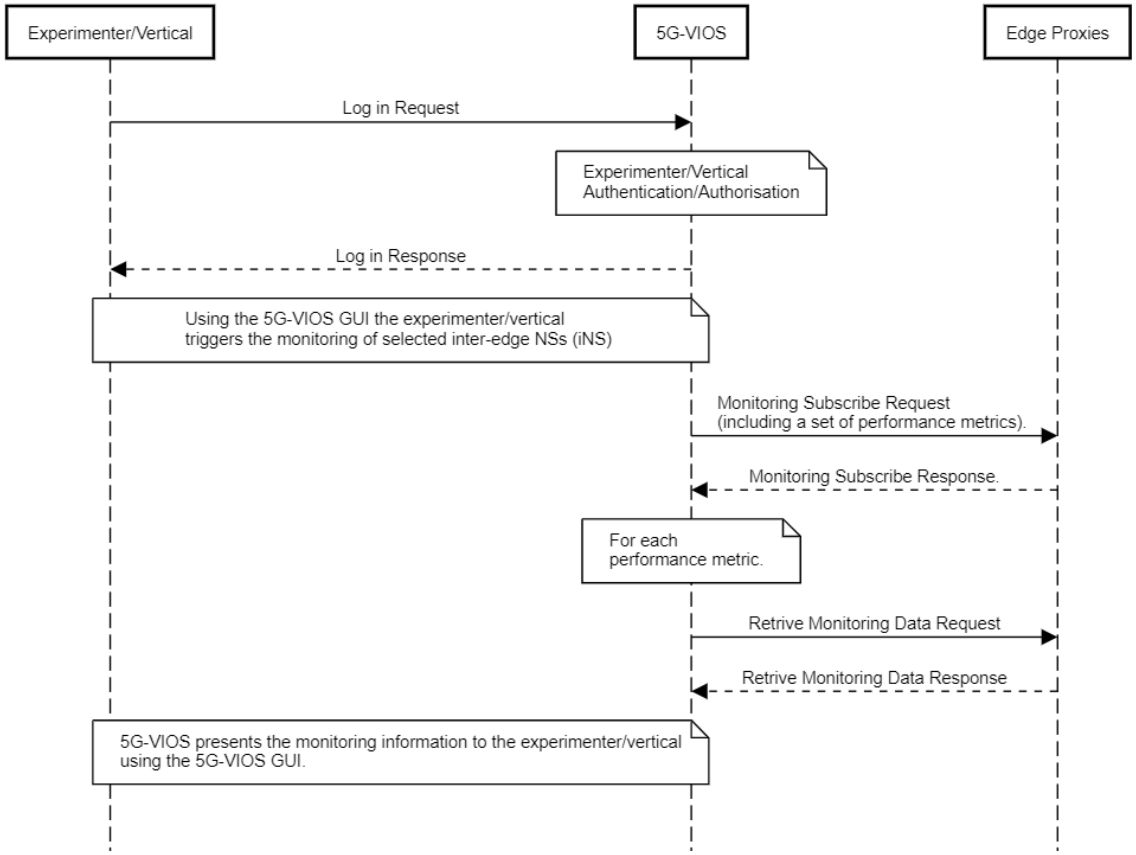

Figure 4-3 Service Monitoring and Profiling

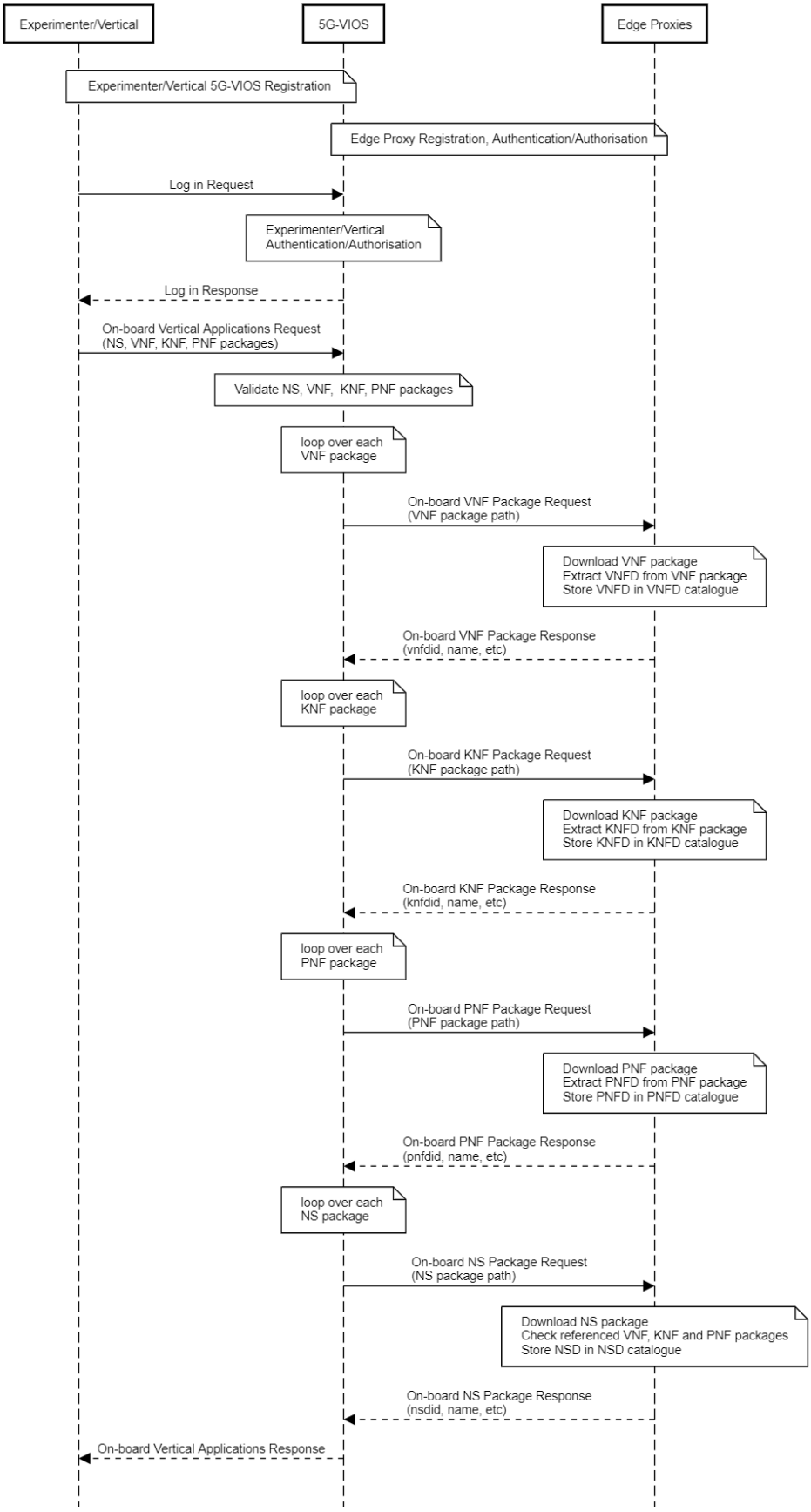

Figure 4-4 On-boarding Vertical applications

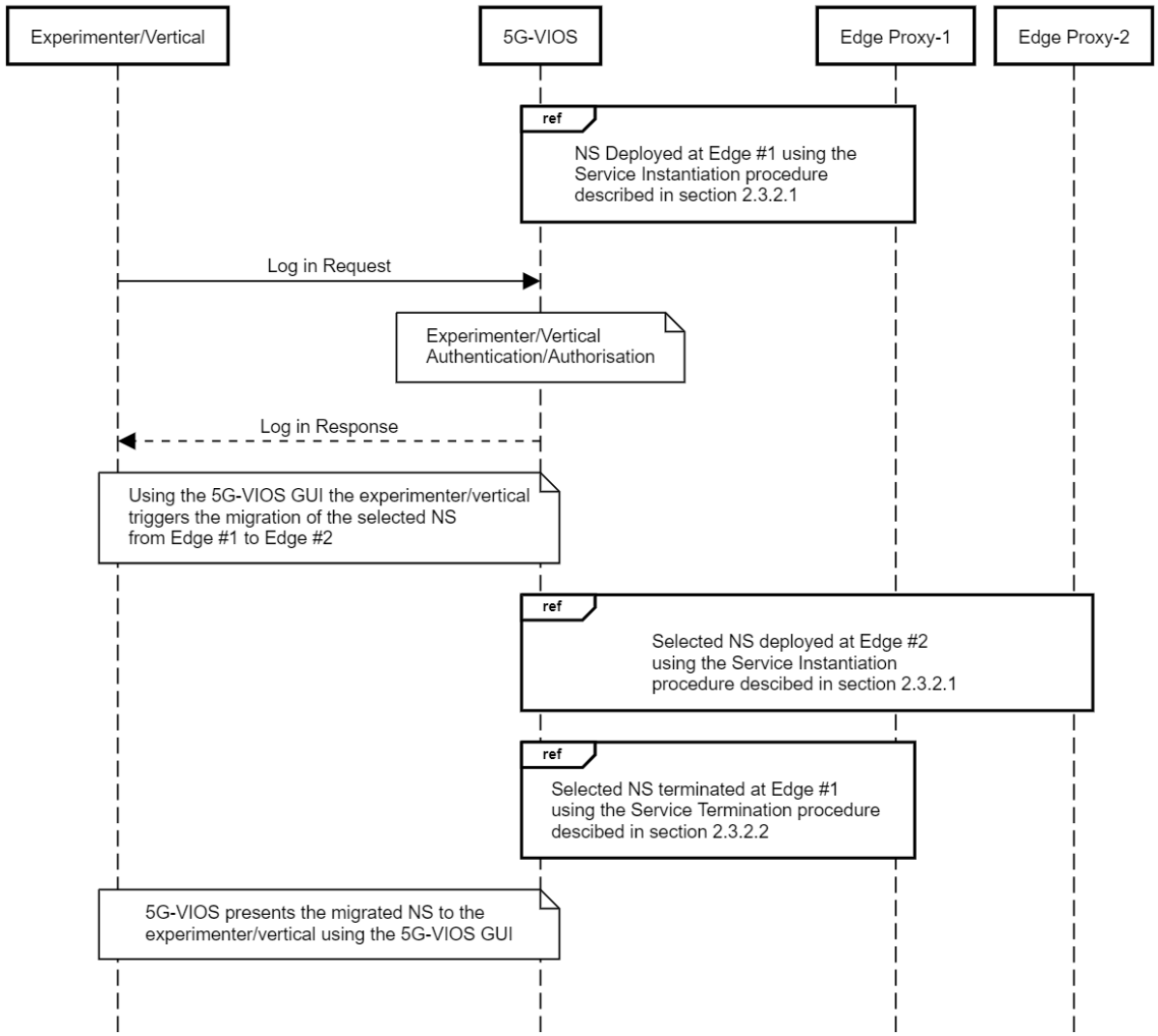

Figure 4-5 Service Migration

5 Conclusions

This deliverable outlines the methodology and guidelines for running the field trials in 5G-VICTORI. The preparation and execution of these trials is the future work of the parallel facility-specific WP4 tasks: T4.1, T4.2, T4.3, and T4.4. The cross-facility integration of 5G-VIOS, the orchestration brokering platform described in this deliverable, will be the work in T4.5, which kicks-off approximately at the time of submission of this deliverable. The framework put forward in this deliverable was drafted in coordination with parallel WP3 activities –specifically T3.1, T3.2, and T3.3– in order to align the test cases necessary for the UCs with the experimentation methodology employed at the 5G-VICTORI facilities.

This document represents the first release of **WP4** and will be a reference document for the definition of the test cases related to the vertical services in **WP3**, which will employ the 5G-VICTORI architecture and allow demonstration of 5G-VICTORI functionalities as part of the upcoming work in WP4.

The 5G-VICTORI common methodology and the guidelines to be followed by each facility site for preparing and executing the facility and cross-facilities field trials are presented in this document. All four facilities have very similar testing procedures/workflows that facilitate the interactions between the verticals and the facilities. 5G-VIOS will provide an additional level of orchestration framework on top of the facilities individual orchestrators, which allows either brokering of experimentation procedures to the facilities or even direct orchestration of them.

In alignment with the concepts and work performed in the 5G-PPP TMV WG, the priority of which is to provide methodologies and Test Cases for the validation of the E2E services delivered to the verticals, the 5G-VICTORI experimentation methodology revolves around the common definition, and alignment in terms of procedures/ operations workflows to be followed by all 5G-VICTORI facilities, and around the profiling of experiments including specific configurations and conditions. As identified, all four facilities have very similar testing procedures/workflows that are supported by their specific (diverse) technologies. In order to facilitate the accommodation and testing of 5G-VICTORI vertical UCs across the different ICT-17 platforms and to enable productive interactions between the verticals and the facilities, the 5G-VICTORI field trials methodology focuses on the following aspects:

- Formalization of concepts and adoption of a common language between stakeholders and facilities.
- Classification of stakeholders.
- Procedures/ Operations to be performed before, after and at the time of execution of field trials.
- Identification of measurements/metrics to be retrieved, mapping/relating those to vertical UC KPIs and evaluation of results.
- Testing/ Experimentation unit's definition/description (in a common way), adhering to the previous aspects.
- Cross-facility experimentation capabilities (through 5G-VIOS).

The 5G-VICTORI high-level methodology comprises the following three main stages related to the procedures to be implemented across facilities:

1. Experimentation Design, including the procedural steps starting from the definition of UCs to the network infrastructure deployment, and to the high-level definition of the experiments.
2. Experimentation Development, constituting the workflow of following three steps:
   a) Definition of Experiment Descriptors, including the roles involved in the trial, specific end-user / service / network functionalities, and test cases, in the form of specific templates common for all UCs and all facilities, the Scenarios and Network Slice(s).
   b) Creation of Experiment, by translating the Experiment Descriptors to specific test scripts, in ways understandable for each facility (their specific User / Experimentation interfaces).
   c) Test Scenario & Network Slice Selection.

3. Operations / Experimentation Execution, which focuses on the:
    a) Execution of Experiment, as detailed in the Descriptors, by performing human and / or facility interactions / operations including the collection of measurements and monitoring of metrics.
    b) Analysis and Reporting, at which point the results are exposed to the experimenters or authorised users through Analytics and Performance tools.

At this third stage, the performance evaluation of 5G-VICTORI UCs will be performed on the basis of key vertical services/applications KPIs, besides the network and network services KPIs for each deployment. Part of 5G-VICTORI WP3 work is dedicated to the definition and evaluation of vertical services/applications KPIs. Methodologically, for the evaluation of the vertical services/applications KPIs a mapping/combination between Network and Vertical Services KPIs will be performed, and network and network services KPIs will be refined accordingly, following and also contributing to the work performed currently in 5G-PPP TF of the TMV WG.

The 5G-VICTORI experimentation methodology goes one step further to the capability of the facilities to utilize service blueprints developed at platform level or even facilitate co-design and co-development of experiments over the interconnected facilities. Regarding the cross facility / cross vertical experimentation, methodology it is assumed that several service blueprints will be developed within each facility and all such services will be exposed to the 5G-VICTORI ecosystem as ready to be scheduled through 5G-VIOS.

Technology and architecture validation in 5G-VICTORI will be carried out considering the most critical parameters of each vertical sector under real life conditions. The vertical-specific KPIs will be validated against specific performance targets, through well-defined experimentation procedures, so that results retrieved are: specific, meaningful, reproducible, and achievable in similar contexts.

For the architecture validation we not only consider the stringent requirements of the vertical applications but also the introduction of new business models. This validation will therefore take in WP4 both a technology and a business perspective.

From the technical point of view, 5G-VIOS is the orchestration brokering platform that communicates with the individual facilities orchestrators (e.g. 5G-VINNI's Openslice) or/and directly with the facilities resources (as in the case of 5GUK) and enables the execution of workflows related to management of slices, resources and orchestration of E2E vertical network service deployed across the across the multiple 5G-VICTORI domains, sites and facilities. 5G-VIOS will provide network service deployment across different sites, dynamic layer-2 (L2) or layer-3 (L3) cross-site service interconnections, inter-site service composing and on-boarding, E2E slice monitoring and management for the deployed E2E services. 5G-VIOS provides the verticals (Energy, Transportation, Media and Smart Factories) with a common entry point into the 5G-VICTORI system analogous to the ETSI NFV SLPOC. The vertical services are accessible through the 5G-VIOS GUI that allows end-users to interact with the 5G-VICTORI facilities, infrastructure and services.

The methodological approaches described in this deliverable will steer the technology integration, validation and field trial activities of **WP4** and provide guidelines for the vertical experimentation and evaluation activities to be performed in the context of **WP3**.

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7 Acronyms

Acronym	Description
5G NSA	5G Non Stand Alone
5G-VIOS	5G-VICTORI Operation System
API	Application Programming Interface
BYOD	Bring Your Own Device
CN	Core Network
CNF	Containerised Network Function
CPU	Central Processing Unit
CSP	Communication Service Provider
CUPS	Control/User Plane Separation
DCM	Data Collection Manager
DCS	Data Collection and Storage component
DUT	Device Under Test
E2E	End-to-End
ELM	Experiment Lifecycle Manager
ELK	Elasticsearch, Logstash, Kibana
eMBB	Enhanced Mobile Broadband
ETSI	European Telecommunications Standards Institute
GUI	Graphical User Interface
I/O	Input/Output
iNSD	iNS Descriptor
KPI	Key Performance Indicator
L2	Layer-2 of OSI stack
L3	Layer-3 of OSI stack
LCM	Life-Cycle Management
MaaS	Monitoring as a Service
MANO	Management and Orchestration
MEC	Multi-Access Edge Compute
m/eMTC	massive/enhanced Machine Type Communications
MFA	Multi Factor Authentication
mIoT	massive Internet of Things
ML	Machine Learning
MIMO	Multiple-Input Multiple-Output
MON	Monitoring
MPLS	Multi-Protocol Label Switching
MVB	Merchant Venturers Building
NBI	North Bound Interface
NFV	Network Function Virtualization
NFVI	Network Function Virtualisation Infrastructure
NFVO	NFV Orchestrator
NS	Network Service

NSaaS	Network Slice as a Service
NSD	NS Descriptor
NST	Network Service Template
OAI	OpenAirInterface
ONAP	Open Network Automation Platform
OSM	Open Source MANO
OSS	Operations Support Systems
PDSCH	Physical Downlink Shared Channel
PNF	Physical Network Function
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
RBAC	Role-Based Access Control
RO	Resource Orchestrator
SBI	Southbound Interface
SDN	Software Defined Networking
SLA	Service Level Agreement
SLPOC	Single Logical Point of Contact
SUT	System Under Test
TF	Task Force
TMV	Test, measurement and KPI Validation
UC	Use case
URLLC	Ultra-Reliable Low Latency Communications
VSD	Vertical Service Descriptor
VIM	Virtualised Infrastructure Management
VM	Virtual Machine
VNF	Virtual Network Function
WAN	Wide Area Network
WIM	WAN Infrastructure Manager
WTC	We The Curious (museum in Bristol)