ONBOARDING VERTICAL APPLICATIONS ON 5G-VINNI FACILITY

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EXECUTIVE SUMMARY

The four main 5G sites of 5G-VINNI in UK, Norway, Spain and Greece are now operational. The target of these 5G sites is to demonstrate that:

- these sites can be accessed and used by vertical industries to set up research trials of innovative use cases and
- the key 5G PPP network KPIs can be met.

This whitepaper sheds light on these two aspects:

- by providing an in-depth tutorial on how to onboard vertical applications on 5G-VINNI facility and
- by listing the initial KPI measurement results from 5G-VINNI facility.

5G-VINNI adopts Network Slice as a Service (NSaaS) delivery model to offer customized service experience to verticals. The architecture which allows this model is based on guidelines from telecom industry organizations and the normative specifications from standards bodies to ensure interoperability and reproducibility. To this end, TM forum OpenAPIs are exposed towards the verticals from 5G-VINNI service portal and the service catalogue. The APIs allow the verticals to directly trigger necessary operations for service ordering from a 5G-VINNI service catalogue. Upon receiving the order, the customer is offered with a service instance which in case of 5G-VINNI is related to the 5G-VINNI Service Blueprint (SB). The 5G-VINNI-SB is a template capturing the complete description of a given service. This template is used as a reference to conduct service management procedures both at instantiation and at run-time.

To cover the necessities of any vertical with the use of a single service platform, 5G-VINNI has defined four (4) different exposure levels in order to provide customized access and insight into the slice instance. As a general principle, a higher exposure level offers more advanced capability to the vertical albeit requiring much more customization.

Onboarding a vertical on a 5G test platform is challenging as it involves various iterative and parallel steps. 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. It is therefore of utmost importance that 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. This white paper presents in detail the 5G-VINNI vertical onboarding process which can be summarized as consisting of *co-design period* to understand vertical needs and how to enable them, the *co-development period* which involves the vertical customer and the 5G facility provider to jointly develop the final service including testing-as-a-service and monitoring-as-a-service and, *the operational and KPI testing period* which allows the vertical customer to make repeatable and scheduled service orders of the developed service blueprint and perform KPI testing, monitoring and assessment.

The whitepaper concludes with initial KPI results from several categories of tests conducted on the 5G-VINNI facility. These tests, executed using state-of-the-art open source and commercial testing tools, have measured the current capabilities of the 5G-VINNI infrastructure that can be used by verticals as of today.

ABBREVIATIONS	
3GPP	3rd Global Partnership Project
5G-VINNI	5G Verticals Innovation Infrastructure
5G-VINNI-SB	5G-VINNI Service Blueprint
5G-VINNI-SC	5G-VINNI Service Catalogue
API	Application Programming Interface
BSS	Business Support System
CFS	Customer-Facing Service
CSP	Communication Services Provider
DL	Downlink
eMBB	Enhanced Mobile Broadband
EMS	Element Management System
ETSI	European Telecommunications Standards Institute
FCAPS	Fault, Configuration, Accounting, Performance and Security (Management)
GST	Generic network Slice Template
KPI	Key Performance Indicator
MaaS	Monitoring as a Service
mMTC	Massive Machine-Type Communication
NAT	Network Address Translation
NFV	Network Functions Virtualisation
NFVI	NFV Infrastructure
NFVO	NFV Orchestrator
NSaaS	Network Slice as a Service
NSD	Network Service Descriptor
OSS	Operations Support System
RFS	Resource-Facing Service
SID	TM Forum Information Framework formerly known as Shared information and data model
SO	Service Orchestrator
SST	Slice Service Type
TaaS	Testing as a Service
TC	Test Case

TOSCA	Topology and Orchestration Specification for Cloud Applications
UE	User Equipment
UL	Upload
UML	Unified Modelling Language
uRLLC	Ultra-Reliable Low Latency Communication
V2X	Vehicle-to-everything
VNF	Virtual Network Function
VNFD	VNF Descriptor
YANG	Yet Another Next Generation (ETSI)

1 INTRODUCTION

The main goal of this whitepaper is to give a description of the process of onboarding vertical applications onto the 5G-VINNI facility sites. A second goal is to present the initial Key Performance indicator (KPI) results from the 5G-VINNI facility.

The whitepaper is structured as follows:

- This first section describes the Network Slice-as-a-Service (NSaaS) delivery model provided by the 5G-VINNI facility and the 5G-VINNI Service Blueprint used for onboarding vertical applications, while also presenting the different levels of how the 5G-VINNI facility services can be exposed to the vertical customers.
- The second section describes the onboarding process of vertical customer services and applications, where the reader is taken through the journey of designing and launching the customer facing service and the resource facing services, which also includes the option of automated services for testing and monitoring.
- The third section presents the initial KPI results from the 5G-VINNI facility.

More information about the scope of the 5G-VINNI project and its facility site map is available on the 5G-VINNI website [1].

1.1 NETWORK SLICE AS A SERVICE (NSAAS) DELIVERY MODEL

5G-VINNI adopts the Network Slice as a Service (NSaaS) delivery model, whereby 5G-VINNI facility provisions tailored network slices to verticals upon request. Each vertical uses the slice that has been provided to meet their requirements for trialling activities, setting up different use cases and assessing their KPIs under different network conditions.

5G-VINNI incorporates into its architecture the guidelines from telecom industry organisations and the normative specifications from standards bodies to ensure interoperability and reproducibility. The 5G-VINNI high level architecture which allows NSaaS delivery model is shown in Figure 1, where the 5G-VINNI portal and service catalogue expose TM Forum Open APIs [2] towards verticals to allow them to directly trigger necessary operations for service ordering. The 5G-VINNI Service Catalogue derives content from Facility Service Catalogue offerings hosted by the respective Service Orchestrators (SO). The service order is then passed to the SO in one of the main 5G-VINNI facility sites which are located in UK, Norway, Spain and Greece. The SO, which implements the 3GPP Network Slice Management Functionality [3], then instantiates the network slice by subsequent calls to the respective network function orchestrator (NFVO). The NFVO implements the northbound interface [4] using ETSI SOL 005 [5]. This normative specification defines the protocol and data model for the interface capabilities in the form of RESTful APIs which have become de-facto solutions for most of the industrial and open-source NFVOs.

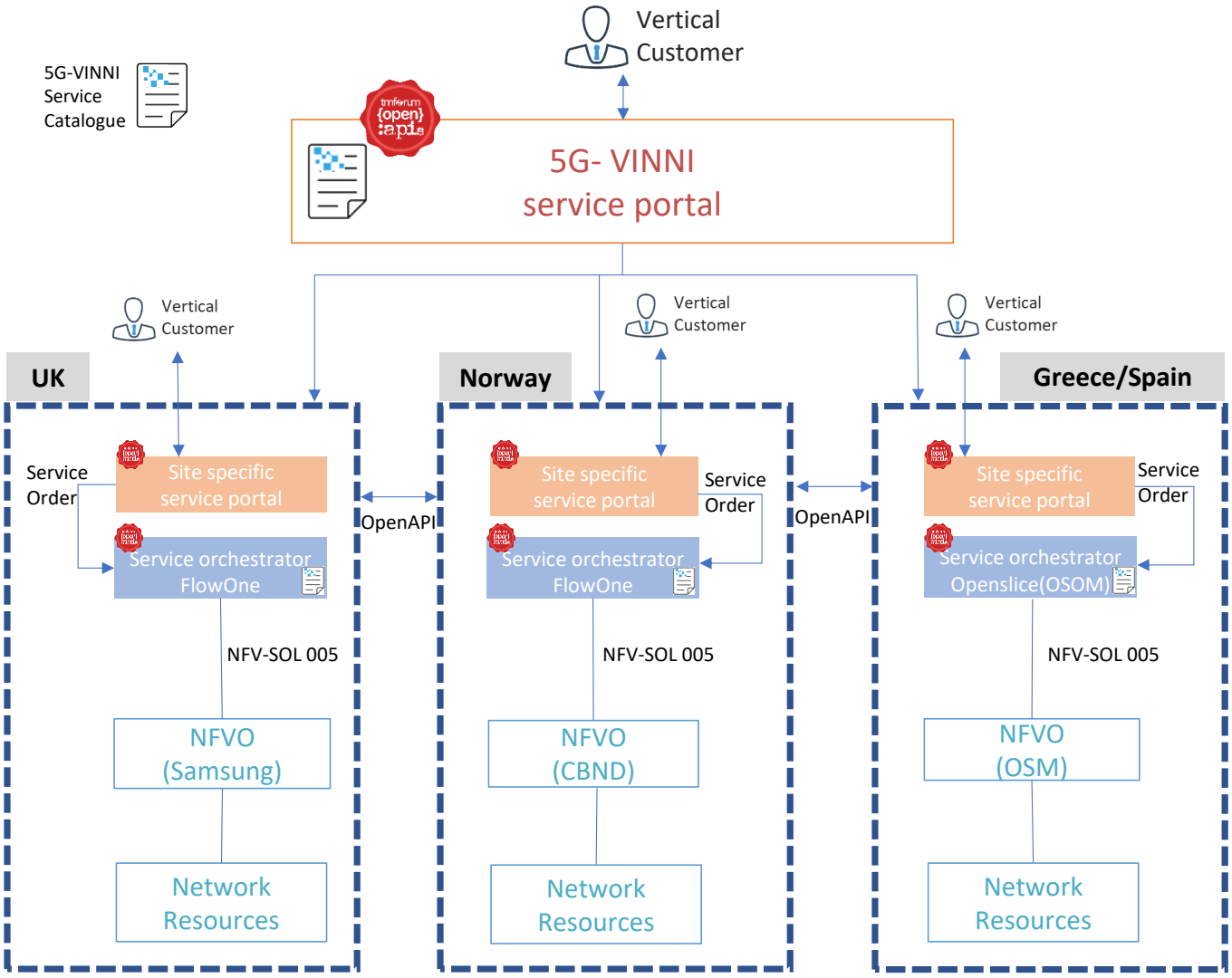

Figure 1 – 5G-VINNI architecture to enable network as a service delivery model

1.2 THE 5G-VINNI SERVICE BLUEPRINT AND SERVICE CATALOGUE

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

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

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

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

1.2.1 THE 5G-VINNI SERVICE BLUEPRINT MODEL

A 5G-VINNI-SB is a baseline, model-based service template describing a given network slice to be provisioned using NSaaS. This service template is a structured document that provides a complete description of a given network slice, including information on service topology and expected behaviour. It is used by the Communication Services Provider (CSP) as a reference to conduct service management procedures, both at instantiation time (deployment procedures) and at run-time (operational procedures).

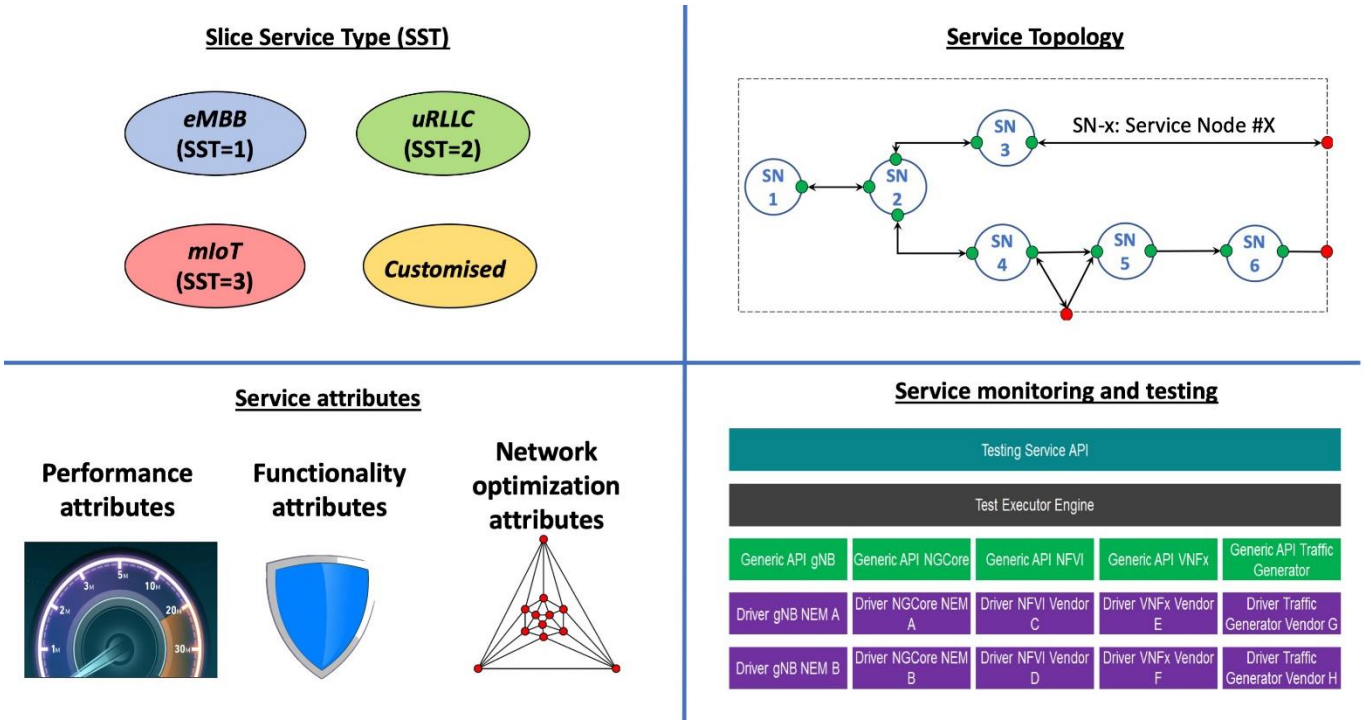

Figure 2 – 5G-VINNI Service Blueprint (SB) structure to be used by the CSPs

The 5G-VINNI-SB structure is arranged into four main parts as illustrated in Figure 2. These are:

Slice Service Type (SST) is a 3GPP parameter [6] that specifies the 5G service category the slice is meant to support. The following SST values are defined: "1" (eMBB), "2" (uRLLC) and "3" (mMTC). There is also a custom slice type SST>3 which allows for the definition of other slice types for example "SST=4" for Vehicle to everything (V2X) service.

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

The slice default topology can be flexibly extended thus offering the verticals the opportunity to bring their own NFs and applications into slice definition by simply attaching them to define slice access points (red connection points in Figure 2).

Service attributes correspond to generic network slice template (GST) attributes as defined in GSMA NG 116 [7]. The specification of values for these attributes allows the vertical to provide the service requirements the slice must satisfy, based on SLAs that the vertical requires the facility to provide. The attributes available in 5G-VINNI-SB are listed in Table 1 where for each attribute, the following information is defined:

- parameter value specification (e.g. integer, float, binary, etc.),
- measurement unit,
- selectable options (if needed) and
- conditional relationships with other parameters.

Table 1 – Parameters for service requirements specifications

Group	Parameter Name	Parameter ID
Performance	Peak data rate	P.PERF_1
	User data rate	P.PERF_2
	Area traffic density	P.PERF_3
	5G QoS	P.PERF_4
	Reliability	P.PERF_5
	Availability	P.PERF_6
	Service deployment time	P.PERF_7
Functionality	Deployment option	P.FUNC_1
	Access technology	P.FUNC_2
	Predominant device type	P.FUNC_3
	Radio spectrum	P.FUNC_4
	Isolation	P.FUNC_5
	Support for value-added functionality	P.FUNC_6
	3rd party VNF hosting	P.FUNC_7
	Positioning	P.FUNC_8
Network Optimisation	Number of devices	P.NO_1
	Device density	P.NO_2
	Coverage profile	P.NO_3
	Mobility profile	P.NO_4
	Service lifetime	P.NO_5

Service monitoring and testing allows the verticals to execute use case trials at run-time. This is relevant in experimentation environments and for service assurance and closed loop automation. *Service testing* allows the vertical to specify the tools needed from 5G-VINNI test framework to execute trialling activities within the slice. *Service monitoring* on the other hand allows the vertical to specify telemetry information required to get from 5G-VINNI monitoring framework, including data sources and metric collection methods (threshold-based alarms or periodic notifications).

The overall aim of the 5G-VINNI-SB is to provide a customer-facing service (CFS) description of any network slice which can easily be understood by the verticals. The CFS description can then be mapped into a resource-facing service (RFS)

description of the slice, which provides details on how the slice is deployed at the resource layer. This means translating slice nodes and slice attributes into concrete Network Service Descriptors (NSD)/VNF Descriptors (VNFDs) along with instantiation information, e.g. placement of Network Services/VNFs and their resource allocation.

Following TM Forum's Information Framework [8] (commonly referred to as shared information and data model (SID)), the 5G-VINNI-SB is a top-level construction that can be modelled as a bundle of classes, each defining the invariant characteristics and behaviour (attributes, methods, constraints and relationships) of a component taking part in the structure of that top-level construction. For 5G-VINNI-SB, the following classes have been defined: *serviceRequirements*, *serviceTopology*, *3rdPartyVNF*s, *serviceTesting* and *serviceMonitorin*g.

Figure 3 provides a unified modelling language (UML) representation of SID-driven 5G-VINNI-SB model. The classes are of "ServiceSpec" type representing CFS aspects. In addition to these classes, the 5G-VINNI-SB model also includes other types of classes, known as "LogicalResourceSpec" in SID terminology representing RFS aspects of the slice. Relationships between both types of classes allow establishment of mappings between CFS and RFS. For example, 3rdPartyVNF class has 1:1 relationship (reference, pointer) with the VNFD class, which represents the VNF information model [9].

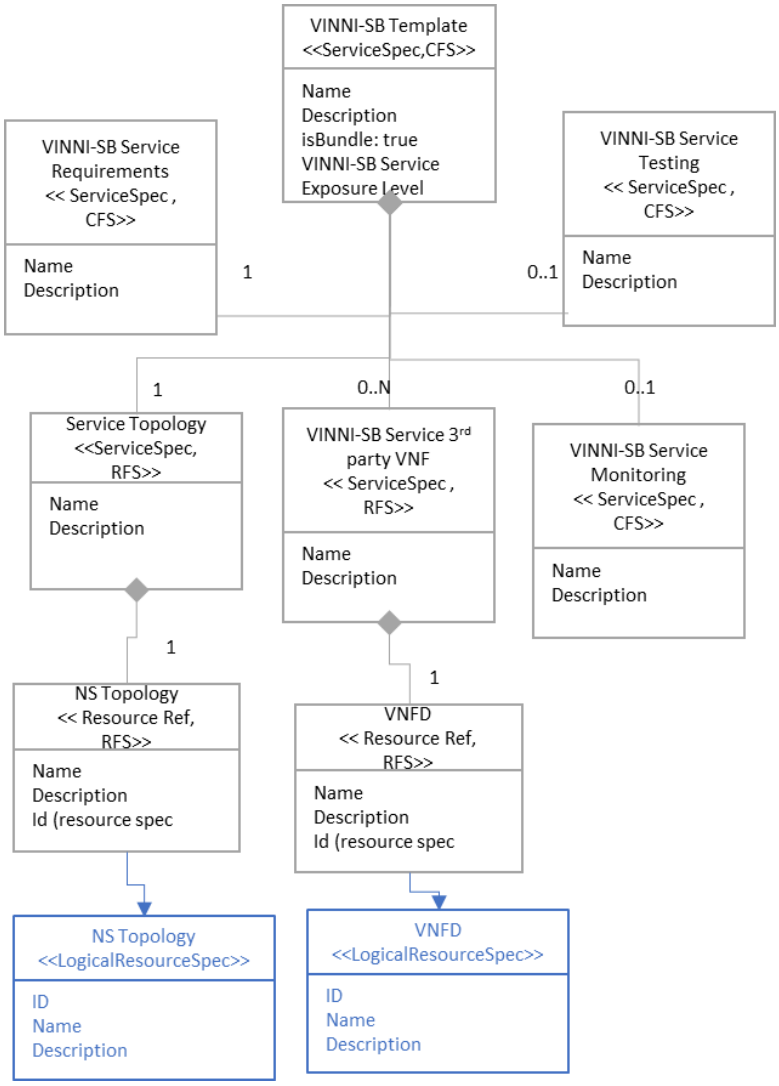

Figure 3 – The 5G-VINNI-SB Template Model diagram

Further details on the Service Blueprint design can be found in 5G-VINNI D3.1 [10].

1.2.2 THE 5G-VINNI SERVICE CATALOGUE

The 5G-VINNI-SBs announced by each facility site are registered and published into a single service catalogue called 5G-VINNI-SC. This approach allows providing verticals with a unified marketplace, informing them about available service offerings in the entire 5G-VINNI facility.

Any authorized vertical is in position to browse the 5G-VINNI-SC, select a 5G-VINNI-SB, fill it according to the service requirements, and issue a service order. Upon receiving this service order, 5G-VINNI facility proceeds with the CFS-RFS translation, mapping the service order (CFS) into a network slice instance (RFS), deployed across one or more facility sites.

At the time of writing this white paper the consensus is to use Openslice [11] to expose the 5G-VINNI-SC. Openslice is a prototype open source operations support system (OSS)[1] which offers TMForum Open APIs for Service Catalogue management and Ordering as well as a UI Portal for easy access. Figure 4 provides an example of a 5G-VINNI-SB with attributes in Openslice.

[1] The BSS layer is under the control of the CSP, hence 5G-VINNI facility specific portal may be utilized depending on the needs of the specific facility site and/or the CSP.

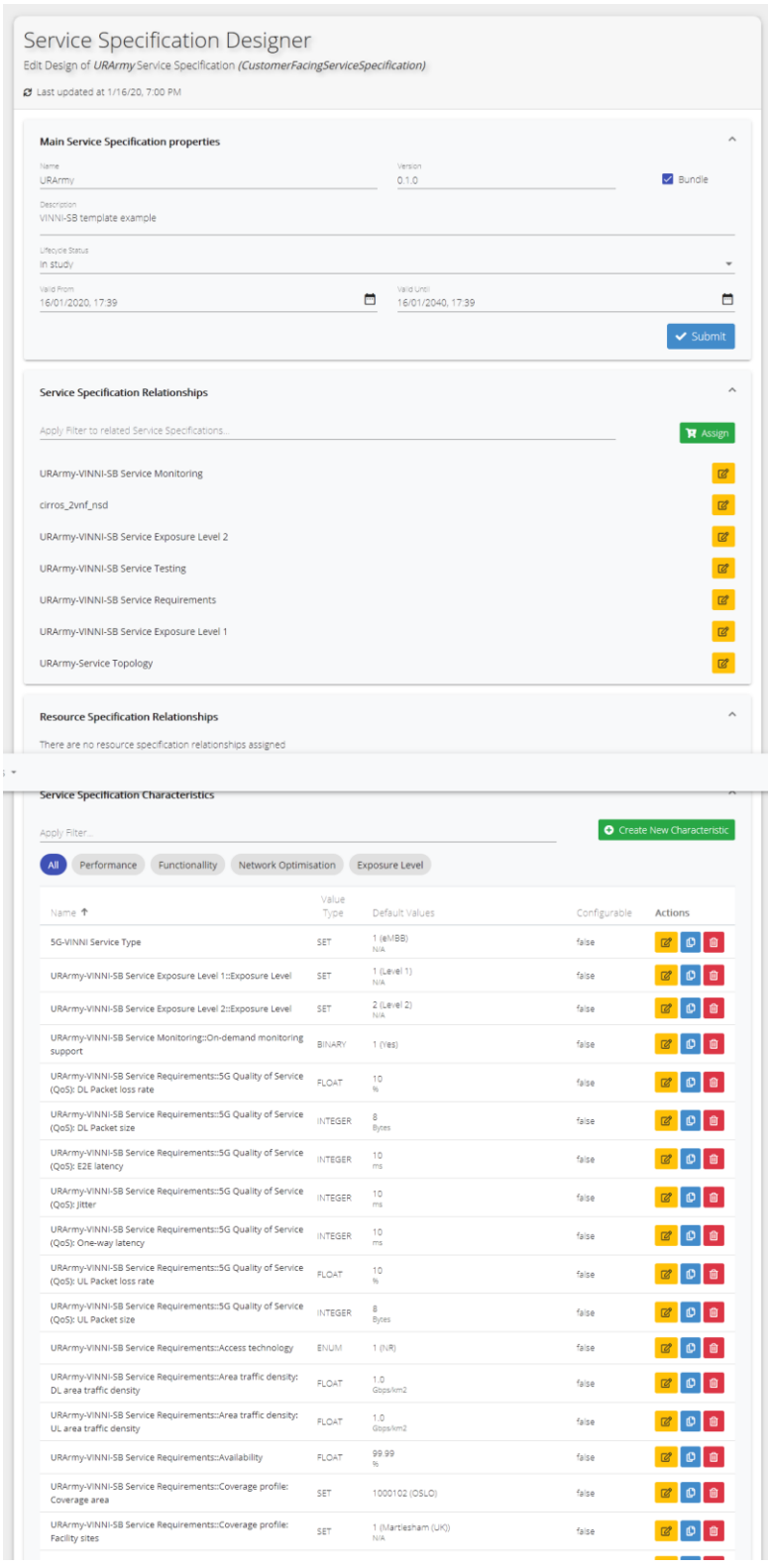

Figure 4 – A 5G-VINNI service blue print example in Openslice

1.3 SERVICE EXPOSURE LEVELS

The use of the defined service delivery model is key to make the 5G-VINNI facility a real 5G-ready service platform for advanced vertical experimentation activities. NSaaS allows each vertical customer to order a slice instance on demand and consume it as a service for use case trialing activities. From the point of view of a vertical customer, the slice is seen as an isolated and tailored experimentation platform (e.g. with pre-provisioned 5G-VINNI monitoring and testing tools). Such a slice can be used to run one or more use cases to assess their behavior and readiness say under different load conditions.

To allow every vertical customer to take the lead on the above-referred experimentation activities, the 5G-VINNI facility provides the customer with insight and access to the slice instance being used. For this a service capability exposure is required. This exposure can be defined as the ability of the 5G-VINNI facility service provider to securely expose the management capabilities of every slice instance towards the vertical customer. This requires proper isolation mechanisms to be embedded in the slice instance in order to avoid security and privacy breaches say between slice instances used by other vertical customers. An example of such an isolation would be limiting the network slice instance ID advertisement to a particular zone. This by regulating the service exposure, the 5G-VINNI facility service provider can define the degree of visibility and control the vertical can have of the respective slice instance.

As per the one-one interaction between 5G-VINNI facility coordinators and ICT-19 project representatives, not all the verticals in the ICT-19 projects want to have the same degree of control and visibility of the slice instance. Most of them are only interested in collecting service KPIs and fault alarms from their running use cases. This means that they only want to keep track of the performance of their use cases without worrying about how their corresponding slice instances are actually deployed. However, there are some verticals that do need to know resource-layer details of their deployed slice instances to have a complete understanding of the environments where they execute their use case trials. To cover the necessities of any vertical with the use of a single service platform, 5G-VINNI has defined four different service capability exposure levels as listed in Table 2.

Table 2 – The different exposure levels in 5G-VINNI highlighting that *higher the exposure level, the more advanced capabilities the vertical can get*

5G-VINNI is able to consume operations related to….	**Level 1**	**Level 2**	**Level 3**	**Level 4**
E2E network slice application layer config & management	✓	✓	✓	✓
Network slice subnet / network function application layer config & management	×	✓	✓	✓
Network slice subnet / network function virtualized resource layer config & management -> ETSI NFV Network Service (and VNF) orchestration	×	×	✓	✓
Infrastructure resource control & management -> NFVI with optional EPA capabilities and infrastructural SDN control.	×	×	×	✓

Note : The capabilities offered by a given level also include the ones offered by the level immediately above.

2 ONBOARDING

Onboarding a vertical on a 5G test platform is challenging as it involves various iterative and parallel steps. 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. It is therefore of utmost importance that 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.

Figure 5 displays the 5G-VINNI vertical onboarding process. The process consists of several phases which are discussed in detail in subsequent sections.

i) **The co-design period** which involves stakeholders such as vertical customers, 5G-VINNI 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 5G facility provider to jointly develop the final service to be ordered including the development of any VNFs, test scripts and monitoring services. Testing as a Service (TaaS) and Monitoring as a Service (MaaS) can be integrated during the preparation of the VNFs and development of service templates. This is subject to availability of TaaS and/or MaaS in the 5G-VINNI facility site.

iii) **The operational and KPI testing KPI period**: In this phase the vertical customer can make repeatable and scheduled service orders of the developed service blueprint via the portal and perform KPI testing, monitoring and assessment.

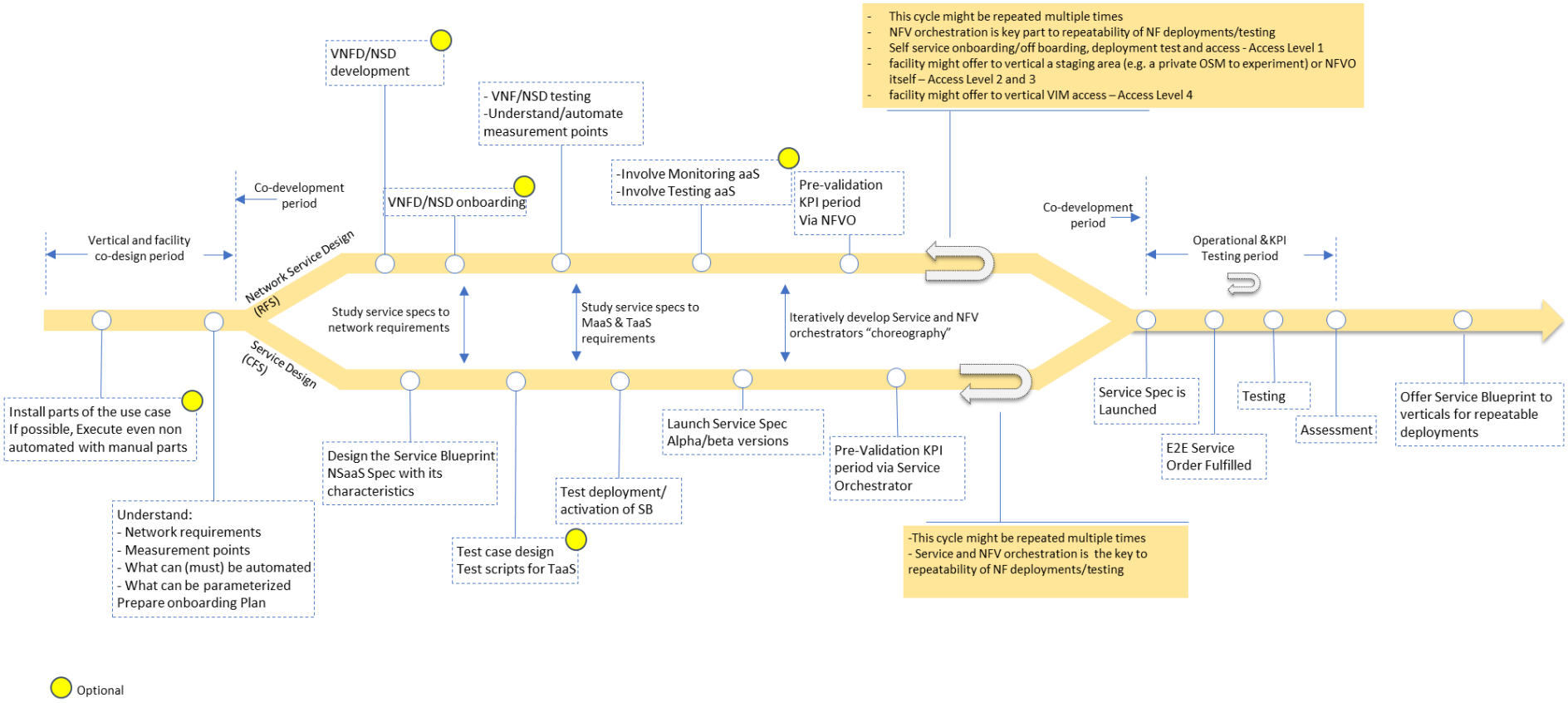

Figure 5 – The 5G-VINNI vertical onboarding process

2.1 VERTICAL AND FACILITY CO-DESIGN PERIOD

During this initial period the involved stakeholders such as vertical customer, 5G-VINNI facility providers, CFS/RFS developers need to understand the vertical customer needs from the 5G facility in terms of:

- what needs to be extended and co-developed
- what and where can be measured and tested
- what is the plan for onboarding?

Since orchestration is a key part of automatically configuring, activating and deactivating services and network slices in a repeatable fashion, certain components must be developed either by the vertical or the 5G-VINNI facility.

To understand better the vertical customer, and to ease this process, the following phases are envisioned:

2.1.1 EARLY INSTALLATION OF THE VERTICAL USE CASE

This phase involves a sanity check of the vertical use case by instantiating key components required to execute the service. As this is an initial sanity check so the instantiation need not to be automated.

2.1.2 COMMON UNDERSTANDING

The advantage of the early installation of the vertical use case enables all the stakeholders to reach a common understanding with respect to

- vertical requirements from the 5G system and the capabilities of the 5G facility.
- service onboarding as some parts of the vertical services might need to be developed for automated deployment by orchestrators. Here the verticals need to understand the target orchestrator and the supported NFV models (YANG, TOSCA).
- what can be parameterized. This involves verticals to clearly identify if there are any exposed parameters from the vertical services that can be parameterized and reconfigured during orchestration.
- the procedure and tools for automated test, measurement and validation. This also involves shepherding the vertical in order to reuse test scripts and develop the plugins for testing.

Upon reaching a common understanding, the vertical and the 5G facility can proceed with a co-development period. We identify here two main processes:

i) the Network Service Design process which is related to resource facing services (RFS)

ii) the Service Design process which is related to customer facing services (CFS)

2.2 CO-DEVELOPMENT PERIOD– SERVICE DESIGN PROCESS (CFS)

During this phase the 5G facility develops the service blueprint (SB) together with the vertical customer. The SB is pre-launch/pre-ordered via the Service Orchestrator which also involves validation of the Taas and MaaS to be correctly orchestrated. The process is iterative and interacts with the Network Service Design process.

2.2.1 DESIGN THE SERVICE BLUEPRINT

During this process, the Vertical and the 5G facility can define the attributes of the 5G-VINNI-SB. This step might need some research on defining the proper parameter values in which the stakeholders need to be pragmatic on how these requirements are "translated" towards the SO and NFVO. In later stages, the 5G-VINNI-SB will be used to automatically trigger the complete orchestration of the network slice instance. Proper definition of the 5G-VINNI-SB requires some work initially but this will benefit the vertical customer to consequently reproduce the service instantiation via the service catalogues at later stages with potential minor updates to the 5G-VINNI-SB.

2.2.2 TEST CASE DESIGN

The 5G-VINNI-SB will have the option to include testing as a service (TaaS). For example, by including relevant test scripts for TaaS. The test scripts will represent specific Test Cases (TCs) that are targeted at stressing specific aspects or KPIs of the Service. It is important to understand that there are two types of TCs: 1) TCs for validating fundamental network KPIs like throughput, delay, and 2) TCs for validating the service of the vertical customer that might include the vertical's application. While the former can be offered as part of the service design with minimal configuration, the latter might require significant work.

Training on TCs design methodologies will be offered by 5G-VINNI facility as part of the available documentation. It is of fundamental importance that in order to achieve consistent and repeatable results, all actors in the value chain, including the vertical customer, is capable of designing solid TCs. Ongoing consulting support will be provided in the design phase, where most of the work will consists in creating specifications rather than scripts. Only afterward, the scripts can be reliably developed.

2.2.3 TEST AND VALIDATE SERVICE BLUEPRINT DEPLOYMENT/ ACTIVATION OF SB

At this point the 5G-VINNI-SB has been co-created with the vertical. The next step is to test and validate its proper operation via the SO. This involves pre-launching/pre-ordering the 5G-VINNI-SB via the portal to check that the 5G-VINNI-SB can be correctly orchestrated via the SO. In this step, the 5G-VINNI facility tries to instantiate, test and validate the defined 5G-VINNI-SB. This is also related to developments in Openslice itself as well as development in the SO part. During this step, the 5G-VINNI-SB attributes might be redefined based on the interaction with the 5G-VINNI facility.

2.2.4 LAUNCH SERVICE SPEC - ALPHA/BETA VERSIONS

Since the 5G-VINNI-SB is instantiated and validated successfully, the 5G-VINNI facility can start launching different versions of the 5G-VINNI-SB towards the SO and NFVO while involving TaaS and MaaS, checking and assessing their interoperability.

2.2.5 PRE-VALIDATION

In this step, a pre-validation period can start and required adjustment can be made to the service order. The vertical customer and 5G-VINNI facility can check that the KPIs can be extracted properly. Since the orchestration of 5G-VINNI-SB parts have been verified, the vertical customer and the 5G-VINNI facility can schedule and perform a pre-validation of the service and validate the proper deployment of the Network Service as discussed in section 2.3. At this stage it can be verified that the developed CFS can extract the proper KPIs. This process might also involve TaaS. By invoking TaaS during service deployment, the vertical customer and 5G facility will validate that the 5G-VINNI-SB and TaaS/MaaS work as expected.

2.3 CO-DEVELOPMENT PERIOD - NETWORK SERVICE DESIGN PROCESS (RFS)

The Network Service design process is related with the NFV specifics of onboarding. This process is iterative and interacts with the Service Design process.

2.3.1 VNFD/NSD DEVELOPMENT

This step is optional, depending on whether or not the vertical customer need to on-board any additional VNFs during orchestration.

Prior to development of VNFs/NSDs, the developer must understand the specifics of the target 5G facility and plan for any specific requirements (e.g., hardware acceleration, Internet access for VNF). Creating VNF packages or Network Service descriptors is a tedious task and depends on the target NFV Orchestrator (e.g. OSM, Nokia CloudBand Network Director) and the standard followed. For the creation of VNFs the following should be considered:

- Preparing the Virtual Machine image
- Implement a VNF descriptor according to target orchestrator model
- Implement any configurations related to the VNF Manager and especially the Element Management System (EMS). EMS is responsible for the functional management of VNF, i.e. FCAPS (Fault, Configuration, Accounting, Performance and Security Management), which often involves VNF management using proprietary interfaces.
- VNF packaging

Similarly, for Network Service descriptors, the task includes:

1. Creating folder structure
2. Completing the NSD YAML file, with the Network Service metadata, constituent VNFDs and Virtual Link Descriptors
3. Packaging the Network Service

2.3.2 VNFD/NSD ONBOARDING

This is an iterative task performed by the VNF/NSD developers. Usually the developers get access to an orchestrator in order to develop and test their VNF/NSDs. The 5G facility might also give access to their own orchestrator.

The following options might be available to the vertical customer:

- Manual onboarding of VNFD/NSD performed by the 5G facility operator.
- Self-service onboarding/off boarding, deployment test and access (Exposure Level 1)
    - Automated self-service onboarding can be done by Openslice NFV portal when offered by the 5G facility
- The 5G facility might offer a staging area (e.g. a private OSM to experiment) or offer the use of the production NFVO itself (Exposure Level 2 and 3)
- The 5G facility might offer VIM access (Exposure Level 4)

The vertical customer must upload any VM images to the 5G facility so that these can be stored in the image repository.

2.3.3 VNFD/NSD VALIDATION

In this step, it is recommended to test the NSD orchestration only by the NFVO to identify any errors in which case the previous steps of developing, on-boarding, test orchestration might be repeated.

When the pre-validation and testing are performed and the VNFDs and NSDs can be repeatedly orchestrated and instantiated without errors, it is advised to on-board the VNFDs and NSDs to the production NFVO of the 5G facility via its tools and processes.

It needs to be highlighted that remote access through VPN is provided by the 5G-VINNI facility for accessing the instantiated VNFs and the running NSs.

2.3.4 VNFD/NSD MAAS AND TAAS

While this step is optional, the vertical customer should consider the involvement of monitoring and testing services during VNFD and NSD development. Such services can be consumed both as a human-driven or an automated interaction. It is necessary to understand that such services require actions from the vertical customer side in order to be properly consumed such as the VNF exposing its functionality to a monitoring system.

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

MaaS is targeted at having a constant overview of the health and performance of the system, and it consists of two main categories of services: Network Monitoring and Telemetry. The former is the traditional overview of the traffic flowing across the network, in particular emphasizing the visibility in specific critical points in the network. The latter is focused on providing the health and performance of the individual Network Service or VNFs/application components. The two categories are very different despite being offered under the same umbrella of MaaS.

TaaS consists of a set of testing tools that can be deployed, configured, and automated through a set of offered web services. A typical example of testing tools is traffic generators, that can emulate realistic traffic and protocols. The offered services allow the vertical customer to:

- onboard specific drivers for automating vertical applications and use cases
- create and execute individual test scripts for automating the tests or the experimentation
- create and execute test campaigns, i.e. batch of test scripts that can be executed on multiple target infrastructures
- visualize logs and results through the offered visualization systems
- allow the vertical to develop customized visualizations

In order to better understand how to consume a TaaS service, an example is depicted in Figure 6

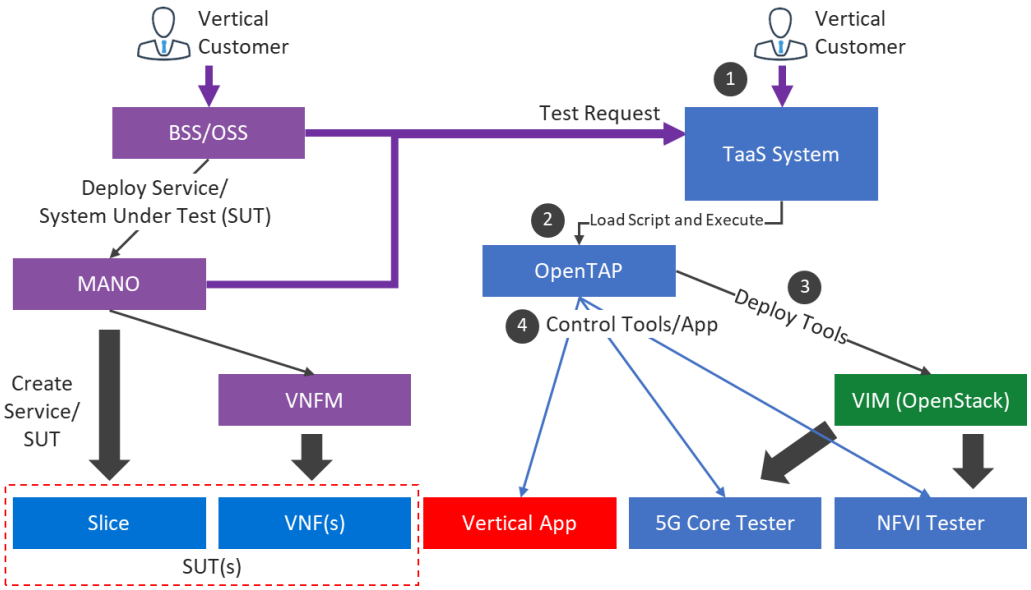

Figure 6 – Consuming a TaaS service

In Figure 6, two examples are depicted for how to consume the testing service. The first case is for service validation. While deploying the Network Service, a set of test cases can be automatically requested by the BSS/OSS and executed after the deployment in order to verify the health or performance of the service. In this case the test cases are programmatically requested via API calls[2] to the TaaS.

The other way of consuming the service is through the use of web services[3], that allow manual execution of the tests. The manual execution allows for a more comfortable way of configuring the tests to perform more exploratory experiments.

After the tests is requested (1), the test scripts present in the TaaS repository are loaded and executed on OpenTAP, an open source technology that is at the heart of the 5G-VINNI TaaS system. OpenTAP allows to programmatically deploy tools e.g. in an OpenStack cloud, and configure them to target the newly deployed service.

Before consuming the service, the vertical customer has the need of performing a full onboarding process, in order to guarantee the effectiveness of the workflow. The onboarding process is outlined as follows:

- Training: a set of webinars will be offered in order to cover all the different aspects, from how to design effectively experiments and tests cases, to the use of specific tools.
- Design of TCs: the vertical customers shall foresee a phase where the KPIs of interest, and how to stress them (the testing conditions) are formalized, before considering scripting or launching experiments
- Development and onboarding of connecting plugins: if the vertical customers wish to include their own application as part of the experiment under the control of the automation framework (strongly suggested for guaranteeing results consistency), they will need to develop the drivers for connecting OpenTAP to the application via an exposed API. Furthermore, if the KPIs of interest lay on the vertical application domain, the customers shall prepare the application for exposing specific metrics for collection.
- Development and onboarding of Test Scripts: finally, it will be possible to develop the automation scripts needed for executing the tests and experiments in a consistent and repeatable fashion.

[2] TaaS APIs are not yet published

[3] TaaS web services are available and will be supported for 5G-VINNI Release 2

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

Let's analyse in more detail what the 5G-VINNI project is expected to offer in future releases. As previously mentioned, two types of monitoring services will be offered: network monitoring and telemetry. The former is a service that is considered almost transparent to the vertical customer who only needs to define the visibility scope and provide the tool for performing the analysis.

The 5G-VINNI project will offer a set of virtual network taps that can be deployed in specific points of the network, as described by the NSD, and eventually a packet broker for performing a preliminary sorting of the selected traffic flows. The network taps are capable of sniffing (north-south and east-west) traffic, simple filtering, and re-routing the traffic to a specific destination. Such destination can be an analysis tool (currently not provided by 5G-VINNI) or a packet broker. This component is capable of more advanced filtering, aggregation, and re-routing options to either an analysis tool or a traffic recording server. An example of possible deployment is depicted in Figure 7.

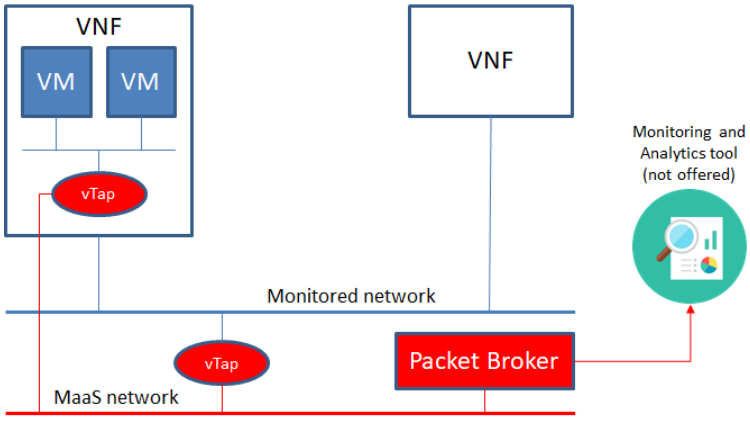

Figure 7 – An example of possible deployment

Given the amount of overhead, in terms of computation capabilities but also additional network bandwidth required, it is suggested to carefully select which portions of the Network Service is necessary to observe for specific experiments or use cases.

Telemetry is instead intended for monitoring the health but also the performance of each individual Network Service component (typically VNF, but PNF as well can be monitored). The typical example is a VNF that exposes metrics that can be either actively pushed, or passively collected, in order to be stored in a database, as e.g. a Prometheus time series one. This is common practice in modern virtualized solutions, and the 5G network is no exception. Telemetry can be effectively used for:

- exposing health metrics
- exposing performance metrics (e.g. network buffers status)
- exposing directly measured KPIs

All the possibilities are valid, and it is up to the vertical customer to include in the VNFDs and the NSDs whatever is relevant for the specific use case or need. The Telemetry portion of MaaS is currently in discussion in the 5G-VINNI project and specific details will be provided in the future.

2.3.5 PRE-VALIDATION KPI PERIOD VIA NFVO

After a vertical customer together with the 5G-VINNI facility have developed the VNFs and NSDs, the next step is to test these for proper instantiation via the 5G facility's NFV orchestrator. Since, at this point in the process, the orchestration has been verified, the vertical customer and the 5G facility can schedule and perform a pre-validation of the Network Service.

This step might also involve TaaS. By invoking TaaS during VNF and Network Service deployment, the vertical customer and 5G-VINNI facility need to validate that the VNFs and TaaS/MaaS work as expected.

The above defined steps of the Network Service design process might be repeated multiple times since NFV orchestration is key to repeatability of Network Service deployments and testing.

2.4 OPERATIONAL AND KPI TESTING PERIOD

During this period and since CFS and RFS are in place, an official Testing period can start according to the 5G-VINNI facility plan. This process is again iterative and if necessary, developers might revisit previous steps. The following steps are planned.

2.4.1 SERVICE BLUEPRINT SPECIFICATION LAUNCHED

The latest developed 5G-VINNI-SB is officially launched in the 5G facility catalogue and ready for service orders.

2.4.2 E2E SERVICE ORDER FULFILMENT

The Service Order takes place and the subsequent services are instantiated.

2.4.3 TESTING

In this 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. These data stores cannot be defined at the present moment and will be strongly dependent on the use cases and tools used.

2.4.4 ASSESSMENT

The monitoring data is available to the vertical customer for any assessment.

2.5 OFFER THE SERVICE BLUEPRINT TO THE VERTICAL COMMUNITY

After the testing and validation period the defined 5G-VINNI-SB can be publicly offered to the vertical customer community for repeatable deployments.

3 INITIAL KPI RESULTS

The 5G-VINNI facility sites have undergone a rigorous validation procedure that included several categories of tests. Such test cases, executed using state-of-the-art open source and commercial testing tools, have measured the current capabilities of the 5G-VINNI infrastructure that can be used by verticals as of today.

The test categories include:

- **End-to-End Network performance**: End-to-End measurements have been carried out by using handsets and CPEs in order to validate which type of performance the Vertical applications might expect.
- **NFVI Network Performance**: the network fabric of the entire infrastructure has been tested to verify the solidity of performance in supporting the NFV architecture.
- **NFVI Compute Resource Performance**: these tests have been needed to verify if the NFV hardware profile was capable of supporting the NFV architecture.

The results of such tests can be seen in Table 3.

Table 3 – Initial KPI results from 5G-VINNI facility sites

Category	KPIs	Achieved Values	Description
E2E Network Performance	UL Maximum Throughput (Mbit/s)	104.27 Mbit/s	mmWave, 27.3-27.5 GHz, 4T4R, 1 stream
	DL Maximum Throughput (Mbit/s)	883.69 Mbit/s	mmWave, 27.3-27.5 GHz, 4T4R, 40 streams.
	UL Latency (ms)	13.77 ms	3.6GHz, low foot-print traffic profile with 100Kbit/s bandwidth.
	DL Latency (ms)	9.15 ms	
	UL Jitter (ms)	1.01 ms	mmWave, 27.3-27.5 GHz, 4T4R, low foot-print traffic profile with 100Kbit/s bandwidth.
	DL Jitter (ms)	0 ms	
	UL Frame Loss (%)	0.01%	3.6GHz, low foot-print traffic profile with 100Kbit/s bandwidth.
	DL Frame Loss (%)	0%	
NFVI Network Performance	Maximum Throughput (0 Frame Loss)	4.573 Gbit/s	two compute nodes, DPDK was configured in the test environment.
	Latency between VMs	0.067 ms	
NFVI Compute Resource Performance	CPU Benchmarking Score	3,510	Yardstick CPU/Memory/Storage tests.
	Memory Read Latency	7.97 ns	
	Memory r/w Bandwidth	25.641 GB/s	

	Storage r/w IOPS	5.65 k / 4.21 k	
	Storage r/w Latency	188 / 621 ms	
	Storage r/w Bandwidth	1,018 / 425 MB/s	

The values appear to be in line with the expected status of development of the 5G-VINNI infrastructure, but even improved performance is expected to be reported soon.

4 GET INVOLVED AND CONCLUSIONS

This paper lays out the way in which 5G-VINNI facility sites will interact with experimenters to enable them to access the platform that the 5G-VINNI project has designed and built. The level of interaction and integration is flexible to enable anything from a very simple experiment that can be conducted with minimal presence, through to a process with extensive co-design and integration activity. 5G-VINNI's aim is to be available to all to allow vertical industries to try out any number of use cases and to investigate how 5G can add value for them.

Facilities have setup communication with verticals via ticketing systems and wiki. Please consult D3.2 [12] for details. Most facilities can arrange VPN for accessing the facility remotely. To contact an individual facility to directly enquire about experimentation, please use the following contact details.

General enquiries - 5G-VINNI-Contact@5g-ppp.eu

Norway Facility - norway-facility@5g-vinni.eu

UK Facility - uk-facility@5g-vinni.eu

Spain Facility - spain-facility@5g-vinni.eu

Greece Facility - greece-facility@5g-vinni.eu

Portugal Facility - portugal-facility@5g-vinni.eu

Berlin Facility - germany-berlin-facility@5g-vinni.eu

Munich Facility - germany-munich-facility@5g-vinni.eu

5 REFERENCES

[1] 5G Verticals Innovation Infrastructure – 5G-VINNI project website [Online]. Available: https://5g-vinni.eu

[2] TM Forum Open APIs [Online]. Available: https://www.tmforum.org/open-apis/#

[3] 3GPP TR 28.801 V15.1.0 (2018-01); Technical Specification Group Services and System Aspects; Telecommunication management; Study on management and orchestration of network slicing for next generation network (Release 15)

[4] ETSI, GS NFV-IFA 013; Network Functions Virtualisation (NFV) Release 3; Management and Orchestration; Os-Ma-nfvo reference point – Interface and Information Model Specification [Online]. Available: https://www.etsi.org/deliver/etsi_gs/NFV-IFA/001_099/013/03.02.01_60/gs_NFV-IFA013v030201p.pdf [Last accessed 7-02-2020]

[5] ETSI GS NFV-SOL 005 V2.7.1 (2020-01); Network Functions Virtualisation (NFV) Release 2; Protocols and Data Models; RESTful protocols specification for the Os-Ma-nfvo Reference Point [Online]. Available: https://www.etsi.org/deliver/etsi_gs/NFV-SOL/001_099/005/02.07.01_60/gs_NFV-SOL005v020701p.pdf [Last accessed 7-02-2020]

[6] 3GPP TS 23.501 V16.3.0 (2019-12); Technical Specification Group Services and System Aspects; System architecture for the 5G System (5GS); Stage 2 (Release 16)

[7] GSMA, Generic Network Slice Template, Version 2.0, 16 October 2019 [Online]. Available: https://www.gsma.com/newsroom/wp-content/uploads/NG.116-v2.0.pdf

[8] TM Forum Information Framework (SID) [Online]. Available: https://www.tmforum.org/information-framework-sid/

[9] ETSI GS NFV-IFA 011 V3.3.1 (2019-09); Network Functions Virtualisation (NFV) Release 3; Management and Orchestration; VNF Descriptor and Packaging Specification [Online]. Available: https://www.etsi.org/deliver/etsi_gs/NFV-IFA/001_099/011/03.03.01_60/gs_NFV-IFA011v030301p.pdf

[10] 5G-VINNI, D3.1 Specification of services delivered by each of the 5G-VINNI facilities [Online]. Available: https://doi.org/10.5281/zenodo.3345612

[11] OpenSlice [Online]. Available: http://openslice.io

[12] 5G-VINNI, D3.2 Publication of first version of service catalogues to vertical consumers https://doi.org/10.5281/zenodo.3345620

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