Deliverable D3.1

Specification of services delivered by each of the 5G-VINNI facilities

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Abstract

5G-VINNI aims at providing a realistic 5G end-to-end test and experimentation facility that can be used by industry verticals to set up trials of innovative use cases, assessing their readiness and validating their KPIs under different load conditions. To allow different verticals to deploy their own use cases and execute test scenarios with isolation guarantees, 5G-VINNI provides them with isolated, tailored environments (network slices) as a service. This document specifies the network slice services offered per facility site, including information on their exposed capabilities and the APIs made available for vertical's consumption. To enable desired reusability and reproducibility of network slice services across facility sites in the upcoming project releases, model-based service templates are proposed for the specification of these service offerings. Lessons learned during the implementation phase and feedback from ICT-19 verticals will be considered for the further refinements of these templates.

[End of abstract]

Disclaimer

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Executive summary

The success of 5G will be judged by the level of utilisation of its advanced capabilities by industry verticals to deliver new and innovative services that are stable enough to introduce into the market. As the 5G standards mature and awareness of the capabilities of the technology increases, verticals are becoming more eager to test new services and develop them to the level of maturity required for adoption by the market. Consequently, there is a growing urgency to provide a realistic 5G experimentation environment that is open to verticals and which supports rapid and agile testing of real-world use cases. 5G-VINNI project comes in response to this urgency. It aims at developing an advanced 5G E2E facility infrastructure that can be accessed and used by vertical customers such as from ICT-19 projects to set up trials of innovative use cases and validate their KPIs.

This document is the first Work Package 3 (WP3) deliverable and is mainly focused on the services offered by the different facility sites. These services will be network slices, delivered to vertical customers under the Network Slice as a Service (NSaaS) model. This model allows each customer to use the provided slice to set up and run one or more use cases with complete independence, assessing their behaviour and readiness under different contexts through the execution of a set of trials. The adoption of NSaaS as service delivery model is key to make 5G-VINNI facility a real 5G test and experimentation platform with multi-service and multi-tenancy support.

This deliverable provides an analysis of 5G-VINNI facility from a customer-facing viewpoint, with a special focus on the NSaaS model and the advanced control and testing capabilities it brings for vertical-driven experimentation activities. The first part of the document lays the foundation for this analysis, with the definition of concepts and terminology for NSaaS to be adopted by the 5G-VINNI project, and with the presentation of an overview of the related state-of-the-art solutions in industry fora and standardisation bodies, research projects and open source initiatives. The second part of the document presents how model-based service offerings and automated functions will be exposed through APIs to verticals such as in the ICT-19 projects to facilitate zero-touch management of their network slice services, from service ordering to service decommissioning. Finally, the 5G-VINNI service portfolio is presented, with the publication of the different service offerings per facility site.

This deliverable is the cornerstone for the detailed implementation activities within WP3, including the detailed design of service templates for the description of the different service offerings, and the development of APIs allowing customer-facing network slicing management for and across 5G-VINNI facility sites. In addition, it aims at guiding the activities related to testing capabilities and their exposure to verticals, under WP4 responsibility.

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Abbreviations

3GPP	3rd Generation Partnership Project
5G	Fifth Generation (mobile/cellular networks)
5G-PPP	5G Public Private Partnership
5GC	5G Core
AGV	Automated Guided Vehicle
API	Application Programming Interface
AR	Augmented Reality
B2B	Business to Business
B2B2X	Business to Business to Everything
B2C	Business to Consumer
B2H	Business to Household
BBF	Broadband Forum
BSS	Business Support Systems
CI/CD	Continuous Integration / Continuous Development
CN	Core Network
CSC	Communication Service Customer
CSP	Communication Service Provider
CU	Centralised Unit
DL	Downlink
DU	Distributed Unit
E2E	End-to-End
eMBB	Enhanced Mobile Broadband
EPC	Evolved Packet Core
ETSI	European Telecommunications Standards Institute
FWA	Fixed Wireless Access
GSMA	GSM Association
GST	Global Slice Template
HD	High Definition
IETF	Internet Engineering Task Force
IMS	IP Multimedia Subsystem
KPI	Key Performance Indicator
L2VPN	Layer 2 Virtual Private Network
L3VPN	Layer 3 Virtual Private Network
LTE	Long Term Evolution
MaaS	Monitoring-as-a-Service
MANO	Management and Orchestration
MEF	Metro Ethernet Forum
mIoT	Massive Internet of Things
mMTC	Massive Machine-Type Communications
MVNO	Mobile Virtual Network Operator
NaaS	Network-as-a-Service
NBI	Northbound Interface
NEST	Network Slicing Task Force
NETCONF	Network Configuration Protocol
NFV	Network Functions Virtualisation
NFV-NS	NFV Network Service
NFVIaaS	NFVI-as-a-Service

NGMN	Next Generation Mobile Network
NOP	Network Operator
NR	New Radio
NSA	Non-Standalone
NSaaS	Network Slice-as-a-Service
NSD	Network Service Descriptor
NSI	Network Slice Instance
NST	Network Slice Template
ODA	Open Digital Architecture
ONAP	Open Network Automation Platform
OSM	Open Source MANO
OSS	Operation Support Systems
PPDR	Public Protection and Disaster Relief
QoS	Quality of Service
RAN	Radio Access Network
RRH	Radio Remote Header
SA	Standalone
SC	Service Component
SDO	Standards Development Organisation
SECaaS	Security-as-a-Service
SLA	Service Level Agreement
SRTP	Secure Real-time Transport Protocol
SST	Slice Service Type
TaaS	Testing-as-a-Service
TCP	Transmission Control Protocol
TM Forum	Tele Management Forum
TOSCA	Topology and Orchestration Specification for Cloud Applications
UAV	Unmanned Aerial Vehicle
UDP	User Datagram Protocol
UHD	Ultra High Definition
UL	Uplink
UPF	User Plane Function
uRLLC	Ultra Reliable Low Latency Communications
V2X	Vehicle to Everything
VDU	Virtual Deployment Unit
VNF	Virtualised Network Function
VNFaaS	VNF-as-a-Service
VNFD	VNF Descriptor
VPN	Virtual Private Network
VR	Virtual Reality
VSB	Vertical Service Blueprint
ZOOM	Zero-touch Orchestration, Operations and Management
ZSM	Zero-touch Network and Service Management

1 Introduction

The mission of 5G-VINNI is to develop a large-scale, end-to-end (E2E) 5G facility that can be used to demonstrate that the performance capabilities conforming to 5G Key Performance Indicators (KPIs) can be met at realistic usage situations. To ensure that intended demonstrations are both representative and comprehensive, 5G-VINNI needs to achieve high use case diversity. To achieve this the engagement of industry verticals such as those taking part in 5G Public Private Partnership (5G-PPP) Phase 3 projects [1] (e.g. ICT-19 projects) is key. These verticals will bring a wide variety of innovative use cases that will be used to test and validate the 5G-VINNI facility and its components against 5G KPIs. To support the concurrent execution of different industry vertical use cases with isolation guarantees as foreseen in forthcoming commercial 5G systems, 5G-VINNI will rely on the use of network slicing technology.

5G-VINNI's combination of network infrastructures, service orchestration framework and testing tools will provide verticals with a unique platform for trialling diverse use cases. To facilitate the on-boarding of these verticals, 5G-VINNI will expose network slice lifecycle management functions through Application Programming Interfaces (APIs). By using these APIs, the verticals will be able to discover, order, provision and manage their slices in an isolated manner. With this network slice as a service (NSaaS) model, each vertical may be able to use the 5G-VINNI provided network slice to implement and test one or more use cases, executing different trials to evaluate their KPIs under different load scenarios.

1.1 Objective of this document

This document constitutes the first deliverable of WP3 "5G-VINNI End-to-End Facility Readiness and Operation". According to the project description [2], the objective of this deliverable is to "specify the network slice services to be offered by the 5G-VINNI facility sites supporting the selected 5G-VINNI use cases". For service specification, the principles of abstraction and customisability governing NSaaS capabilities will be considered.

The specific activities of this document include:

- Define and discuss the implications on the usage of NSaaS in 5G-VINNI facility.
- Definition and design of model-based service templates to describe 5G-VINNI service offerings. Made available via a centralised catalogue, these templates allow verticals to issue service orders, specifying the network slices they want to get from the 5G-VINNI facility.
- Identify and specify the management operations the verticals can consume from 5G-VINNI facility to discover, order, provision and operate their slices through their lifecycle. These operations will be exposed to verticals through APIs.
- Specify 5G-VINNI service portfolio, by declaring the service offerings available per facility site.

1.2 Scope of this document

The present document forms the starting point of much of the work that is to be undertaken in WP3. It lays the foundation to provide operational facilities for readily defining and managing network slice service specifications and instances based upon re-usable service specifications. These service definitions and automated management functions will be exposed through external-facing interfaces to industry verticals to facilitate zero-touch lifecycle management of the network slices. The verticals will make use of these APIs to consume the network slices as a service, using them to deploy, test and validate their own use cases under different scenarios in terms of traffic load and application context.

In addition, this document bears relationship with deliverables from other WPs as follows:

- **WP1**: *D1.2 "Design of network slicing and support subsystems – v1" (input) and D1.3 "Design for systems and interfaces for slice operation – v1" (input)*. D3.1 builds on D1.2 [3] as a starting point for NSaaS definition, and on D1.3 [4] for the design of model-based service templates as well as the specification of management operations exposed to verticals. Although both D1.3 and D3.1 scope network slicing from a management and orchestration view, they address this topic from a counterpart view; indeed, D1.3 is focused on resource-facing issues, while D3.1 handles network slicing from a customer-facing perspective. This clear demarcation of scopes is illustrated in Figure 1.1.
- **WP2**: *D2.2 "5G-VINNI Solution facilities Ready for Operation report – v1" (output)*. D3.1 outcome will be used in D2.2 [5] to enhance the management and orchestration capabilities per facility site, at both the NFVO and Service Orchestration layers.
- **WP4**: *D4.1 "Initial report on test-plan creation and methodology, and development of test orchestration framework" (input) and D4.2 "Intermediate report on test-plan creation and methodology, and development of test orchestration framework" (output)*. On one hand, testing principles and KPIs discussed in D4.1 [6] have been taken into consideration for the design of model-based service templates designed in D3.1. On the other hand, the API exposed testing operations presented in D3.1 will guide the development of tools and components of the test orchestration framework detailed in D4.2 [7].
- **WP5**: *D5.1 "Ecosystem analysis and specification of B&E KPIs" (output).* The 5G-VINNI service ecosystem presented in D3.1 will be used as a reference for further discussion on potential actor role models in D5.1 [8].

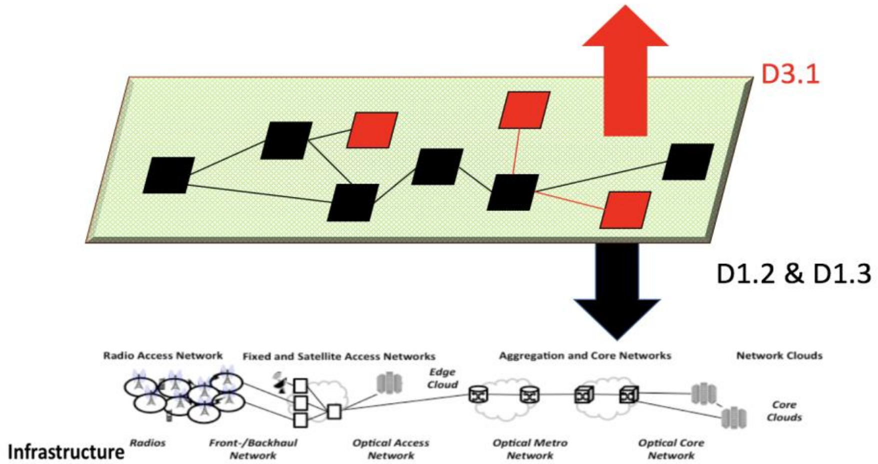

Figure 1.1: Demarcation point between D1.3 (resource-facing view on network slicing) and D3.1 (customer-facing view on network slicing).

Finally, this document covers the following 5G-VINNI milestones from the perspective of the facility service definition and specification:

- **MS2** "Release 0 of E2E facility" (Month 12, or M12), in which E2E slicing will be implemented in the facility supporting basic lifecycle events.
- **MS3** "Service offer and on-boarding roadmap for ICT-18-19-22 projects" (Month 15, or M15), in which initial results of KPI validation on Release 0 E2E network slicing will be included.
- **MS4** "Release 1 of E2E facility" (Month 18, or M18). For this milestone, E2E slicing will be implemented supporting all planned lifecycle events, making 5G-VINNI facility ready for use by ICT-18-19-22 projects and other external use cases.
- **MS5** "Release 2 of E2E facility" (Month 24 or M24), in which at least a minimum 2 vertical use cases from ICT-18-19-22 project(s) and 3 use cases from other external verticals will be on-boarded and running on network slices provided as a service by 5G-VINNI facility.

- **MS7** "Release FINAL of E2E facility" (Month 36 or M36), in which at least a minimum 4 vertical use cases from ICT-18-19-22 project(s) and 6 use cases from other external verticals will be on-boarded and running on network slices provided as a service by 5G-VINNI facility.

This document aims at providing guidelines for the implementation phase. Please note that the view on model-based service templates and vertical-facing management operations presented in this deliverable illustrates the desired outcome for the end of the project (MS7). For the first release (MS2), the different facility sites will use their specific implementation on service templates and APIs, which are dependent on their orchestration solutions. However, as the project progresses and interoperability becomes mature, the different facility sites will begin to update their implementations, adapting them to the guidelines presented in this deliverable, in order to provide a common, converged platform where site-specific implementation details can be abstracted to vertical customers.

1.3 Structure of this document

The rest of this document is structured as follows:

- Chapter 2 addresses the concept of NSaaS identified by pre-existing work and discuss the implications that the adoption of this service delivery model brings to 5G-VINNI service ecosystem.
- Chapter 3 provides an overview of the state-of-the-art and pre-existing work in areas related to service capability exposure and customer-facing network slices specification and operation. This overview will include research activities and outcomes from standardisation efforts, industry initiatives, research projects and open source initiatives.
- Chapter 4 captures the principles applicable to the design of model-based service templates describing 5G-VINNI network slice offerings. These templates can be used by 5G-VINNI vertical customers to make appropriate service orders, with information about the type and characteristics of network slices they want to obtain from the facility. The subsections within this chapter detail the structure of a 5G-VINNI service template, including constituent parts along with their parameters.
- Chapter 5 presents the set of service templates published in the 5G-VINNI service catalogue and remarks the differences that exist between their parameters (and their allowed value ranges). In addition, this chapter illustrates how service orders resulting from the invocation of these templates naturally leads to the Service Level Agreement (SLA) definitions.
- Chapter 6 provides an overview of network slicing management in NSaaS scenarios, focusing on how vertical customers can consume the management operations exposed via APIs to manage and control their slices during their lifecycle.
- Chapter 7 presents an initial service portfolio of the overall facility. In this portfolio, each facility site declares the types of network slices they plan to offer as a service to vertical customers, including information on delivery dates, capability exposure levels, and supported vertical use cases. Apart from being used by verticals for testing and KPI validation activities, these use cases will allow facility sites to assess the readiness of their service offerings, and if needed, improve them.
- Finally, Chapter 8 provides concluding remarks.

2 Service ecosystem in 5G-VINNI facility

5G-VINNI aims at building an end-to-end 5G infrastructure that integrates networking, computing and storage resources as well network softwarisation technologies to transform the network into a flexible, reliable and secure well-orchestrated facility across multiple administrative domains. This facility is conceived to be an experimentation platform that can be accessed and used by industry verticals to set up trials of innovative use cases. To allow verticals to test and validate their use cases, 5G-VINNI facility shall provide an adequate level of openness and exposure. This level shall ensure that different vertical customers can make use of required capabilities from the 5G-VINNI facility in such that they can execute their use case trials with isolation guarantees.

To address the above issue, 5G-VINNI facility will leverage network slicing. The reason behind this decision is twofold. First, network slices are isolated from each other in terms of performance, management and security, thus behaving as separate logical networks. Secondly, network slices can be designed on a per vertical basis. This means that a given network slice can be optimised (e.g. in terms of capacity, functionality, etc.) to satisfy the specific use case requirements of a given vertical. According to this reasoning, network slices can be seen as vertical-tailored network environments where verticals can conduct trialling activities with their use cases with complete independence. Drawing upon this idea, 5G-VINNI can deploy different network slices, and provide them to corresponding verticals as a service, so they can consume them as desired. With this Network Slice as a Service (NSaaS) model, a vertical can use the provided network slice to deploy, configure and test one or more use cases, assessing their behaviour and readiness under different contexts through the execution of a set of trials.

In this section, we will present the service ecosystem in 5G-VINNI, assuming the adoption of NSaaS as a service delivery model. First, we will provide an overview of potential verticals that can access and use the 5G-VINNI facility infrastructure to run their own use cases. Then, we provide some notions on how 5G-VINNI facility can support the execution of these use cases, including a description of network slicing and enabled service delivery models. Later, the service delivery model of NSaaS will be presented, reinforcing the importance to provide verticals with tailored environments where they can execute their use cases with isolation guarantees. Finally, the implications of NSaaS in 5G-VINNI service ecosystem will be discussed.

2.1 Verticals in 5G-VINNI facility

One of the key assets of the project is the ability to allow authorised customers to access 5G-VINNI facility infrastructure for testing and validation purposes. Most of these customers will be organisations and enterprises from non-telco environments, the so-called vertical industries. These industries are gaining great attention, as their integration into telco industry is considered key to boost service innovation and contribute towards global digital transformation.

Customers that can benefit from 5G-VINNI are of quite different types. This include verticals of different size, with different market perspectives and from different industries. Global5G project [9] has defined the following vertical industries:

- Agriculture and farming (AGR)
- Automotive (AUTO)
- Energy (ENRGY)
- Health (HEALTH)
- Industry 4.0 (I4.0)
- Media & entertainment (M&E)
- Public safety & divide resorption (PS)
- Smart cities (SMART)
- Transport & logistics (TRAN).

The on-going 5G-PPP Phase 2 projects [10] take the above list to identify potential customers of their architectural frameworks. Table 2-1 presents a cartography with the vertical industries targeted by these projects.

Table 2-1: Verticals cartography for 5G-PPP Phase 2 projects

5G-PPP Project	AGR	AUTO	ENRGY	HEALTH	I4.0	M&E	PS	SMART	TRAN
5GCAR		X							
5GCity						X		X	
5G ESSENCE						X			
5G-MEDIA						X			
5G-MoNArch								X	X
5G-PICTURE						X		X	X
5G-PHOS					X			X	
5G-TANGO					X	X			
5G-TRANSFORMER		X		X		X	X		
5G-XCast						X	X		
BlueSpace						X		X	
IoRL						X			
MATILDA		X			X	X	X	X	
METRO-HAUL						X	X		
NGPaaS							X		
NRG-5			X						
one5G	X	X			X	X		X	
SaT5G	X					X	X		X
SLICENET			X	X					

5G-VINNI facility expects to serve verticals from the abovementioned industries throughout the project's lifetime. However, what verticals will finally become 5G-VINNI customers will depend on partners involved in financed ICT-19 projects.

2.2 Vertical use cases: Characterisation and mechanisms for their support

5G-VINNI facility is intended to be a multi-service experimental infrastructure, able to satisfy the myriad of service requirements imposed by the use cases that vertical customers will bring. These use cases represent application scenarios of innovative, 5G communication services satisfying both human and industrial communication. Unlike today's Mobile Broadband (MBB) services in 4G, focused on user-centric voice and Internet services with a certain control of Quality of Service (QoS), the new communication services will meet the needs from a wide variety of vertical industries, some of them scoping completely different performance requirements and business goals.

This section provides a summary of the main concepts the 5G-VINNI facility leverages to support the upcoming vertical use cases. This includes a brief overview on 5G communication services, a description of the network slicing technology, and a reasoning on the role this technology plays when network slices become an integral part of service provisioning mechanisms.

2.2.1 5G Communication Services

Communication services in 5G likely have a plethora of performance requirements, ranging from low bit rate high latency services to high bitrate low latency services, and everything in between. Indeed, 5G systems may support services requiring very low and very high bandwidths, very dense connectivity as well as coverage of areas where few connections are active at a given moment, centralisation of functions to drive economy of scale, but also distribution of functions very close to the user to reduce latency and deliver content with local context. As seen, these requirements are not only quite different, but also incompatible with each other in some cases.

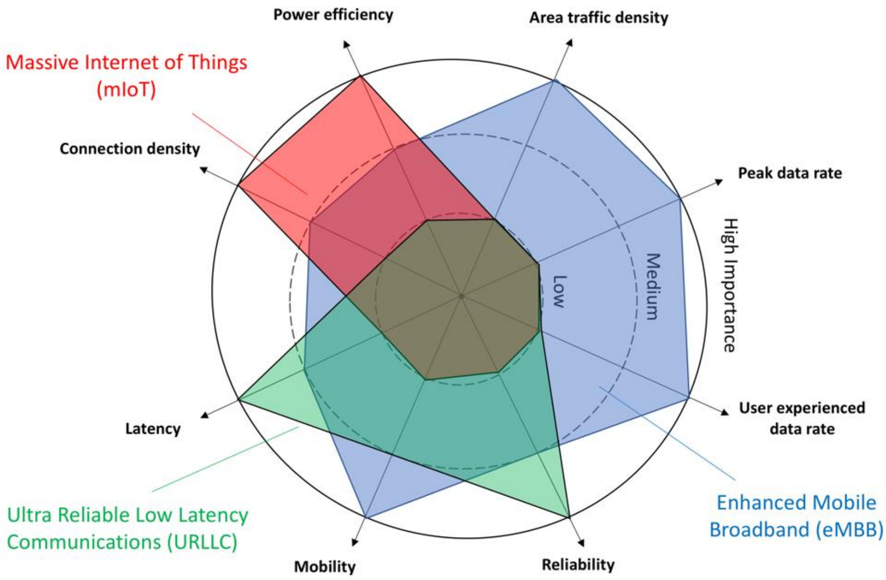

Figure 2.1: Classification of 5G communication services

To deal with this heterogeneity, many Standards Development Group (SDOs), industry forums and alliances have agreed in the necessity to define a classification where services with similar requirements can be grouped into the same category. For example, International Telecommunication Union (ITU) [11], 5G-PPP [12] and 3GPP [13] have proposed a classification consisting in three big service categories: enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communication (uRLLC) and Massive Internet of Things (mIoT). This classification has become de-facto for 5G, and assumes the following: depending on its performance requirements, any 5G communication service can fall into one of the following categories (see Figure 2.1):

- *eMBB:* this category includes communication services able to provide high data rates and supporting high traffic density values. eMBB service type is meant to extend traditional MBB scenarios, particularly those that require higher data rates, lower latency, and a more seamless user experience (reliable broadband access) over large coverage areas. eMBB distinguishes between two types of scenarios: hotspot scenarios and wide-area coverage scenarios. On the one hand, hotspot scenarios handle static users in indoor environments with high throughput requirements and with no (or very low) mobility. On the other hand, wide-area coverage scenarios support users in outdoor environments with medium to high mobility, providing them with uniform and seamless service experience.
- *uRLLC:* this category includes communication services fulfilling performance requirements of low-latency and high availability and reliability.
- *mIoT:* also referred to as massive Machine-Type Communications (mMTC), this category includes communication services offering improved network coverage with high connection density support. Most of these services involve the presence of a very large number of power-constrained IoT devices with long operational lifetime, transmitting volumes of non-delay sensitive data to exchange information with other devices or apps hosted in remote cloud servers.

2.2.2 Network Slicing

One of the key drivers of 5G-VINNI is the need to support communication services from different verticals in a cost-effective manner and with great sustainability. As studied in Section 2.2.1, these services are expected to have quite different requirements. Additionally, some of these services need to be executed concurrently. This entails a great challenge, considering that a single 5G facility infrastructure shall be able to satisfy these diverging service requirements, potentially at the same time. To cope with this heterogeneous set of service requirements at reduced costs, 5G-VINNI facility adopts a novel architectural approach: network slicing. In this section, a brief notion on network slicing technology will be provided.

Network slicing is a cutting-edge technology that aims at splitting the E2E network infrastructure into a set of logical network partitions, each optimised (in terms of resources, topology, functions, configuration and management) to satisfy a given set of service requirements. These requirements can come from one or more communication services. For more information about key principles that network slices build on, please see D1.2 [3].

Network slices are deployed and operated in the infrastructure in the form of Network Slice Instance (NSIs). The following definitions are considered for the concept of NSI:

- An NSI (object) is the result of instantiating a given network slice (class). This means that:
  - Multiple NSIs can be instantiated from the same network slice.
  - An NSI can accommodate one or more communication service instances.
- NSIs are executed in parallel on top of a single, shared E2E network infrastructure.
- NSIs are isolated from each other in terms of performance, management and security.

Figure 2.2 illustrates the network slicing approach by showing three NSIs that are executed on top of a common network infrastructure. These NSIs corresponds to instances of three types of network slices: eMBB (NSI#1), uRLLC (NSI#2) and mIoT (NSI#3). For sake of simplicity, one NSI from each network slice is shown. In this example, instances of communication services requiring very high data rates, mobility and traffic area density could be accommodated in NSI#1, while those one requiring very high reliability and ultra-low latency could be accommodated in NSI#2. Finally, communication service instances requiring very high connection density and energy efficiency would be accommodated in NSI#3.

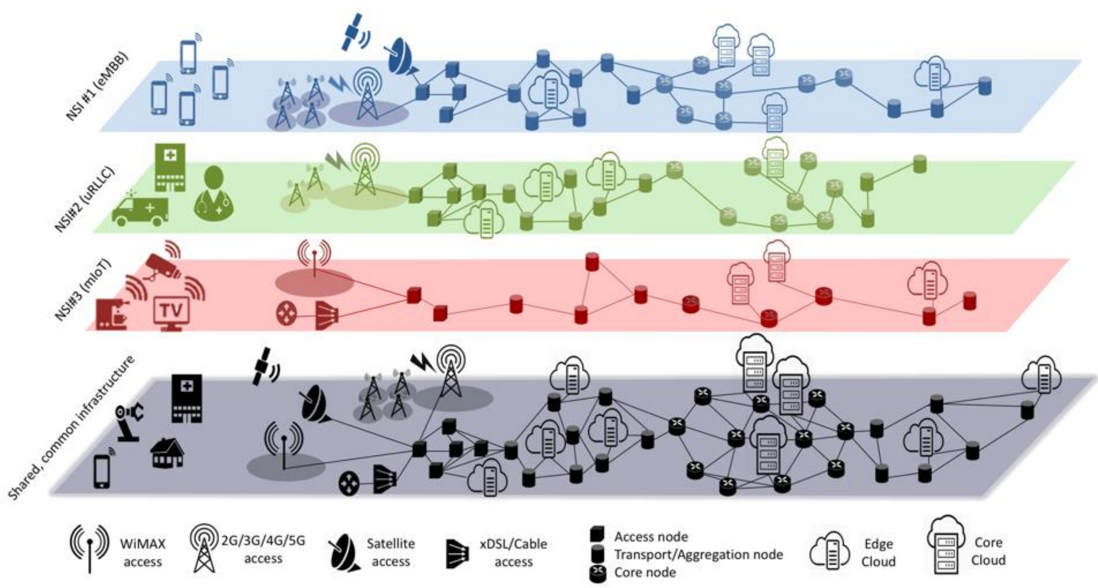

Figure 2.2: Illustration of network slicing concept (adapted from [14])

As mentioned earlier, a network slice can accommodate one or more communication services. This depends on network slice criteria design. This design can be of quite different types, ranging from coarse-grained network slices, i.e. one network slice for each 5G service category, to more fine-grained network slices, i.e. one network slice for communication service. On the one hand, the first option allows working with a small number of network slice types, which bring significant advantages in terms of reusability multiple NSIs can be deployed from the same network slice type) and management (the less the number of network slice types, the easier their maintenance and operation) at the cost of lacking customisation. This approach assumes each network slice is able to accommodate all the communication service that fall under corresponding 5G service category. On the other hand, the second option allows more customisation, at the cost of preventing reusability and introducing scalability burdens in the management plane.

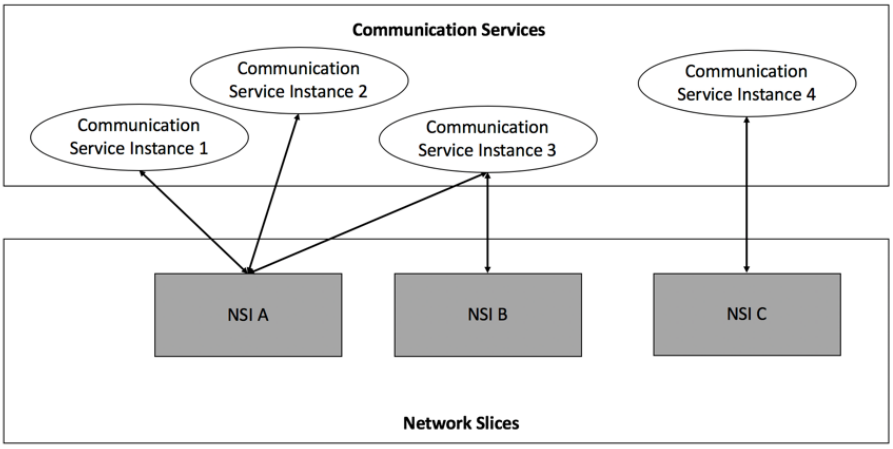

Figure 2.3: Relationships between communication services and network slices. Scenario 1

According to the above discussion, different criteria for network slice design may result in different relationships between communication service (instances) and network slice (instances). Figure 2.3 shows an example of their mapping. For sake of simplicity, we assume NSIs and communication service instances are deployed from different network slices and communication services, respectively. In this setup, it can be noted that network slices A and C are coarse-grained and fine-grained network slice types, respectively. The first is able to satisfy the requirements of communication services 1, 2 and 3, while the latter is optimised to support communication service 4. However, the major novelty comes when analysing communication service 3. As it can be seen, it needs both network slices A and B. This situation may happen when two conditions are met:

- Designed network slices are coarse-grained. In our example, network slices A and B could be of eMBB and uRLLC types.
- The communication service brings very specific service requirements that cannot fall into a single service category but result from the combination of two or more. In our example, communication service 3 could be an automotive service requiring very high throughput for infotainment (eMBB) but also very low latency and high reliability for autonomous driving (uRLLC).

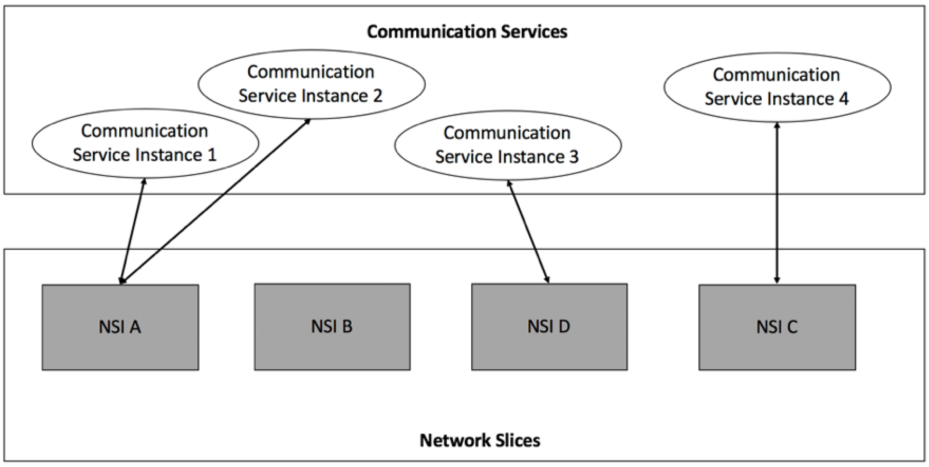

Figure 2.4: Relationships between communication services and network slices. Scenario 2

A solution to solve this issue could be to design a fine-grained NSI (NSI 4) optimised for communication service 3. With this approach, the new scenario would remain as shown in Figure 2.4.

2.2.3 Service delivery models with network slicing support

The aim of this section is to present the business models that can be established when network slicing is used for the provisioning of communication services. These models assume the existence of innovative provider-client relationships between actors involved in the service value chain, with these actors taking different roles, according to the position in the service value chain. Figure 2.5 shows the roles that 3GPP has defined for service ecosystem in 5G. As done in [3][4], these roles will be used as a reference in 5G-VINNI. For more information on this framework, see 3GPP TS 28.530 [13].

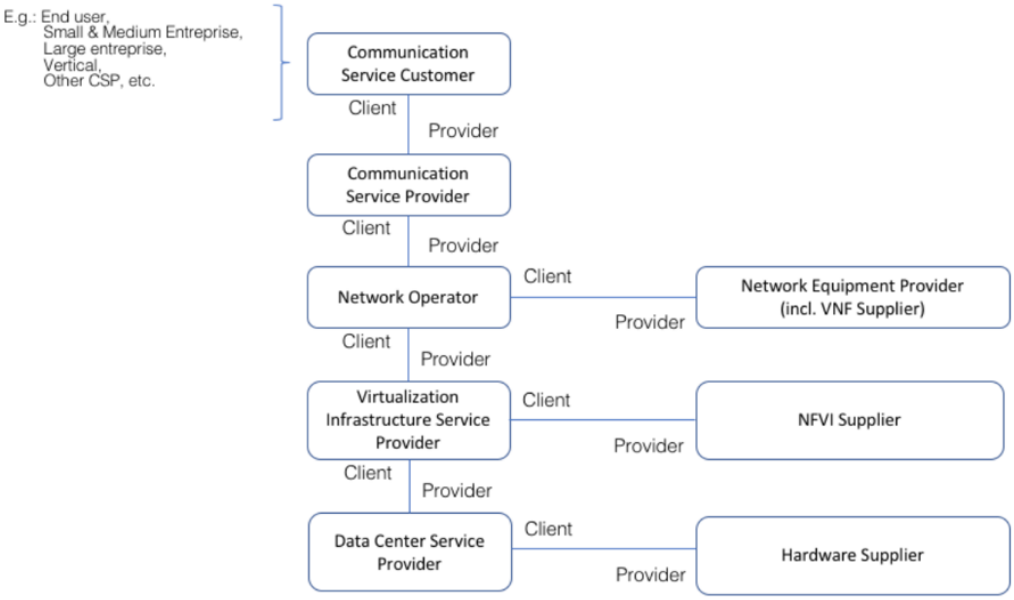

Figure 2.5: Roles on 3GPP service ecosystem for 5G (source: [13])

Scoping network slices and communication services, the following roles apply:

- *Network operator (NOP):* deploys and operates instances of one or more network slices. The components of NSIs, including shared and dedicated instances of NFV network services (NFV-NSs), are also under the management scope of this role.

- *Communication Service Provider (CSP):* deploys and operates instances of one or more communication services. The CSP can map these instances into corresponding NSIs.
- *Communication Service Customer (CSC):* consumes the communication services provided by the CSC.

As seen from the above description, the NOP deals with network slices, while the CSP focuses on communication services. CSP could leverage NSIs to bring business innovation for service provisioning towards CSC, hence opening up new opportunities in terms of service monetisation. This innovation depends on whether NOP makes managed NSIs available to the CSP or not. Using this criterium, two scenarios can be considered:

- *NOP does not expose managed NSIs to the CSP*. The NOP uses NSIs to host communication service (instances) from the CSP in an optimised manner, but do not make them available to the CSP; indeed, the mapping between communication services and network slices is up to the NOP. In this situation, only the NOP has knowledge of the existence of network slices, but not the CSP, who becomes slice-agnostic. This means that network slices are not part of the CSP service offering and hence CSP does not have the opportunity to use network slicing from a business perspective. The service delivery model derived from this scenario is known as *network slices as NOP internals*, and it is shown in Figure 2.6a.
- *NOP exposes managed NSIs to the CSP*. The NOP makes NSIs available to the CSP, allowing the latter to consume them at its own. In this scenario, when the CSP is provided with an NSI from the NOP, it could proceed in two ways. On the one hand, the CSP could use the NSI to host one or more communication services that will be later delivered to the CSC. This is very similar to the first scenario, with the exception that the CSP is the one that controls mapping between communication services and network slices. On the other hand, the CSP could offer the NSI to the CSC in the form of a communication service, allowing the CSC to consume it as desired. This situation when the CSP makes an NSI available to the CSC is called *Network Slice as a Service (NSaaS)*. An example of NSaaS is illustrated in Figure 2.6b. As it can be seen, the CSC can play the role of CSP and offer their own communication services on top of the provided NSI. In this model, both CSP offering NSaaS and CSC consuming NSaaS have the knowledge of the existence of network slices. Depending on service offering, CSP offering NSaaS may impose limits on the NSaaS characteristics exposure to the CSC, and the CSC can manage the NSI according to NSaaS characteristics and agreed upon limited level of management by the CSP.

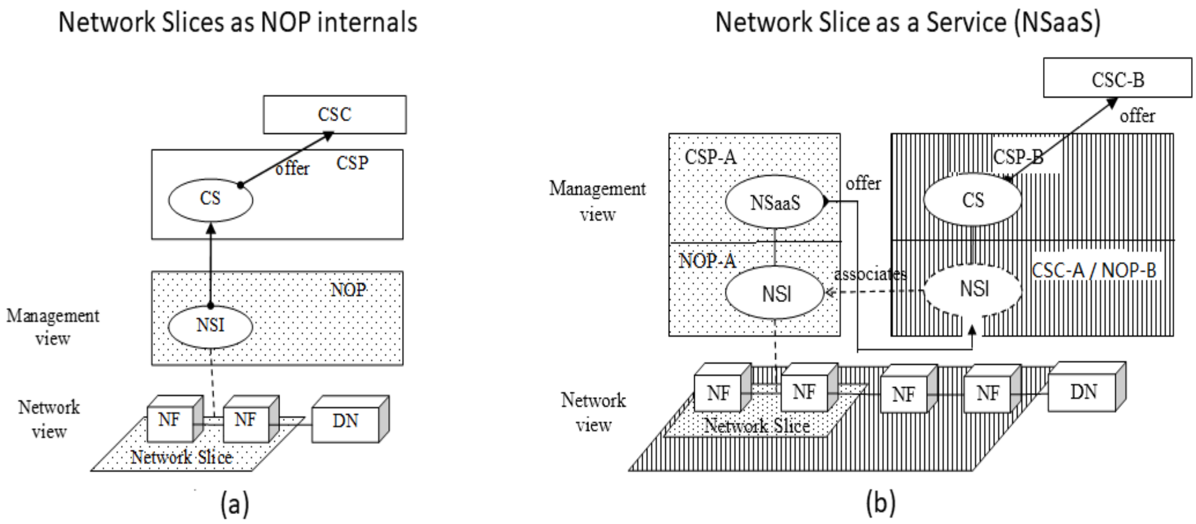

Figure 2.6: Service delivery models with network slicing support (source: 3GPP TS 28.530 [13])

As seen from the above descriptions, the first delivery model is useful in the context of Business to Consumer (B2C), Business to Household (B2H) and Business to Business (B2B) services, where the CSC is an individual customer, household and business, respectively. However, NSaaS goes a step further, allowing Business to Business to Everything (B2B2X) scenarios. In B2B2X, a business entity (CSP) provides the service to another business entity (CSC), who in turn make use of the provided service to offer new services (CSP) to its own customers. This is illustrated in Figure 2.6b, where the same business entity on the right side takes the role of CSC-A (i.e. when receiving the network slice from the CSP-A) and of CSP-B (i.e. when providing communication service to CSC-B). In 5G-VINNI, this business entity would be an ICT-19 vertical accessing 5G-VINNI facility. These are the type of scenarios that 5G-VINNI is interested in. For this reason, NSaaS will be the selected service delivery model for the project. However, this does not limit the implementation of other service delivery models using the 5G-VINNI facility, as discussed in D5.1 [8].

2.3 NSaaS in 5G-VINNI facility

The scope and applicability of NSaaS in 5G-VINNI facility can be well explained with the above example. As seen in Figure 2.6b, a network slice is provided to CSC-A by CSP-A. Unlike the communication service delivered to end customers, the communication service is the actual network slice. CSC-A can use the network slice provided by CSP-A and optionally extend it by adding some network functions. In such a case, CSC-A also plays the role of NOP-B. Later, CSC-A (NOP-B) provides the (extended) network slice to CSP-B. Finally, CSP-B can use the offered network slice built by CSC-A (NOP-B) to deliver communication services to end customers (CSC-B).

This scenario can be easily applied in the context of 5G-VINNI, as described in Table 2-2.

Table 2-2: Applicability of NSaaS in 5G-VINNI project

5G-VINNI actor	Role	Description	5G-VINNI scope
5G-VINNI facility	NOP-A	Designs network slices. Deploys and operates network slice (instances) in the facility infrastructure.	Yes (resource-facing)
	CSP-A	Takes network slices (instances) and offer them as services to 5G-VINNI customers, under the NSaaS model. A network slice (instance) offered with NSaaS is a network slice service (instance).	Yes (customer-facing)
5G-VINNI customer, e.g. ICT-19 vertical	CSC-A	Consumes the network slice service (instance) provided by 5G-VINNI facility.	Yes (customer-facing)
	NOP-B (Optional)	Extends the network slice service (instance) provided by 5G-VINNI facility, adding some 3rd party NFs.	Yes (customer-facing)
	CSP-B	Designs one or more use cases, each representing an application scenario of a given 5G communication service. Deploys and operates use cases in the network slice service (instance).	No
5G-VINNI customer's customer (e.g. ICT-19 vertical's customer)	CSC-B	End customer of the 5G-VINNI customer.	No

From the roles referred in Table 2-2, note that CSP-B and CSC-B roles are up to industry verticals (e.g. ICT-19 verticals), and thus out of scope of 5G-VINNI project. From the other roles, we can classify them into two big groups:

- *Customer-facing service roles*: focus on the interaction of the 5G-VINNI customer with the 5G-VINNI facility. Examples of issues addressed by these roles include the design and maintenance of a service portal to allow verticals to gain access to the 5G-VINNI facility, model-based service templates to announce offered network slices to verticals, and external-facing APIs that vertical can consume from service ordering to service decommissioning, and mechanisms for the provisioning and fulfilment of network slice service (instances) from deployed NSIs. Roles that fall within this group are CSP-A and CSC-A (optionally NOP-B).

- *Resource-facing service roles*: focus on the deployment and operational aspects of the 5G-VINNI facility infrastructure. Examples of issues addressed by these roles include lifecycle management of network slice (instances) and the allocation/placement of their components (e.g. virtualised and physical network functions arranged into one or more NFV-NS) in multi-domain environments. NOP-A is a role that falls within this group.

According to the above discussion, the service ecosystem in 5G-VINNI remains as shown in Figure 2.7. Deliverable D3.1 will focus on network slicing in 5G-VINNI from a customer-facing perspective, with the NSaaS at the centre of the discussion, and with CSP-A and CSC-A (optionally NOP-B) as relevant roles. This constitutes the counterpart view of the work done in D1.3 [4], addressing network slicing for a resource-facing viewpoint, and scoping NOP-A and underlying roles.

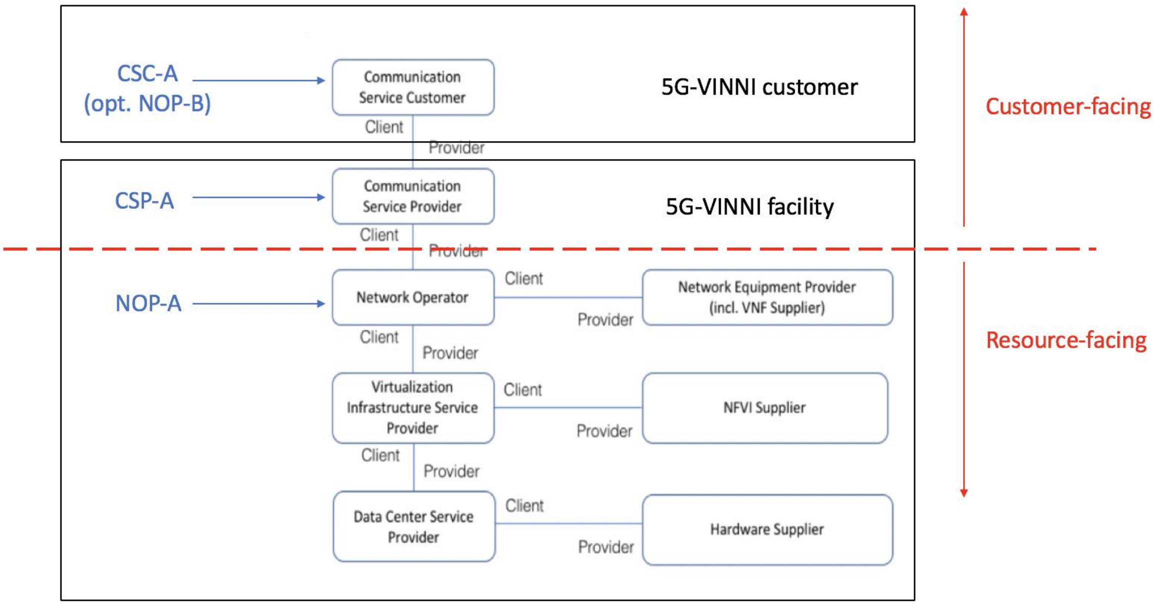

Figure 2.7: 5G-VINNI service ecosystem

For the sake of simplicity, from here onwards the role of CSP-A will be referred to as CSP, and CSC-A (NOP) will be referred to as CSC.

In the following subsections, we clarify some implications about NSaaS that are relevant in the context of the above ecosystem.

2.3.1 Network slice vs network slice service

In any as-a-service delivery model, there always exists an abstraction between what is offered (as a service) and what is really deployed. This can be noticed not only in cloud-based IT models like Infrastructure as a Service (IaaS) and Platform as a Service (PaaS), but also in recent networking models like NFV Infrastructure as a Service (NFVIaaS) and VNF as a Service (VNFaaS). The intended abstraction is also applicable to NSaaS, where CSP might intentionally hide some details of the deployed NSI to the CSC. The fundamental reasons for this strategy are two. First, it allows preserving a clear demarcation point between the CSP and the CSC in terms of management, security and privacy. Secondly, it may help to hide complexity to CSC, which is of particular interest to those verticals with low networking expertise.

According to the above reasoning, the concepts of network slice (instance), i.e. what CSP has at its disposal, and network slice service (instance), i.e. what CSC requests to/receives from CSP, are not the same. Network slice service (instance) is the set of capabilities of a network slice (instance) that are exposed by the CSP to a CSC. The exposed capabilities can be consumed by the CSC using external-facing APIs provided by the CSP. With the invocation of these APIs, the CSC can take the control of the network slice service (instance) and use it as expected: as an isolated and tailored network environment where the CSC can conduct trialling activities with one or more use cases.

2.3.2 5G-VINNI service offerings: design and publication

To inform CSCs of service offerings in 5G-VINNI, the CSP will define a service catalogue, with different model-based service templates, each describing a different network slice service. Similar to existing Network Service Descriptors (NSDs) [15] and VNF Descriptors (VNFDs) [16], these templates are reusable and conceived to provide a self-contained specification of required network slice service (instances), so that their deployment and operation can be automated as much as possible. Additionally, to gather vertical-specific requirements in service specification, the templates provide some degree of customisation, allowing the CSCs to modify (adjust) some fields in the templates with values according to their specific needs. For more details on these templates and their registration/publication on a service catalogue, see Chapters 4 and 5.

2.3.3 5G-VINNI service management

When coming to 5G-VINNI, CSC may browse the service catalogue, select (and fill) a given service template, and issue the corresponding service order towards the CSP. Upon receiving the order, the CSP needs to provide the CSC with a network slice service instance. This instance is the exposed set of capabilities of an NSI, with this NSI being dedicated (option 1) or shared (option 2). On the one hand, option 1 allows achieving a more isolated environment, at the cost of preventing multiplexing gains and introducing some scalability issues in the management plane. On the other hand, option 2 provides worst levels of isolation, but allows better resource usage and the execution of lower number of NSIs, which is desired from a resource-facing perspective.

This decision of choosing one or another option is up to the CSP, and depends mainly on the service requirements issued by CSC in the service order, with a special focus on the following ones: performance, level of isolation, and above all the level of control it wants to take over the provided network slice. Indeed, some CSCs (i.e. CSCs with low networking expertise) may want the service instances to deploy use cases and simply carry out passive monitoring activities, while others CSC may want to have a real control of the slice, leading testing and managing activities within it. In the first case, option 2 could be selected, while option 1 is the best choice for the second case. The CSP makes the decision of one or another option in the preparation phase, when CSC and CSP have agreed on exposed capabilities.

After the abovementioned decision, CSP provides the network slice service instance to the CSC. The instance may include a set of external-facing APIs that the CSC will consume to manage the instance at run-time as agreed in the preparation phase.

Figure 2.8 illustrates the interaction between CSP and CSC from a management viewpoint. As seen, during the preparation phase (i.e. the network slice service instance has not been created yet), the CSC gains access to the CSP’s E2E Service Management and Orchestration, where negotiation and agreement on exposed capabilities takes place. In the run-time phase (i.e. the instance has been deployed and delivered to the CSC), the CSC may use the provided external-facing APIs to interact with different CSP’s management functions, consuming their exposed operations according to the above agreement. For more information on interaction between CSC and CSP throughout the lifecycle of a network slice service, see Chapter 6.

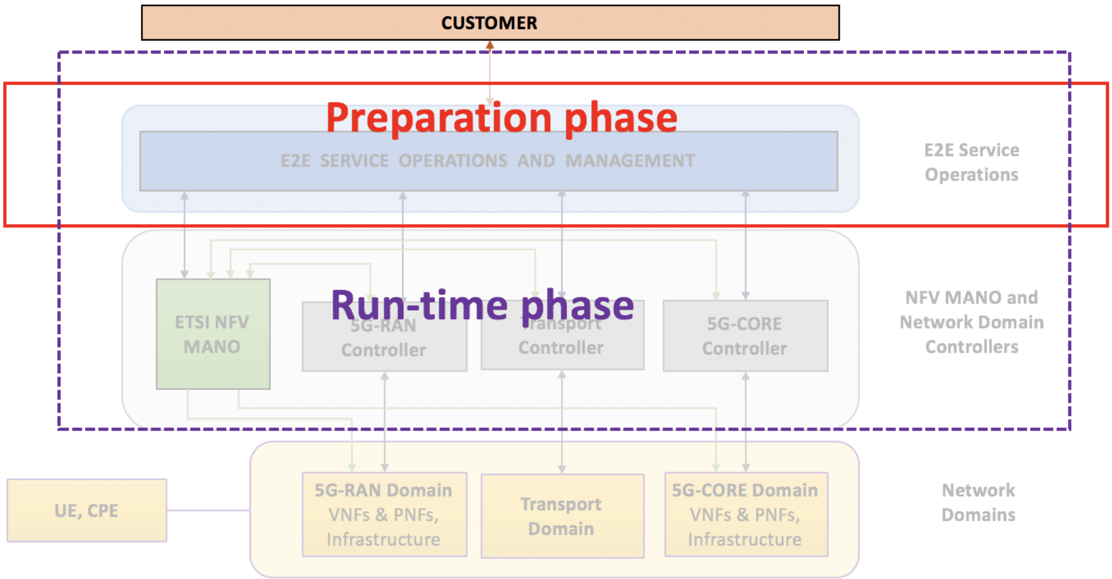

Figure 2.8: CSC accessibility to CSP's management domains in each lifecycle phase

3 State of the art

This chapter provides an (non-exhaustive) overview of those solutions that are relevant to handle customer-facing service operability issues in the context of the 5G-VINNI project. These issues, key to turn deployed network slices into experimentation platforms where CSCs can set up trials of different use cases, can be arranged into three big topics:

- Architectural enhancements, for model-driven realisation of NSaaS
- Network slice capability exposure to CSCs
- Testing and validation

The abovementioned topics will be discussed and analysed in relation to the activities and outcomes from existing industry associations and SDOs (Section 3.1), research projects (Section 3.2), and open source communities (Section 3.3). This state-of-the-art study of customer-facing network slicing complements the overview presented in D1.3, also focused on network slicing but from a resource-facing viewpoint.

For the sake of brevity, only high-level conclusions are presented in Chapter 3. For more details of the intended discussion and analysis, please see Annex A.

3.1 Industry fora and SDOs

This section provides some details of research activities in different organisations that are relevant for customer-facing service management issues in 5G-VINNI facility. This includes outcomes from vertical industry organisations, telco industry organisations and SDOs. Figure 3.1 depicts a landscape of organisations followed by 5G-VINNI project, including relationships between them.

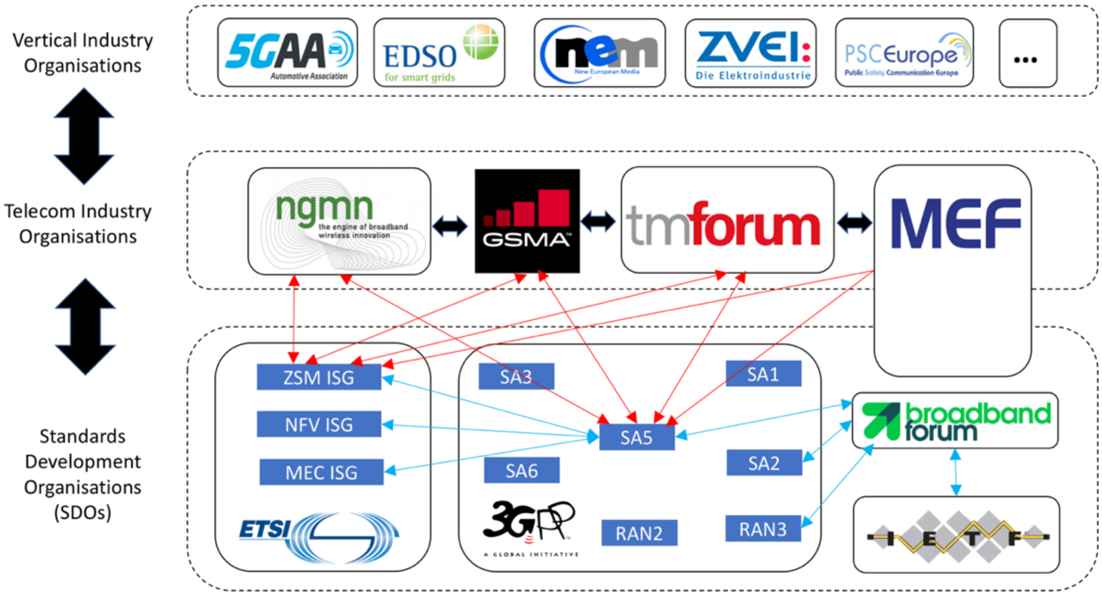

Figure 3.1: Industry fora and SDOs relevant for 5G-VINNI project

In this deliverable, we mostly focus on telco industry associations. Their mission is to collect information on vertical-specific service requirements from industry associations of different vertical sectors, identify potential technologies that can satisfy these requirements, and inform corresponding SDOs, so that they can develop appropriate technology solutions. Most of SDOs have been already presented in D1.1 [17] and discussed in D1.3 [4]. Additionally, most of the topics addressed by these SDOs are resource-facing issues. For this reason, they will be omitted in this document.

Telco industry organisations analysed in this deliverable include Next Generation Mobile Networks (NGMN) Alliance, GSM Alliance (GSMA), Tele Management Forum (TM Forum) and Metro Ethernet Forum (MEF). A brief summary of the scope of these organisations in relation to the topics addressing customer-facing service operability issues concerning 5G-VINNI is shown in Table 3-1. More details can be found in Annex A.1 and Annex A.2.

Table 3-1: Relevant telco industry associations and their relationship with customer-facing topics in 5G-VINNI

Telco industry association	Architecture and modelling	Capability exposure	Testing and validation
NGMN	✓	✓	✓
GSMA	✓	✓	×
MEF	×	✓	✓
TM Forum	✓	✓	✓

3.2 Research projects

The aim of this section is to high the main research projects whose activities and outcomes are relevant for the 5G-VINNI project in terms of how a CSP can provide different CSCs with isolated, experimental environments for use case verification, validation and testing. Although there are a high number of 5G-PPP Phase 2 projects in course (see Table 2-1), 5G-VINNI focuses on 5G-TRANSFORMER, 5GTANGO and SLICENET. These three projects along with 5GinFIRE (project from FIRE programme) are the ones selected for discussion.

A brief summary of the scope of these organisations in relation to the topics addressing customer-facing service operability issues concerning 5G-VINNI is shown in Table 3-2. More details can be found in Annex A.2 and Annex A.4.

Table 3-2: Relevant research projects and their relationship with customer-facing topics in 5G-VINNI

Research project	Architecture and modelling	Capability exposure	Testing and validation
5G-TRANSFORMER	✓	✓	×
5GTANGO	×	×	✓
SLICENET	✓	✓	×
5GinFIRE	×	✓	✓

3.3 Open Source Platforms

Finally, this section provides an overview of customer-facing service topics covered by open source platforms. In the context of 5G-VINNI project, solutions from Open Network Automation Platform (ONAP) and Open Source MANO (OSM) projects are relevant. Table 3-3 provides a summary of the scope of the two big open source platforms. More details can be found in Annex A.3 and Annex A.4.

Table 3-3: Relevant open source platforms and their relationship with customer-facing topics in 5G-VINNI

Open source platform	Architecture and modelling	Capability exposure	Testing and validation
ONAP	✓	✓	×
OSM	✓	✓	×

4 Guidelines for the design and publication of 5G-VINNI services

The aim of this chapter is to provide some guidelines for the design and publication of network slice services in a service catalogue, so the CSP can showcase their availability to CSCs. Section 4.1 will introduce the concept of 5G-VINNI service catalogue. As pointed in Section 2.3.2, this catalogue will include model-based service templates to describe the CSP service offerings. The design principles of these templates will be discussed in Section 4.2. Finally, Section 4.3 will provide a detailed description of what specific information a template may have.

4.1 5G-VINNI service catalogue

5G-VINNI has a service catalogue to announce offered network slice services to vertical customers. The design and maintenance of the service catalogue brings benefits to both CSP and CSCs. On the one hand, the service catalogue provides a unified marketplace where the CSP can register and publish its service offerings at reduced costs. It also allows the CSP to create, centrally manage and execute DevOps toolchains, which is of particular interest for the application of Continuous Integration Continuous Delivery (CI/CD) practices in the maintenance and updating of those service offerings. On the other hand, the service catalogue provides mechanisms enabling self-service automation, which allows the CSC to carry out browsing and service ordering activities with great automation and in a user-friendly manner.

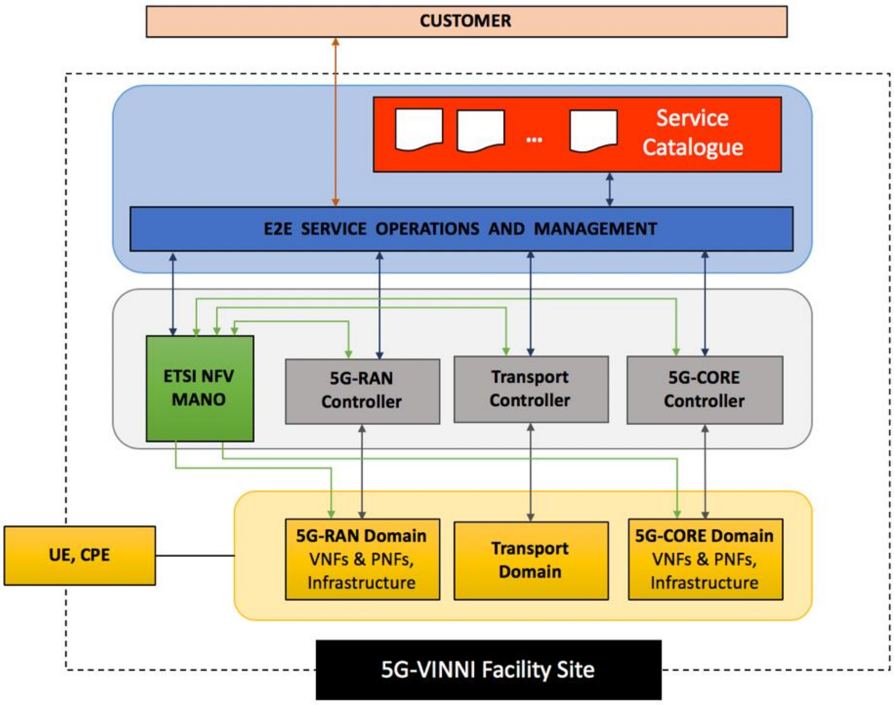

Figure 4.1: Service catalogue per facility site (first releases of the project)

In the earlier releases of the project, where interworking across sites is expected not to be mature enough, service provisioning may be carried out per facility site. This means that different facility sites will take the role of different CSPs, each with their own service offerings. In this situation, there is a service catalogue within each facility site, as shown in Figure 4.1. This (site-specific) service catalogue will be accessible through the E2E Service Management & Operations. However, as long as the project evolves and interoperability across sites becomes more mature, it is expected that the different facility sites agree to have a common catalogue, e.g. Greece and Spain may share the catalogue, as done today in the 5GinFIRE project. The end goal is to have a single CSP for the whole project, and thus a single (site-independent) service catalogue as depicted in Figure 4.2. To allow

CSCs to gain access to this service catalogue, the CSP will design a digital storefront providing a single-entry point to 5G-VINNI facility. The implementation of this storefront has not been decided yet by the 5G-VINNI consortium, although the use of a web portal is positioned as the most likely option.

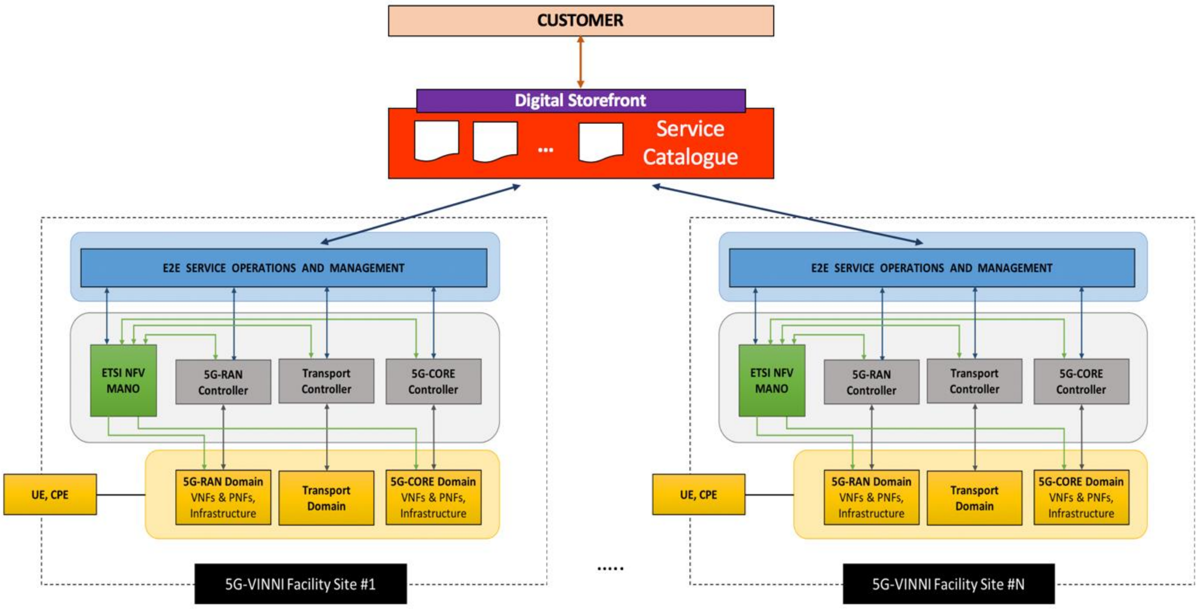

Figure 4.2: A single service catalogue for the overall 5G-VINNI facility (last release of the project)

4.2 Model-based service templates in 5G-VINNI

The network slice services registered and published in the 5G-VINNI catalogue are described using model-based service templates.

A service template is a structured document that provides a complete description of a given service, including information on service topology and expected behaviour. The service template is used by the CSP as a reference to conduct service management procedures, both at instantiation time (deployment procedures) and at run-time (operational procedures). The use of modelling in the design of a service template allows the CSP to streamline and optimise the management procedures, bringing automation and agility in their execution.

The use of model-based templates in the industry is not new. Indeed, different SDOs, alliances and fora have proposed templates to model entities under their management scope. In this context, it is worth noting the work carried out by ETSI ISG NFV, with the definition of three different templates: NSD, VNFD and Virtual Deployment Unit (VDU). The first two scope NFV-NSs and VNFs, while the latter is used to model VNF components. Following this strategy, other SDOs have also define their own templates for different manageable entities, including IETF (e.g. for L2VPN and L3VPN services), BBF (e.g. for mobile-converged services) or MEF (e.g. for connectivity and cloud services).

In the context of network slicing, some models have been proposed so far, including both resource-facing (D1.3 scope) and customer-facing (D3.1 scope) perspectives. In the resource-facing group, the following models are important: the Network Slice Template (NST), i.e. scoping 3GPP network slice, the Network Slice Subnet Template, i.e. scoping 3GPP RAN and CN network slice subnets, Transport Network Slice Template, i.e. scoping BBF transport network slice subnet, and the lower part of the ETSI ISG NGP model for network slicing. In the customer-facing group, the models discussed in Annex A are relevant, with a particular mention to the Global Slice Template (GST) model from the GSMA and the Vertical Service Blueprint (VSB) from the 5G-TRANSFORMER project.

In 5G-VINNI, service templates included in the service catalogue are called 5G-VINNI Service Blueprints (VINNI-SBs). A VINNI-SB is a baseline, model-based service template describing a given network slice service. The design of a VINNI-SB shall rely on the following principles:

- *Principle 1 – Stability:* a VINNI-SB shall have the ability to be used continuously and repeatedly.
- *Principle 2 – Reproducibility*: a VINNI-SB shall have the ability to generate repeatable instances at multiple location and at different instants.
- *Principle 3 – Reusability*: multiple instances of a given network slice shall be able to be deployed from a VINNI-SB. This allows different CSCs to make service orders against the same VINNI-SB when requiring instances of the same network slice service.
- *Principle 4 – Customisability*: deployed instances from a VINNI-SB shall be able to gather CSCs-specific requirements when requested from different CSCs. This means a VINNI-SB shall allow flexibility in service definition, allowing CSCs to take an active role in service specification.

A VINNI-SB consists of a set of parameters to describe the capabilities that the network slice service can provide. Section 4.3 provides an overview of these parameters along with their values. To facilitate customisation in service specification while allowing reusability in the use of VINNI-SB, some of the parameters defined in the VINNI-SB shall admit modification from CSCs, allowing each CSC to specify them with those values that best fit its service requirements (note that this approach is similar to the one followed by GSMA's GST and 5G-TRANSFORMERS's VSD). The set of parameters that are marked as modifiable in the VINNI-SB, and the values that can be selected for each of them, is up to the CSP defined policy. For the cases when a CSC is not interested in modifying one of these parameters, the CSP shall specify a default value for that parameter.

5G-VINNI service catalogue will have as many VINNI-SBs as different types of network slice services. According to this reasoning, the number of VINNI-SBs depends on network slice criteria design. As stated in Section 2.2.2, these criteria could lead to network slices with very different scopes, ranging from coarse-grained network slices, i.e. one network slice for each 5G service category, to fine-grained network slices, i.e. one network slice for each different communication service. Considering the vertical customers taking part in accepted ICT-19 projects, 5G-VINNI consortium has adopted a trade-off solution that considers four types of network slice services: eMBB, uRLLC, mIoT and customised. This means 5G-VINNI service catalogue will allow CSCs to select among four VINNI-SBs, one for each service type.

In the next section (Section 4.3), we provide a detailed view on the structure of a VINNI-SB. This description is focused on the commonalities that can be found in the content of any VINNI-SB, with independence of the service offering they refer to. Drawing upon this content, some differences can be established among VINNI-SBs. The highlight of these differences is done in Section 5.2.

4.3 VINNI-SB content

The VINNI-SB is the core of the 5G-VINNI service catalogue. In this section, we provide an overview of the content of a VINNI-SB, identifying the parameters that are needed to provide a self-contained description of a given network slice service. This overview will be used as a reference for the different facility sites in the following implementation phase.

Figure 4.3 provides a high-level view on the structure of any VINNI-SB. As seen, it consists of four main parts, each addressing a different scope:

- Service type.
- Service topology
- Service requirements
- Service exposure, testing and monitoring

These aspects will be further detailed through sections 4.3.1 to 4.3.4.

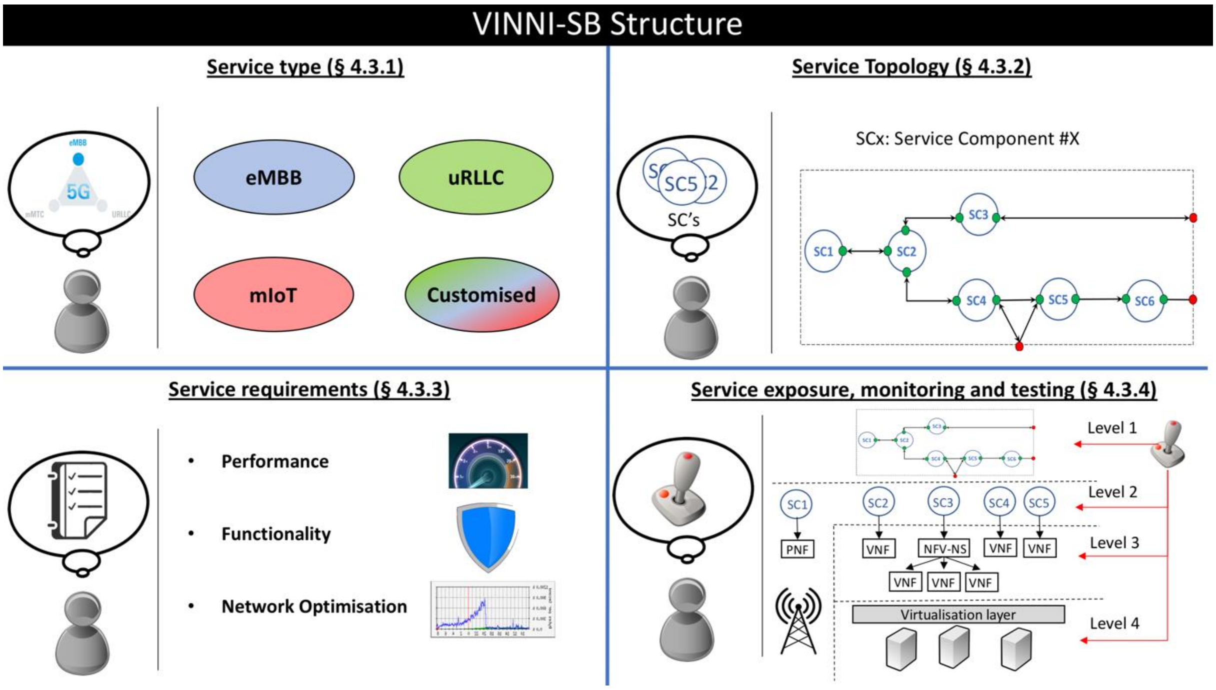

Figure 4.3: Structure and content of a VINNI-SB

4.3.1 Service type

The service type is a parameter that identifies the type of communication services the slice is designed to support. 3GPP has already introduced in [18] the concept of Slice/Service Type (SST) for this end, defining up to three possible values that the SST parameter can adopt: SST = 1 for eMBB, SST = 2 for uRLLC, and SST = 3 for mIoT. This approach, based on the initial classification shown in Section 2.2.1, acknowledges and adopts as true the following assumptions:

- Any communication service needs to be classified into one - and only one - of the following 5G service categories: eMBB, uRLLC and mIoT. These service categories have well-pre-defined capabilities in terms of performance (KPI value ranges) and functionality.
- There are as many network slice types as service categories.

5G-VINNI consortium does not totally share this vision. It considers that there exist some communication services (e.g. specially V2X services) whose performance characteristics do not fall into one single category; instead, they can be formulated as a combination of two or more service categories (e.g. eMBB and uRLLC), or as an enhanced service category (e.g. uRLLC+, formulated as uRLLC with very high mobility support). Taking into account this reasoning, 5G-VINNI needs to go beyond 3GPP scope. For this reason, 5G-VINNI project proposes a new classification where, besides the eMBB, uRLLC and mIoT, a fourth service type is considered: customised.

Table 4-1 provides a brief description of the meanings of each service type.

Table 4-1: Service types available for selection in 5G-VINNI

5G-VINNI Service Type	3GPP SST value	Description
eMBB	SST = 1	The network slice offered to the CSC is optimized to support use cases that fall under eMBB category. It provides enhanced data rates, capacity and coverage, serving scenarios with high traffic load and stringent QoS requirements.

5G-VINNI Service Type	3GPP SST value	Description
uRLLC	SST = 2	The network slice offered to the CSC is optimized to support use cases that fall under uRLLC category. It provides very low latency and extremely high reliability for mission-critical services.
mIoT	SST = 3	The network slice offered to the CSC is optimized to support use cases that fall under mIoT category. It provides connectivity support for a very large number of power-constrained devices requiring high energy efficiency and long battery lifetime.
Customised	N/A	The network slice offered to the CSC is optimised to support use cases having performance requirements that can be formulated as a combination of two or more pre-defined service types (SST= 1, 2, and 3), or as a modified (enhanced) version of one of them. Use cases with advanced functionality (e.g. in terms of access technologies, security considerations, etc.) will be also accommodated in network slices classified under this service type.

4.3.2 Service topology

The second part of the VINNI-SB is the service topology, which provides the CSC with guidance on how the 5G-VINNI service (i.e. the network slice service) is constructed from a logical viewpoint. The service topology specifies (a) what nodes the service consists of, including information on their individual functionality, and (b) how these nodes are connected with each other along the entire service chain, including information on their connectivity type. These nodes are the fundamental building blocks of the topology of a network slice service. For sake of simplicity, they will be referred to as Service Components (SCs) throughout this document.

A SC is a unified abstraction of a given network functionality that can take part in a service chain. A SC has three main defining features:

- *Modular*: modularity in SC design enables the decomposition of the entire SC functionality into granular sub-components, each providing a self-contained functionality. This approach, relying on cloud-native design principles, provides flexibility of sizing and scaling, and enables instantiating the SC with only the features needed for the network slice service (instance).
- *Composable*: this means that a SC can be flexibly chained with other SCs to form end-to-end topologies. For this end, a SC is provided with one or more connection points allowing the SC to interface with other SCs participating in the topology. With this approach, a 5G-VINNI service can be built up by logically connecting the connection points from the participating SCs.
- *Vendor-independent*: any SC relies on a unified, vendor-agnostic information model. This allows that SCs from different vendors can be work together in the context of service.

The three abovementioned features make SCs manageable entities that can be designed to represent different types of constructions, including NFV-NSs, VNFs and PNFs. For example, a SC providing 5G Core (5GC) functionality can be designed as a single VNF or an NFV-NS, either simple or composite. In the same way, a SC implementing gNB functionality can be deployed as a single PNF or an NFV-NS with the Centralised Unit (CU) as a VNF and the Distributed Unit (DU) and Remote Radio Header (RRH) deployed as PNFs. In addition to SC design, SC implementation can vary, including physical appliances (to host PNFs), virtual machines (e.g. to host large size, rather static VNFs) and cloud-native containers (e.g. to host NFV-NSs with lightweight, dynamic VNFs). In any case, the decision on SC design and implementation is a resource-facing topic that is only up to the NOP of the facility site.

In contrast, CSP and CSC focuses on customer-facing aspects on SCs. For these two roles, a given SC can be entirely described by its capabilities, functionality, and connection points. With this information, the topology of the service can be easily constructed, by simply connecting required SCs as needed. For this end, connection points from involved SCs and logical links enabling their connectivity needs to be specified. To make this topology a forwarding graph that describes how traffic flows across the SCs, information on upstream/downstream traffic can also be added. However, the implementation of this feature depends on the capability / mechanisms developed by each facility site.

The service topology defined in a VINNI-SB is pre-defined, CSC-independent. This topology contains all the SCs that the CSP provides by default for the selected service type (Section 4.3.1), along with the logical links providing connectivity across them. However, it may happen that customers want to bring their own VNFs (i.e. 3rd party VNFs) into the service definition, making it more appropriate to their specific needs. In such a case, the default topology needs to be extended and/or modified. To allow this, the CSP defines one or more service access points as part of the topology. These service access points represent connection points where the default topology can be accessed for its extensibility and/or modification, and where CSCs are allowed to attach 3rd party VNFs.

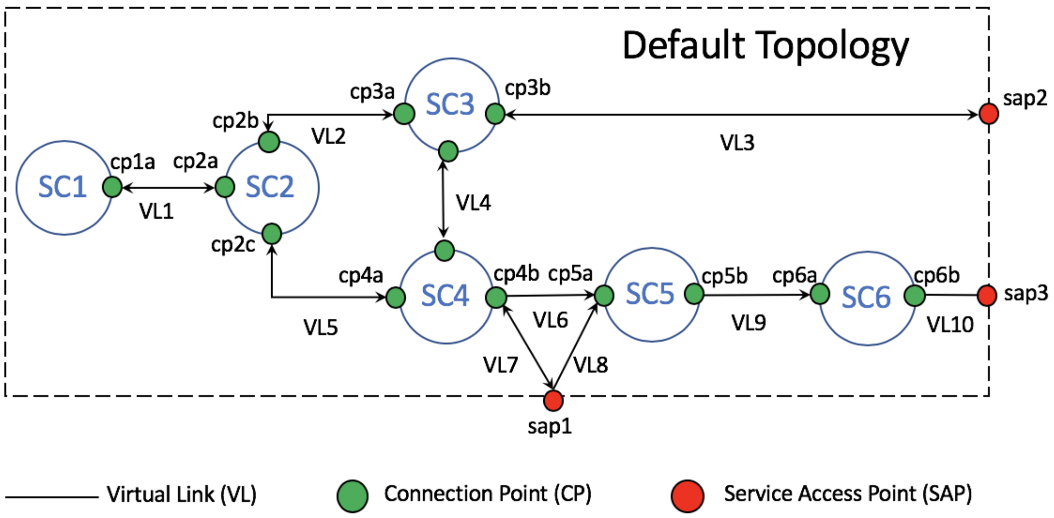

Figure 4.4: Example of a service topology for eMBB service type, as presented in a VINNI-SB. The figure shows the main concepts involved in the topology, including SCs and their connection points, virtual links and service access points

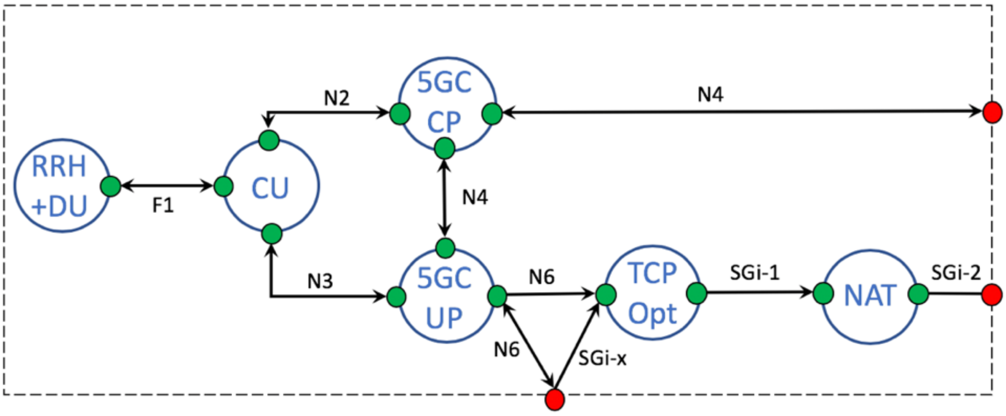

Figure 4.5: Example of a service topology as presented for eMBB service type, as presented in a VINNI-SB. This figure shows the name of the different SCs and some of their interfaces. For simplicity, name of the connection points and service access points have been omitted

Figure 4.4 and Figure 4.5 show an example of how a default topology could be presented in a VINNI-SB. For this example, a network slice service from eMBB service type has been considered. Figure 4.4 presents the default topology focusing on the main concepts involved, including CSP's SCs (blue circles) and their connection points (green points), virtual links and service access points (red points). Figure 4.5 presents the topology specifying which functionality each SC provides. SC1 and SC2 provide gNB functionality, with SC1 providing the lower layer of the NR protocol stack (e.g., RRH+DU), and SC2 the rest (e.g., CU). SC3 and SC4 provide 5GC functionality, with SC3 implementing the control plane and SC4 the user plane, i.e. User Plane Function (UPF). Finally, just after SC4, there is SC5 and SC6. These SCs represent L4 network functions that go just after the 5GC user plane, and thus logically belong to 3GPP Data Network: TCP optimiser (SC5) and Network Address Translator (SC6). Note that the figure also presents the interfaces that connect the different SCs, being these 3GPP reference points.

Finally, Figure 4.6 presents the above topology after the inclusion of 3rd party VNFs from CSC side. Particularly, two VNFs have been added: one MEC function (just after SC4) and an application server (just after SC6). The MEC function modifies the default topology, with the addition of new path between SC4 and SC5, while the application server simply extends it.

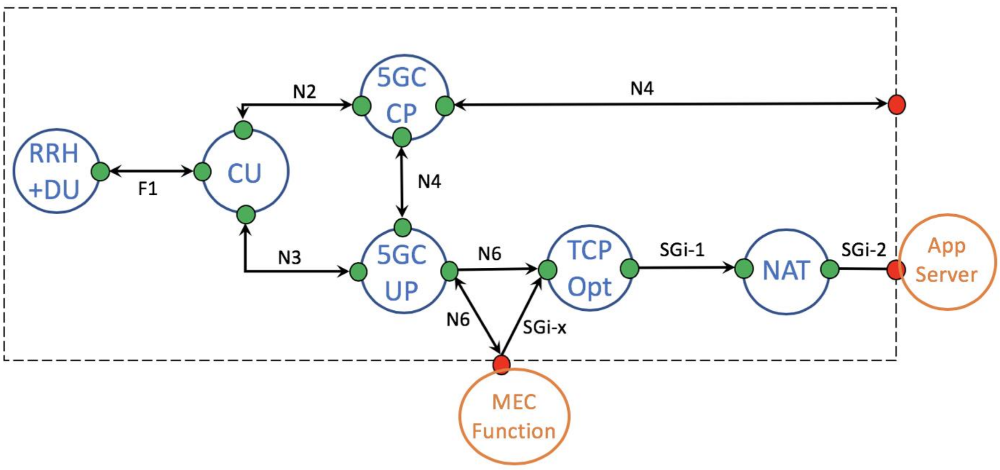

Figure 4.6: Topology after the inclusion of 3rd party VNFs

For the cases where a CSC attach a 3rd party VNFs to the default topology, it needs also to specify where these VNFs are to be deployed. For this, the CSC needs to inform the CSP of the 5G-VINNI facility site where each 3rd party VNFs should be instantiated, so that the CSP can issue deployment actions to the NOP.

4.3.3 Service requirements

The VINNI-SB includes a set of service parameters facing 5G-VINNI customers. The specification of the values of the different parameters have implications on both CSC and CSP. On the one hand, the CSC specifies the values of the parameters to indicate the requirements on the network slice services they need from the 5G-VINNI facility. These requirements are customer-facing service requirements. On the other hand, the CSP receives the customer-facing requirements from the CSC and translates them into network slice requirements that will be forwarded to NOP. These requirements are resource-facing service requirements.

In this document, we specify the customer-facing service requirements, focusing on how the CSC can indicate them through the specification of the different service parameters that are present in a VINNI-SB. As shown in Figure 4.3 these parameters are classified into three groups:

- *Performance*: allows describing how the service is expected to behave in quantitative terms. Specified performance parameters (translated by CSP into network slice requirements) will have an impact on how NOP decides to deploy each SC, including selection of appropriate deployment flavours from corresponding NSD (if the SC is a NFV-NS), VNFD (if the SC is a VNF) or PNFD (if the SC is a PNF).
- *Functionality*: allows describing how the service is expected to behave from a functional viewpoint. Specified functionality parameters (translated by the CSP into network slice requirements) will have an impact on the specific functionalities the NOP decides to include for each SC.
- *Network optimisation*: helps the NOP to instantiate and operate the slice in an optimized manner. Specified parameters (translated by the CSP into network slice requirements) will have an impact on how NOP decides to realize each SC, including decisions on SC placement and resource allocation, control plane mechanisms for effective traffic handling, or scheduling mechanisms to exploit multiplexing gains.

The parameters for within each of these three groups are listed in Table 4-2, and discussed separately throughout this subsection. For each parameter, the following information will be provided: *parameter value specification* (e.g. integer, float, binary, etc.), *measurement unit*, *selectable options* (e.g. if needed) and *conditional relationships* with other parameters.

Table 4-2: Parameters for service requirements specification

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

P.PERF_1 – Peak data rate

It is defined as the highest theoretical data rate achievable for a single device located at the best location within a cell, assuming error-free transmission conditions (i.e. excluding overhead and retransmitted data packets) when all available radio resources for the corresponding link direction are utilized (i.e. excluding radio resources that are used for physical layer synchronization, reference signals or pilots, guard bands and guard times). For the calculation of peak data rate, 5G-VINNI facility may include the details on the assumed MIMO configurations and bandwidth.

Peak data rate shall be specified in both link directions: downlink (DL) and uplink (UL). For this reason, P.PERF_1 consists of two parameters:

- *P.PERF_1A – DL peak data rate:* this KPI describes the maximum achievable downstream throughput at IP layer of one single device under ideal conditions. This throughput is generated at N6 interface[1] and measured at the device side.
- *P.PERF_1B – UL peak data rate:* this KPI describes the maximum achievable upstream throughput one single device under ideal conditions. This device transmit the IP packets up to the N6 interface.

Table 4-3 provides details on P.PERF_1 specification. Values adopted for the peak data rates in both link directions highly depend on the use case consideration. For some examples, see Section 5.1.

Table 4-3: P.PERF_1 specification

Param ID	Value	Unit	Options	Conditional relationship
P.PERF_1A	Float	Gbps	N/A	No
P.PERF_1B	Float	Gbps	N/A	No

P.PERF_2 – User data rate

It is defined as the user experienced data rate required for the device to get a quality experience that is assumed to be enough for the considered use case. Unlike P.PERF_1, P.PERF_2 does not presume ideal conditions; instead, it considers the presence of other devices also served by the same base station, and assumes that the device under evaluation is not always at the best location within the cell.

User data rate is specified in both link directions:

- *P.PERF_2A – DL user data rate:* this KPI describes the experienced downstream throughput at IP layer of one single device, generated at N6 interface and measured at the device side.
- *P.PERF_2B – UL user data rate:* this KPI describes the experienced upstream throughput one single device transmitting the IP packets up to the N6 interface.

5G-VINNI facility shall include the details on the x-th percentile of the cell coverage area that is considered for the calculation of the above KPIs.

Table 4-4 provides details on P.PERF_2 specification. Values adopted for the user data rates in both link directions highly depend on the use case consideration. For some examples, see Section 5.1.

Table 4-4: P.PERF_2 specification

Param ID	Value	Unit	Options	Conditional relationship
P.PERF_2A	Float	Mbps	N/A	No
P.PERF_2B	Float	Mbps	N/A	No

P.PERF_3 – Area traffic density

It is defined as the total traffic throughput (i.e. number of correctly received bits of IP packets per time interval) per area unit. This KPI can be also referred to as area traffic capacity[2]. P.PERF_3 consists of two parameters, each specifying the area traffic density for a different link direction:

[1] N6 interface is the one connecting core network user plane with data network.

[2] The adoption of term density instead of capacity is motivated by the intuitiveness of the former, and to avoid confusion with the term "capacity" originally introduced by Shannon.

- *P.PERF_3A – DL area traffic density:* this KPI describes the total throughput per area unit in the downstream direction.
- *P.PERF_3B – UL area traffic density:* this KPI describes the total throughput per area unit in the upstream direction.

Table 4-5: P.PERF_3 specification

Param ID	Value	Unit	Options	Conditional relationship
P.PERF_3A	Float	Gbps/km^2	N/A	No
P.PERF_3B	Float	Gbps/km^2	N/A	No

P.PERF_4 – 5G Quality of Service (QoS)

It represents a set of typical QoS parameters that are relevant for traffic handling in 3GPP networks, from Rel-15 onwards. The parameters listed as part of P.PERF_4 are the following:

- *P.PERF_4A – One-way latency:* it is the time it takes for a IP packet to travel from a device to a destination node. Depending on the considered use case, the node at the destination end could be different, e.g. a given 5G-VINNI SC or a 3rd party VNF. The value for this parameter can range from few milliseconds (e.g. for delay-critical uRLLC applications) to tens of seconds (e.g. for mIoT scenarios where sensors forward non-delay-sensitive data).
- *P.PERF_4B – E2E latency:* similar to P.PERF_4A, but considering the Round Trip Time (RTT).
- *P.PERF_4C – Jitter*: it is the highest deviation in the latency value that can be acceptable for the targeted use case. Jitter quantifies the variation in the delay of received packets, being this variation due to the stochastic nature of the network state (e.g. subjected to network congestion, improper queuing, etc.). Very low jitter is key for those applications where synchronicity and determinism are main requirements (e.g. factory automation in industry 4.0). Jitter values can range from very few microseconds to hundreds of milliseconds. In any case, they need to be much smaller that values for E2E latency.
- *P.PERF_4D – DL Packet loss rate*: it is the percentage of lost packets to the total number of packets sent in the DL direction. A packet is marked as lost when it does not arrive at the receiver side. While eMBB scenarios can tolerate packet loss rates beyond 10%, some mission-critical scenarios in automotive, public safety and industry 4.0 sectors could require rates as low as 0.001%.
- *P.PERF_4E – UL Packet loss rate*: similar to P.PERF_4D but considering the UL direction.
- *P.PERF_4F – DL Packet size*: specifies the maximum packet size to be supported by the considered use case in the DL direction. Examples of typical packet sizes for different applications can be found in [19].
- *P.PERF_4G – UL Packet size*: similar to P.PERF_4F but considering the UL direction.

The CSP must ensure that the value ranges allowed for these parameters are compliant with the 5G QoS Indicator (5QI) values defined in 3GPP Release 15, and tabulated in [18]. Otherwise, conflicts may occur.

Table 4-6: P.PERF_4 specification

Param ID	Value	Unit	Options	Conditional relationship
P.PERF_4A	Integer	ms	N/A	No
P.PERF_4B	Integer	ms	N/A	No
P.PERF_4C	Integer	us	N/A	No
P.PERF_4D	Float	%	N/A	No
P.PERF_4E	Float	%	N/A	No
P.PERF_4F	Integer	Bytes	N/A	No
P.PERF_4G	Integer	Bytes	N/A	No

Note that latency has only been specified for the user plane (see P.PERF_4A and P.PERF_4B), but not for the control plane. The reason is that ICT-19 verticals do not foresee control plane latency as a key requirement for their use cases, at least so far. Notwithstanding, as soon as this KPI becomes necessary for use case specification, 5G-VINNI may extend P.PERF_4 with the necessary parameters related to the control plane latency.

P.PERF_5 – Availability

It is an indicator that represents the risk of service outage in terms of the acceptable level of unplanned downtime. To measure this level, 5G-VINNI will use the time-based availability formula, from which service availability can calculated as follows:

$$Availability\ (X\ \%) = \ 100\%\ \text{x}\ \left(1 - \frac{\text{Downtime}}{\text{Uptime} + \text{Downtime}}\right)$$

As seen, availability is defined as the percentage value of the amount of time the service is operational, and thus can be accessed by the CSC. For the calculation of this KPI, the 5G-VINNI facility does not only need to need to specify the time period over which the availability is evaluated, but also provide information on the x-th percentile of the cell coverage considered for the calculation.

Table 4-7: P.PERF_5 specification

Param ID	Value	Unit	Options	Conditional relationship
P.PERF_5	Float	%	N/A	No

Table 4-8 shows examples how much downtime is permitted to reach different values for availability rate, considering different time periods for the evaluation. Although not typical in today's MBB scenarios, upcoming CSCs could bring to 5G-VINNI use cases that require the provisioning of network slice services with very high availability, including values of 99.99% (e.g. discrete automation), 99.999% (e.g. remote driving), or even 99.9999% (cloud robotics for factory automation)[3].

[3] To meet these stringent values on availability, two solutions have been proposed in 5G-VINN project: (i) autonomous edge, i.e. if link to edge breaks the edge should be able to operate as a full mobile network in the area, and (ii) satellite backhaul as a backup mechanism for some sites.

Table 4-8: Downtime and availability rate values

Availability rate	Max Downtime allowed				
	Per year	Per month	Per week	Per day	Per hour
99%	3.65 days	7.2 hours	1.68 hours	14.4 min	36 sec
99.9%	8.76 hours	43.2 min	10.1 min	1.44 min	3.6 sec
99.99%	52.6 min	4.32 min	60.5 sec	8.64 sec	0.36 sec
99.999%	5.26 min	25.9 sec	6.05 sec	0.87 sec	0.036 sec
99.9999%	31.56 sec	2.6 sec	0.61 sec	0.087 sec	0.0036 sec

P.PERF_6 – Reliability

It is an indicator that represents the risk of service misbehaviour within the time constraints required for the targeted use case. To measure reliability, 5G-VINNI relies on the following formula:

$$Reliability\ (X\ \%) = \ 100\%\ \mathrm{x}\ \left(1 - \frac{\text{Properly received packets}}{\text{Total Number of sent packets}}\right)$$

As seen, reliability is defined as the percentage value of packets that are successfully delivered to the destination (in both upstream and downstream directions) within the maximum tolerable latency for the use case. Similar to availability, reliability needs to be evaluated over some time period and considering some percentile of cell coverage area.

Table 4-9: P.PERF_6 specification

Param ID	Value	Unit	Options	Conditional relationship
P.PERF_9	Float	%	N/A	Yes: P.PERF_4A/B and P.PERF_4D/E -> latency and packet loss rate are inherent to reliability definition.

P.PERF_7 – Service deployment time

It is the time it takes the CSP to set up the network slice service (instance), with the network level guarantees specified in P.PERF_1 and P.PERF_6. This parameter measures the time that passes from service ordering (i.e. a CSC issue a service order to the CSP) to service operational readiness (i.e. the network slice service is ready to be used by the CSC). During this time, NSI day-0 (i.e. instantiation)[4] and day-1 (configuration) operations shall be performed, and testing framework shall be configured accordingly.

Table 4-10: P.PERF_7 specification

Param ID	Value	Unit	Options	Conditional relationship
P.PERF_10	Integer	minutes	N/A	No

[4] Day-0 operation is required if any existing NSI could be reused for the requested network slice service.

P.FUNC_1 - Deployment option

The specification of this parameter allows selecting how the 3GPP network architecture will be deployed as part of the network slice service. For 5G-VINNI facility, the following architecture options will be considered:

- Legacy, based on today's operational deployments: Long Term Evolution (LTE) + Evolved Packet Core (EPC). This deployment option will be available in the main facility sites by Rel-0.
- Rel-15 Non-Standalone (NSA), with the adoption of Option 3: Rel-15 New Radio (NR) + EPC.
- Rel-15 Standalone (SA), with the adoption of Option 2: Rel-15 NR + Rel-15 5GC.

The implications of deployments based on NSA and SA modes are discussed in D1.1 [17], and their differences are illustrated in Figure 4.7. For information about the availability of deployments based on NSA and SA modes in 5G-VINNI facility, see D2.1 [21].

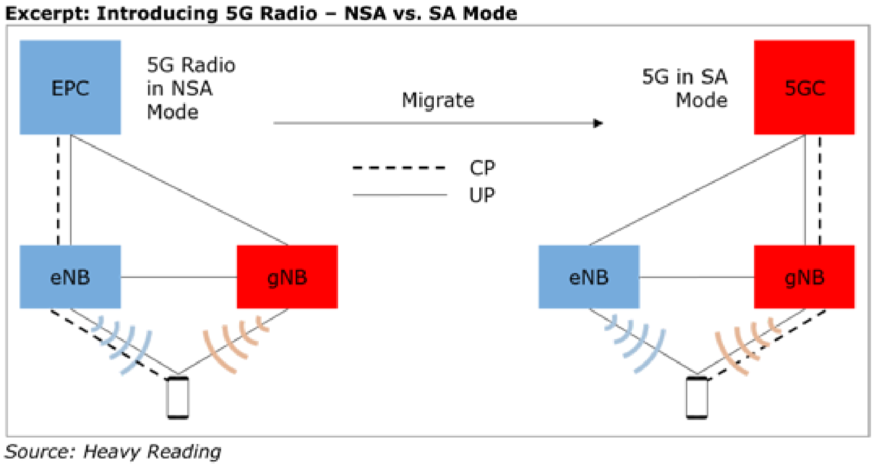

Figure 4.7: NSA vs SA for 5G deployment (source: [20])

Table 4-11 provides some details on the specification of P.FUNC_1.

Table 4-11: P.FUNC_1 specification

Param ID	Value	Unit	Options	Conditional relationship
P.FUNC_1	Integer	N/A	0: Legacy 1: Rel-15 NSA (Option 3) 2: Rel-15 SA (Option 2) 3: Other (to be defined)	No

Note that this parameter also includes the possibility to extend the number of architecture options available for CSC selection (see option 3 in P.FUNC_1). Examples of these options might include Rel-16 NSA & SA modes, aimed at supporting notably advanced vertical use cases. The availability of any of these options will be subjected to the standards evolution and the maturity of the different facility sites, and in any case can be expected sooner that MS7 (5G-VINNI Release 4).

P.FUNC_2: Access technology

The specification of this parameter (see Table 4-12) allows selecting the technologies to be supported by the network slice service for the access part. In 5G-VINNI facility, at least two access technologies will be available for CSC selection: LTE and NR. These technologies will allow the deployment options specified in P.FUNC_1, and will be offered by the four main facility sites (and some experimental facility sites).

In addition to LTE and NR, some facility sites will deal with alternative access technologies including Narrow-Band IoT (NB-IoT), LTE-M, satellite access and fixed wireless access (FWA)[5] [21]. These (3GPP and non-3GPP) access technologies could be made available to CSCs for experimentation purposes. For a such case, option "2" in P.FUNC_2 is reserved.

Table 4-12: P.FUNC_2 specification

Param ID	Value	Unit	Options	Conditional relationship
P.FUNC_2	Integer	N/A	0: LTE 1: NR 2: Other (specific for 5G-VINNI facility site)	No

P.FUNC_3: Predominant device type

This parameter lists the type of devices that can be attached to the 5G-VINNI service the CSP will provide to a CSC. These devices will act as source (end) nodes in the UL (DL) direction, and will be brought, set up, and maintained by the CSC. Table 4-13 shows the different options that can be selected for P.FUNC_3 specification. Note than more than one type of device can be selected for a 5G-VINNI service (e.g. a customised service for the automotive industry where participant vehicles have on-boarded sensors). For this end, the option "5" should be selected.

Table 4-13: P.FUNC_3 specification

Param ID	Value	Unit	Options	Conditional relationship
P.FUNC_3	Integer	N/A	0: UE 1: CPE 2: Sensor 3: Vehicle 4: Factory actuator 5: Combination from the above (to be specified)	No

P.FUNC_4: Radio spectrum

This parameter provides a list of the spectrum bands that can be supported by the offered 5G-VINNI service. The CSCs needs to select those bands matching their device capabilities; in fact, most of devices are designed to only work in certain bands.

The parameters listed as part of P.FUNC_4 are as follows:

- *P.FUNC_4A – LTE operating bands*: assuming option "0" has been selected for P.FUNC_2, this parameter list the LTE-defined spectrum bands [22] that can be supported by the network slice service. Depending on the devices that will be connected to the service (see P.FUNC_3 specifications), one or more bands can be selected.
- *P.FUNC_4B – NR operating bands:* assuming option "1" has been selected for P.FUNC_2, this parameter list the NR-defined spectrum bands [23] that can be supported by the network slice service. Depending on the devices that will be connected to the service (see P.FUNC_3 specifications), one or more bands can be selected.

[5] FWA can be used in conjunction with NR, as planned for Norway and UK facilities.

- *P.FUNC_4C – Other bands*: allows listing bands that do not match LTE or NR, either because they are based on other access technologies (e.g. NB-IoT, LTE-M, satellite access and FWA) or because they are part of vertical-owned spectrum (e.g. as it happens with Defense in Norway, or with public safety sectors). The specification of P.FUNC_4C presumes that option "2" has been selected for P.FUNC_2.

Table 4-14: P.FUNC_4 specification

Param ID	Value	Unit	Options	Conditional relationship
P.FUNC_4A	{String, string...}	N/A	See [22]	Yes: P.FUNC_2 -> if set to "1", P.FUNC_4A shall be omitted.
P.FUNC_4B	{String, string…}	N/A	See [23]	Yes: P.FUNC_2 -> if set to "", P.FUNC_4B shall be omitted.
P.FUNC_4C	{String, string…}	N/A	Depending on access technology selected for P.FUNC_2, option "2".	Yes: P.FUNC_2 -> only if set to "2".

P.FUNC_5: Isolation

Isolation constitutes the cornerstone for service delivery in multi-tenant environments such as 5G-VINNI, where NSIs intended for multiple CSCs will be deployed and operated on top of a shared infrastructure. In [29], NGMN makes this statement with respect isolation on network slicing: an NSI may be fully or partly, logically and/or physically, isolated from another NSI.

5G-VINNI consortium agree on taking the above as a reference for the specification of the isolation level of a 5G-VINNI service. As seen in Table 4-15, P.FUNC_5 is composed of two parameters:

- *P.FUNC_5A – Isolation support*: allows specifying if isolation is required/desired for the network slice service the CSP delivers to CSC.
- *P.FUNC_5B – Isolation type*: assuming isolation is required/desired, this parameter allows specifying how much the service needs to be isolated, by indicating the type of isolation that is required for each constituent SC: no isolation, logical isolation or physical isolation. If "no isolation" option is specified for at least one SC, then the service can be considered partly isolated.

The information provided by P.FUNC_5 is used by CSP to assist the NOP in the design and orchestration activities of corresponding NSIs.

Table 4-15: P.FUNC_5 specification

Param ID	Value	Unit	Options	Conditional relationship
P.FUNC_5A	Binary	N/A	0: No 1: Yes	No
P.FUNC_5B	({SC, SC,..}, {Binary, Binary,…})	N/A	0: No isolation 1: Logical isolation 2: Physical isolation	Yes: P.FUNC_5A -> if set to "0", P.FUNC_5B shall be omitted.

P.FUNC_6: Value-added functionality

This parameter includes the list of advanced features that the CSP can include as part of the network slice service offered to the CSC, providing it with an enriched functionality. In the 5G-VINNI project, the following features are being considered:

- *P.FUNC_6A – 3rd party VNF hosting*: allows a CSC to bring his own VNFs and attach them to the default service topology (see example in Figure 4.6), expanding/modifying it to get a value-added network slice service. 3rd party VNF hosting assumes the CSC upload VNF Packages to the CSP, which validates and on-boards them onto the corresponding catalogue (i.e. NFVO's VNF catalogue). In case 3rd party hosting is supported, then more details on this value-added functionality shall be provided. For more information of these details, see 3rd party VNF specification in P.FUNC_7.
- *P.FUNC_6B – Positioning*: it is the ability to provide geo-localisation methods as part of the network slice. With these methods, device locations can be extracted and tracked with high precision and in an "always on" manner. In case position is supported, then more details on this adds-on functionality shall be provided. For more information of these details, see positioning specification in P.FUNC_8.
- *P.FUNC_6C – Distributed data fabric*: it is the ability to provide data fabric functionality as part of the provided network slice. Data fabric services allows extracting, compute/transform and move data across the distributed network nodes [21]. How these data fabric services are embedded in the slice is transparent to the CSC, and it is up to CSP/NOP.
- *P.FUNC_6D – Security-as-a-Service (SECaaS)*: it is the ability to provide automated infrastructure security to CSC, as part of the offered slice service. Examples of security services that the CSC can request for the network slice includes L4-L7 firewalls, app/content/user security functionality and behavioural analytics.
- *P.FUNC_6E – Monitoring-as-a-service (MaaS):* allows a CSC to consume 5G-VINNI telemetry services for performance/fault activities at run-time. With these services, the CSC can check the behavior of the network slice service throughout its lifecycle. For more information on this feature, please see Section 4.3.4.2.
- *P.FUNC_6F – Testing-as-a-service (TaaS):* allows a CSC to consume capabilities from the 5G-VINNI testing framework for trialling and KPI validation purposes. For more information on this feature, please Section 4.3.4.3.

Table 4-16 provides a summary for P_FUNC.6 specification. As it can be seen, for each of the listed value-added features, the CSC shall specify whether he wants it or not. Those features marked with "Yes" (option "1") will be provided to CSC as an integral part of the network slice service.

Table 4-16: P.FUNC_6 specification

Param ID	Value	Unit	Options	Conditional relationship
P.FUNC_6A	Binary	N/A	0: No 1: Yes	No
P.FUNC_6B	Binary	N/A	0: No 1: Yes	No
P.FUNC_6C	Binary	N/A	0: No 1: Yes	No
P.FUNC_6D	Binary	N/A	0: No 1: Yes	No
P.FUNC_6E	Binary	N/A	0: No 1: Yes	No
P.FUNC_6F	Binary	N/A	0: No 1: Yes	No

P.FUNC_7: 3rd party VNFs

This parameter provides details on the 3rd party VNFs that the CSC brings for the requested network slice service (see Table 4-17). It assumes that the VNF Packages describing those VNFs have already been uploaded by the CSCs and been validated and on-boarded by the CSP.

Table 4-17: P.FUNC_7 specification

Param ID	Value	Unit	Options	Conditional relationship
P.FUNC_7	{3rdPartyVNF, 3rdPartyVNF, …}	N/A	see Table 4-18	Yes: P.FUNC_6A -> if set to "0", P.FUNC_8 shall be omitted.

For each 3rd party VNF that CSC plans to attach to the default service topology, the following information shall be provided (see Table 4-18):

- *VNF Package ID*: identifier of the on-boarded VNF Package. The VNF Package includes at least the following components: the VNF Descriptor (VNFD), a model-based template used for the deployment and operation of instances of a given VNF in NFV environments; one or more software images (one for each VDU) providing the VNF logic; and some metadata (e.g. name, logo, description, VNF designer). For more information on VNF Package structure, see [16].
- *VNF attachment points:* specifies where the 3rd party VNF will be attached into the default topology. A single VNF can be connected to the topology via one or more two attachment points. Each attachment point is uniquely defined by the pair {CP, SAP}, where the CP is the connection point of the 3rd party VNF, and the SAP is the service access point of the default topology, and towards which the CP will be connected to. Example in Figure 4.6 considers that each 3rd party VNF have a single attachment point.
- *Scaling support*: specifies if the VNF can be scaled or not during its lifetime.
- *Scaling rules*: provide one or more rules that specify under which conditions the VNF should scale, and what is the scale level (or instantiation level) the VNF should be after the scaling operation.
- *LCM primitives*: scripts for the execution of lifecycle management operations on the VNF. For those primitives intended for scaling, the scripts will contain reference to the abovementioned scaling rules.
- *Management responsibility*: specifies if the VNF is under the CSC's management scope or not. Two options are considered: tenant-managed VNF (e.g. the CSC is in charge of managing the VNF, with the help of its own VNFM) and operator-managed VNF (e.g. the NOP manages the VNF via the corresponding MANO stack).

Table 4-18 provides a summary of the specification of the 3rd party VNF. Although scaling rules and LCM primitives are specified as parameters separate from the VNF Package, they might also be included in the VNF package, as stated in [16].

Table 4-18: 3rdPartyVNF object specification

Field Name	Value	Unit	Options	Conditional relationship
VNF Package ID	Identifier	N/A	N/A	No
VNF attach. points	[{CP, SAP}, {CP, SAP},…]	{N/A, N/A}	N/A	No
Scaling support	Binary	N/A	0: No 1: Yes	No
Scaling rules	{rule, rule,…}	N/A	N/A	Yes -> if *Scaling support* = "0", it shall be omitted.
LCM primitives	{primitive, primitive,…}	N/A	N/A	
Management responsibility	Binary	N/A	0: No 1: Yes	No

P.FUNC_8: Positioning

It provides details on positioning. The set of parameters that are relevant for positioning are summarized in Table 4-19, and are as follows:

- *P.FUNC_8A – Positioning accuracy*: specifies the accuracy required for positioning in meters. This parameter specifies an upper bound in the error between estimated position and actual position. High-precision positioning might be very important for some verticals, not only working in in-door environments, but also in outdoor.
- *P.FUNC_8B – Measurement frequency:* specifies how often the location information is provided.

Table 4-19: P.FUNC_8 specification

Param ID	Value	Unit	Options	Conditional relationship
P.FUNC_8A	Integer	cm	N/A	Yes: P.FUNC_6B -> if set to "0", P.F_9A shall be omitted.
P.FUNC_8B	Integer	ms	N/A	Yes: P.FUNC_6B-> if set to "0", P.F_9B shall be omitted.

P.NO_1: Number of devices

It is defined as the maximum number of devices that can be subscribed to the network slice service. Depending on the considered scenario the service will be intended to, the value of this parameter can vary from a few tens of devices (e.g. UEs for in-door hotspot or actuators for closed-loop control in industry 4.0) to hundreds of thousands of devices (e.g. UEs in open-air musical festivals) or even millions of them (e.g. sensors in large-scale IoT environments).

Table 4-20: P.NO_1 specification

Param ID	Value	Unit	Options	Conditional relationship
P.NO_1	Integer	N/A	N/A	No

P.NO_2: Device density

It is defined as the number of devices per area unit that can maintain active connections with the network slice service. With active connection, we mean that devices are able to exchange data with the network. By way of example, while there are scenarios that usually requires high density values (e.g. in mIoT, with up to 10,000 devices/km^{-2}), there are others where the network is sparse, and low density is required (e.g. coverage support in rural or remote areas).

Table 4-21 provides details on P.NO_2. This parameter, along with P.NO_1, is key for the optimization of the NSI(s) the NOP provides to CSP for service provisioning. Indeed, once CSP translates the specification of these parameters into network slice requirements, the NOP can use the information to optimize the corresponding NSI at the radio access network part (e.g. properly design PRB scheduling algorithms), core network part (e.g. sizing and dimensioning) and transport network part (e.g. reserve enough capacity at front-/mid-/backhaul links). How the NOP deals with this optimization in NSI is a resource-facing issue, and thus discussed in [4].

Table 4-21: P.NO_2 specification

Param ID	Value	Unit	Options	Conditional relationship
P.NO_2	Integer	km^{-2}	N/A	No

P.NO_3: Coverage profile

It specifies the geographical areas where the devices can access the network slice service. The coverage profile consists of two parameters (see Table 4-22):

- *P.NO_3A – Facility sites:* define the list of 5G-VINNI facility sites capable of supporting the deployment of the network slice service. The CSC shall select at least one of them. For those cases where the CSC wants to execute use case trials involving more than one administrative domain, he needs to select the involved facility sites.
- *P.NO_3B – Coverage area:* defines the spatial boundaries where network slice service will provide coverage with a quality that is enough for the targeted use case. This quality is expressed through edge cell coverage probability, a safety factor used to determine the guaranteed level of probability (e.g. 90%, 95%, 99%) of a successful radio communication of any device placed within the specified coverage area[6]. The spatial boundaries representing the coverage area are specified as a list of geographical areas, one for each facility site selected in P.NO_3A. The description of a geographical area is as follows: *i)* an epicentre, specified by the GPS coordinates of the facility site, and *ii)* a radius[7], specified in km.

According to P.NO_3 specification, the NOP could take some optimization-related decisions on the radio access part, e.g. power transmission and modulation and codification scheme (MCS), and in the core network part, e.g. placement of latency-sensitive SCs.

[6] The closer the device is to the base station, the higher the probability.

[7] Note that in case a non-5G-VINNI site (i.e. mobile/fixed ICT-19 facility like a factory) wants to be connected to the facility site, it is important that the distance between the two sites to be lower than the specified radius; otherwise, the non-5G-VINNI site should remain out of the coverage area.

Table 4-22: P.NO_3 specification

Param ID	Value	Unit	Options	Conditional relationship
P.NO_3A	Integer	N/A	0: Oslo (Norway) 1: Martlesham (UK) 2: Madrid (Spain) 3: Patras (Greece) 4: Aveiro (Portugal) 5: Berlin (Germany) 6: Munich (Germany)	No
P.NO_3B	{geographicArea, geographicArea ,…}	(GSP, km)		Yes: P.NO_3A -> if more than one option is selected, more than one geographical area shall be specified.

P.NO_4: Mobility

Mobility refers to the ability of providing seamless service experiences to devices while moving. It can be defined as the maximum device speed at which a certain QoS (specified in P.PERF_4) can be achieved. To facilitate mobility specification, 5G-VINNI will follow the ITU recommendation in [24], allowing the CSC to specify the device speed (in km/h) by selecting one of the following mobility classes: stationary (0 km/h), pedestrian (0 km/h to 10 km/h), vehicular (10 km/h to 120 km/h) and high speed vehicular (120 km/h to 500 km/h). The CSC simply must select one of these four classes.

Table 4-23: P.NO_4 specification

Param ID	Value	Unit	Options	Conditional relationship
P.NO_4	Integer	N/A	0: Stationary: 0 km/h 1: Pedestrian: 0-10 km/h 2: Vehicular: 10-120 km/h 3: High speed vehicular: 120-500 km/h	No

P.NO_4 specification is of key importance for the NOP to optimize mobility management procedures in the core network, and to handle dynamic resource allocation.

P.NO_5: Service lifetime

It provides information on some aspects that deserve attention during the lifetime of a network slice service. As seen in Table 4-24, P.NO_5 includes the following parameters:

- *P.NO_5A – Service duration (start-end)*: allows CSC to specify when it wants the service running, and when it can be decommissioned. The duration for a network slice service can be highly variable, ranging from short-lived services (e.g. an uRLLC slice service provided to public safety for disaster management) to long-lasting services (e.g. an eMBB slice service provided to a MVNO).
- *P.NO_5B – Service deactivation-activation support:* indicates if service deactivation-activation operations (i.e. once deactivated, the service is activated again) is allowed throughout the service duration. This parameter can take three values: not supported, supported without periodicity, and supported with periodicity. "Not supported" value means deactivation-activation operations are not available for a network slice service. For this reason, this option could be ideal for a network service that needs to be operative 24/7. "Supported without

periodicity" value means that CSP can trigger these operations, but they must be requested on-demand by the CSC. Finally, "supported with periodicity" allows programming the execution of these operations, taking into account calendaring considerations.

- *P.NO_5C – Periodicity type*: assuming "supported with periodicity" is selected for P.NO_5B, this parameter allows specifying if the periodicity for deactivation-activation is programmed on a daily basis (e.g. service operative during the day, and deactivated at night), weekly basis (e.g. service operative from Monday to Friday, and deactivated for the weekend) or monthly basis.
- *P.NO_5D – Daily service deactivation-activation*: allows programming the time interval the service shall remain deactivated (from hh:mm to hh:mm) every day.
- *P.NO_5E – Weekly service deactivation-activation*: allows programming the time interval the service shall remain deactivated (from dd hh:mm to dd hh:mm) every week.
- *P.NO_5F – Monthly service deactivation-activation*: allows programming the time interval the service shall remain deactivated (from mm-dd-yyyy hh:mm to mm-dd-yyyy hh:mm) every month.

Table 4-24: P.NO_5 specification

Param ID	Value	Unit	Options	Conditional relationship
P.NO_5A	[Date - Date]	[mm-dd-yyyy hh:mm, mm-dd-yyyy hh:mm]	N/A	No
P.NO_5B	Integer	N/A	0: Not supported 1: Supported without periodicity 2: Supported with periodicity	No
P.NO_5C	Integer	N/A	0: Daily basis 1: Weekly basis 2: Monthly basis	Yes: P.NO_5B -> if not set to "2", P.NO_5D shall be omitted.
P.NO_5D	[Date - Date]	[hh:mm, hh:mm]		Yes: P.NO_5C-> if not set to "0", P.NO_5D shall be omitted.
P.NO_5E	[Date - Date]	[dd hh:mm, dd hh:mm]		Yes: P.NO_5C-> if not set to "1", P.NO_5E shall be omitted.
P.NO_5F	[Date - Date]	[mm-dd hh:mm, mm-dd hh:mm]		Yes: P.NO_5C-> if not set to "2", P.NO_5F shall be omitted.

P.NO_5 specification is of key importance for the NOP to make resource reservation and scheduling operations as part of the resource orchestration, with the purpose of having enough resources to satisfy service requirements during the time periods specified in P.NO_5.

4.3.4 Service exposure, monitoring and testing

This is the last part of a VINNI-SB. It allows specifying the capabilities the CSC can get from 5G-VINNI facility for the requested service, including information on service exposure (Section 4.3.4.1), monitoring (Section 4.3.4.2) and testing (Section 4.3.4.3).

4.3.4.1 Service exposure

In 5G-VINNI, service exposure can be defined as the ability of a CSP to securely expose management capabilities of 5G-VINNI facility towards an authorised CSC. This is a key asset to allow vertical players from ICT-19 projects to test and experiment in the context of their provided slices. The importance of service exposure in slicing environments has been already highlighted in [35], where GSMA claims service capability exposure to be one of the three key value-added features in the network slicing value chain. This idea is even reinforced by NGMN in [34], where secure exposure of 5G capabilities to customers and trusted 3rd parties is discussed.

Service exposure in multi-tenant environments like 5G-VINNI brings some implications, particularly considering that different tenants (i.e. CSCs) could want to have different levels of management over their serving slices. This fact makes necessary to define different levels of exposure. Some proposals have been suggested so far to address this problem. For example, in [25] Luis Contreras-Murillo and D. Lopez proposes a exposure model with two types of slices (see Figure 4.8): i) *provider-managed slices*, meaning that the provider keeps the full control and management of the slice, while the customer can merely use the network resources of the provided slice, without any further capability of managing or controlling them; and ii) *tenant-managed slices*, implying that tenant has access to a (limited) set of operations and/or configuration actions, and the provider just segregates the infrastructure as required for that purpose. On the other hand, Nokia has suggested a more advanced classification where up to three levels are considered, as shown in Figure 4.9.

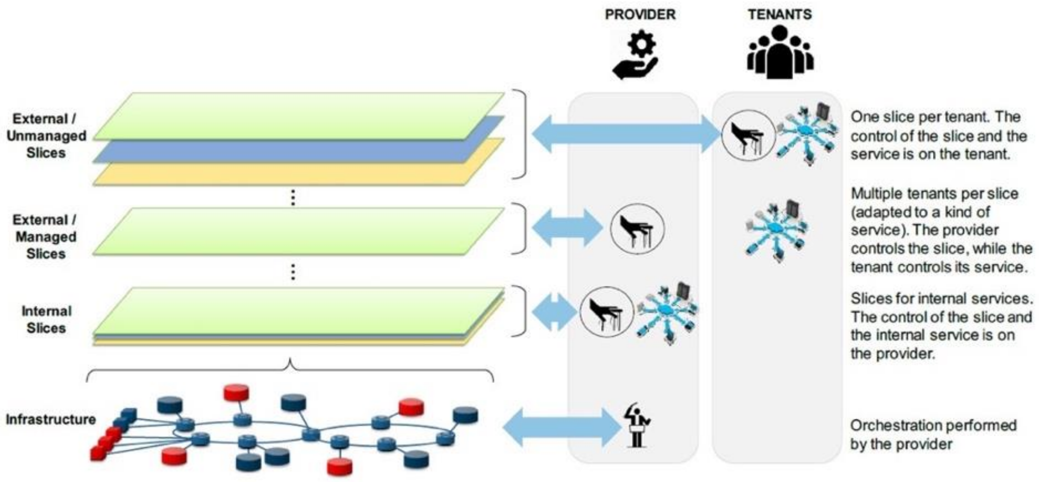

Figure 4.8: Different capabilities of network slices in NSaaS (source: [25])

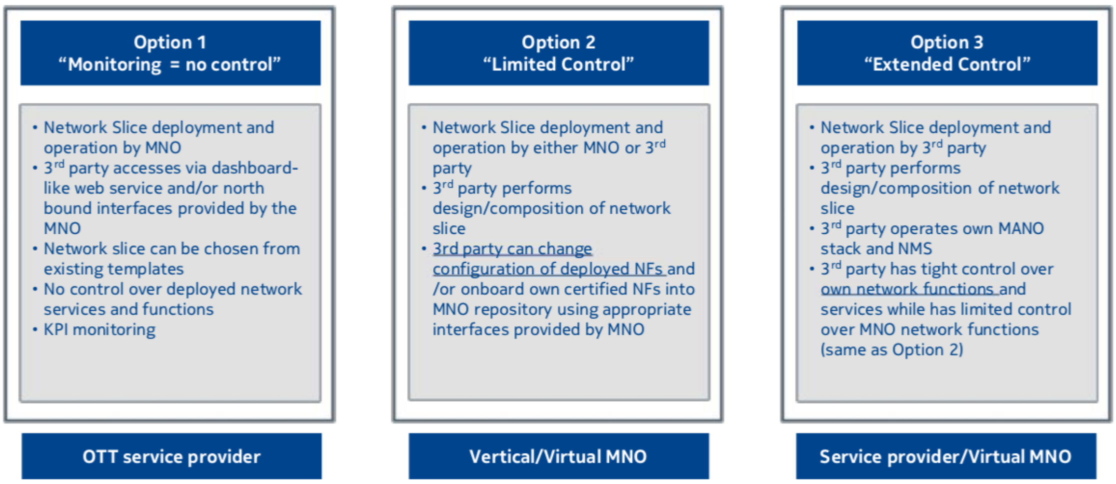

Figure 4.9: Control levels exposed to 3rd parties in network slicing (source: [26])

Taking into account the above reasoning, we propose our own level-based classification for service exposure, adapted to the specificities of 5G-VINNI as a service delivery platform intended for vertical experimentation. This classification is shown in Figure 4.10

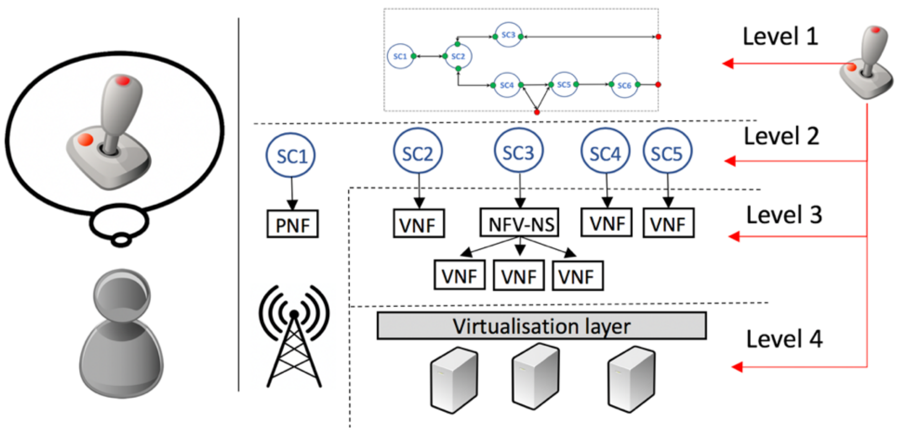

Figure 4.10: Illustration of exposure levels considered in 5G-VINNI

As it can be seen, four levels of exposure have been defined: Level 1, Level 2, Level 3 and Level 4. Unlike the abovementioned proposals, the criterium we followed for this classification answers the following question: "*Up to which management block the CSC is allowed to access?*". Table 4-25 lists the four exposure levels defined for 5G-VINNI and specifies their meanings. This classification brings two implications: (i) the higher the exposure level is, the more advanced the capabilities the CSC can get from the 5G-VINNI facility will be; and (ii) the capabilities offered by a given level also includes the ones offered by the level immediately above. By way of example, consider Level 3, where the CSP allows the CSC to access up to the NFVO. This means that the CSC can access the following management blocks: E2E Service Management and Operation (Level 1), Domain controllers (Level 2) and NFVO.

Table 4-25: Description of capability exposure levels

Exposure Level	Management block exposed to the CSC	Equivalent service delivery model
Level 1	E2E Service Management and operation (includes 3GPP NSMF)	N/A
Level 2	5G-RAN Controller (includes 3GPP NSSMF), 5G-CORE Controller (includes 3GPP NSSMF) and Transport Controller	N/A
Level 3	NFVO (optionally VNFM)	VNF as a Service (VNFaaS)
Level 4	VIM	NFVI as a Service (NFVIaaS)

The criterium selected for the classification allows providing a completed, self-contained specification of what capabilities a CSC can consume from 5G-VINNI facility for a given exposure level. These capabilities are the ones exposed by the management blocks made available to the CSC for that level. To allow the CSC to consume the capabilities from a given management block, the CSP marks the CSC as authorized client of the NBI of that management block.

Table 4-26 summarises the operational capabilities a CSC can get from the 5G-VINNI facility depending on selected exposure level.

Table 4-26: Capabilities consumed by the CSC

CSC is able to consume…	Level 1	Level 2	Level 3	Level 4
Service application layer configuration and management operations	✓	✓	✓	✓
SC application layer configuration and management operations (3GPP scope for RAN and CN, and IETF/BBF scope for TN)	×	✓	✓	✓
SC management operations at the virtual resource layer, including operations related to VNF/NFV-NS lifecycle, performance and fault management (NFV scope)	×	×	✓	✓
Resource control and management operations at the infrastructure layer, including (i) VDU/VM lifecycle management, (ii) considerations on Enhanced Platform Awareness capabilities, and (iii) assistance for SDN control	×	×	×	✓

4.3.4.2 Monitoring

Monitoring in 5G-VINNI is about supervising network slice services (instances) in progress to ensure that they are on-course and on-schedule in meeting the objectives and performance targets as defined in Section 4.3.3. Conducted by CSP and enforced by the NOP, monitoring activities involves gathering data from different sources, including performance measurements and fault alarms. The CSP can use collected data to handle internal management procedures, i.e. performance management and fault supervision activities within the boundaries of the 5G-VINNI facility, but also to expose relevant information to corresponding CSCs, i.e. out of the boundaries of the 5G-VINNI facility. The latter is the case we focus on this deliverable.

One of the key features that 5G-VINNI brings is MaaS support. With MaaS, CSC can retrieve performance/fault management data from multiple sources for the supervision of the network slice service at run-time, getting insight of its state and checking if it behaves as expected. In case CSC does want to consume MaaS (P.FUNC_6E="1"), the CSP shall allow the CSP specify which metrics he wants to retrieve from the network slice service. To enable this, VINNI-SB includes the following parameters:

- *P.MON_1 – On-demand monitoring support*: indicates if the CSC is allowed or not to request new monitoring information at run-time. The selection of "No" option means the following: once the service is deployed and running, the CSP will not admit from the CSC requests for modifications/updates on the monitoring information initially specified in the VINNI-SB.
- *P.MON_2 – Monitored objects:* allows specifying the list of manageable objects that wants to be monitored. These objects will be the sources from which management data will be collected.

Table 4-27: Monitoring parameters

Param ID	Value	Unit	Options	Conditional relationship
P.MON_1	Binary	N/A	0: No 1: Yes	Yes: P.FUNC_6F -> if set to "0", P.MON_1 shall be omitted.
P.MON_2	{monObject, monObject, …}	N/A	N/A (see Table 4-28)	Yes: P.FUNC_6F -> if set to "0", P.MON_1 shall be omitted.

Table 4-28 shows how a monitored object could be specified. As seen, the following fields could apply:

- *Object ID*: identifies the object that wants to be monitored.
- *Object type*: specifies what the above object represents: the whole network slice service, a SC, an NFV-NS/VNF, or a virtualised resource.
- *Management data availability*: allows specifying what type of management data the CSC wants to receive from the object: only performance measurements, only alarms, or both of them.
- *Subscribed performance measurements*: allows specifying the list of performance measurements the CSC wants to receive from the object. For more information on how a performance measurement should be specified, see Table 4-29.
- *Subscribed alarms*: allows specifying the list of performance measurements the CSC wants to receive from the object. For more information on how a performance measurement should be specified, see Table 4-30

Table 4-28: monObject object specification

Field name	Value	Unit	Options	Conditional relationship
Object ID	Identifier	N/A		No
Object type	Integer	N/A	0: Service 1: SC 2: VNF / NFV-NS 3: Virtualised resource	Yes: *selected service exposure level* (see Section 4.3.4.1) -> • If set to "0", *Object type*="0" is available • If set to "1", *Object type* = {"0", "1"} are available • If set to "2", *Object type* = {"0", "1", "2"} are available If set to "3", *Object type* can take all values.
Management data availability	Integer	N/A	0: Only performance measurements 1: Only alarms 2: Both	No
Subscribed performance measurements	{perfMeas, perfMeas,…}	N/A	N/A (see Table 4-29)	Yes: *Management data availability* -> If set to "1", *subscribed performance measurements* field shall be omitted.
Subscribed alarms	{alarm, alarm,…}	N/A	N/A (see Table 4-30)	Yes: *Management data availability* -> If set to "1", *subscribed alarms* field shall be omitted.

Table 4-29 shows how a performance measurement from a given monitored object (Table 4-28) is specified. This includes:

- *Measurement ID*: identifies the measurement that wants to be collected from the object. Examples of measurements could be memory usage, bandwidth link utilisation, etc.
- *Measurement description:* human-readable description of what the measurement means.

- *Performance parameter ID:* specifies to which KPI the measurement refers to. For example, bandwidth link utilisation can be linked to user data rate, latency and packet loss rate KPIs. Note that the measurements can only refer to the KPIs listed in Section 4.3.3.
- *Measurement format*: specifies the format on which the measurement will be reported to the CSC. Two options are available for selection: raw or aggregated.
- *Measurement aggregation type*: in case aggregated format is selected above, this parameter allows specifying the type of aggregation for the measurement presentation.
- *Measurement reporting period*: it defines how often measurement is reported to the CSC. It is specified in seconds. For streamed reporting (i.e. data is continuously forwarded to the CSC), the measurement adopted for this parameter will be 0 seconds. For batched reporting, the CSC can define the desired reporting period, e.g. every 30 seconds, every 5 minutes, etc.

Table 4-29: perfMeas object specification

Field name	Value	Unit	Options	Conditional relationship
Measurement ID	Identifier	N/A	N/A	No
Measurement description	String	N/A	N/A	No
Performance parameter ID	Identifier	N/A	N/A	Yes: *performance parameters* (Section 4.3.3) -> only those parameters can be referred.
Measurement format	Binary	N/A	0: Raw 1: Aggregated	No
Measurement aggregation type	Integer	N/A	0: Average 1: Sum 2: Cumsum 3: Min / Max 4: Other (to be specified)	Yes: *measurement format* -> If set to "0", then *measurement aggregation type* shall be omitted.
Measurement reporting period	Integer	seconds	N/A	No

Finally, Table 4-30shows how an alarm from a given monitored object (Table 4-28) is specified. This includes:

- *Alarm ID*: identifies the alarm that wants to be collected from the object.
- *Alarm description:* human-readable description of what the alarm means.

Table 4-30: alarm object specification

Field name	Value	Unit	Options	Conditional relationship
Alarm ID	Identifier	N/A	N/A	No
Alarm description	String	N/A	N/A	No

4.3.4.3 Testing

5G-VINNI facility is capable of providing Testing-as-a-Service (TaaS). TaaS is a model whereby the CSP exposes and offers testing capabilities from the 5G-VINNI test framework to CSCs, allowing them to assess their use cases in their provided network slices. This exposure is done through an automation and interface layer that allows CSP to connecting all the testing tools that are needed for use case KPI validation [27]. Figure 4.11provides an overview of the 5G-VINNI testing framework.

With the concept of TaaS, the following concepts emerge:

- *Test case*: defines a test targeting a specific performance measurement. It includes information which is related to the configurations of the CSP's experimentation infrastructure needed for receiving the measurement. The specification of a given test case is done through a test case descriptor, which is stored in the test case repository. Examples of fields present in a test case descriptor includes KPI definition, the measurements methodology and the information for the equipment preparation. For more details on test case descriptor, see [27].
- *Test campaign*: it is a collection of test cases to run.
- *Test execution:* it is the execution of a test case in the context of a test campaign.

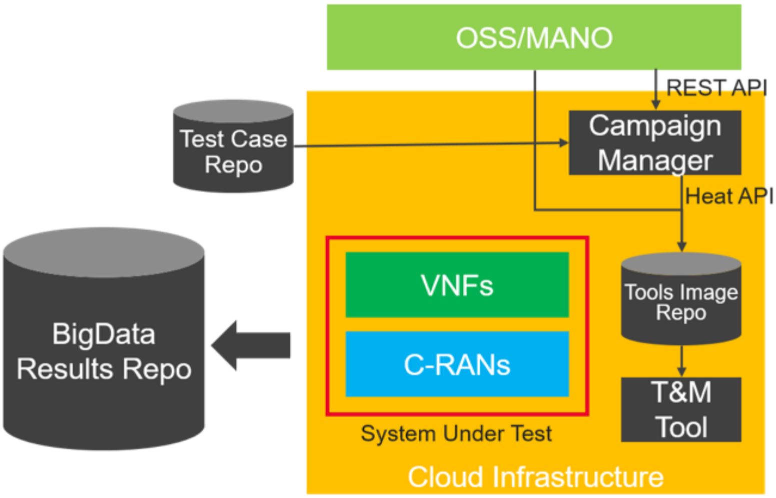

Figure 4.11: Testing framework in 5G-VINNI

With TaaS, a CSP will allow CSCs to create their own test campaigns, and to execute them in the CSP's test framework. For the test campaign definition, a CSC selects the test cases that wants to be executed. These tests can be defined by the CSP or by the CSC itself. On the one hand, the first types of test are applicable to SCs taking part in the default topology and are specified with descriptors that the CSP stores beforehand in the test framework's test catalogue. This catalogue is exposed towards the CSC, allowing him/her to select the test cases it needs. On the other hand, the second type of tests are applicable to 3rd party VNFs and specified with descriptors that the CSC submits to the CSP's test framework. Once their integrity is validated, the CSP proceeds with their on-boarding into the test catalogue.

The decision to leverage 5G VINNI testing framework for KPI validation and test campaign management is up to the CSC. In case CSC does want to consume TaaS (P.PERF_6F="1"), the VINNI-SB should include the following parameters with respect to testing:

- *P.TEST_1 – On-demand TaaS support:* if yes, it means that the CSC can modify/update test campaigns at run-time.
- *P.TEST_2 – Subscribed test cases:* allows the CSC to specify the test cases it wants to get subscribed to. The CSC can only select from the list of test case descriptors exposed by the CSP. To know which test case descriptors can made available towards the CSC, the CSP applies the following maxim: a test case can be exposed to a CSC if, and only if, the system under test specified in its descriptor is one of the monitored objects selected by the CSC in P.MON_2. With this approach, the CSP ensures two things: first, the system under test can be monitored; secondly, the testing activities are compliant with the selected exposure level.

The latter ensures e.g. that the CSC is unable to conduct testing activities at the VIM level, when level 2 has been selected in Section 4.3.4.1.

- *P.TEST_3 – Test campaign definition:* allows the CSC to define one or more test campaigns.

Table 4-31: Testing parameters specification

Param ID	Value	Unit	Options	Conditional relationship
P.TEST_1	Binary	N/A	0: Raw 1: Aggregated	No
P.TEST_2	{testCase, testCase,…}	N/A	N/A	Yes: P.MON_2 -> A test case can be selected only if its system under test is one of the monitored objects specified in P.MON_2.
P.TEST_3	{testCampaign, testCampaign}	N/A	N/A (see table below)	No

Table 4-32 shows an example content of the test campaign specified in P.TEST_3, which includes:

- *Campaign description*: human-readable description of the scope of test campaign. The name of this campaign is up to the CSC.
- *Campaign type:* allows the CSC to select the type of campaign it wants to execute.
- *Campaign setup:* allows the CSC to set up the campaign, defining the test cases that will be included as part of the campaign and describing the environments where they can be executed. Only subscribed test cases can take part in a test campaign.

Table 4-32: testCampaign object specification

Field name	Value	Unit	Options	Conditional relationship
Campaign ID	Identifier	N/A		No
Campaign description	String	N/A		No
Campaign type	Integer	N/A	0: Performance 1: Scalability 2: Conformance 3: Interoperability	No
Campaign setup	N/A	N/A	Out of scope.	Yes: P.TEST_4 -> Only subscribed test cases can be included in the campaign definition.

4.4 Dependencies on VINNI-SB

As seen in Section 4.3, VINNI-SB parameters can be classified into five big groups: performance (P.PERF_X), functionality (P.FUNC_X), network optimisation (P.NO_X), monitoring (P.MON_X) and testing (P.TEST_X). From the description of these parameters, it can be realised that there exist some dependencies between these groups.

On the one hand, some dependencies can be observed between performance and network optimisation groups. For example, values specified for user data rate (P.PERF_2) and area traffic density (P.PERF_3) shall be consistent with the values specifies for device density (P.NO_2).

On the other hand, there are dependencies involving performance, monitoring and testing groups. These dependencies rely on the following idea: all KPIs and system under tests specified in P.PERF_X and P.TEST_X shall be validated using the measurements received from the monitoring framework. This means that the specification of performance and testing parameters are highly constrained by the monitoring parameters available for selection (i.e. what can be measured, and how it can be measured). As a matter fact, it does not make sense to specify KPIs or system under tests from which the monitoring framework cannot get measurements, since there is no way to proceed with their validation, and thus guaranteeing service assurance.

The kind of dependencies referenced in this section shall be taken into account for VINNI-SB implementation activities.

5 5G-VINNI services specifications

5G-VINNI service catalogue will allow CSCs to select among four VINNI-SBs, one for each service type: eMBB, uRLLC, mIoT and customised.

The objective of Chapter 4 was to provide a detailed overview of the content of a VINNI-SB, including a description and characterisation of their parameters. This overview is valid for any VINNI-SB and allows CSCs to have a good understanding of what type of information they could find when browsing the service catalogue. However, precisely because of its generality, this overview does not highlight the divergencies that exist between different VINNI-SBs. These divergencies are due to the inherent differences that exist between the four service types in terms of service topology (section #2 of a VINNI-SB, section 4.3.2 of D3.1) and service requirements (section #3 of a VINNI-SB, section 4.3.3 of D3.1). On the other hand, service capability exposure, monitoring and testing (section #4 of a VINNI-SB, section 4.3.4 of D3.1) is not dependent on the service type, but on the CSC interaction with CSP for service management and testing purposes.

The goal of Chapter 5 is to study the divergencies that exist among the four VINNI-SBs, with a focus on the differences on their service requirements: performance, functionality and network optimisation requirements. This approach allows remarking the specificities of each VINNI-SB, which means going from the generalities in Chapter 4 to the particularities in Chapter 5. In addition, this chapter will introduce the concept of SLA document, describing its elaboration based on the service requirements specified from a given VINNI-SB.

5.1 Specificities of the different VINNI-SBs

The parameters of any VINNI-SB were detailed in Sections 4.3.3-4.3.4 of this document. These parameters can belong on *service requirements* group (oriented to service behaviour, highly dependent on service type) or *service exposure, monitoring and testing* group (oriented to CSC capabilities, agnostic of service type). As stated in the introduction of Chapter 5, only the first group of parameters is the one that can be used to remark the particularities of each VINNI-SB.

In this section, the differences between VINNI-SBs will be identified from a service requirements viewpoint. These differences will not only allow the CSP to appropriately design each VINNI-SB, but also help the CSC to focus only on the parameters (and their allowed value ranges/selectable options) that are relevant for the network slice service corresponding to the selected VINNI-SB. For this task, a large set of vertical industry use cases of different 5G-VINNI service types (i.e. eMBB, uRLLC, mIoT and customised) have been analysed. The result of this analysis, which includes information on relevant KPIs and potential CSCs on a per use case basis, can be found in Annex B.

Table 5-1 summarises the main differences between the VINNI-SBs in terms of performance requirements. As seen, for each parameter P.PERF_X detailed in Section 4.3.3, the following information is provided per VINNI-SB:

- *Flag:* states if the P.PERF_X is mandatory, optional or not applicable (N/A) per VINNI-SB.
- *Specification:* provides details on how P.PERF_X shall be specified per VINNI-SB, indicating what P.PERF_X measurement unit represents (e.g. peak value, average value, minimum / maximum value, etc.) and the value ranges allowed for that measurement unit (e.g. low, moderate, high, etc.) in the context of that VINNI-SB.

Table 5-1: Comparison on performance requirements

Param ID	eMBB VINNI-SB	uRLLC VINNI-SB	mIoT VINNI-SB	Customised VINNI-SB
P.PERF_1A (Gbps)	**Mandatory** Peak value *(high ~ very high)*	**Optional** Peak value *(low ~ high)*	**N/A**	**Mandatory** Peak value *(all ranges)*
P.PERF_1B (Gbps)	**Mandatory** Peak value (*low ~ moderate*)	**Optional** Peak value *(low ~ high)*	**N/A**	**Mandatory** Peak value *(all ranges)*
P.PERF_2A (Mbps)	**Mandatory** Min guaranteed value *(high ~ very high)*	**Mandatory** Min guaranteed value *(low ~ moderate)*	**Optional** Average value *(very low)*	**Mandatory** [Min /Average] value *(all ranges)*
P.PERF_2B (Mbps)	**Mandatory** Min guaranteed value (*low ~ moderate)*	**Mandatory** Min guaranteed value *(low ~ moderate)*	**Optional** Average value (*very low ~ low)*	**Mandatory** Min /Average] value *(all ranges)*
P.PERF_3A (Gbps/km^2)	**Mandatory** Average value (*high ~ very high)*	**Mandatory** Min guaranteed value *(very low ~ moderate)*	**Mandatory** Peak value *(low ~ moderate)*	**Mandatory** [Peak/Min/Average] value *(all ranges)*
P.PERF_3B (Gbps/km^2)	**Optional** Average *(low ~ moderate)*	**Mandatory** Min guaranteed value (*very low ~ low*)	**Optional** Peak value *(high ~ very high)*	**Mandatory** [Peak/Min/Average] value *(all ranges)*
P.PERF_4A (ms)	**Mandatory** Max tolerable value *(low ~ moderate)*	**Mandatory** Max tolerable value *(very low)*	**Mandatory** Max tolerable value *(high ~ very high)*	**Mandatory** Max tolerable value *(all ranges)*
P.PERF_4B (ms)	**Mandatory** Max tolerable value *(low ~ moderate)*	**Mandatory** Max tolerable value *(very low)*	**Optional** Max tolerable value *(high ~ very high)*	**Mandatory** Max tolerable value *(all ranges)*
P.PERF_4C (us)	**Optional** Max tolerable value *(low ~ moderate)*	**Mandatory** Max tolerable value *(very low)*	**N/A**	**Mandatory** Max tolerable value *(very low ~ moderate)*
P.PERF_4D (%)	**Optional** Max tolerable value (*low*)	**Mandatory** Max tolerable value *(very low)*	**Optional** Max tolerable value *(low ~ moderate)*	**Mandatory** Max tolerable value *(very low ~ moderate)*
P.PERF_4E (%)	**Optional** Max tolerable value *(low)*	**Mandatory** Max tolerable value *(very low)*	**Optional** Max tolerable value *(low ~ moderate)*	**Mandatory** Max tolerable value *(very low ~ moderate)*
P.PERF_4F (Bytes)	**Optional** Discrete value *(moderate ~ very high)*	**Mandatory** Discrete value *(very low ~ moderate)*	**Optional** Discrete value *(low ~ moderate)*	**Optional** Discrete value *(very low ~ very high)*

Param ID	eMBB VINNI-SB	uRLLC VINNI-SB	mIoT VINNI-SB	Customised VINNI-SB
P.PERF_4G (Bytes)	**Optional** Discrete value (moderate ~ very high)	**Mandatory** Discrete value (very low ~ moderate)	**Optional** Discrete value *(low ~ moderate)*	**Optional** Discrete value *(low ~ very high)*
P.PERF_5 (%)	**Mandatory** Min guaranteed value (moderate ~ very high)	**Mandatory** Min guaranteed value *(very high)*	**Mandatory** Min guaranteed value *(low ~ moderate)*	**Mandatory** Min guaranteed value *(moderate ~ very high)*
P.PERF_6 (%)	**Mandatory** Min guaranteed value *(moderate ~ very high)*	**Mandatory** Min guaranteed value *(very high)*	**Mandatory** Min guaranteed value *(low ~ high)*	**Mandatory** Min guaranteed value *(moderate ~ very high)*
P.PERF_7 (min)	**Optional** Max tolerable value *(CSC specific)*	**Mandatory** Max tolerable value *(CSC specific)*	**Optional** Max tolerable value *(CSC specific)*	**Optional** Max tolerable value *(CSC specific)*

Table 5-2 summarises the main differences between the VINNI-SBs in terms of functionality requirements. Note that the approach followed here is similar to the one used for Table 5-1, with the exception that unlike the P.PERF_X parameters, characterised by the semantics of their measurements unit and allowed value ranges, the P.FUNC_X parameters are totally specified by their selectable options.

Table 5-2: Comparison on functionality requirements

Param ID	eMBB VINNI-SB	uRLLC VINNI-SB	mIoT VINNI-SB	Customised VINNI-SB
P.FUNC_1	**Mandatory** Select. options: 0,1,2	**Mandatory** Select. options: 0,1,2	**Mandatory** Select. options: 0,1,2	**Mandatory** Select. options: all
P.FUNC_2	**Mandatory** Select. options: 0,1	**Mandatory** Select. options: 0,1	**Mandatory** Select. options: 0,1	**Mandatory** Select. options: all
P.FUNC_3	**Mandatory** Select. options: 0,1	**Mandatory** Select. options: 0,3,4	**Mandatory** Select. option: 2	**Mandatory** Select. options: all
P.FUNC_4	**Mandatory** Select. options: 0,1	**Mandatory** Select. options: 0,1	**Mandatory** Select. options: 0,1	**Mandatory** Select. options: all
P.FUNC_5A	**Optional**	**Mandatory**	**Optional**	**Mandatory**
P.FUNC_5B	**Optional** Select. options: 0,1	**Mandatory** Select. Opti ons: 1,2	**Optional** Select. options: 0,1	**Mandatory** Select. options: all
P.FUNC_6A	**Optional**	**Optional**	**Optional**	**Mandatory**
P.FUNC_6B	**N/A**	**Optional**	**N/A**	**Optional**
P.FUNC_6C	**Optional**	**Optional**	**Optional**	**Optional**

Param ID	eMBB VINNI-SB	uRLLC VINNI-SB	mIoT VINNI-SB	Customised VINNI-SB
P.FUNC_6D	**Optional**	**Optional**	**Optional**	**Optional**
P.FUNC_6E	**Optional**	**Optional**	**Optional**	**Optional**
P.FUNC_6F	**Optional**	**Optional**	**Optional**	**Optional**

Finally, Table 5-3 summarises the main differences between the VINNI-SBs in terms of network optimisation requirements.

Table 5-3: Comparison on network optimisation requirements

Param ID	eMBB VINNI-SB	uRLLC VINNI-SB	mIoT VINNI-SB	Customised VINNI-SB
P.NO_1	**N/A**	**Mandatory** Peak value *(very low ~ moderate)*	**Optional** Peak value *(moderate ~ very high)*	**Mandatory** Peak value *(very low ~ very high)*
P.NO_2 ($\mathbf{km^{-2}}$)	**Mandatory** Average value *(low ~ moderate)*	**N/A**	**Mandatory** Peak value *(moderate ~ very high)*	**Mandatory** [Peak/Average] value *(low ~ moderate)*
P.NO_3A	**Mandatory** Select. options: all	**Mandatory** Select. options: all	**Mandatory** Select. options: all	**Mandatory** Select. options: all
P.NO_3B ({GPS, km})	**Optional** {Discrete, discrete} value *(CSC specific)*	**Optional** {Discrete, discrete} value *(CSC specific)*	**Optional** {{Discrete, discrete} value *(CSC specific)*	**Optional** {Discrete, discrete} value *(CSC specific)*
P.NO_4	**Mandatory** Select. options: all	**Mandatory** Select. options: all	**Mandatory** Select. options: 0,1	**Mandatory** Select. options: all
P.NO_5A ({start, end})	**Mandatory** {Discrete, discrete} value *(CSC specific)*	**Mandatory** {Discrete, discrete} value *(CSC specific)*	**Mandatory** {Discrete, discrete} value *(CSC specific)*	**Mandatory** {Discrete, discrete} value *(CSC specific)*
P.NO_5B-F	**Optional**	**Optional**	**Optional**	**Optional**

5.2 Service orders and SLA elicitation

This section provides an overview of how going from a VINNI-SB to the sign of an SLA document.

5.2.1 Service order

Any parameter of a given VINNI-SB (i.e. either belonging to *service requirements* group or *service exposure, monitoring and testing* group) shall be classified as "modifiable" or "not modifiable". A parameter shall be marked as "modifiable" when it admits modification from CSC side (i.e. the CSC can modify its default value, according to the CSP defined policy). Otherwise, it shall be marked as "not modifiable", which means that it cannot be changed. For more information, see Section 4.2.

The above statement applies to both mandatory and optional parameters. As a result, some considerations are provided below:

- All the mandatory parameters of a VINNI-SB shall be specified. Two possible scenarios:
    - A mandatory parameter marked as "not modifiable": in this scenario, the value that this parameter takes is the one the CSP defined for that VINNI-SB at design time.
    - A mandatory parameter marked as "modifiable": in this scenario, the CSP shall always provide a default value for this parameter. This will prevent this parameter from being unspecified for the cases where the CSCs decide not to modify it.
- The specification of an optional parameter is not required. This means that the CSC can decide on enabling/disabling an optional parameter, depending on whether is relevant/irrelevant for the service it wants. Three possible scenarios:
    - An optional parameter irrelevant for the CSC: in this scenario, the CSC simply ignores the parameter.
    - An optional parameter relevant for the CSC, and marked as "not modifiable": in this scenario, the CSC enables the parameter, and accepts it with the value that CSP defined for that VINNI-SB at design time.
    - An optional parameter relevant for the CSC, and marked as "modifiable": in this scenario, the CSC enables the parameter, and can customise it according to its needs. If the parameter remains empty, the CSC fills in it with a value. Otherwise, the CSC simply modifies the default value.

When a CSC wants to specify the network slice service instance it wants to get from the 5G-VINNI facility, the CSC shall send the CSP the selected VINNI-SB, with the mandatory and optional parameters specified in compliance with the considerations mentioned above. The result is a service order. This service order provides a complete, self-contained service specification that is documented in a 5G-VINNI Service Descriptor (VINNI-SD). A VINNI-SD is a VINNI-SB filled with values based on CSC service requirements. Note that the relationship between VINNI-SB and VINNI-SD is similar (although not the same) to the one GSMA states for GST and NEST.

5.2.2 SLA document

Once the CSP has designed and published the different VINNI-SBs, any CSC is in a position to browse the service catalogue, select the VINNI-SB that best fits his needs, and issue a service order. The desired outcome of this service order is the generation of an SLA, a formal document that states all the specific and measurable service parameters agreed between CSP and CSC for the selected service offering. The sign of an SLA between CSC and CSP may have implications at the:

- *Service layer (WP3 scope)*: the CSP will use the information documented in the SLA (i) to inform the NOP on how the NSI shall be deployed and configured, and (ii) to know the set of capabilities of that NSI that shall be exposed to the CSC. Additionally, the SLA will be used as a reference for the operation of the network slice service instance at-run time, including activities on lifecycle management, performance monitoring, fault supervision and testing. These activities can be led by the CSP or CSC, depending on selected exposure level.
- *Business layer (WP5 scope)*: the SLA could be used for billing and charging activities. These activities are led by the CSP.

5.2.3 From a service order to the SLA

This section provides an overview of how going from a VINNI-SB to the sign of an SLA document. In this process, the following steps apply (see Figure 5.1):

1. The CSC browses the service catalogue, identifies the type of slice that it is more appropriate for him, and selects the corresponding VINNI-SB.
2. (Optional) If 3rd party VNF hosting is allowed and the CSC wants to on-board its own VNFs, he uploads them.
3. (Optional) If CSC has uploaded 3rd party VNFs, the CSP proceeds verifies and validates them. Two possible scenarios:
    a. If uploaded VNFs are OK, then go to step 4.
    b. Otherwise, the CSP informs CSC of the cause of error, and we go back to step 2.
4. The CSC issues a service order. For this end, the CSC first fills in the selected VINNI-SB, specifying values for the modifiable parameters according to his specific needs. Then, the CSC submits the filled VINNI-SB to the CSP's E2E Service Management & Operation block.
5. The CSP verifies if the received information is correct. For this end, the CSP analyses the mandatory and optional parameters, and checks if they are compliant with the scenarios described at the end of Section 5.2. Two possible scenarios:
    a. If the analysis of service order is OK, then go to step 6.
    b. Otherwise, the CSP informs CSC of the cause of error, and we go back to step 4.
6. The CSP generates a VINNI-SD out of the service order and makes it available for the CSC. Until completion of step 7, the CSC can query, update and delete the service order.
7. The CSP puts the service order in queue for feasibility check. In this step, CSP assess if the service requirements declared in the VINNI-SD be satisfied at the infrastructure level. For this end, resource-facing activities are needed, and thus interactions between CSP and NOP. Two possible scenarios:
    a. If VINNI-SD is feasible, then go to step 8.
    b. Otherwise, the CSP informs CSC of the cause error, and we go back to step 4.
8. The CSP creates the SLA, taking the relevant information from the VINNI-SD.

Signed by the CSC and the CSP, the SLA documents the commitment of both parties for service provisioning and operation. For this reason, the SLA shall only contain the information that is strictly necessary to guarantee the network slice service (instance) will be provided as requested by the CSC. At the service layer (WP3 scope), this information includes:

- Mandatory parameters of the VINNI-SB, and their values.
- Enabled optional parameters of the VINNI-SB (i.e. optional parameters that are relevant for the CSC), and their values.

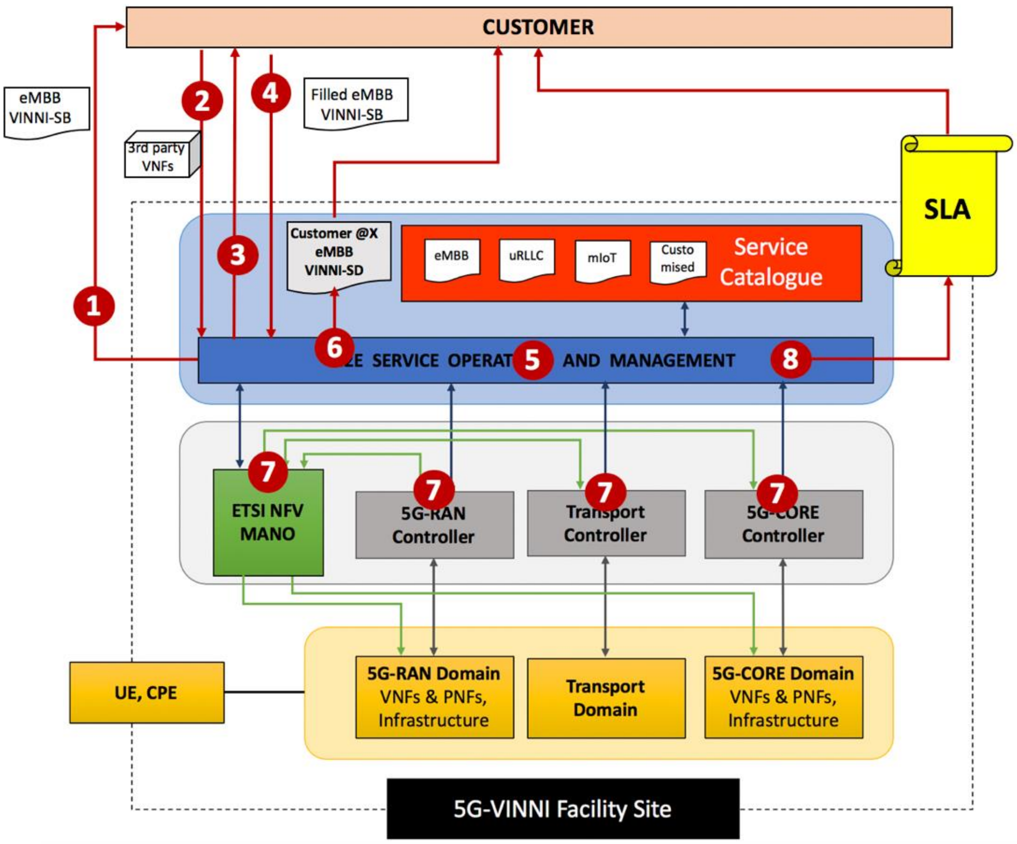

Figure 5.1: From a service order to an SLA. In this example, the CSC selects the VINNI-SB corresponding to the eMBB service type.

6 Lifecycle management of a network slice service

According to the reasoning presented in Section 2, network slicing can be addressed under two different but complementary perspectives. On the one side, there is a resource-facing perspective, which focuses on how NSIs are deployed in the CSP/NOP domain. On the other side, there is a customer-facing perspective, which focuses on how network slice service instances are delivered to CSCs. The relationship between the objects managed by each perspective can be defined as follows: a network slice service instance is the set of capabilities of an NSI that are exposed by the CSP to a CSC. This exposure means introducing an abstraction layer between what is offered to the CSC (i.e. a network slice service instance) and what is really deployed (i.e. an NSI).

From the above discussion, it can be stated that the concepts of network slice service (instance) and network slice (instance) are not the same, and neither their lifecycles. The NSI lifecycle has already been discussed and agreed in 3GPP. The result is the schema shown in Figure 6.1, extracted from 3GPP TS 28.530 [13]. As it can be seen, 3GPP vision assumes the lifecycle of an NSI can be split into four phases: preparation phase, commissioning, operation and decommissioning. For more details of these phases, see D1.3 [4].

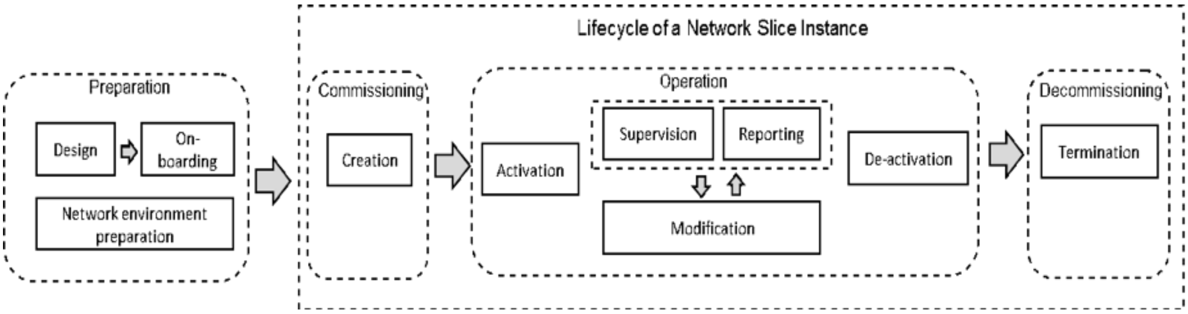

Figure 6.1: 3GPP view on NSI lifecycle (source: [13])

However, this deliverable will turn the spotlight on the lifecycle of a network slice service instance, where two phases have been defined:

- *Preparation phase*: it includes all steps from the moment the CSC access to 5G-VINNI and makes a service order to the moment when SLA is signed between CSC and CSP. Some notions on these steps have been already provided in Section 5.3. In this phase, the network slice service instance does not exist yet.
- *Operation phase:* in this phase, the network slice service instance does exist and has been set by the CSP ready for CSC's consumption. The operation phase represents the run-time execution of the service instance, which can be moved between different states throughout its lifetime as a result of the CSC operations, including performance monitoring (i.e. collect measurements on KPIs), fault supervision (i.e. receive fault alarms), lifecycle management (e.g. scale) and testing.

To understand the lifecycle management of a network slice service instance across these two phases, it is important to specify the capabilities the CSC can get from that instance. These capabilities are materialised into a set of operations that the CSC can consume, and that allows him to manage and use the instance as expected: as an isolated and tailored network environment where use case trials can be executed. These operations are exposed to the CSC via CSP defined APIs. In this chapter, we provide an overview of these operations, including details on the messages exchanged between the CSP and CSC.

The aim of this chapter is to lay the foundation for later implementation activities within WP3, where specific APIs providing these operations shall be developed per facility site.

6.1 Preparation phase

The operations allowing the CSP-CSC interaction in this first lifecycle phase are described in this section. Figure 6.2 provides a workflow illustrating the execution of these operation.

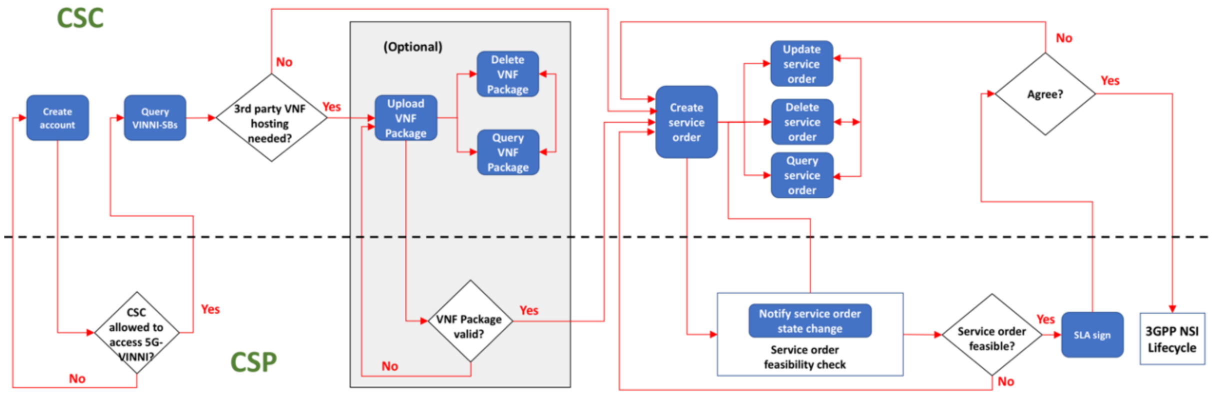

Figure 6.2: Overview of the preparation phase. Operations impacting CSC-CSP interaction are marked in blue colour

6.1.1 Create account

This operation allows a vertical to register in 5G-VINNI as a CSC. After registration, the CSC is provided with a unique identifier, an URL and a set of API endpoints. On the one side, the CSC ID allows the CSP to identify the vertical customer for authentication, authorisation and accounting purposes. On the other side, the URL allows the CSC to communicate with the CSP during the preparation phase, exchanging request-response/notification messages resulting from the operations allowed by the API endpoints.

The create account messages are specified in Table 6-1.

Table 6-1: Create account messages

Message	Direction	Description	Parameters
Create account request	CSC→CSP	Request to create an account for a vertical in 5G-VINNI	• Vertical ID
Create account response	CSP→CSC	Response with the result of the operation. In case of successful registration, the CSC is provided with account details: CSC ID, URL and a list of API endpoints.	• Result code • CSC ID • URL: URL where the CSC will connect to use 5G-VINNI facility. • List <API endpoint>

6.1.2 Query VINNI-SBs

This operation allows a CSC to browse the 5G-VINNI service catalogue, retrieving all the VINNI-SBs that match the input filter. This filter enables setting up criteria to query only the set of VINNI-SBs that interest CSC the most. It can be a single service type (e.g. eMBB), multiple service types (e.g. eMBB, uRLLC) or wildcard. This means that filtering criteria for this operation are based on the service type parameter of the VINNI-SB (see Section 4.3.1).

The query VINNI-SBs messages are specified in Table 6-2.

Table 6-2: Query VINNI-SBs messages

Message	Direction	Description	Parameters
Query VINNI-SBs request	CSC→CSP	Request to retrieve the VINNI-SBs matching the input filter.	• CSC ID • Filter: defines the service types of the VINNI-SBs on which the query applies.
Query VINNI-SBs response	CSP→CSC	Response including the details of the requested VINNI-SBs	• Result code • List <VINNI-SB>

6.1.3 Upload VNF Package

This operation allows a CSC to upload a VNF Package describing a 3rd party VNF to the 5G-VINNI facility. Once validated/certified, the VNF Package is on-boarded onto the CSP's VNF Catalogue. Immediately after VNF Package on-boarding, the CSP generates an unique VNF Package ID that is returned to the CSC. The CSC can use this ID to:

- retrieve information about the content of VNF Package, using the query VNF Package primitive (see Section 6.2.4).
- remove the VNF Package from the CSP's VNF catalogue, using the delete VNF Package primitive (see Section 6.2.5).
- issue a service order specifying a service topology that includes the 3rd party VNF, using the create service order primitive (see Section 6.2.6). For more information on how to use VNF Package ID in the service order, see P.FUNC_8 in Section 4.3.3.

The upload VNF Package messages are specified in Table 6-3.

Table 6-3: Upload VNF Package messages

Message	Direction	Description	Parameters
Upload VNF Package request	CSC→CSP	Request to upload a VNF Package describing a 3rd party VNF onto 5G-VINNI facility.	• CSC ID • VNF Package (reference format specified in NFV IFA-014 [15]) • Is Public (set to true if the VNF Package is visible to other CSCs)
Upload VNF Package request	CSP→CSC	Response with the result of the operation, and the ID of the uploaded VNF Package	• Result code • VNF Package ID

6.1.4 Query VNF Package

This operation allows a CSC to retrieve one or more VNF Packages from the CSP's VNF Catalogue, based on a given filter. The CSC can retrieve only the VNF Packages that have been uploaded by the CSC itself, or the VNF Packages that are declared as public.

The information a CSC can get from a VNF Package includes VNFD, metadata and the software image(s) used for VNF application.

The query VNF Package messages are specified in Table 6-4.

Table 6-4: Query VNF Package messages

Message	Direction	Description	Parameters
Query VNF Package request	CSC→CSP	Request to retrieve VNF Packages matching the input filter.	• CSC ID • Filter: defines the IDs of the VNF Packages on which the query applies.
Query VNF Package request	CSP→CSC	Response including the details of the requested VNF packages	• Result code • List <VNF Package> (reference format specified in NFV IFA-014 [15])

6.1.5 Delete VNF Package

This operation allows CSC to delete one or more VNF Packages from the CSP's VNF Catalogue, providing their IDs. A CSC can delete only the VNF Packages that have been uploaded by the CSC itself.

The delete VNF Package messages are specified in Table 6-5.

Table 6-5: Delete VNF Package messages

Message	Direction	Description	Parameters
Delete 3rd party VNFs request	CSC→CSP	Request to delete the specified VNF Packages.	• CSC ID • List <VNF Package ID>
Delete 3rd party VNFs request	CSP→CSC	Response with the result of the operation	• Result Code

6.1.6 Create service order

This operation allows a CSC to issue a service order to the CSP. For this end, the CSC first selects a VINNI-SB from the catalogue and then fills it, specifying values for the modifiable parameters according to his specific needs. Upon the reception of a service order request, the CSP verifies if it is correct or not (see step 5 in Section 5.3). If so, the CSP puts the service order in queue for feasibility check. In parallel, it creates a new entry in the VINNI-SD repository, generating an ID that is returned to the CSC. The VINNI-SD ID can be used by the CSC to:

- retrieve information of the service order, using the query service order primitive (see Section 6.2.8).
- update the content of the service order, using the update service order primitive (see Section 6.2.9).
- cancel the service order, using the delete service order primitive (see Section 6.2.10). The triggering of this operation should be allowed only before service order feasibility check process (step 7 in Section 5.3) gets finished.

The create service order messages are specified in Table 6-6.

Table 6-6: Create service order messages

Message	Direction	Description	Parameters
Create service order request	CSC→CSP	Request to issue a service order based on the specified VINNI-SB.	• CSC ID • VINNI-SB ID • VINNI-SB parameter values
Create service order response	CSP→CSC	Response including the ID of the generated VINNI-SD.	• Result code • VINNI-SD ID

6.1.7 Notify service order state change

This one-way operation allows the CSP to keep a CSC informed of any change in the state of an existing service order. It is assumed that this service order has been previously requested by the CSC itself, using the create service order primitive (see Section 6.2.7). States of a service order could include the following ones: "awaiting processing" (i.e. the order is still queued), "in progress" (i.e. the CSP is executing the service order feasibility check process), "successful" (i.e. the service order feasibility check process has been successfully completed, which means that the order is feasible), "failed" (i.e. the outcome of the service order feasibility check process states that the service order is not feasible).

The notify service order state change messages are specified in Table 6-7.

Table 6-7: Notify service order state change messages

Message	Direction	Description	Parameters
Notify service order state change	CSP→CSC	Notification of a change in the service order state	• VINNI-SD ID • Service order state

6.1.8 Query service order

This operation allows a CSC to retrieve information about an existing service order, based on the input filter. The filtering criteria for this operation are based on the attributes of the service order, which include not only the parameter values recorded in the VINNI-SD, but also information of the different states (together with their timestamps) the service order has gone through since its creation.

The query service order messages are specified in Table 6-8.

Table 6-8: Query service order messages

Message	Direction	Description	Parameters
Query service order request	CSC→CSP	Request to retrieve information of a service order matching the given VINNI-SD ID.	• CSC ID • VINNI-SD ID • Filter: defines the attributes of the service order on which the query applies.
Query service order response	CSP→CSC	Response including details of the service order matching the input filter.	• Result code • Map <service order attribute; value>

6.1.9 Update service order

This operation allows a CSC to update an existing service order, providing the new values for those attributes that wants to be updated. Only those VINNI-SD attributes representing modifiable parameters in the selected VINNI-SB could be updated with new values.

The updated service order generates a new VINNI-SD ID. The previous version is still accessible with the old VINNI-SD ID.

The query service order messages are specified in Table 6-9.

Table 6-9: Update service order messages

Message	Direction	Description	Parameters
Update service order request	CSC→CSP	Request to update a service order matching the given VINNI-SD ID	• CSC ID • VINNI-SD ID • Updated attribute values.
Update service order response	CSP→CSC	Response with the result of the operation, including the new ID of the updated service order.	• Result code • VINNI-SD ID

6.1.10 Delete service order

This operation allows CSC to delete an existing service order. The delete service order messages are specified in Table 6-10.

Table 6-10: Delete service order messages

Message	Direction	Description	Parameters
Delete service order request	CSC→CSP	Request to delete a service order matching the given VINNI-SD ID.	• CSC ID • VINNI-SD ID
Delete service order response	CSP→CSC	Response with the result of the operation.	• Result code

6.1.11 SLA sign

This operation allows the CSP to send the generated SLA document to the CSC (see step 8 in Section 5.3). Upon reception of the SLA, the CSC takes a take a detailed look at the document and (if satisfied with the document) signs it.

The SLA sign messages are specified in Table 6-11.

Table 6-11: SLA sign messages

Message	Direction	Description	Parameters
SLA sign request	CSP→CSC	Request to sign the generated SLA	• Service order ID • SLA document
SLA sign response	CSC→CSP	Response with the result of the operation.	• Result code • Is Signed (set to true if the CSC agrees with the SLA).

Upon the completion of this operation, the next lifecycle phase begins.

6.2 Operation phase

The operations allowing the CSP-CSC interaction in this second lifecycle phase are described in this section.

6.2.1 Notify service instance availability

This one-way operation allows the CSP to inform a CSC that the network slice service instance is already available to be used. It is assumed that the NSI on which this service instance is built has already been commissioned, i.e. instantiated and configured, fulfilling with the start time specified by the CSC in the service order (see P.NO_5A in Section 4.3).

To allow CSC to consume the service instance, the CSC shall send the notification with the following information: service instance ID and a set of API endpoints. On one hand, the service instance ID provides a unique identifier for the service instance. This ID can be used (i) by the CSC, to manage and monitor the service instance; (ii) by the CSP, to send the CSC notifications about the service instance. On the other hand, the API endpoints define the set of operations the CSC can consume from the service instance with respect to performance monitoring (Sections 6.2.6, Sections 6.2.10), fault supervision (Section 6.2.11), lifecycle management (Sections 6.2.3, 6.2.5, 6.2.9) and testing (Sections 6.2.7, 6.2.8). The concrete set of API endpoints depends on the exposure level specified by the CSC in the service order. This dependency is established in the following terms:

- The exposure level does not have an impact on the operations exposed by the API endpoints. These operations (e.g. query, modify, subscribe/notify, execute test, etc.) will be addressed in this section, and are always the same, regardless of the selected exposure level.
- The exposure level defines the object types over which the above operations can be applied. According to the concepts discussed in Section 4.3.3, different levels allows the CSC to manage different object types:
    - Level 1: object types = “network slice service”
    - Level 2: object types = append (Level 1 object types, “SC”)
    - Level 3: object types = append (Level 2 object types, “NFV-NS”, “VNF”)
    - Level 4: object types = append (Level 3 object types, “Virtualisation resource”)

  With the above reasoning, it is clear that the selected exposure level does have an impact on the number of API endpoints exposed to the CSC. The higher the selected exposure level, the higher the number of object types the CSC can manage, and thus the higher number of APIs available for the CSC.

The notify service instance availability message is specified in Table 6-12.

Table 6-12: Notify service instance availability messages

Message	Direction	Description	Parameters
Notify service instance availability	CSP→CSC	Notification of availability of the network slice service instance. The instance is created out of an NSI, based on the SLA generated and signed at the end of the preparation phase.	• Service instance ID • List <API endpoint>

6.2.2 Activate service instance

This operation allows a CSC to activate the network slice service instance, changing its state from "deactivated" to "activated". From the CSP perspective, the activation request means that NSI shall be activated in case it is not. From the CSC perspective, it means the service instance is ready to receive connection requests from CSC devices, and to support the execution of use cases trials.

The activate service instance messages are specified in Table 6-13.

Table 6-13: Activate service instance messages

Message	Direction	Description	Parameters
Activate service instance request	CSC→CSP	Request to activate the network slice service instance matching the given ID.	• Service instance ID • CSC ID
Activate service instance response	CSP→CSC	Response with the result of the operation.	• Result code

6.2.3 Modify service instance

This operation allows a CSC to modify the service instance, including modifications over constituent (SC, VNF/NFV-NS, virtualised resource) instances. Depending on the selected exposure level, the CSC can request modifications over one or more instances of the same or different object types. For each instance that needs to be modified, the CSC can provide the following information:

- The ID of the instance. This instance can be one of the following object types: network slice service (minimum exposure level required is 1), SC (minimum exposure level required is 2), NFV-NS or VNF (minimum exposure level required is 3) and virtualisation resource (minimum exposure level required is 4).
- The lifecycle management operation that wants to be executed over the instance. One example of this operation is scaling, although others can also be considered (e.g. upgrading, healing). The concrete set of lifecycle management operations that can be triggered depends on the implementation of the management systems at the different facility sites.
- Input information sent when invoking the lifecycle management operation. This information is instance- and operation-specific. Some examples of input information needed for different lifecycle operations can be found in NFV-IFA 013 [28][8].

For example, if Level 3 was selected, the CSC should be allowed to trigger some lifecycle management operations over VNF/NFV-NS instances within the service instance.

For a 3rd party VNF included as part of the service instance, the selected exposure level does not apply. In such a case, the set of modification operations that can be executed on that VNF are already defined by the CSC itself (see P.FUNC_7).

The modify service instance messages are specified in Table 6-14.

[8] In 5G-VINNI, these operations can only be invoked by the CSC if selected exposure level is 3 or 4.

Table 6-14: Modify service instance messages

Message	Direction	Description	Parameters
Modify service instance request	CSC→CSP	Request to modify a network slice instance, with the application of one or more lifecycle management operations (e.g. scaling, upgrading, etc.). The input parameters are dependent on selected exposure level.	• Service instance ID • CSC ID • List <[Object type] instance ID> • List <LCM operation ID> • List <LCM operation Info>
Modify service instance response	CSP→CSC	Response with the result of the operation.	• Result code

6.2.4 Deactivate service instance

This operation allows a CSC to deactivate the network slice service instance, changing its state from "activated" to "deactivated". The new state means that the service instance is not operative.

Note that changes from activation to deactivation can be supported if the service instance does not require to be operative 24/7. For more information, see P.NO_5 in Section 4.3.3.

The deactivate service instance messages are specified in Table 6-15.

Table 6-15: Deactivate service instance messages

Message	Direction	Description	Parameters
Deactivate service instance request	CSC→CSP	Request to activate the network slice service instance matching the given ID.	• Service instance ID • CSC ID
Deactivate service instance response	CSP→CSC	Response with the result of the operation	• Result code

6.2.5 Query service instance

This operation allows a CSC to retrieve information from the record of a network slice service instance, based on the input filter. The filtering criteria for this operation are based on the attributes of the service instance. Examples of attributes included in this record are the following:

- Network slice service instance ID (see Section 6.2.1)
- Network slice service instance name: human-readable description of the service instance.
- Network slice service instance state (e.g. activated, deactivated)
- Network slice service instance exposed API endpoints (see Section 6.2.1)
- SLA: content of the SLA out of which the network slice service instance has been created.
- Records of instances within the network slice service instance, including:
    - Records of SC instances, available only if selected exposure level is at least 2.
    - Records of VNF/NFV-NS instances, available only if selected exposure level is at least 3. Examples of how records of these instances could look like can be found in NFV-IFA 013 [28].
    - Records of virtualisation resource instances (e.g. VMs), available only if selected exposure level is 4.

The query service instance messages are specified in Table 6-16.

Table 6-16: Query service instance messages

Message	Direction	Description	Parameters
Query service instance request	CSC→CSP	Request to retrieve information of a network slice service instance matching the ID. The input parameters are dependent on selected exposure level.	• Service instance ID • CSC ID • Filter: defines the attributes of the service instance on which the query applies.
Query service instance response	CSP→CSC	Response including details of the service order matching the input filter.	• Result code • Map <service instance attributes values>

6.2.6 Query service instance performance measurements

This operation allows a CSC to retrieve performance measurements from a network slice service instance, including measurements from constituent (SC, VNF/NFV-NS, virtualised resource) instances as long as the granted exposure level allow this. In such a case, the CSC shall indicate the IDs of that instances from which it wants to retrieve measurements.

The CSP will only return measurements of the performance parameters the CSC is subscribed to.

The query service instance performance measurement messages are specified in Table 6-17.

Table 6-17: Query service instance performance measurements messages

Message	Direction	Description	Parameters
Query performance measurement requests	CSC→CSP	Request to retrieve monitoring parameters about the network slice instance matching the given ID. The input parameters are dependent on selected exposure level.	• Service instance ID • CSC ID • List <[Object type] instance ID>
Query service instance response	CSP→CSC	Response including requested performance measurements from the service instance.	• Result code • Map <[Object type] instance ID; performance parameter; value; timestamp>

6.2.7 Execute test case

This operation allows a CSC to order the execution of a given test case on a network slice service instance. This test case is defined in the context of a given test campaign that the CSC had specified in the service order. Upon the completion of test case execution, the CSC generates a report that is immediately returned to the CSC.

The execute test case messages are specified in Table 6-18.

Table 6-18: Execute test case messages

Message	Direction	Description	Parameters
Execute test campaign request	CSC→CSP	Request to execute a given test (test case ID) from a test campaign (test campaign ID) on a network slice service instance.	• Service instance ID • CSC ID • Test campaign ID • Test case ID • Test case execution information.
Execute test campaign response	CSP→CSC	Response including the result of the operation.	• Result code
Notify test report	CSP→CSP	Notification including details of the executed test case.	• Service instance ID • Test case report

6.2.8 Query test campaign information

This operation allows a CSC to retrieve information about a given test campaign. The record of a test campaign contains information about the test cases taking part in this campaign, including their descriptions (see Section 4.3.4.3) and historical data on their states (e.g. not initiated, in execution, completed, failed).

The query service instance messages are specified in Table 6-19.

Table 6-19: Query test campaign information messages

Message	Direction	Description	Parameters
Query test campaign info request	CSC→CSP	Request to retrieve information of a test campaign matching the given ID.	• Service instance ID • CSC ID • Test campaign ID • Filter: defines the test case IDs on which the query applies.
Query test campaign info response	CSP→CSC	Response including details of the service order matching the input filter.	• Result code • Map <test case ID; test case parameter; value>

6.2.9 Subscription/Notification about service instance lifecycle management

This operation allows a CSC to subscribe with the CSP to receive notifications about lifecycle events. Every time a lifecycle management operation is executed within the network slice service instance, a lifecycle event is generated. This event reported to the CSC includes the following information: the ID of the lifecycle management operation that produces the event, the ID of the (SC, VNF/NFV-NS or virtualised resource) instance over which the operation is executed, the event type (start/end of the operation) and the timestamp (start/end time).

The CSP only notifies the events of those lifecycle management operations to which the CSC is subscribed.

The subscription/notification messages about service instance lifecycle management are specified in Table 6-20.

Table 6-20: Subscription/notification messages about service instance lifecycle management

Message	Direction	Description	Parameters
Create lifecycle management subscription request	CSC→CSP	Request to create a new subscription for receiving notifications about the start/end of a given lifecycle management operation.	• Service instance ID • CSC ID • LCM operation ID
Create lifecycle management subscription response	CSP→CSC	Response with the ID of the subscription.	• Result code • Subscription ID
Delete lifecycle management subscription request	CSC→CSP	Requested to delete a subscription matching the given ID.	• Service instance ID • CSC ID • Subscription ID
Delete lifecycle management subscription response	CSP→CSC	Response with the result of the operation.	• Result code
Query subscription information response	CSC→CSP	Request to retrieve information of subscriptions matching the input filter.	• Service instance ID • CSC ID • Filter: defines the IDs of the subscriptions on which the query applies
Query subscription information response	CSP→CSP	Response including the details of the requested subscriptions.	• Result code • List <subscription>
Notify lifecycle event	CSP→CSC	Notification of a lifecycle event	• Service instance ID • Subscription ID • Map <[object type] instance ID, event type; timestamp>

6.2.10 Subscription/Notification about service instance performance monitoring

This operation allows a CSC to subscribe with the CSP for performance monitoring activities related to a network slice service instance that were not specified in the original service order (see Table 4-29). A subscription in the context of this operation can be based on performance monitoring jobs (i.e. specification of collection and reporting information on one or more performance metrics) and thresholds (i.e. specification of threshold values on one or more performance metrics for which notifications will be generated when crossed). For more information on which information is needed for the creation of a performance management job or threshold, please see [28].

Note that the main difference between the two types of subscriptions is that the first generates synchronous notifications (based on specified reporting period), while the latter generates asynchronous notifications (when the threshold value is crossed).

Depending on selected exposure level, the CSC can trigger the creation of performance monitoring jobs and thresholds over (SC, VNF/NFV-NS, virtualised resource) instances within the service instance.

The subscription/notification messages about service instance performance management are specified in Table 6-21.

Table 6-21: Subscription/notification messages about service instance performance management

Message	Direction	Description	Parameters
Create performance monitoring subscription request	CSC→CSP	Request to create a new subscription for receiving notifications about a performance job or threshold. The input parameters are dependent on selected exposure level.	• Service instance ID • CSC ID • PM operation (i.e. “PM job” or “threshold”) • PM operation data (see [28]). • [Object Type] instance ID: the ID of the instance over which the PM operation is executed.
Create performance monitoring subscription response	CSP→CSC	Response with the ID of the subscription.	• Result code • Subscription ID
Delete performance monitoring subscription request	CSC→CSP	Requested to delete a subscription matching the given ID.	• Service instance ID • CSC ID • Subscription ID
Delete performance monitoring subscription response	CSP→CSC	Response with the result of the operation.	• Result code
Query performance monitoring request	CSC→CSP	Request to retrieve information of subscriptions matching the input filter.	• Service instance ID • CSC ID • Filter: defines the IDs of the subscriptions on which the query applies
Query performance monitoring response	CSP→CSC	Response including the details of the requested subscriptions.	• Result code • List <subscription>
Notify performance measurement	CSP→CSC	Notification about measurements of a given performance job or threshold crossed event.	• Service instance ID • Subscription ID • Map <performance parameter; value; timestamp>

6.2.11 Subscription/Notification about service instance fault supervision

This operation allows a CSC to subscribe with the CSP for fault supervision activities related to a network slice service instance that were not specified in the original service order (see Table 4-30). Every time a failure occurs, the CSP generates an alarm, informing the CSC about the failure cause.

The subscription/notification messages about service instance fault supervision are specified in Table 6-22.

Table 6-22: Subscription/notification messages about service instance fault supervision

Message	Direction	Description	Parameters
Create fault supervision subscription request	CSC→CSP	Request to create a new subscription for receiving notifications about failure events. The input parameters are dependent on selected exposure level. The input parameters are dependent on selected exposure level.	• Service instance ID • CSC ID • Fault alarm • [Object Type] instance ID: the ID of the instance over which fault supervision is executed.
Create fault supervision subscription response	CSP→CSC	Response with the ID of the subscription.	• Result code • Subscription ID
Delete fault supervision subscription request	CSC→CSP	Requested to delete a subscription matching the given ID.	• Service instance ID • CSC ID • Subscription ID
Delete fault supervision subscription response	CSP→CSC	Response with the result of the operation.	• Result code
Query fault supervision request	CSC→CSP	Request to retrieve information of subscriptions matching the input filter.	• Service instance ID • CSC ID • Filter: defines the IDs of the subscriptions on which the query applies
Query fault supervision response	CSP→CSC	Response including the details of the requested subscriptions.	• Result code • List <subscription>
Notify fault alarm	CSP→CSC	Notification of a failure event	• Service instance ID • Subscription ID • Failure cause

6.3 Considerations on 5G-VINNI service lifecycle management

Despite being different, some relationships can be found between the lifecycle phases of a network slice service instance (i.e. preparation phase, operation phase) and of an NSI (3GPP preparation phase, 3GPP commissioning phase, 3GPP operation phase and 3GPP decommissioning phase). In particular, the following relationships deserve attention:

- Preparation phase in network slice service instance lifecycle:
    - Starts before the 3GPP preparation phase, as long as there does not exist an NSI able to satisfy the SLA. In such a case, the 3GPP preparation phase starts just after the completion of preparation phase in network slice service instance lifecycle. In fact, upon reception of the "SLA sign response" message (Section 6.2.11), the CSP shall immediately start all the previous work (e.g. NST on-boarding, network environment preparation) that needs to be done before deploying the corresponding NSI.

    - Starts in the 3GPP commissioning phase, if there exists an NSI able to satisfy the SLA, with that NSI not activated yet.
    - Starts in the 3GPP operation phase, if there exists an NSI able to satisfy the SLA, with that NSI
- Operation phase in network slice service instance lifecycle:
    - Always starts after the 3GPP commissioning phase, upon the reception of the "notify service instance availability" message (Section 6.3.1). In fact, NSaaS presumes that there shall always exist an NSI based on which the CSP can deliver the network slice service instance to the CSC.
    - Influence the 3GPP operation phase at run-time. Every time network slice service instance is modified (e.g. scaled up), the corresponding NSI also changes (i.e. capacity increase).
    - Always ends before the 3GPP decommissioning phase.

7 5G-VINNI Facility Service Portfolio

A 5G-VINNI facility site is the deployment of the 5G-VINNI architecture in one administrative domain. 5G-VINNI project consists of multiple facility sites distributed across Europe (e.g. one operator). These facility sites can be classified into two types: *main facility sites* (i.e. 5G-VINNI sites with E2E 5G capabilities that offer services to 5G-PPP Phase 3 projects via well-defined SLAs) and *experimentation facility sites (*i.e. 5G-VINNI sites that provide environments for advanced focused experimentation and testing possibilities on elements and combinations of the E2E model).

Figure 7.1 illustrates the overall 5G-VINNI facility, with the main facility sites (Norway, UK, Spain and Greece) and the experimentation facility sites (Portugal, Germany/Munich, Germany/Berlin and Luxembourg).

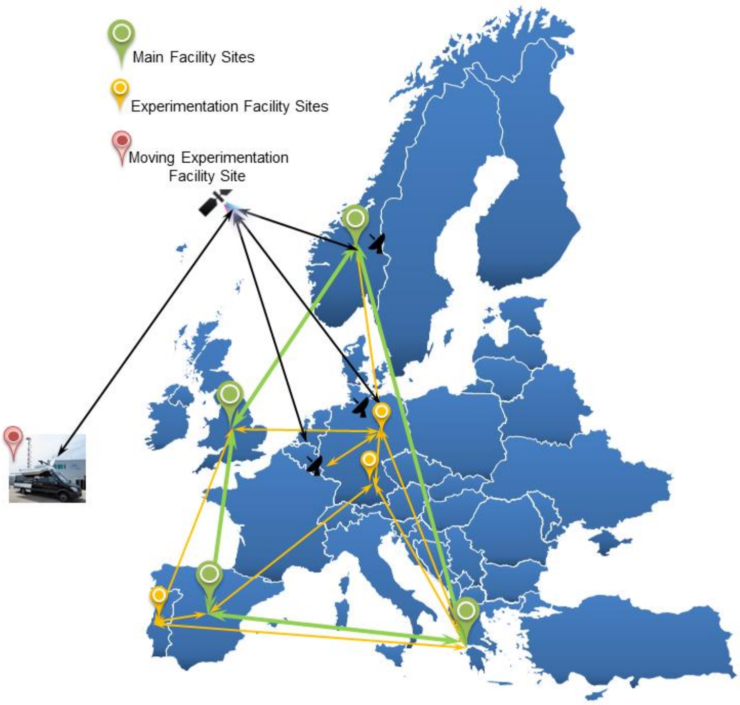

Figure 7.1: 5G-VINNI facility

The goal of this chapter is to define the service portfolio per 5G-VINNI facility site. Each portfolio specifies the different service offerings of a given facility site, including information on their capabilities. These service offerings are network slices, aimed at supporting the execution of trials of different vertical use cases, and delivered to 5G-VINNI customers using the NSaaS model.

7.1 Main Facility Sites

Table 7-1 provides information on the service portfolio of each main facility site.

Table 7-1: Service portfolio in the main facility sites

Service offerings	Norway	UK	Spain	Greece
eMBB network slice as a service	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1
uRLLC network slice as a service	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1
mIoT network slice as a service	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1
Customised network slice	YES, after Rel-1	YES, after Rel-1	YES, after Rel-1	YES, after Rel-1

Value-added functionality	Norway	UK	Spain	Greece
3rd party VNF hosting	YES, in Rel-1	YES, in Rel-1	YES, after Rel-1	YES, after Rel-1
Positioning	Not decided yet	Not decided yet	Not decided yet	Not decided yet
Distributed data fabric	YES, after Rel-1	YES, in Rel-1	YES, in Rel-1	NO
SECaaS	YES, in Rel-1	YES, after Rel-1	YES, after Rel-1	YES, after Rel-1
MaaS	YES, after Rel-1	YES, after Rel-1	YES, in Rel-1	YES, after Rel-1
TaaS	YES, after Rel-1	YES, after Rel-1	YES, after Rel-1	YES, after Rel-1

This section provides a more detailed description of the main facility sites with respect to the above service portfolio. For each facility site, the following information will be provided:

- The set of vertical use cases the facility site will focus on for KPI validation and demonstration purposes. This includes *internal use cases*, defined and executed to assess the operational readiness of the facility site, and *external use cases,* brought by e.g. industry verticals from ICT-19 projects.
- The characterisation of the service offerings specified in the facility site portfolio, including a tentative mapping between use cases and network slices.

7.1.1 Norway facility site

Norway facility site mainly aims to provide 5G technologies to support the stringent requirements that vertical customer may bring, far from traditional telco environment. This facility includes two locations (Oslo and Konsberg) provisioned with proprietary management and orchestration systems covering access, transport and core network segments to serve a rich set of industry verticals in an E2E manner within the same administrative domain.

In Norway facility site, the following use cases are selected as the main candidates for 5G-VINNI validation purposes:

- *UC1 – Telemedicine using hololense (vertical industry: health).* In this use case, paramedics in the ambulance send over electronic patient care records and initiate video conference and/or 3D streaming to remote expert located in the hospital in order to take best decision for patient treatment and orientation. The hololense is worn by the parademic and provides the video stream to the remote hospital.
- *UC2 – Drone control for Public Protection and Disaster Relief (vertical industry: public safety & divide resorption).* In this use case, drones are used to assist the fire brigade or the police. A drone and a pilot will be located on a fire truck or police car. After arriving at the scene, the drone will be airborne and provide information to the response team using the drone's camera. In case of fire, the drone can be used to generate fire maps and 3D models.
- *UC3 – Remote ultrasound (vertical industry: health)*. In this use case, an ultrasound probe mounted on a small robot will be controlled by an expert in a remote location. The expert will use a "joystick" that get haptic feedback from the robot and perform an ultrasound examination of the patient. Existing audio, video and ultrasound streaming systems will be demonstrated over 5G.
- *UC4 – Fixed wireless broadband* (*vertical industry: N/A*). This use case will enable checking behavior of fixed wireless access using 5G radio. This an internal use case that Nokia and Telenor will lead as the main actors of Norway site.
- *UC5 – Remote Interventional Support (vertical industry: health)*. This use case aims to take advantages of the advanced and rich media communications to realize remote monitoring, education and robotics in patient diagnostics and treatment. It utilizes a combination of high

definition video and audio, ultra-reliable and low latency control commands and feedback in a synchronized manner. The Norway facility will provide a slice service to support the ultrasonic imaging and diagnostic operation by the Oslo University Hospital. In general, it requires high bandwidth for AR/VR to enable remote diagnostic in real-time and uRLLC to facility remote control of an ultrasound robot with haptic feedback.

- *UC6 – PillCam (vertical industry: health)*. This use case aims to use colon capsule (an alternative to colonoscopy for treating colon cancer) and real-time video transmission as an approach to control the pill and improve diagnosis. The Norway facility will provide a slice service for the pill cameras to record and transmit videos in real-time to an access point or a gateway for uploading data securely. In general, it requires real-time and secure video communications.
- *UC7 – Vital-sign patches with advanced geolocation (vertical industry: health)*. This use case utilizes direct-to-cloud, disposable, vital-sign patches to realize continuous monitoring of ambulatory patients anytime and anywhere. The “direct-to-cloud” connectivity requires to remove the need for a gateway/smartphone in the middle to improve the out-of-the-box experience. The use case has high requirements on availability, coverage, privacy and security. The Norway facility is expected to provide a mIoT-type service with key KPIs like low cost, long battery life and minimum peak power consumption. The objective is to optimize the power consumption and device cost while offering the service.

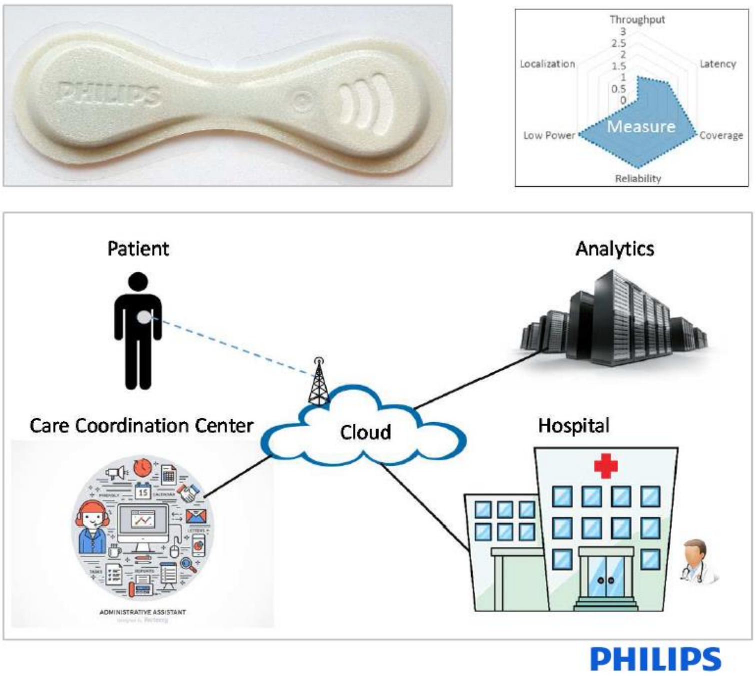

Figure 7.2: Norway UC7 – Vital-sign patches with advanced geolocation

- *UC8 – Remote monitoring of water and fish quality for Aqualculture* (*vertical industry: agriculture and farming*). This use case aims to equip the pilot sites with various devices to monitor the water and fish quality in pilot sites. The monitoring devices include underwater pan/tilt machine vision cameras (HD, 4K, potentially plenoptics, 3D and 8K), surface PTZ cameras, IoT sensors (monitoring oxygen, salinity, wind, depth, and temperature, etc.), IoT underwater LED lights, IoT winch systems, and potentially ROVs and autonomous sensor carriers. The Norway facility plays a role in complementing the main pilot in Greece, supported by the 5G-EVE project. In Norway, the pilot site is a commercial production site of Atlantic Salmon in the middle region of Norway. Considering the variety in the monitoring devices and generated data, the Norway facility is expected to provide a slice service of combined eMBB and mIoT to test various data transmission levels.

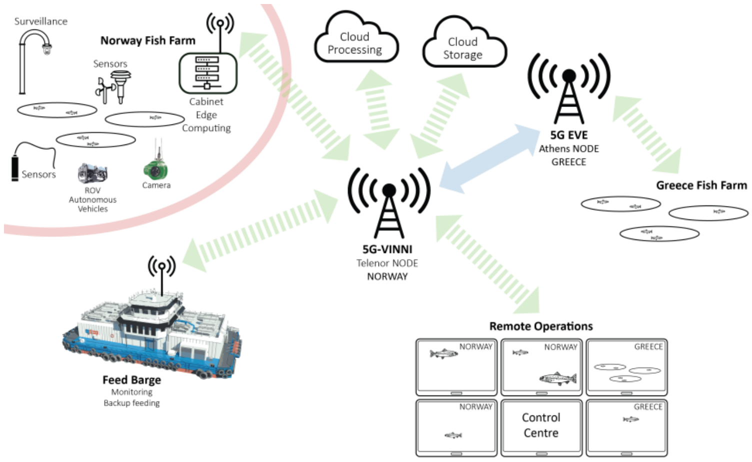

Figure 7.3: Norway UC8 – Remote monitoring of water and fish quality

- *UC9 – On-site Live Event Experience (Vertical industry: media & entertainment).* This use case requires eMBB and mIoT. The Norway facility is expected to provide inter-facility capabilities in collaboration with the Greece facility.

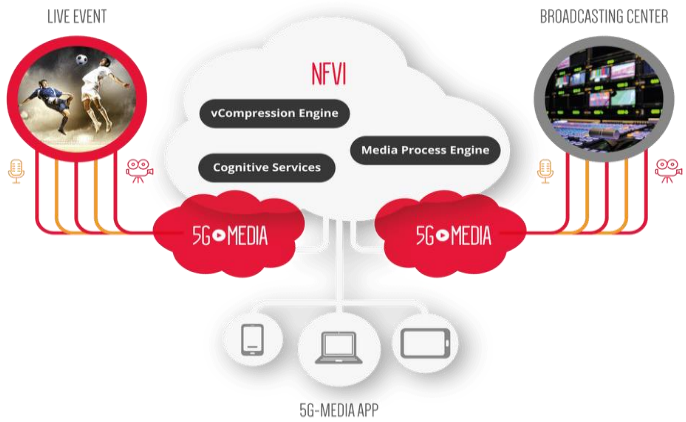

Figure 7.4: Norway UC9 – On-site live event experience

- *UC10 – Rapid deployment, auto-/re-configuration and testing of new robots (vertical industry: industry 4.0)*. This use cases aims to explore the possibilities of utilizing the core functionalities of 5G to achieve one major feature of Industry 4.0, e.g. significantly lower expenses and reduced time for either commissioning or reconfiguring robotized manufacturing. It involves auto-onboarding and auto-configuration of mobile robots when new robots are deployed into existing plants. The required 5G services include configuration for interconnection/interworking across solutions from different vendors. The Norway facility is expected to provide the core function, to which new 5G RAN node will be connected to for this use case. The expected customized service is a combination of eMBB, uRLLC and mIoT requirements.
- *UC11 – Smart city co-creation (vertical industry: smart cities).* This use case aims to provide a wider range of approaches for Smart City/IoT co-creation and exploring, in collaboration with a H2020 Smart City Lighthouse project (+CityxChange) managed by NTNU Sustainable Smart City (SSC) and other relevant projects within the scope of NTNU SSC. It will use and assess the urban Living lab innovation and co-creation way of work and methodologies. The Norway facility is expected to provide open access for the testing framework and 3rd party function onboarding of this use case, as well as the core network, to which the new 5G RAN node will be connected to. This use case is a combination of eMBB and mIoT requirements.

- *UC12 – Autonomous assets and logistics for smart port (vertical industry: transport and logistics)*. This use case aims to demonstrate the capabilities of 5G technology to support real-time operation and integration support for autonomous assets (e.g., ships or port vehicles) in a logistics hub at Herøya, Porsgrunn, Norway. It will test both the smart port and the logistics solution to the plant cargo loading area, which will be operated in a mixed traffic environment. A dedicated autonomous vessel (Birkeland) will be co-located with the autonomous land-based cargo handling assets. This use case has a high requirement on safety, reliability, security, and the positioning accuracy (in order to support autonomous operations without additional GPS equipment). It also requires support for 3rd party applications with assured quality connectivity. The Norway facility is expected to provide the core network, to which the new RAN node will be connected to. In addition, the capability exposure is required for rapid re-deployment of this use case. The expected service is of type “customised” as a combination of eMBB, uRLLC and mIoT.
- *UC13 – Monitoring and detection of irregular sounds for port safety* (*vertical industry: transport and logistics)*. This use case aims to deploy a detection system (e.g., with sensitive microphones and UHD + 360 CCTV cameras) through the use of a reliable 5G networks to transmit real-time audio-visual information on events to the port operation center such that the port authorities can act immediately once an incident occurs and identify the exact location of the incident. It has a high requirement on latency (for real-time monitoring) and reliability (accurate information transmission). The Norway facility is expected to provide a service mixing mIoT (sensing) and eMBB (video surveillance).
- *UC14 – Defense and Public Safety (vertical industry: public safety & divide resorption)*. This use case is the focus of the Norway facility in 2019. It aims to provide dedicated network slices with secure and reliable communications services to the defense customer. Three phases are planned. In Phase 1, a dedicated IMS is deployed to enable services such as VoLTE. In addition, E2E encryption (SRTP) and QoS is supported in real-time communications services such as VoLTE and VoNR (for later) and prioritized services if required. Fixed mobile convergence will be available to connect mobiles and SIP clients. In Phase 2, on-demand coverage will be supported with flexible backhaul. Autonomous mobile edges will be added by moving full EPC+IMS functionality into the Multi-Access Edge Computing (MEC) to achieve full autonomy when backhaul is not available. There is also expectation for multicast/broadcast capabilities to support peer-top-peer (P2P) applications and mission critical services (e.g. push-to-talk). In Phase 3, RAN will be enhanced, such as RAN as sensor to detect jamming and drones, and robust RAN (avoid jamming) by using advanced antennas technologies like beamforming or robustness mechanisms in the 5G NR signaling. In general, the Norway facility will provide uRLLC services with adds-on functionalities such as MEC, enhanced RAN, etc.

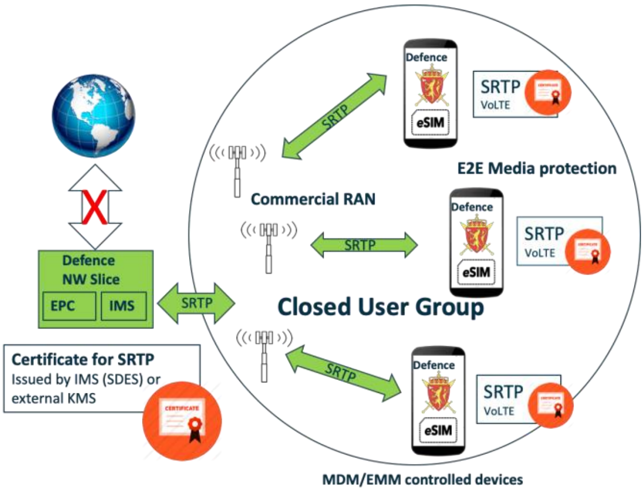

Figure 7.5: Norway UC14 – Defence and public safety

The service offerings referred in Norway portfolio are detailed in Table 7-2 including information on their service exposure level and their ability to support the abovementioned use cases. For more information on service exposure level in 5G-VINNI, see Section 4.3.4.

Table 7-2: Service offerings in Norway facility site

Service offerings	Service exposure	Supported use cases
eMBB network slice as a service	Level 1	UC1, UC4, UC9
uRLLC network slice as a service	Level 1	UC2, UC14
mIoT network slice as a service	Level 1	UC7
Customised network slice	Level 1	UC3, UC5, UC6, UC8, UC10, UC11, UC12, UC13

7.1.2 UK facility site

The UK facility aims to provide a full set of 5G capabilities by implementing a complete end-to-end 5G system, including virtualized radio and core networks.

In UK facility site, the following use cases are selected as the main candidates for 5G-VINNI validation purposes:

- *UC1 – Public Protection and Disaster Relief using 5G aerial solutions (vertical industry: public safety & divide resorption).* This use case will consist of a combination of unmanned aerial vehicle with on-board 4K/UHD camera that provide real-time video to a remote command for later processing. These vehicles include drones and Helikites.

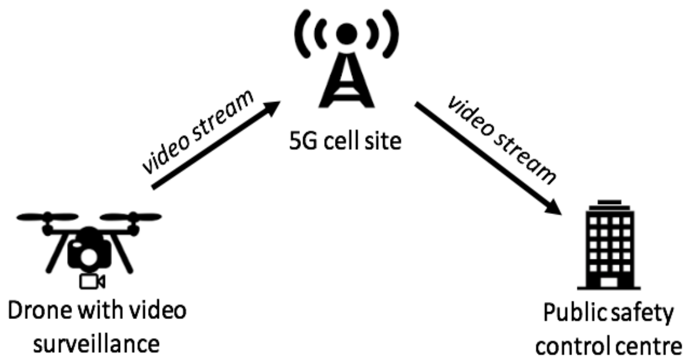

Figure 7.6: UK UC1 – Public Protection and Disaster Relief using 5G aerial solutions

- *UC2 – Remote robotic control (vertical industry: industry 4.0).* This use case demonstrates the remote control of a robot housing a 360-degree camera such as might be used in an industrial environment. The camera provides an immersive telepresence capability to the remote controller who is able to view the content on AR/VR headset providing them with real-time information with which to guide the actuation and movement of the robot. The use case will simultaneously make use of a uRLLC slice to ensure a reliable control path and an eMBB slice for the 360-degree content. In addition, it will make use of edge compute capability to reduce latency in the data plane.
- *UC3 – 5G security in a V2X environment (vertical industry: automotive).* This use case will support the H2020 RESISTO project by providing the testbed to demonstrate resistance to cyber attacks in a V2X environment, where traffic signs and signals are subject to malware intrusion. Data collection of alerts provided by the road-side infrastructure will be used to provide insights and actions to reduce the cyber attach impact. This use case will simultaneously make use of a uRLLC slice to delive real-time control of roadside assets and/or vehicles in order to guarantee road user safety, as well as a mIoT slice for data collection.
- *UC4 – AR/VR in the learning environment (vertical industry: media and entertainment).* This use case will illustrate a cloud-based content streaming service, providing customised 360-degree AR/VR content to the remote classroom or for engineering field training. The use case will make of the eMBB and uRLLC slice types to ensure timely delivery of the content to all learner devices simultaneously.
- *UC5 – Telemedicine using hololense (vertical industry: health).* It is expected that this use will be run in conjunction with Norway facility to show interworking between the two facilities. In this instance, the UK would act as the site for the connected ambulance with Norway acting as the site for the hospital location and/or viceversa.

The service offerings referred in UK portfolio are detailed in Table 7-3, including information on their service exposure level and their ability to support the abovementioned use cases.

Table 7-3: Service offerings in UK facility site

Service offerings	Service exposure	Supported use cases
eMBB network slice as a service	Level 2	UC1*, UC4*, UC5
uRLLC network slice as a service	Level 2	UC3*, UC4*,
mIoT network slice as a service	Level 2	UC3*
Customised network slice	Level 2	UC1, UC3, UC4

Note that UC1, UC3 and UC4 have stringent requirements, making them ideal to be tested in a customised network slice. However, this service offering is expected to be available in the UK portfolio beyond Release 1. In the meantime, these use cases should be executed (with some limited performance and/or functionality) in eMBB, uRLLC and mIoT slices.

7.1.3 Spain facility site

The 5G-VINNI facility site in Spain will be part of the 5TONIC laboratory, an open innovation environment for research in 5G technologies. 5TONIC laboratory includes a solid baseline of facilities, and provides access to a common infrastructure to assist verticals in experiments, trials and demonstrations with particular 5G network technologies, including wireless system areas and network softwarisation trends including SDN, NFV, MEC, and network slicing.

In Spain facility site, the following use cases are selected as the main candidates for 5G-VINNI validation purposes:

- *UC1 – Dynamic enrichment of video (vertical industry: media and entertainment).* This use case focuses on enriching a default, best-effort video delivery service over time, based on the users' preferences and resource availability. This enrichment may become real with the introduction of a large number of value-added features, including resolution enhancement (e.g. ranging from HD ready to 4K/UHD resolution), video track for hearing impaired support, AR/VR-like information, and real-time interaction with other users.

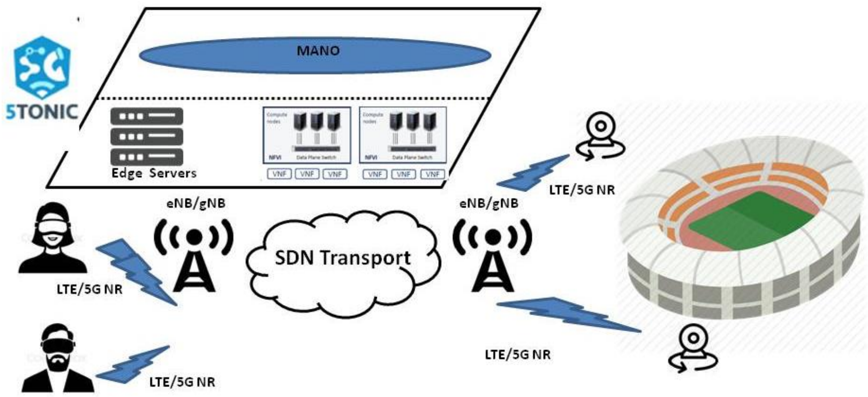

Figure 7.7: Spain UC1 – Dynamic enrichment of video

- *UC2 – Smart Tourism with 360-degree immersive experience (vertical industry: smart cities).* This use case focuses on tourism applications where end users consume end-to-end video service distributed across a hierarchy of edge nodes based on micro-service architecture. This use case will provide measurement of latency at different levels (network, edge and application layer) and assessment of the impact on user experience. A particular scenario of this use case is considered in the next UC3 and 4 where the AGV or UAV has a 360-degree video camera.

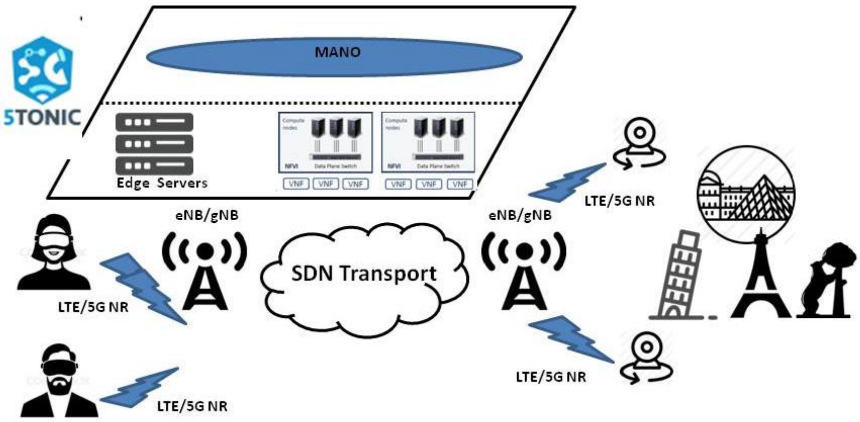

Figure 7.8: Spain UC2 – Smart Tourism with 360-degree immersive experience

- *UC3 – AGV/UAV multiuser remote control and operation in outdoor environments (vertical industry: industry 4.0).* This use considers the application of control and/or coordination tasks for a set of Automated Guided Vehicles (AGVs) and/or Unmanned Aerial Vehicles (UAVs). These robots and/or drones can be remotely controlled in a factory and mix requirements of low latency for the human to control the robots or drones and requirements of minimum bandwidth over the flight or trajectory.
- *UC4 – AGV/UAV multiuser remote control and operation in outdoor environments (vertical industry: public safety and divide resorption).* This use case considers the deployment of micro-VNFs on AGVs/UAVs robots to provide a fast and flexible network edge to support access in case of emergencies. These drones and/or robots will sense and capture video in a remote area. The video will be distributed to the VR devices of the different remote users.

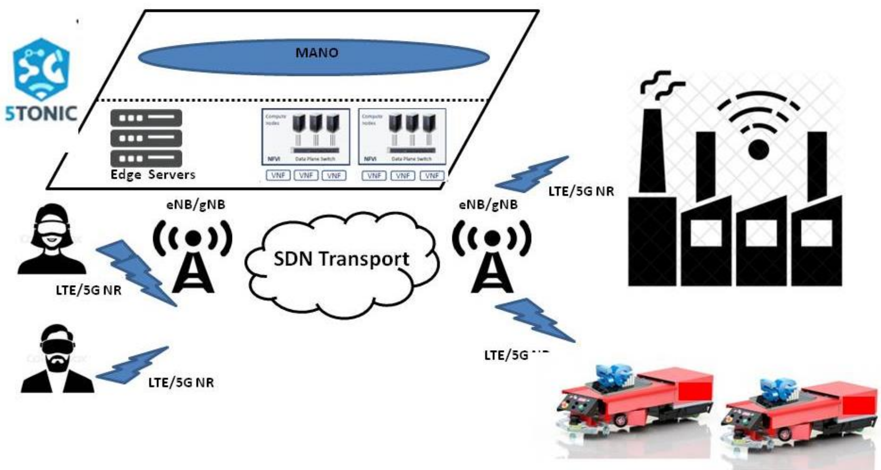

Figure 7.9: Spain UC3 – AGV/UAV multiuser remote control and operation in outdoor environments

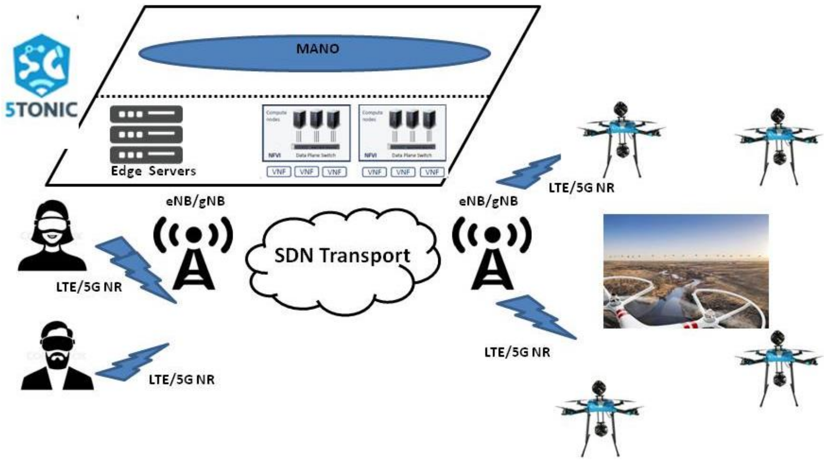

Figure 7.10: Spain UC4 – AGV/UAV multiuser remote control and operation in indoor environments

The service offerings referred in the Spain portfolio are detailed in Table 7-4, including information on their service exposure level and their ability to support the abovementioned use cases.

Table 7-4: Service offerings in Spain facility site

Service offerings	Service exposure	Supported use cases
eMBB network slice as a service	Level 3-4	UC1, UC2
uRLLC network slice as a service	Level 3-4	UC3, UC4
mIoT network slice as a service	Level 3-4	Awaiting arrival of use cases from external projects
Customised network slice	Level 3-4	UC4

Note that UC4 is also likely to be tested in a customised network slice, as soon as this service offering becomes available in the Spain service portfolio, i.e. in Release 3.

7.1.4 Greece facility site

The 5G-VINNI facility site in Patras (Greece) will be an exemplary Open Source 5G-IoT facility. This means that most of the installed components will be offered as Open Source but there will be also dedicated components and services to support 5G-IoT scenarios. Numerous partners will deploy their technologies in the Patras/Greece facility, thus creating a unique 5G playground for KPI validation and support on future verticals.

In Greece facility site, the following use cases are selected as the main candidates for 5G-VINNI validation purposes:

- *UC1 – First Person View remote control vehicle (vertical industry: automotive).* This use case consists of a remote-controlled vehicle with an on-board camera that provides real-time video streaming to the user, allowing him/her to perform remote driving. The camera shows the path followed by the vehicle at any time, so the user can control and move the vehicle as desired by making use of a remote controller. The video streaming aspect of the use case means that significant amount of data needs to be transferred through the 5G network thus high throughput, while the remote-control aspect requires very high transfer speed of the movement commands from the user to the device with low latency and high reliability. To satisfy these requirements, the operator of this communication service may rely on the communication capabilities provided by EMBB and URLLC slices.

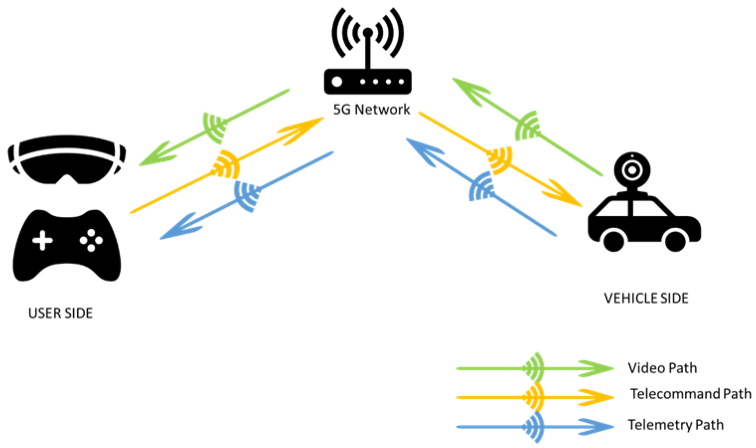

Figure 7.11: Greece UC1 – First Person View remote control vehicle use case

- *UC2 – 360-degree Video broadcast (vertical industry: media and entertainment).* This use case involves the video streaming from a person equipped with a 360-degree camera to a viewer. A possible scenario is during Patras carnival festivities, where participants can be equipped with 5G-enabled devices with 360° cameras in order to transmit the local festivities to remote locations while being able to move around downtown Patras. The main requirements of this use case are extremely high throughput and high connection density, with UEs requiring bandwidth-consuming connectivity in crowded scenarios.

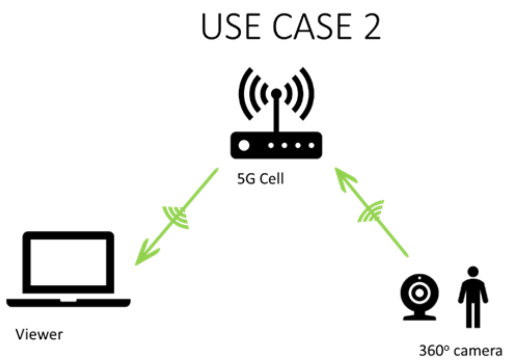

Figure 7.12: Greece UC2 – 360º Video broadcast use case

- *UC3 – NB-IoT Coverage study and IoT slicing study (vertical industry: N/A).* The suggested use case for NB-IoT consists of two phases. In the first phase, a coverage study of NB-IoT devices will be carried out on the University of Patras (see Figure 7.13). In this study, a large number of NB-IoT devices will be deployed and the network coverage will be examined, taking into consideration various factors including (but not limited to) distance from the antenna and penetration power. Once these factors have been analysed, then the second phase gets started. In this second phase, the concept of IoT slicing will be applied, making use of distinct IoT applications that will consume data provided by corresponding virtualized IoT Gateway instances deployed in separated NSIs (see Figure 7.14).

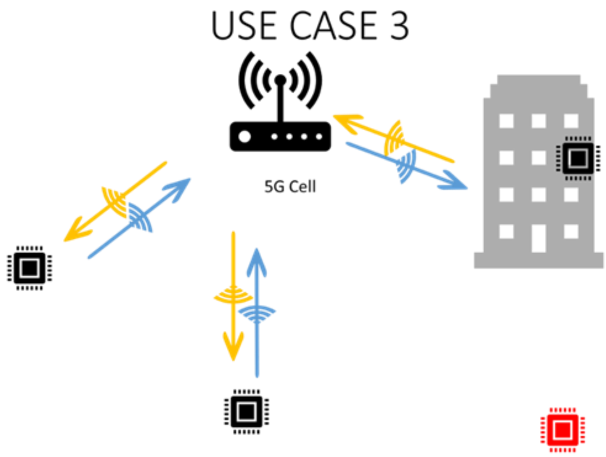

Figure 7.13: Greece UC3 – NB-IoT Coverage

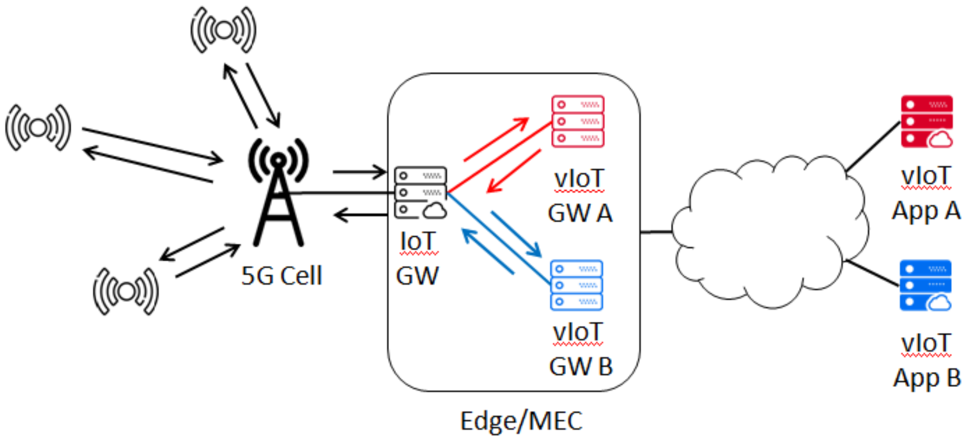

Figure 7.14: Greece UC3 – Concept of IoT slicing

- *UC4 – AR proof of concept (vertical industry: media and entertainment):* This use case describes the delivery of AR annotations on top of a video stream captured by an end user of the service. The end user captures video, which is delivered to an AR application backend responsible for object recognition, tracking and annotation of the video with related information. The video annotation is performed taking into account the position of the identified objects in the video and delivered as an enhanced video stream to the user. This scenarios' main requirement is the very high throughput. To satisfy these requirements, the operator of this use case may rely on the communication capabilities provided by an eMBB slice. This use case is expected to be supported by DFKI, as a member of the Executive Board. The exact application context will be later defined, choosing from the wide DFKI portfolio. A candidate application targets the touristic domain, providing informational annotations on top of identified monuments. The use case targets the use of a MEC location within the Patras facility, as a means to lower latency.

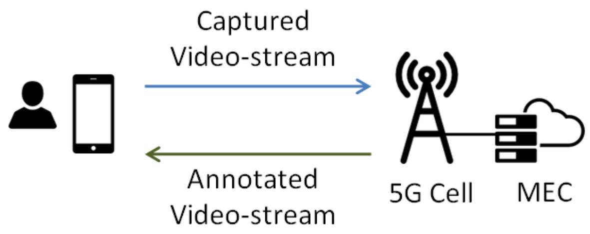

Figure 7.15: Greece UC4 – AR proof of concept

Additionally, please note that these use cases could be combined and create different scenarios, by using some aspects of each distinct use cases, as shown in Figure 7.16.

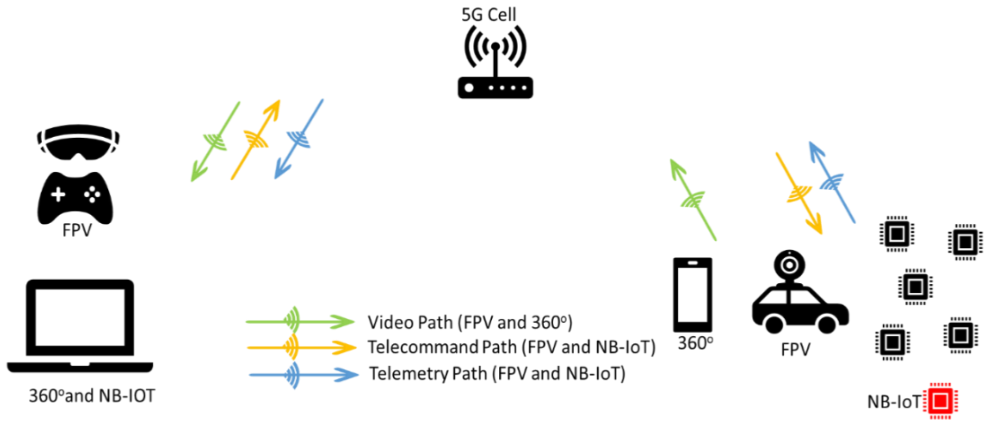

Figure 7.16: Example of a scenario integrating UC1, UC2, and UC3

The service offerings referred in the Greece portfolio are detailed in Table 7-5 including information on their service exposure level and their ability to support the abovementioned use cases.

Table 7-5: Service offerings in Greece facility site

Service offerings	Service exposure	Supported use cases
eMBB network slice as a service	Level 3-4	UC1*, UC2, UC4
uRLLC network slice as a service	Level 3-4	UC1*
mIoT network slice as a service	Level 3-4	UC3 (IoT slicing)
Customised network slice	Level 3-4	UC1, UC3 (NB-IoT coverage)

Because of uRLLC + eMBB characteristicsts, the UC1 should be executed in a customised network slice. Until this service offerings becomes available in the Greece portfolio, UC1 will be executed (with some limited performance and/or functionality) in eMBB and uRLLC network slices offered as a service to the CSC.

7.2 Experimentation Facility Sites

This section is similar to Section 7.1 but applied to 5G-VINNI experimentation facility sites. Table 7-6 provides information on the service portfolio of each main facility site.

Table 7-6: Service portfolio in the experimentation facility sites

Service offerings	Portugal	Germany (Berlin)	Germany (Munich)	Luxembourg
eMBB network slice as a service	YES, in Rel-1	YES, in Rel-1	YES, after Rel-1	YES, in Rel-1
uRLLC network slice as a service	YES, after Rel-1	YES, in Rel-1	YES, in Rel-1	NO
mIoT network slice as a service	YES, after Rel-1	YES, in Rel-1	NO	YES, in Rel-1
Customised network slice	NO	YES, after Rel-1	NO	YES, after Rel-1
Value-added functionality	**Portugal**	**Germany (Berlin)**	**Germany (Munich)**	**Luxembourg**
3rd party VNF hosting	YES, in Rel-1	YES, in Rel-1	YES, after Rel-1	YES, after Rel-1
Positioning	Not decided yet	Not decided yet	Not decided yet	Not decided yet
Distributed data fabric	YES, after Rel-1	NO	NO	NO
SECaaS	YES, after Rel-1	NO	NO	NO
MaaS	Yes, after Rel-1	NO	NO	NO
TaaS	NO	NO	NO	NO

7.2.1 Portugal facility site

Located in Aveiro, the 5G-VINNI facility site in Portugal is based on extensive computational and networking infrastructure available at Altice Labs and Instituto de Telecomunicações. This infrastructure will allow Portugal facility site to serve as experimental platform for the showcase of many vertical scenarios, particularly those requiring the use of 5G fronthauling and backhauling capabilities, as well as edge computing features to test and assess fixed/mobile convergence, bandwidth efficiency, and reduced traffic load while providing low latency values.

In Portugal facility site, the following use cases are selected as the main candidates for 5G-VINNI validation purposes:

- *UC1 – Safety Critical Communications for railway signalling systems (vertical industry: transportation).* To be developed in collaboration with the industrial partner EFACEC, member of the 5G-VINNI External Board, this use case will be based on the use of 5G communications in railway safety critical scenarios. This use case will demonstrate a high performance, but still very flexible, communication architecture provided by 5G to support railway signalling operations, specifically level crossing fail safe environment (see Figure 7.17). 5G communication is required between the level crossing train detector activation points and the level crossing controller, with a view to replacing the traditional copper wire cables. In addition, HD video image is transmitted from the level crossing surveillance cameras to the approaching trains' on-board tablets, while level crossing controller status and alarm events are transmitted to the maintenance agents' tablets. This use case requires transmission of high definition video to the train controllers and safety critical communications between the train detector and the level crossing, as well as for the alarms and controller status to the maintenance agents.

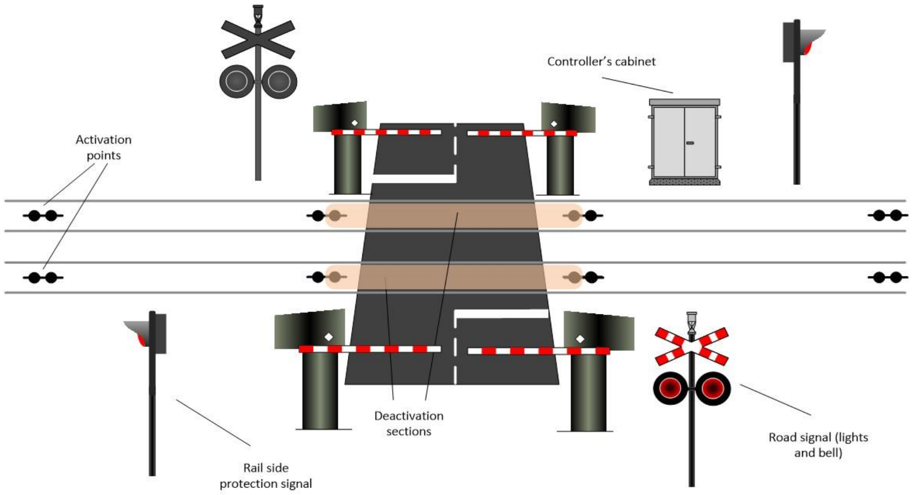

Figure 7.17: Portugal UC1 – Safety Critical Communications for railway signalling systems use case

- *UC2 – Advanced critical signal and data exchange across wide smart metering and measurement infrastructures (vertical industry: energy)*. This use case, also to be promoted in collaboration with EFACEC, addresses critical last-gasping features and enhanced synchronization, on a millisecond basis, between smart devices, e.g., smart meters and sensors, deployed within a smart grid. As critical data from remote real-time monitoring and control must be exchanged between several smart devices – including meters and sensors, distributed controllers and concentrators, cloud-based edge and more centralized advanced management systems –, deployed across an entire infrastructure, the synchronization is particularly relevant. Concerning the last-gasp features, the control and management systems can extract relevant information from the last-gasp data received in order to perform faster and more precise fault detection and location. Low latency communications are therefore required immediately after the power outage is detected by the device, to minimize the demand on the device power supply, enabling the device to perform the required housekeeping and to hold the communication channel active to send the last-gasp message before the device power supply storage capability is totally exhausted. An even lower latency and higher connection density are required when trying to synchronize the referred smart devices (e.g. meters and sensors) for data exchange, which will improve the general quality of the gathered data benefiting advanced control applications dependent on correlation analysis and big data processing. This use case requires mIoT to connect a high number of smart meters and uRLLC for the transmission of critical signals.

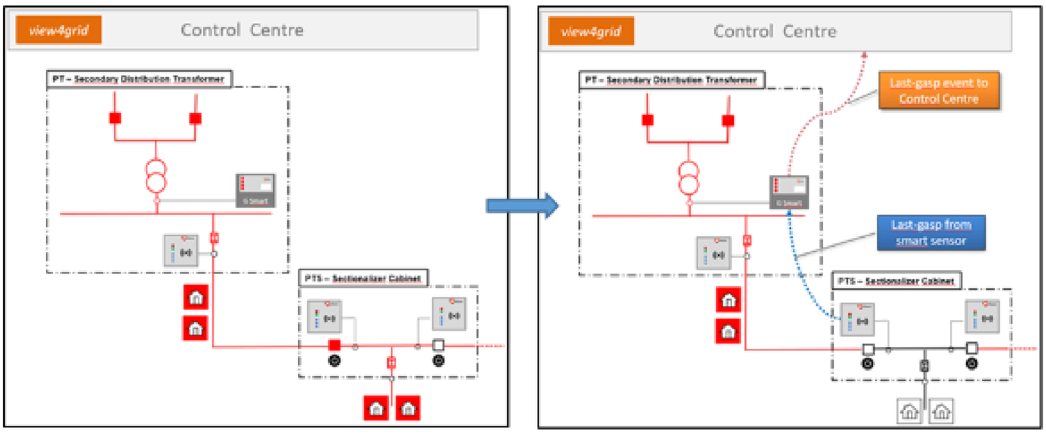

Figure 7.18: Portugal UC2 – Last-gap use case triggered by an outage

The service offerings referred in the Portugal portfolio are detailed in Table 7-7, including information on their service exposure level and their ability to support the abovementioned use cases. Note that as an experimentation facility, Portugal does not offer all the type of services in the same way that the main facility sites do. For example, customised network slice is not included in their service offering.

Table 7-7: Service offerings in Portugal facility site

Service offerings	Service exposure	Supported use cases
eMBB network slice as a service	Level 2	UC1
uRLLC network slice as a service	Level 2	UC2
mIoT network slice as a service	Level 2	UC2

7.2.2 Germany (Berlin) facility site

Berlin is an experimentation facility site whose main goal is to provide customized 5G technologies for addressing the vertical use cases. This includes the provision of a prototype level 5G Core to the 5G-VINNI Patras facility, and the provision of central 5G Core functionality for the nomadic 5G facility from Luxemburg as well as for other research projects. For this end, the experimental Berlin facility will integrate a large number of prototype level technologies including main stream 5G standardised components as well as other non-standard ones.

In Berlin facility site, the following use cases are selected as the main candidates for 5G-VINNI validation purposes:

- *UC1 – Multimedia delivery to remote locations with edge nodes (vertical industry: media and entertainment)*: this use case shows an efficient content broadcasting to remote locations, requiring coverage of the remote location and high throughput data transmission towards the remote node.

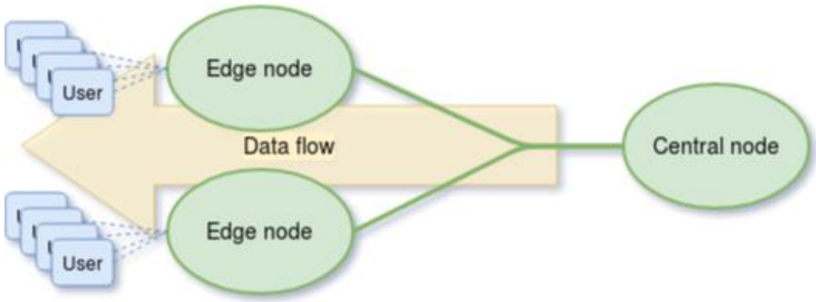

Figure 7.19: Berlin UC1 – Multimedia delivery to remote location with edge nodes

- *UC2 – Content acquisition from nomadic edge node (vertical industry: automotive, health, media and entertainment).* It aims at showing context awareness-based features for rapid response vehicles, eHealth-related scenarios, and live video acquisition at crowded events. This use case brings requirements on coverage of remote locations, and high throughput data transmission when aggregating packets from edge nodes towards the central node.

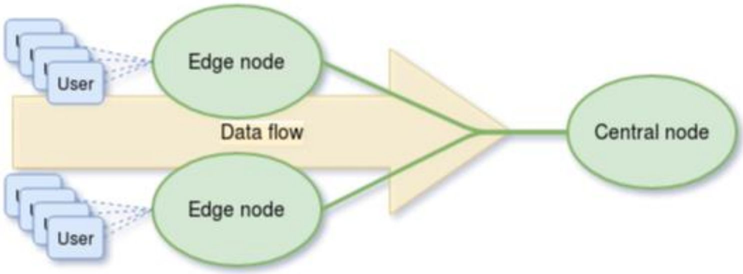

Figure 7.20: Berlin UC2 – Content acquisition from nomadic edge node

- *UC3 – Local highly reliable high capacity communication (vertical industry: N/A)*. This use case is interesting for network operators, and will allow local devices to communicate with each other relying on the capabilities provided by the local edge node, including local content delivery with context-awareness features and high availability processing units to provide ultra-reliable communication in local environments, with low response times between users. This use case will bring different latency requirements depending on the specific type of communication. In any case, high reliability and high throughput rates will be required.

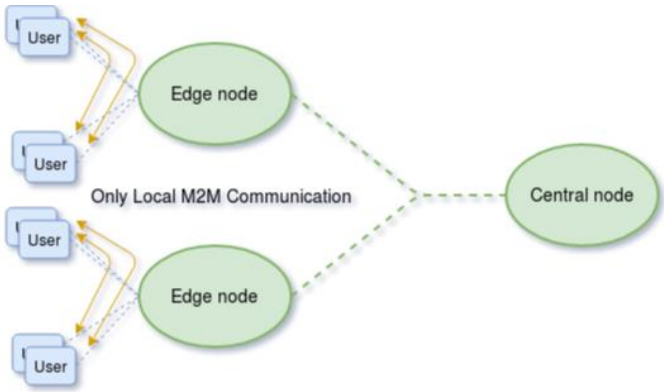

Figure 7.21: Berlin UC3 – Local highly reliable, high capacity communication

UC4 – Local mIoT communication (vertical industry: N/A). This use case aims to seek support for efficient Machine-to-Machine (M2M) communication in the backhaul. For this end, different applications will be installed in the edge nodes, so most of traffic is processed locally. This will enable a significant reduce of traffic load towards the central node, and hence a considerable reduced usage of the networking resources that made up the backhaul.

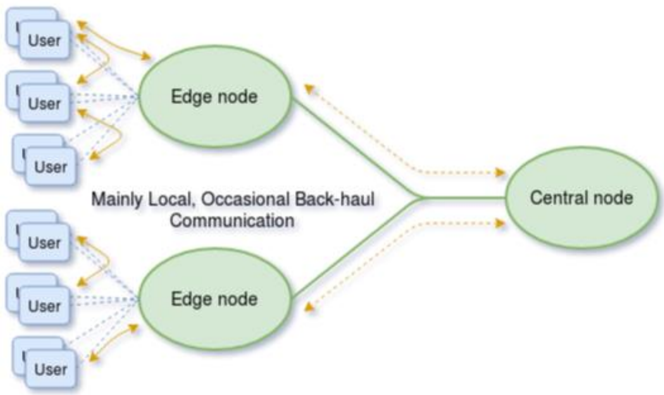

Figure 7.22: Berlin UC4 – Local mIoT communication

The service offerings referred in the Berlin portfolio are detailed in Table 7-8, including information on their service exposure level and their ability to support the abovementioned use cases.

Table 7-8: Service offerings in Berlin facility site

Service offerings	Service exposure	Supported use cases
eMBB network slice as a service	Level 1	UC1, UC2
uRLLC network slice as a service	Level 1	UC3
mIoT network slice as a service	Level 1	UC4
Customised network slice	Level 1	Awaiting arrival of use cases from external projects

7.2.3 Germany (Muchich) facility site

The experimentation facility in Munich is mainly concerned with providing the support for use cases from the automotive industry, based on V2X communications, providing communication capabilities with URLLC features. These use cases will be used by automotive stakeholders joining in upcoming ICT-19 projects to assess and validate the features of this type of communications, performing V2X drive tests as well as tests at pedestrian speed. For this end, Munich site will be equipped with a two-sector 5G base station, a 5G Core network with SDN and NFV capabilities, and a cloud data center.

In the Munich facility site, Huawei will lead the following use case: *urban V2X service (vertical industry: automotive)*. In this use case, cars driving in the coverage area of a base station exchange information on their driving behaviour among each other by using network-assisted V2V communication in a given frequency band pending regulatory issues. To support driving manoeuvres and other road safety applications, different cards need to coordinate among each other. Additionally, data exchange between the cars and the network are considered. If the link between the base station and a single car is obstructed, another car can cooperatively support the connection using the 5G NR sidelink in a smart way.

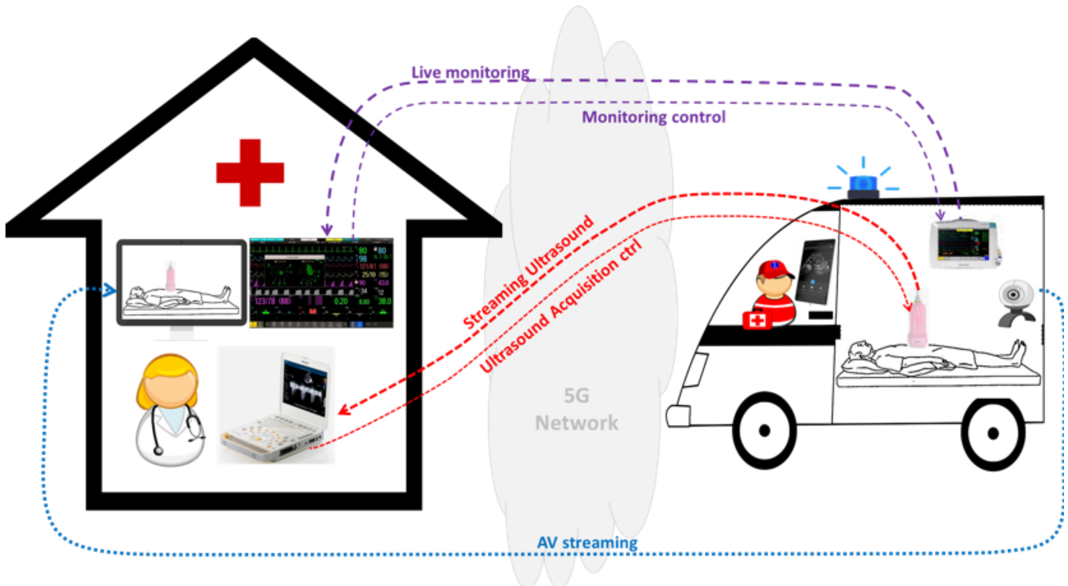

Figure 7.23: Architecture of experimental use case in Munich facility site

Munich will only offer a single service type for the support of urban V2X scenario: uRLLC (see Table 7-9). This URLLC will provide the capabilities that are required to enable V2V/V2N connectivity with high reliability and low latency.

Table 7-9: Service offerings in Munich site

Service offerings	Service exposure	Supported use cases
eMBB network slice as a service	Level 1	Awaiting the arrival of external use cases
uRLLC network slice as a service	Level 1	Urban V2X service

7.2.4 Luxembourg facility site

Luxembourg is a nomadic facility site providing support to Berlin facility site. Luxembourg can be seen as the edge node of Berlin, who will provide the central node.

8 Conclusions

As 5G standards are completed and technical development of 5G products matures and stabilizes, it is a fundamental to the success of 5G as a technology that the industry quickly moves to demonstrate capabilities that are going to deliver against KPIs that are relevant to enabling new use cases for industry verticals. Indeed, industry verticals are eager to see what a 5G network implement can deliver to their industry sector that can extend and expand their capabilities and business opportunities. Consequently, there is a growing urgency to provide a realistic 5G test and experimentation environment that the industry verticals can use to set up trials of use cases, assessing their readiness and validate their KPIs under different load conditions. This is the main objective of 5G-VINNI project. Drawing upon NSaaS, 5G-VINNI facility provides different vertical customers with tailored environments where these can deploy use cases and execute test scenarios with isolation guarantees.

In this deliverable we have provided an insight into the initial service catalogue for 5G-VINNI facility. This catalogue specifies the network slice types the overall facility offers as a service to authorised vertical customers. To allow reproducibility and migration of network slice services across the overall facility, it is required to describe the service offerings in a technology-agnostic manner, making them independent of site-specific implementation details.

Motivated by the above, 5G-VINNI has introduced the concept of VINNI-SB. Built on the principles of serviceability, reproducibility, reusability and customisability, a VINNI-SB has a been defined model-based service template that provides customer-facing information of a given service offering, without delving into underlying resource-facing specificities. 5G-VINNI has defined four VINNI-SBs, one for each service offering published in the catalogue: eMBB, uRLLC, mIoT and customised network slices. Each service offering represents a different service type.

Chapter 4 has captured the principles applicable the design of any VINNI-SB and has provided a detailed view of constituent parameters (and their allowed values). These parameters have been classified into four big groups: (i) service type, (ii) service topology; (iii) service requirements, arranged into performance, functionality and network optimisation requirements; and (iv) service exposure, monitoring and testing capabilities.

Chapter 5 has highlighted the main differences between the four different VINNI-SBs. On the one hand, groups (ii) and (iii) are highly dependent on the selected service type, and hence can significantly vary between different VINNI-SBs. On the other hand, group (iv) is independent of selected service type, and thus of VINNI-SB; indeed, it only depends on the selected capability exposure level, agreed between vertical and 5G-VINNI facility.

Any industry vertical can use the information provided by the different VINNI-SBs to browse the service catalogue, select the service offering that best fits its needs, and issue the corresponding service order against the 5G-VINNI facility. This service order provides a complete, self-contained specification of the network slice that the vertical wants to get from the facility. If feasible, the received service order results in an SLA, which documents the agreement between the CSP and the vertical on service provisioning, and in the deployment of an NSI, which is made available to the vertical via APIs governed by the NSaaS model. The API exposed operations are subjected to the selected exposure level and define the management capabilities the vertical can consume from the provided slice. The more the capability exposure level is, the more control the vertical can take over the provided slice. The aforementioned management capabilities will determine the ability of the vertical to experiment with the network slice, and hence to execute test cases to validate on-boarded use cases. These issues are discussed in Chapter 6.

In summary, this document shall serve as a baseline for upcoming development and implementation activities within the project, particularly in WP2, WP3 and WP4. Facility sites will contribute to the definition of the 5G-VINNI service catalogue, designing and on-boarding service templates for the service offerings specified in Chapter 7. We note, however, that the design of VINNI-SBs (Chapters 4 and 5) and the API exposed operations allowing customer-facing network slicing management procedures (Chapter 6) presented here is subject to future extensions and modifications depending on feedback obtained during the development phase. Additionally, they can vary among facility sites, depending on the capabilities enabled by their management and orchestration systems.

Annex A State of the art (extended version)

This annex provides details on the state-of-the-art solutions summarised in Chapter 3.

A.1 Industry fora and SDOs

This section provides some details of research activities in different organisations that are relevant for customer-facing service management issues in 5G-VINNI facility. This includes outcomes from vertical industry organisations, telco industry organisations and SDOs. Figure A.1 depicts a landscape of organisations followed by 5G-VINNI project, including relationships between them.

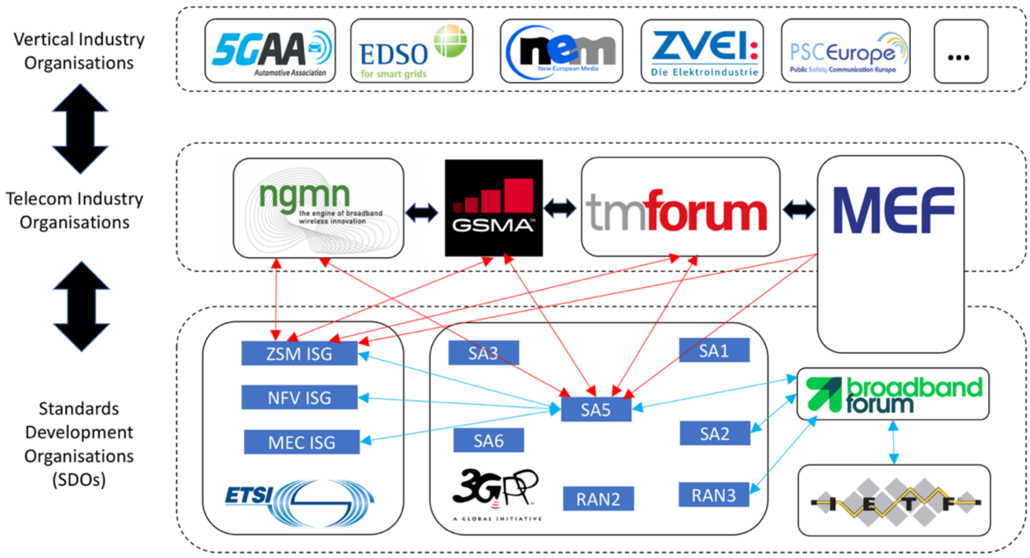

Figure A.1: Industry fora and SDOs relevant for 5G-VINNI project

In this deliverable, we mostly focus on telecommunication industry organisations, particularly in NGMN, GSMA, MEF and TM Forum. The following subsections provide a detailed overview of the activities carried out by these organisations.

A.1.1 NGMN

The Next Generation Mobile Networks (NGMN) Alliance is considered one of the most pioneers in providing an insight into 5G technology, with the publication of two white papers: "5G White Paper" [29] and "Description of Network Slicing Concept" [30]. In [29], NGMN highlighted the main novelties that 5G may bring into communication systems, discussing service innovation from a business and management viewpoints and presenting the network slicing technology as a disruptive paradigm for serving verticals. This technology was further elaborated in [30], where NGMN provided a 3-layer architecture framework for network slicing concept (see Figure A.2) that was later adopted as reference model in many SDOs, including Third Generation Partnership Project (3GPP), European Telecommunications Standards Institute (ETSI), Broadband Forum (BBF) or Internet Engineering Task Force (IETF)

Based on the abovementioned white papers, NGMN has released a series of documents that address many customer-facing issues within the scope of 5G-VINNI, including architectural and orchestration considerations [31][32], testing setup and readiness [33], and secure exposure of 5G network capabilities to 3rd parties [34]. Some brief notions on these documents are given below.

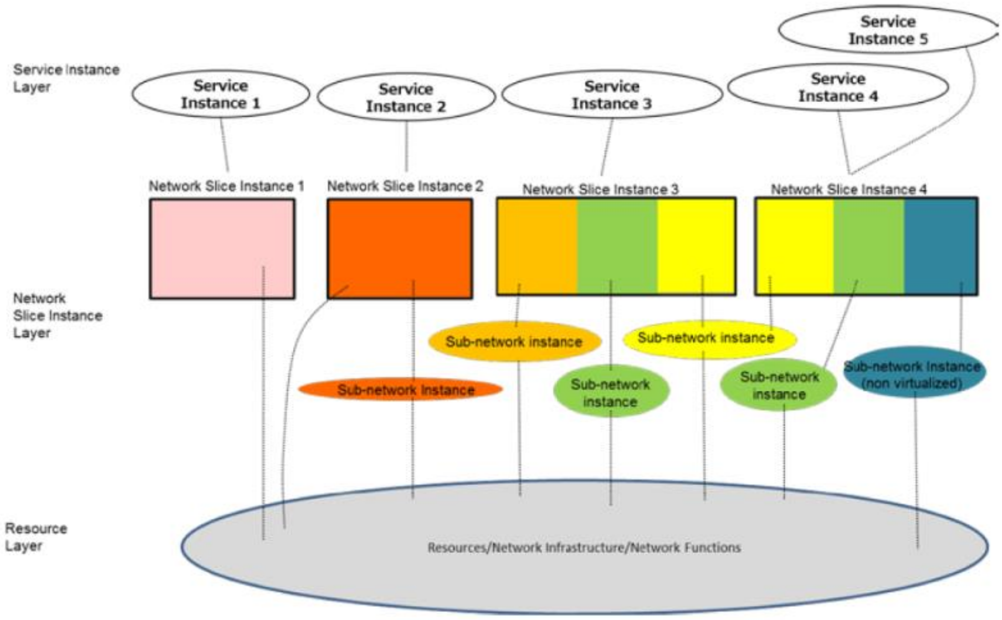

Figure A.2: NGMN network slicing conceptual outline (source: [30])

In [31], NGMN presents the second version of their 5G E2E architecture, whereby NGMN demonstrates how to utilise the network slicing concept to provision user/business services in the 5G telecommunication environment. This paper provides the NGMN vision for:

- Conceptual relationships between the vertical customers (i.e. tenants), service orchestration, the service, the network slice and their associated resources.
- Extension of network slicing concept beyond the telecommunication domain
- Business layer application and enablers
- Security aspects at both business layer and network slice level.

NGMN uses the document in [32] to describe requirements covering all potential parts of future networks (e.g. fixed, mobile, cloud) from a network and service management including orchestration perspective. Some of the issues addressed in this document are the following:

- Management and orchestration use cases: real-time service provisioning, catalogue-driven service introduction and modification, 5G E2E service management, network management and orchestration for network slices and their components, etc.
- Management and orchestration requirements: service and slice self-healing, scalability, optimisation, capacity planning, open management interfaces, data collection, tracing, etc.
- Management and orchestration solutions, some of them with in-built self-organising functionality to allow automation.

With respect to test and validation, NGMN published a paper [33] in its mission to enable a global collaboration of testing activities as a means of supporting an efficient, successful and in-time 5G technology and service introduction. This document reports requirements for trialling activities, including:

- Trials setup: requirements for this activity define the key parameters for the setup of pre-commercial field trials, consisting of main deployment scenarios and the reporting and benchmarking requirements.
- Trial test: requirements for this activity define the KPIs and executable proof points. As NGMN states, every test/KPI should include a definition, test configuration, the success criteria and most importantly a clear testing methodology.

Finally, NGMN claims that the exposition of network capabilities to 3rd parties, allowing them to participate in service definition and operation, is a key asset to foster business and service innovation. Based on the pre-existing work from different SDOs (see Figure A.3), NGMN studies in [34] the implications of the applicability of service exposure in 5G scenarios, identifying different network capabilities exposure scenarios, investigating and proposing security requirements for these scenarios, and presenting and evaluating the corresponding use cases.

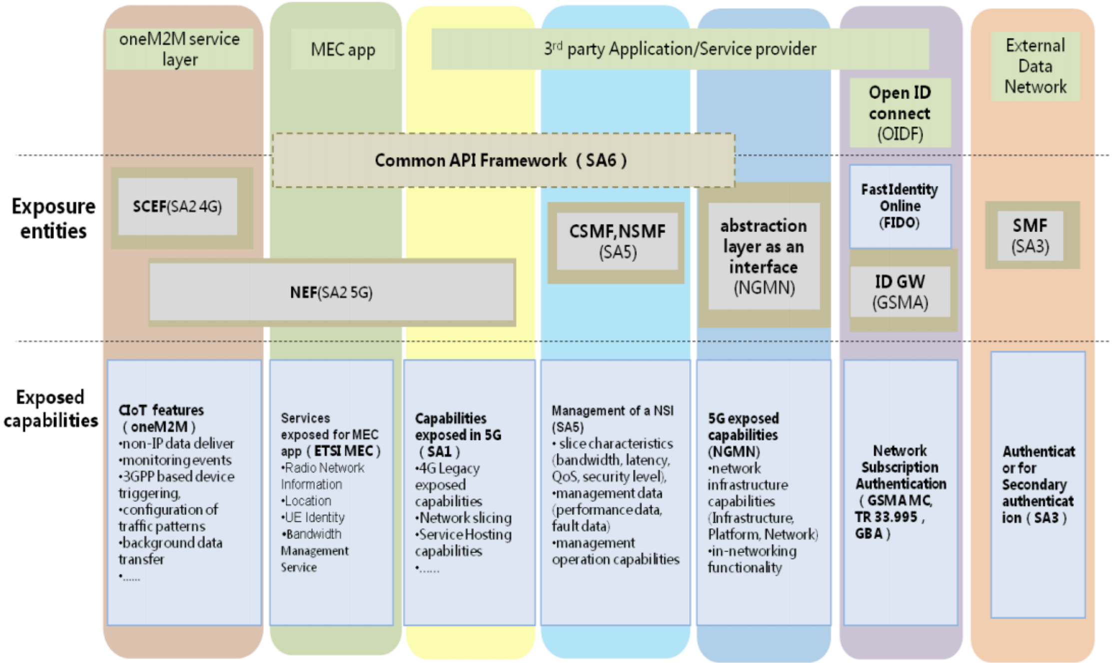

Figure A.3: Overview of capabilities exposure work in SDOs (source: [34])

A.1.2 GSMA

The GSM Alliance (GSMA) is a trade body representing the interests of mobile operators worldwide. GSMA's main work focuses on network slicing, and in particular on how translating service requirements from vertical industry use cases into network slice requirements, so convenient NSIs can be deployed and operated accordingly.

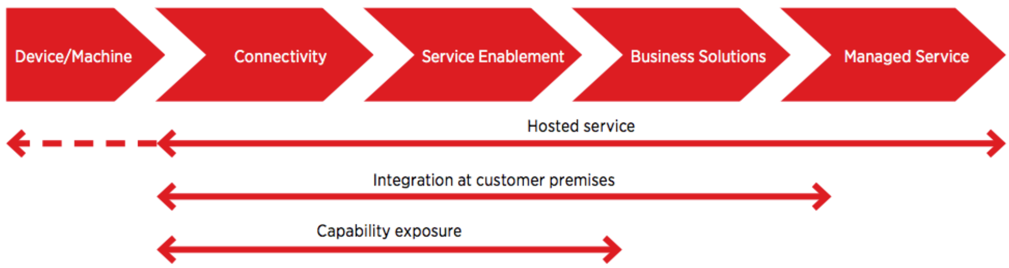

Figure A.4: Potential value chain in network slicing (source: [35])

In [35], GSMA presents their vision in network slicing, identifying capability exposure as one of the key value-added features that network slicing brings (see Figure A.4). This document was followed by the creation of Network Slicing Taskforce, a project initiated by Future Network Programme in GSMA to harmonise slicing definition, identify slice types with distinct characteristics and consolidate parameter and functionality requirements for slice description. Outcomes from this project have resulted in the publication of two GSMA white papers [36] [37].

On the one hand, the document in [36] provides a comprehensive overview about the service requirements on network slicing expressed by vertical customers from different industry sectors, including Augmented/Virtual Reality, automotive, energy, healthcare, manufacturing (industry 4.0), IoT for Low Power Wide Area Applications, public safety and smart cities. The aim of this overview was to analyse these service requirements and provide recommendations towards corresponding SDOs, fostering cross-standardisation collaboration in terms of architecture, management and security. In addition, the document in [36] also provides an overview about the policy aspects around Network Slicing such as network neutrality and cross-operator data transfers.

From the analysis conducted in [36], GSMA noted that service requirements in network slicing could be classified into performance, functional and operational requirements. However, it concluded that there was no agreement on how verticals express these requirements. In this context, GSMA suggested it was necessary to develop a solution able to (i) offer verticals some guidelines on how to issue their service requirements towards operators, and (ii) facilitate operator the SLA sign with verticals. In such a context, GSMA elaborated a new paper [37] where it introduces two novel concepts:

- *General Slice Template (GST)*: a reusable blueprint used for slice description. It contains all the potential attributes a network slice could have and can be regard as a baseline for all network slices offered to verticals.
- *Network Slice Type (NEST)*: defines the characteristics of a network slice by means of filling the GST with values and/or ranges based on specific industry vertical use cases. The GST attributes are envisioned to be sufficient to describe network slice types in that they can be fully constructed by allocating values (or values of ranges) to each relevant attribute in the GST.

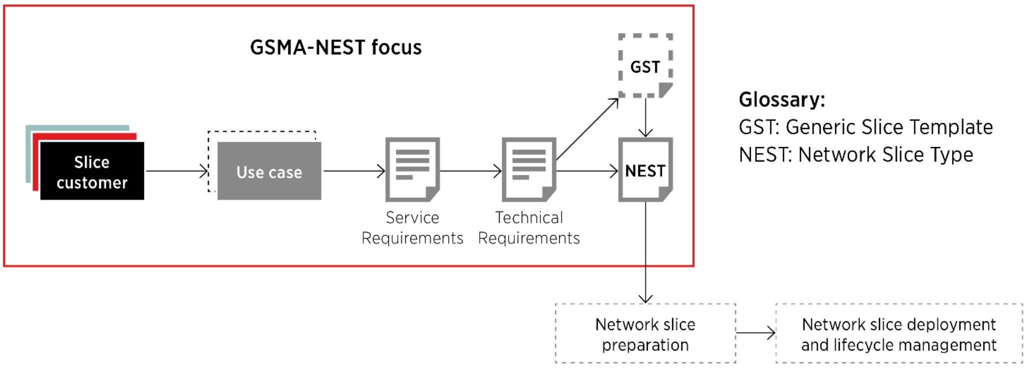

Figure A.5: GST and NEST (source: [37])

The process of creating a NEST from a GST is described in Figure A.5. As seen, first service requirements for vertical industry use cases are translated into technical requirements. Then, these requirements are documented in NEST by filling in the GST attributes accordingly. Once NEST is created, the 3GPP Network Slice Template (NST), i.e. template for NSI deployment, c be designed. Going from NEST to NST means going from customer-facing to resource-facing network slice description (D1.3). To facilitate this translation, number of NESTs match number of NSTs, allowing 1:1 mapping. This is illustrated in Figure A.6.

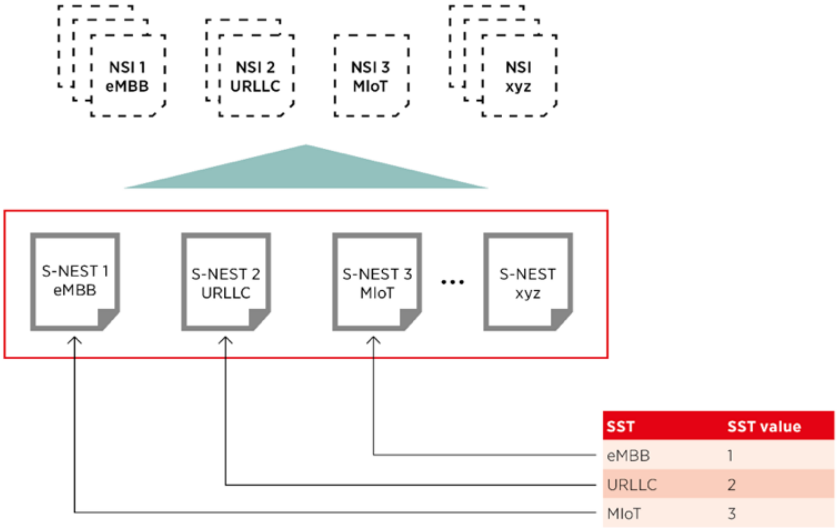

Figure A.6: Examples of NEST's (source: [37]). SST stands for 3GPP Slice/Service Type parameter.

A.1.3 MEF

Metro Ethernet Forum (MEF) has introduced the MEF 3.0 transformational global services framework for defining, delivering, and certifying agile, assured, and orchestrated services across a global ecosystem of networks. MEF 3.0 framework provide an on-demand, cloud-centric experience with unprecedented user and application-directed control over network resources and service capabilities. This is of particular interest for 3rd parties willing to take an active role in service provisioning activities.

MEF is developing LSO (Lifecycle Services Orchestration) specifications to automate the entire lifecycle for MEF 3.0 framework services orchestrated across multiple domains, including technology, network and administrative domains. LSO aims to streamline and automate the service lifecycle for coordinated management and control across all domains responsible for delivering an end-to-end orchestrated service, providing for this end open and interoperable automation of service management operations that include fulfillment, performance, control, assurance, usage, analytics, security, and policy capabilities. For this end, MEF builds on the so-called LSO Reference Architecture (see Figure A.7)

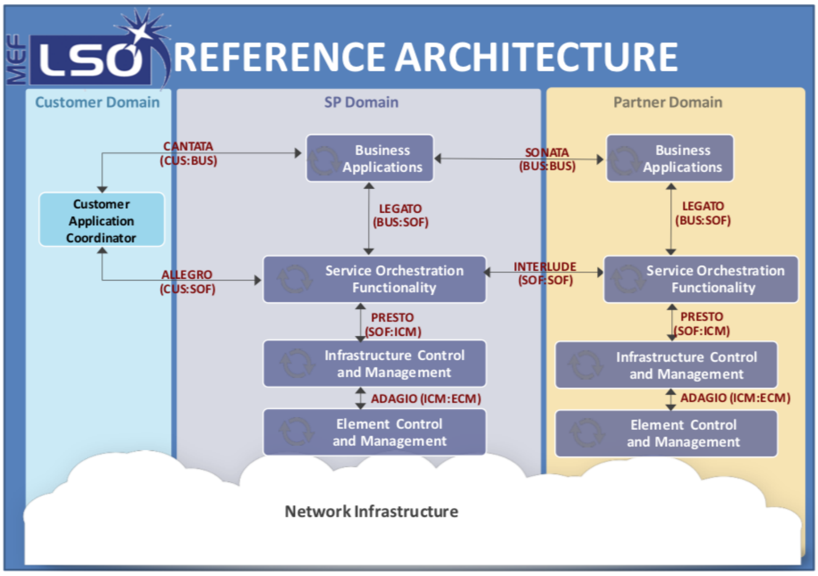

Figure A.7: MEF LSO Reference Architecture (source: [38])

The LSO Reference Architecture [38] describes the management entities needed to support LSO and the management interface reference points between them. These management interface reference points represent sets of open APIs, for which there is ongoing active collaborative development by MEF members. Focusing on the interaction between CSCs (customer domain) and CSP (service provider domain), the following customer-facing management interface reference points apply:

- *ALLEGRO (CUS:SOF)*: provides necessary capabilities to allow a CSC to supervise and control the behaviour of the service under its purview, through interactions between CSC's Customer Application Coordination and CSP's Service Orchestration Functionality. Examples of operations that can be exchanged through ALLEGRO include service instantiation, service operational status query, service modification, service monitoring (by receiving alerts) and service termination.
- *CANTATA (CUS:BUS)*: used for business interactions between CSC's Customer Application Coordination and CSP's Business Applications, including operations such as catalogue browsing, service ordering, billing, and troubleshooting. Note that CANTATA does not include control-related functionality; that falls under ALLEGRO.

A.1.4 TM Forum

Tele Management Forum (TM Forum) is actively working on the digital transformation and evolution of current Operations / Business Support Systems (OSS/BSS), seeking solutions that facilitate their consumption by new customers (e.g. verticals and 3rd parties) and their integration into existing SDO reference architectures and open source platforms (see Section 3.3) In this respect, one of TM Forum's key contributions was the definition of the Digital Platform Reference Architecture [39]. As shown in Figure A.8 , the platform approach has three key concepts:

- *Platform*: instances of a platform are units of deployment. They represent reusable business capabilities defined, governed and administered by an organisation following industry templates.
- *Platform capabilities*: exposed by the platform, they are the units of integration. Platform satisfy a part, or all, of a business value stream and are used by business people to describe the required relationships between the platform and the customers consuming it.
- *Open APIs*: are the units of interoperability that realise platform capabilities. They are standardised and can be conformance and interoperability tested.

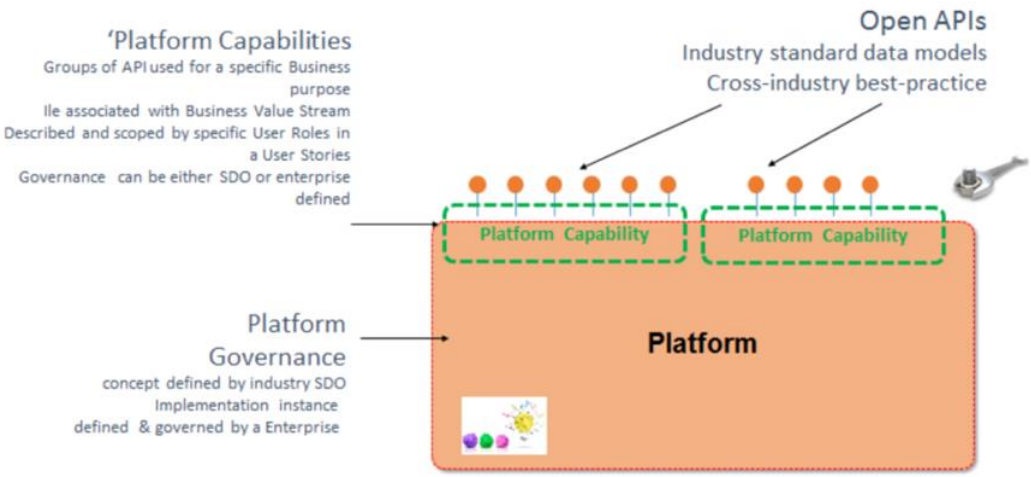

Figure A.8: TM Forum's Digital Platform Reference Architecture

Later, TM Forum extended the above platform to define the Hybrid Infrastructure Platform (see Figure A.9), consisting of three main capabilities: platform management, lifecycle and on-boarding and planning management, and operations [40]. Finally, TM Forum took this platform as the baseline platform, and suggested it could be recursively composed and aggregated into different layers to create a modular, multi-level ecosystem where open APIs exposed by lower platforms can be consumed by upper platforms following the Network as a Service (NaaS) approach [41]. The resulting system is the Open Digital Architecture (ODA), shown in Figure A.10.

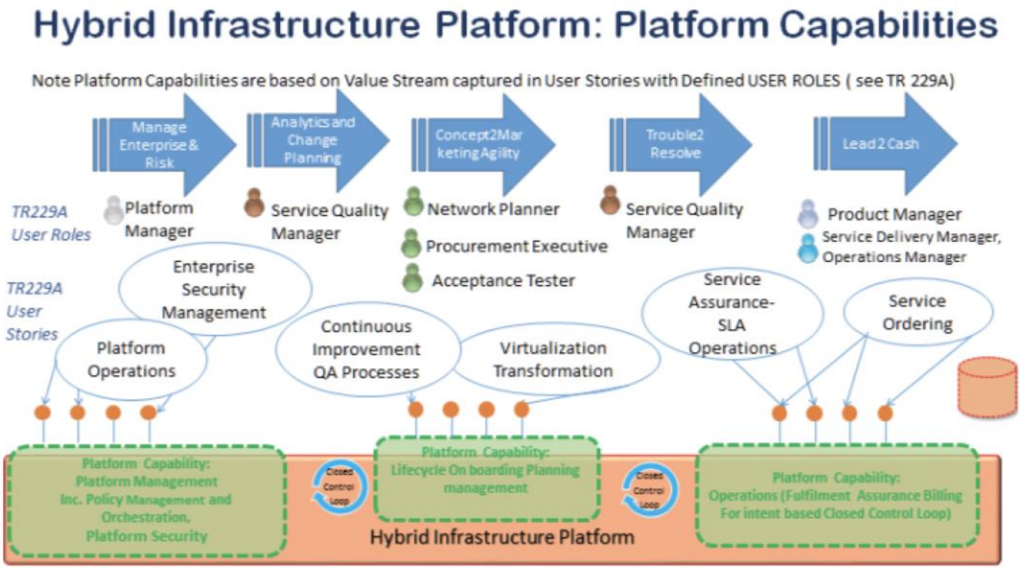

Figure A.9: TM Forum's Hybrid Infrastructure Platform (source: [40])

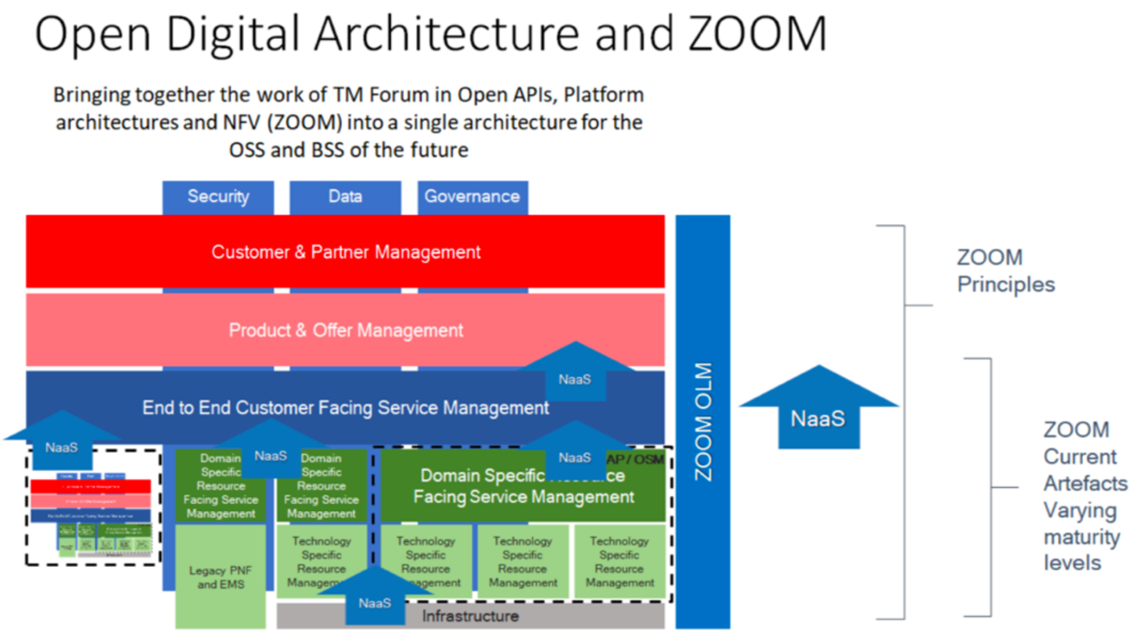

Figure A.10: TM Forum's ODA (source: [41])

TM Forum uses ODA as a reference architecture to discuss network slicing implications. From a customer-facing viewpoint, the following references are relevant:

- IG1152 - Dynamic Network Slices Management and Business Models [42]: defines actors for E2E management and provides an overview on how network slices could be provided by multiple CSPs through APIs.

- TR229A - User Stories for Hybrid Infrastructure Platform [43]: defines actors for slice orchestration policy and governance and present different network slicing use cases, wherein the scenario of multi-service provider in B2B2C model deserves attention.
- GB999 – User Guide for Network Slice Management [44]: presents slice management architecture clarifications and use cases. Additionally, it remarks the set of ODA's Open APIs that could be used for slice management, including APIs for service catalogue management [45], service ordering [46], service inventory management [47], service test [48], service qualification [49], service problem [50], performance management [51] and alarm management [52].

A.1.5 Impact in the 5G-VINNI architecture framework

Figure A.11 illustrates the scope of the different SDOs and telco industry associations in the context of the 5G-VINNI architecture. As seen, some concepts discussed in Annex A.1 are shown in the figure, including TM Forum's Open APIs and MEF's LSO.

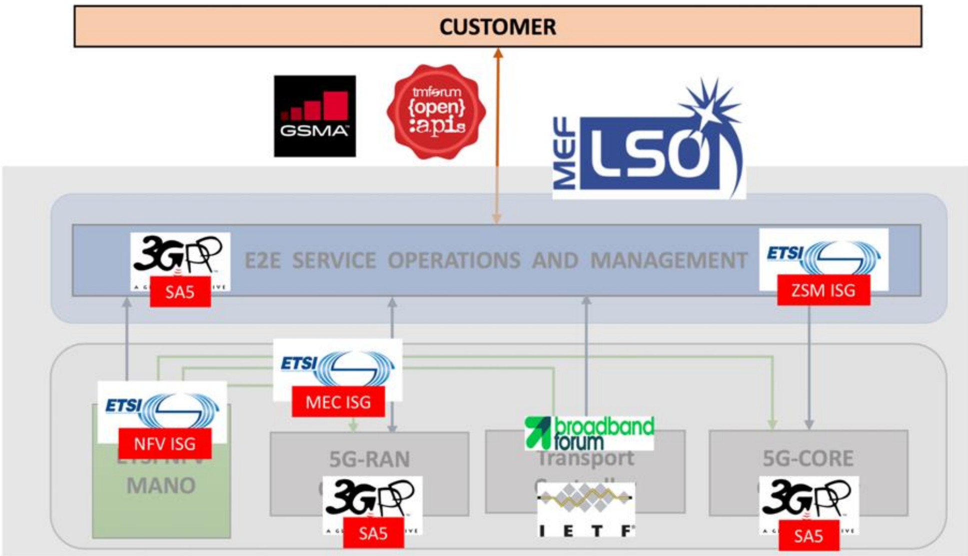

Figure A.11: Impact of telco industry associations and SDOs in 5G-VINNI

A.2 Research projects

This section highlights the main research projects whose activities and outcomes are relevant for the 5G-VINNI project in terms of how a CSP can provide different CSCs with isolated, experimental environments for use case verification, validation and testing. The following projects has been selected for discussion: 5G-TRANSFORMER, 5GTANGO, SLICENET and 5GinFIRE.

A.2.1 5G-TRANSFORMER

5G-TRANSFORMER [53] is a European Commission H2020 5G-PPP Phase 2 project, kicked off in June 2017 with 30-month duration, that aims at designing an SDN/NFV-powered, programmable mobile transport and computing platform able to support the service requirements from different verticals in a cost-effective manner. For this end, 5G-TRANSFORMER relies on the use of network slicing technology, as shown in Figure A.12.

Figure A.13 provides an overview of the 5G-TRANSFORMER system architecture, where three main subsystems have been defined: Mobile Transport and Computing Platform (5GT-MTP), Service orchestrator (5GT-SO) and Vertical Slicer (5GT-VS). While 5GT-MTP and 5GT-SO focuses on the deployment and operation of NSIs throughout a federated virtualised environment involving multiple administrative (and technology) domains, the 5GT-VS is the subsystem that handles the interaction of verticals with the 5G-TRANSFORMER system, allowing them to browse service portfolio, issue service orders, as well as consume the system exposed service capabilities. This means that customer-facing management procedures for network slicing in 5G-TRANSFORMER fall under the scope of 5GT-VS.

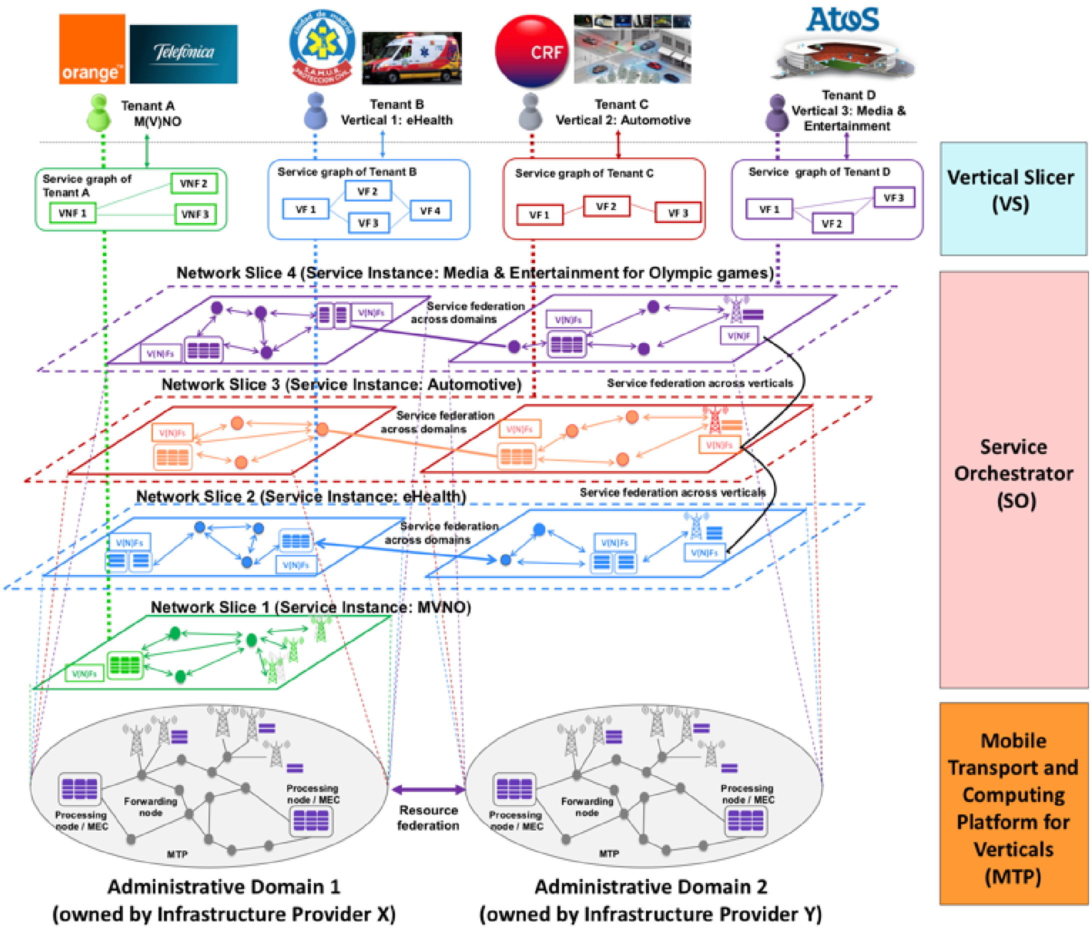

Figure A.12: Network Slicing in 5G-TRANSFORMER (source: [54])

The key concepts of 5GT-VS are the following:

- 5GT-VS is the component of the system that is conscious of the business needs of the verticals, their SLA requirements, and how they are satisfied by mapping them into given network slices.
- 5GT-VS includes a catalogue of vertical service blueprints (VSBs), towards which verticals can issue service orders. A VSB is a baseline template that provides a vertical-oriented description of a service offering, allowing verticals to focus on the service logic and requirements, without caring on how they are eventually deployed at the infrastructure level. For this end, VSB is designed as a simple interconnection model that includes information on service graphs, vertical functions, traffic flows and connection points. The result of issuing a service order towards a given VSB is a Vertical Service Descriptor (VSD).
- 5GT-VS maps customer-facing requirements into resource-facing requirements, being the latter under the scope of 5GT-SO and 5G-MTP. For this end, it translates VSD into an extended Network Service Descriptor (NSD) that is used as deployment template for NSIs.
- 5GT-VS provides two reference points at the NBI: Ve-Vs and Mgt-Vs. The first reference point expose capabilities to verticals, allowing them to browse VSB catalogue, issue service orders, and trigger operations towards the service instance, including lifecycle management operations (e.g. instantiation, scaling, termination) and monitoring operations (e.g. queries

and notification-subscriptions). The second reference point is not exposed to verticals but connected the verticals' OSS/BSS. This reference point allows provides verticals with management primitives related to tenants, VSBs and SLAs.

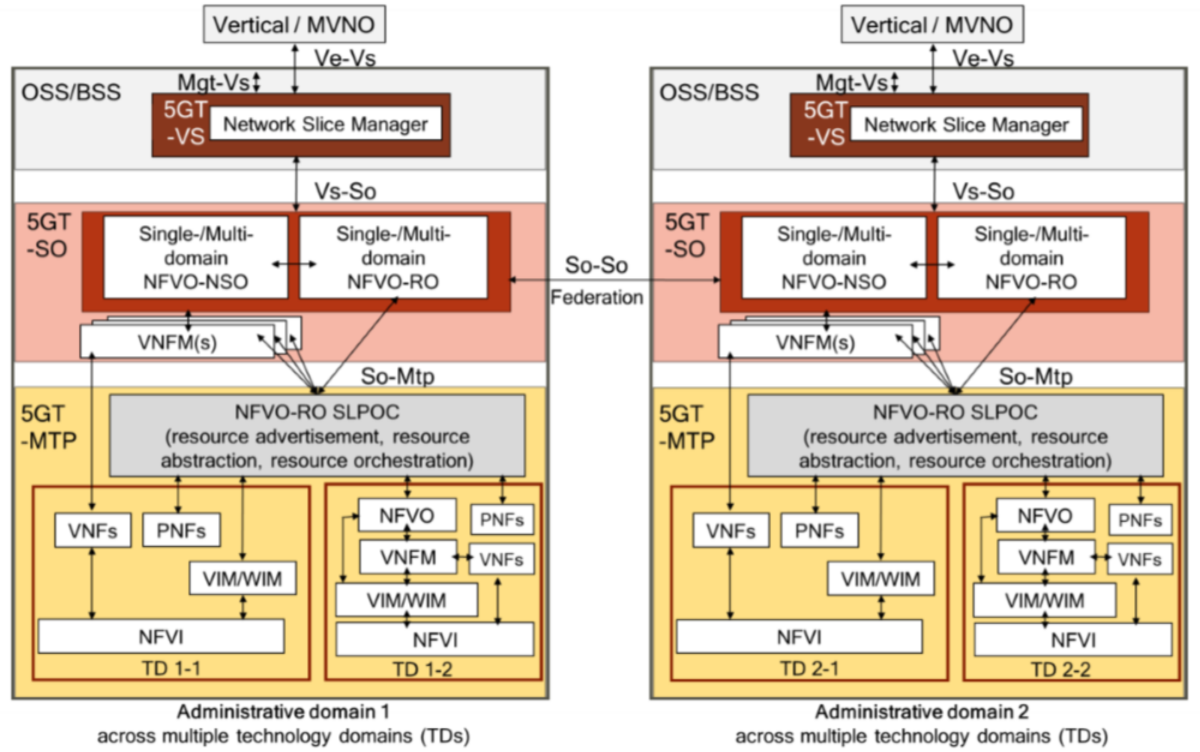

Figure A.13: 5G-TRANSFORMER system architecture (source: [55])

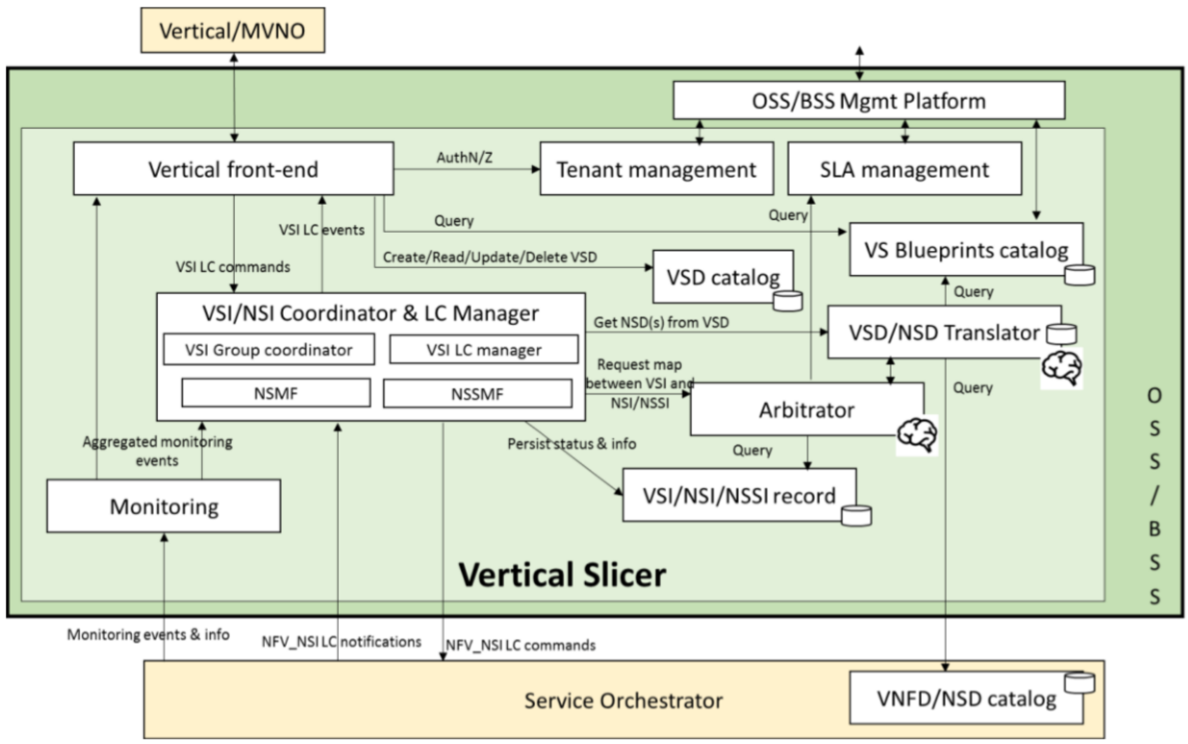

Figure A.14: 5GT-VS internal architecture (source: [55])

Figure A.14 shows the 5GT-VS, showing the internal modules allowing the abovementioned customer-facing features. These features can be used as a guideline to design functionality into the E2E Service Management & Operations block in 5G-VINNI.

A.2.2 5GTANGO

5GTANGO [56] is a European Commission H2020 5G-PPP Phase 2 project, kicked off in June 2017 with 30-month duration, whose purpose is to provide an extended DevOps ecosystem in softwarised environments where multiple actors (e.g. NFV-NS/VNF developers, network operators and verticals) cooperate to cover the different stages in the lifecycle of any NFV-NS , including stages at design-time (service development, testing, verification and validation) and run-time (service operation).

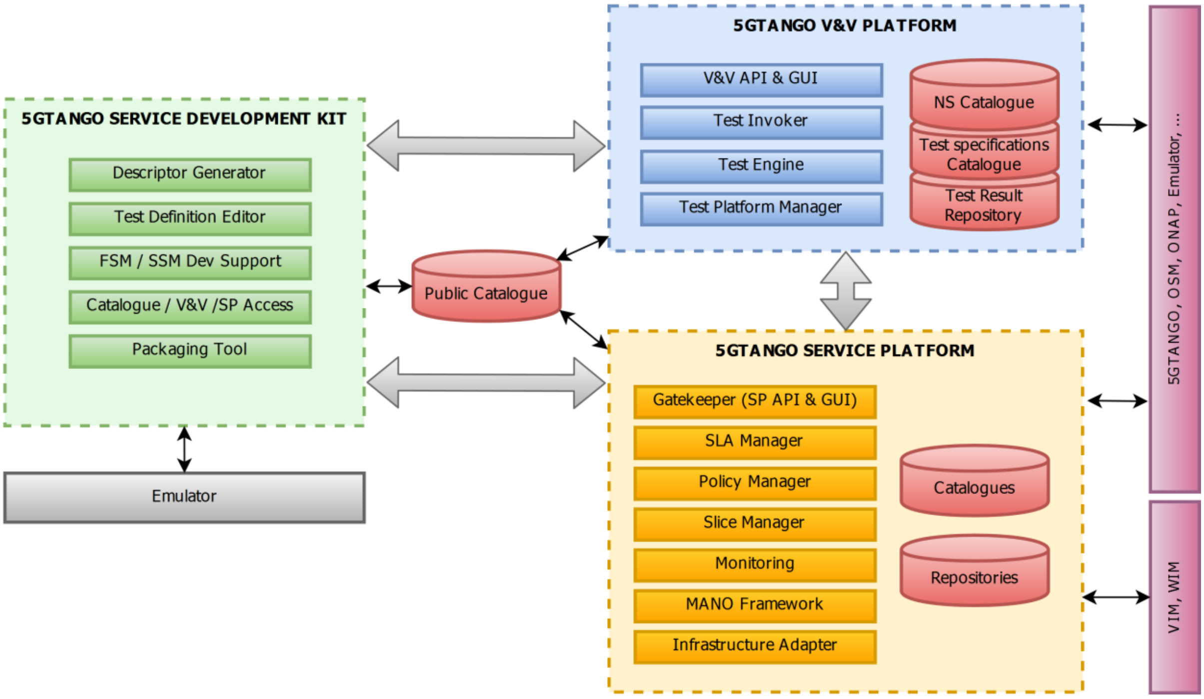

Figure A.15: 5GTANGO system architecture (source: [57])

5GTANGO system architecture is shown in Figure A.15. It is composed of three main subsystems: Service Development Kit (SDK), the Verification & Validation Platform (V&V) and Service Platform (SP). The SP provides an integrated, vendor-independent NFV environment for the deployment and operation of NFV-NSs instances. For the support of slicing, SP includes an internal module called Slice Manager that arrange NFV-NS instances into NSIs and manage them in an independent manner. SP does not handle customer-facing management procedures over these NSIs; indeed, it only focuses on their instantiation and lifecycle management operations following NOP-defined policies, without their exposure towards CSCs. These resource-facing considerations are discussed in D1.3.

Unlike the SP, SDK and V&V does provide functionality that are relevant from customer-facing perspective. The key concepts of both SDK and V&V are the following:

- SDK and V&V can be accessed and used by authorised 3rd parties, including verticals.
- SDK provides a collection of tools that verticals can use for the design of their own 3rd party VNFs, when these VNFs want to be include as part of a NFV-NS; in such a case, the vertical takes the NOP-B role defined in Figure 2.6b. The design includes the definition of corresponding VNFDs, their in-depth syntax/integrity/topology checking based on custom validation rules, and the packaging of these VNFDs and rules along with needed software images into VNF Packages.

- SDK provides a local workspace for VNF pre-testing that verticals can use to check the functional behaviour of designed VNFs, before on-boarding them to the V&V platform. This workspace consists of tools enabling test definition, traffic profile to be used for the test, and test validator.
- V&V platform provides a validation and verification service that test submitted VNFs to ensure they pass a range of tests, including performance tests (e.g. to test VNFs meet intended KPIs) and API tests (e.g. to test VNF exposed APIs behave as expected, responding properly and without unexpected delays in the replies).

5GTANGO centres the discussion of these customer-facing capabilities on NFV-NSs. However, it can also be easily applied to network slice service instances, by simply considering the association network service – network slice that Slice Manager handles.

A.2.3 SLICENET

SLICENET [58] is a European Commission H2020 5G-PPP Phase 2 project, kicked off in June 2017 with 36-month duration, that is focused on management and orchestration of multi-layered services (i.e. from infrastructure services to business services) in SDN/NFV environments through cognitive techniques and artificial intelligence. One of the key technical innovations is the use of network slicing technology, allowing CSPs to open and monetise their networks to vertical customers (CSCs), providing them with network slices under NSaaS model.

Figure A.16 provides a high-level view of the overall SLICENET architecture, with functional blocks executing different functionality at data, control, and management planes. Note that management functions, depending on the abstraction level they work, are logically positioned at different layers: resource management layer, slice management layer and service management layer. SLICENET architecture support customer-facing network slicing management capabilities, allowing verticals to consume their provided slices in their own environments. These capabilities are built on three main pillars: one-stop APIs, model-driven service (NSaaS) orchestration, and Plug & Play (P&P) control.

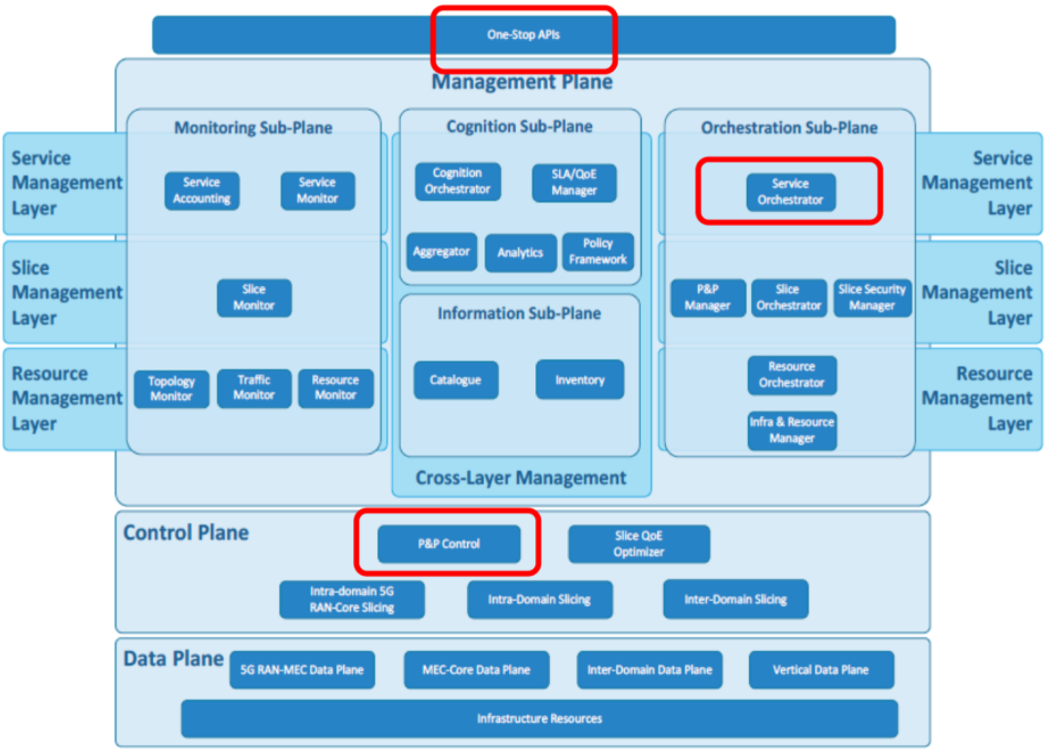

Figure A.16: SLICENET System architecture

The One-Stop APIs concept, represented on top of Figure A.16, provides a single-entry point and abstraction for the verticals to reach the system architecture functionalities. It enables the engagement of verticals into the design and provisioning of their network slice service instances, while hiding underlying complexity. The overall view exposed via the One-Stop API aggregates the resource-facing service offerings (e.g. NFV-NS offerings, VNF/PNF offerings, virtualised resource offerings) as a pool of selectable features that can be identified into the creation request of a network slice service. These selectable features are offered in a way that allow verticals easily identify those aspects that are relevant, according to their specific service requirements, for the delivery of the end-to-end functionality.

The Service Orchestrator (see Figure A.17) is equivalent to the 5GT-VS from 5G-TRANSFORMER, with the exception that does not allow direct interaction with the verticals (this is done with the One-Stop API). As shown in Figure, the following similarities can be found between the two systems:

- Service Templates (ST) and Service Descriptor (SD) in SLICENET are equivalent to Vertical Service Blueprint (VSB) and Vertical Service Descriptor (VSD) in 5G-TRANSFORMER.
- The combination of Service Coordinator (customer-facing) and Slice Orchestrator (resource-facing) in SLICENET is similar to VSI/NSI Coordinator & LC Manager in 5G-TRANSFORMER.
- Both subsystems have translation modules to translate customer-facing specifications (SD/VSD) into resource-facing specifications (NSD/NST).

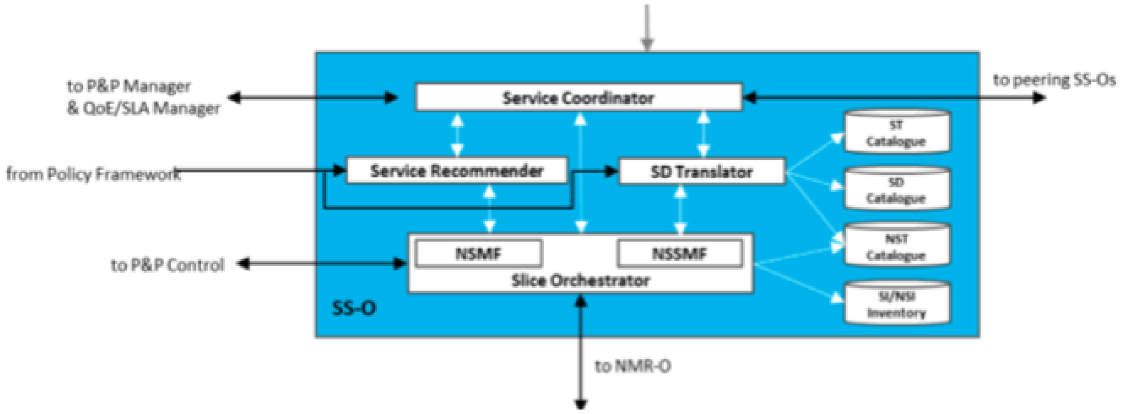

Figure A.17: Service (NSaaS) Orchestrator in SLICENET (source: [59])

Finally, there is the P&P. Logically instantiated per each NSI, the P&P enables NSaaS by exposing the set of capabilities of that NSI towards the corresponding vertical, defining the corresponding network slice service instance. These capabilities offer a novel combination of tailored control functions, APIs and tools to enable the vertical to even plug its own control logics to specialise the instance according to its specific needs. As seen, P&P provides an innovative control environment which offers the vertical significantly enhanced degree of flexibility to operate the provided network slice service instance, allowing him/her to customise the intra-instance management according to its specific needs.

A.2.4 5GinFIRE

5GinFIRE [60] is a European Commission H2020 project, kicked off in January 2017 with 36-month duration, whose purpose is to build and operate an Open and extensible 5G NFV-based based reference ecosystem of experimental facilities capable of supporting vertical use cases based on industry-leading and open source technology. 5GinFIRE ecosystem intends to serve as a forerunner experimental playground for industry verticals, providing them with an experimental testbed provisioned with functionality and toolsets where demonstration of vertical-oriented use cases can be set up. Figure A.18 illustrates the refence model of 5GinFIRE architecture.

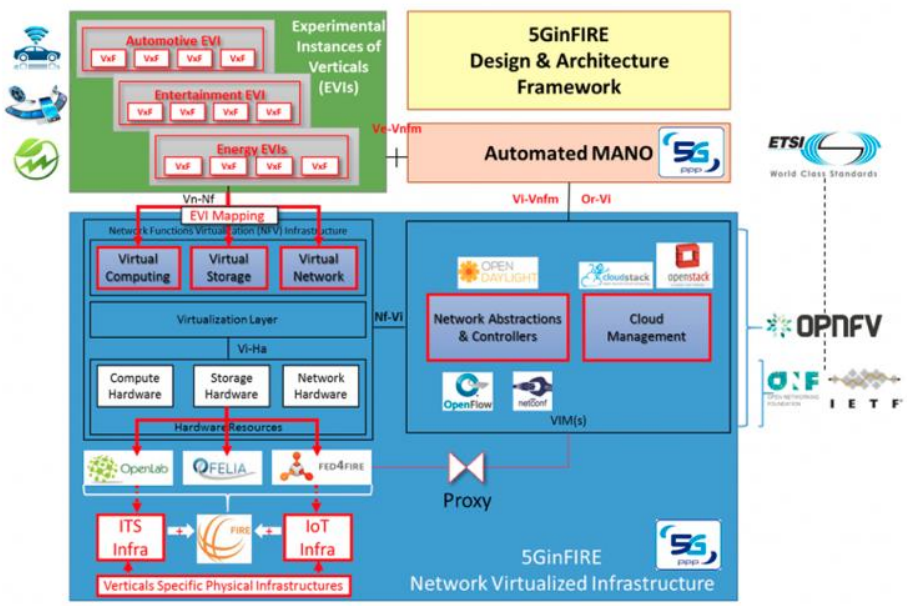

Figure A.18: 5GinFIRE reference model architecture

From a customer-facing perspective, two outcomes of 5GinFIRE are relevant: the definition of different roles with respect to the usage of 5GinFIRE system components, and the design of a portal providing verticals with means to set up and assess trials of their use cases.

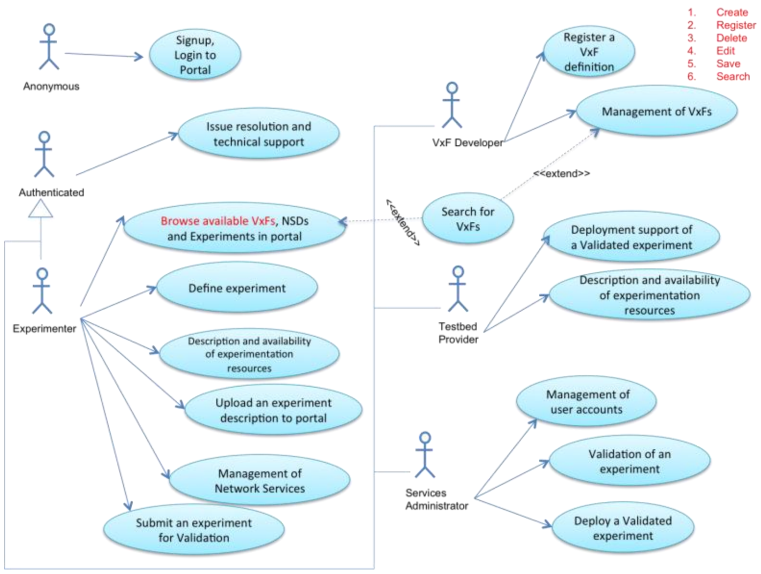

Figure A.19: 5GinFIRE user roles (source: [61])

On the one side, the definition of a clear separation of roles allows 5GinFIRE administrator to have a fine-grained control over the experimental testbed. Figure A.19 shows the different roles, including:

- *Virtual Vertical/Network Function (VxF) developer*: this role is responsible for uploading VNFD and NSDs in 5GinFIRE catalogue. Verticals can take this role when they bring their own VNFs (e.g. MEC apps, 3rd party VNFs) to 5GinFIRE system.
- *Experimenter*: this role represents the user using 5GinFIRE exposed capabilities (i.e. management services and tools) to deploy an experiment. The experiment description is done in terms of one or more NSDs that the user can select from the 5GinFIRE catalogue. Verticals are typically the actors who take this role.

- *Testbed provider*: this role represents the users responsible for testbed administration, configuration, integration, adaptation and support. Example of this users are facility operators.
- *Experiment Mentor*: responsible for monitoring the progress of an experiment, resource usage and allowing or not the deployment of an experiment. Typically, the facility operators are the actors taking this role.
- *Services administrator*: This role represents the user that are responsible for maintenance of the 5GinFIRE services.

On the other side, there is the 5GinFIRE portal. As shown in Figure A.20, this portal supports the experimenter in obtaining access to testbed resources and available functionality, e.g. available VxFs that can be orchestrated and deployed, he/she can use for trialling activities. Examples of tools and management services that experimenter can consume from 5GinFIRE portal include Continuous Integration service for validation of submitted VNFDs/NSDs (i.e. Jenkins), OSM for VNF orchestration, issue management system (i.e. Bugzilla), policies/rule engine, VNF images repositories and monitoring systems for infrastructure health checking.

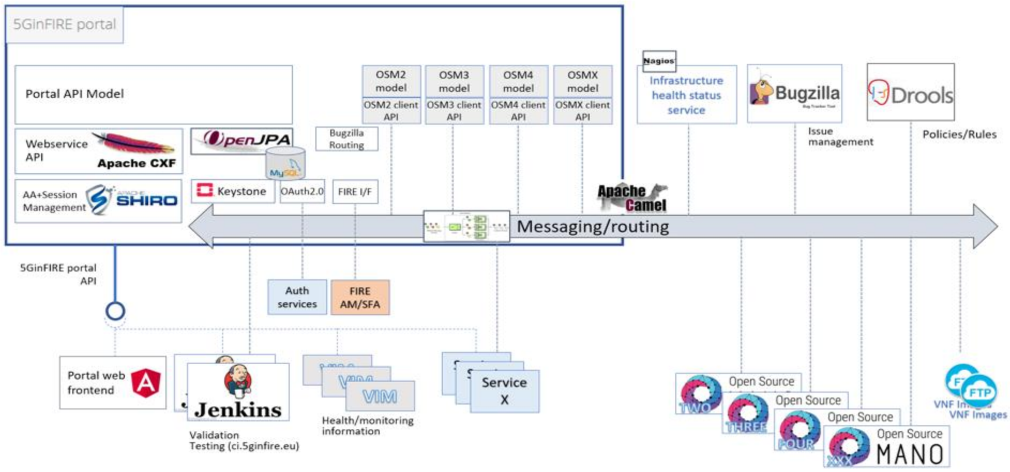

Figure A.20: 5GinFIRE portal architecture (source: [61])

Similar to 5GTANGO, 5GinFIRE centres the discussion of these customer-facing capabilities on NFV-NSs. However, it can also be easily applied to network slices, by making use of network slicing features brought by OSM release 5 (see Annex A.3.2).

A.3 Open source platforms

In this section, customer-facing management aspects will be discussed for ONAP and OSM projects.

A.3.1 ONAP

The Open Network Automation Platform (ONAP) [62] is an open source project that offers model-based management and orchestration capabilities through its platform, allowing its vertical customers and their network/cloud providers to deploy and operate network (function, service, slice) instances in softwarised environments with great level of automation. ONAP's architecture is shown in Figure A.21. Its modular and layered nature simplifies integration, allowing it to support multiple SDN/NFV-based execution environments.

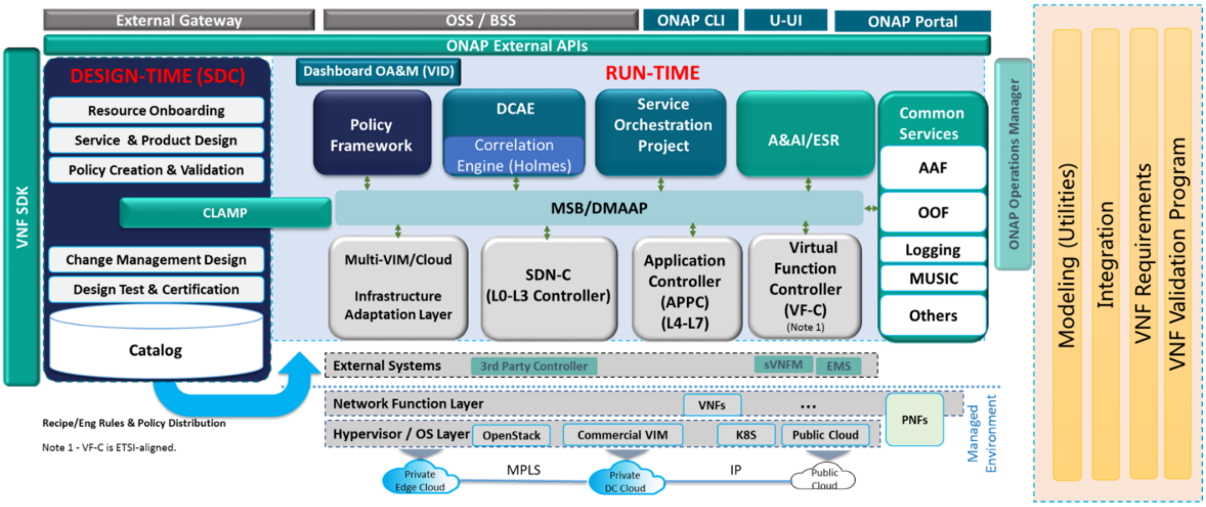

Figure A.21: ONAP architecture

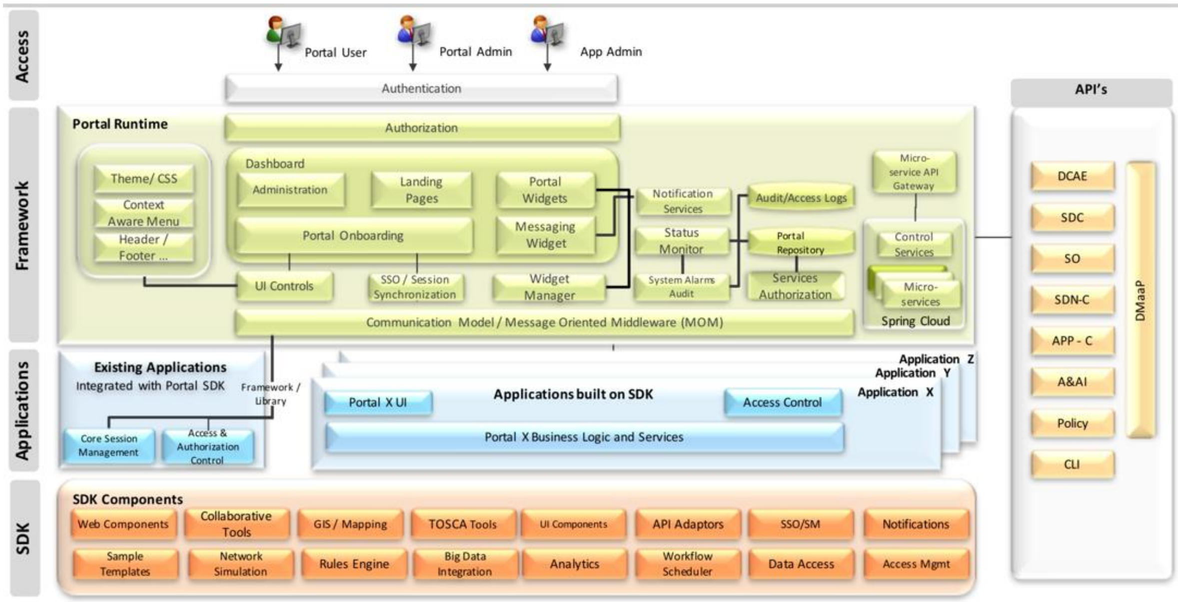

Figure A.22: Customer-facing view on ONAP platform

The customer-facing view on ONAP platform focuses on the interaction between the platform and vertical customers. As it can be seen in Figure A.22, this interaction is achieved through a portal that allow authorised verticals to access the different ONAP components (e.g. DCAE, SDC, SO, SDN-C, APP-C, etc.) through a set of Northbound REST APIs. These APIs expose management capabilities offered by those components, allowing verticals to consume them according to their roles. Depending on granted role, some verticals will be able to have a deeper control of the platform to manage their own NFV-NSs and slices (even individual VNFs), while others will behave as typical end users. Figure A.23 shows an example for illustrative purposes. In this scenario, ONAP's role-based access control grants the vertical (tenant) advanced capabilities to manage an NSI through its whole lifecycle. These capabilities determine which specific actions the vertical can invoke over the NSI, and thus what network slice service instance ONAP platform provides under NSaaS.

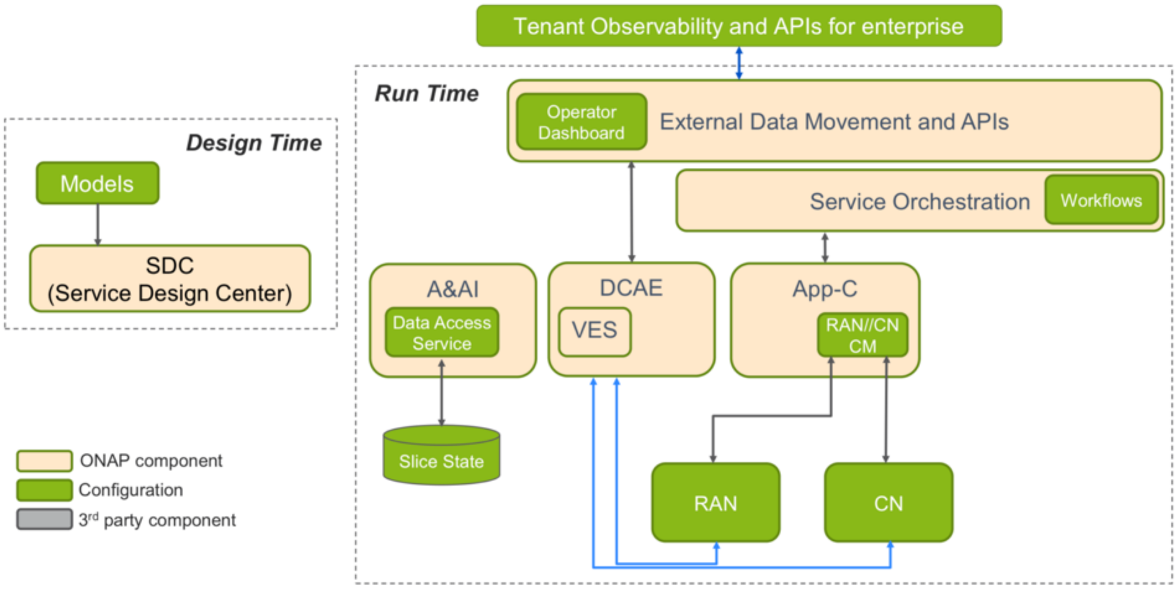

Figure A.23: Network Slicing Proof-of-Concept with ONAP (source: [63])

A.3.2 OSM

Open Source MANO (OSM) [64] is an open source project that provides an E2E Network Service Orchestration aligned with ETSI NFV specification. OSM is a based on a unified architecture and implementation built on the principles of abstraction, layering and modularity (see Figure A.24). OSM provides a well-known, complete and thoroughly tested Information Model to facilitate an accurate and sufficient description of the internal topology, procedures and lifecycle of Network Services and Network Slices. This information model is openly (and freely) available for every industry player, continuously evolved by a large community of industrial players, and being pre-validated in its intended E2E behaviour at the own OSM upstream community.

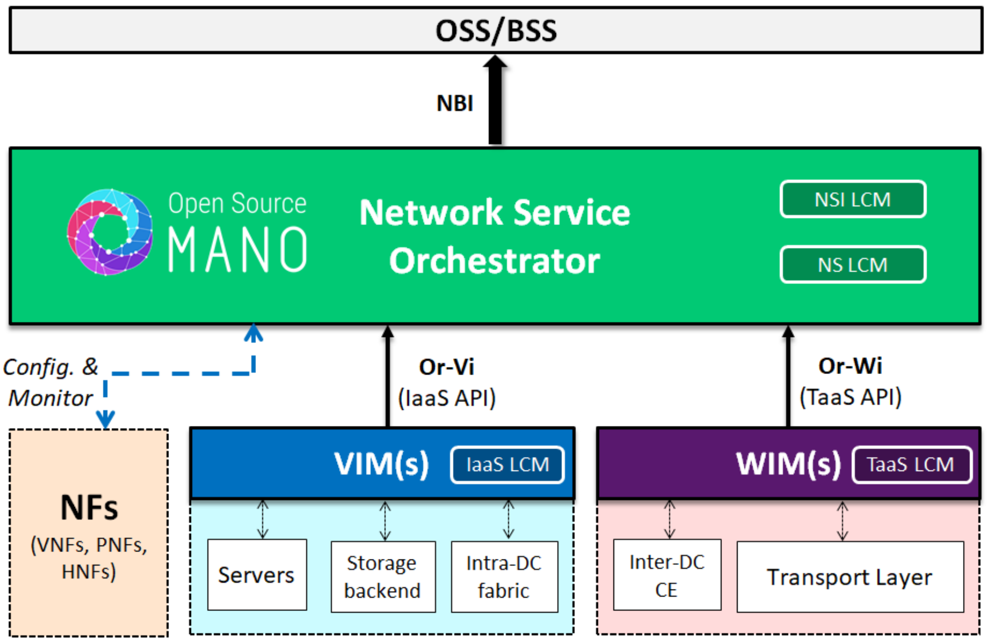

Figure A.24: OSM architecture

To allow consistent and vendor-agnostic operations in NFV environments, OSM has defined a unified Northbound Interface (NBI). OSM's NBI can be consumed by any OSM client (i.e. an authorised user using OSM capabilities), and presents two main features:

- It provides a superset of ETSI NFV SOL005 API calls, with the addition of E2E NS operations capabilities and the ability to handle network slices. This means that the NBI allows OSM clients to request the deployment of NSIs.
- It is openly available in OpenAPI format and can be used as the authoritative reference for interoperability northbound, even facilitating the automated generation of code for client applications. This means that the NBI can be flexibly adapted/extended to enable interworking between OSM platform and these applications. A typical example of a client application is a plug-in allowing communication between OSM and a vertical's management system, with this system taking the role of an OSM client. In the context of network slicing, the OSM could use the NBI to delegate the management of a requested NSI to a vertical, thus enabling NSaaS.

Similar to ONAP, OSM also uses role-based access control to determine which management operation each client is allowed to consume. For those clients eager to have a fine-control of their own slices, OSM can also offer them VNF configuration & monitoring capabilities (Juju), NFVI resource management capabilities (Or-Vi) and WAN resource management capabilities (Or-Wi). This modular and layered approach in capability exposure, where OSM clients are able to access modules placed at different layers, fits with the vision shown in Figure 2.8.

A.4 Conclusions

The aim of this annex was to provide an overview of the activities and outcomes from industry fora and SDOs, reserach projects and open source communities that are relevant for 5G-VINNI project in the context of customer-facing service operability, with network slicing support. The vision given here aimed at complementing the one given in D1.3 (Chapter 2), focused on network slicing from a resource-facing perspective.

The ideas discussed in Chapter 3 can be arranged into three main topics: architectural enhancements for model-driven realisation of NSaaS, network slice capability exposure to verticals, and testing and validation. These topics are key to make of 5G-VINNI facility an experimentation environment where verticals can request slices and take some control over them for trialling activities, executing different test cases for KPI validation. Table A-1 provides some conclusions on these topics.

Table A-1: Relevant inputs for the customer-facing issues relevant in 5G-VINNI

Group	Architecture and modelling	Capability exposure	Testing and validation
NGMN (§A.1)	YES: see [31][32] (architecture)	YES: see [34]	YES: see [33]
GSMA (§A.1)	YES: GST / NEST (modelling)	YES: only at conceptual level (Figure A.4)	NO
MEF (§A.1)	NO	YES: via ALLEGRO and CANTATA	YES: via ALLEGRO
TM Forum (§A.1)	YES: GST / NEST (modelling)	YES: (subset of) all ODA's Open APIs	YES: ODA's Open APIs specified in [48]-[52]
5GTRANSFORMER (§A.2)	YES: 5GT-VS (architecture) and VSB / VSD (modelling)	YES: Ve-Vs reference point (Figure A.12)	NO
5GTANGO (§A.2)	NO	NO	YES: SDK and V&V components (Figure A.15)

Group	Architecture and modelling	Capability exposure	Testing and validation
SLICENET (§A.2)	YES: NSaaS Orch (architecture) ST/SD (modelling)	YES: One-Stop APIs and P&P Control	NO
5GinFIRE (§A.2)	NO	YES: 5GinFIRE Portal components	YES: 5GinFIRE Portal components
ONAP (§A.3)	YES: Service Orchestrator (architecture) and templates in SDC (modelling)	YES: Portal's REST APIs	NO
OSM (§A.3)	YES: upper Service Orchestration functionality (architecture)	YES: OSM NBI	NO

Annex B Vertical industry use cases

This section provides a compilation of 5G use cases falling within each 5G-VINNI service type, identifying their key service requirements and potential CSCs. The use cases detailed in Table B-1, B-2, B-3 and B-4 are representative of those that 5G-VINNI is called to support.

The outcome of this activity will allow the CSP to infer the main differences that exist between use cases from different service types, so he can reflect them into the design of the different VINNI-SBs.

Table B-1: Examples of use cases that can be deployed and tested in eMBB network slices provided by a 5G-VINNI CSP

Use Case	Details
Aerial crop monitoring	**Description**: in this use case, farmers orders drone flights to take a multitude of ultra-high definition (UHD) images of the crop field. As these images are being taken, they are uploaded to a cloud server for their processing in the form of time series animations. Once processed, they are combined to create a complete field view in the form of a digital map that the farmer can use for multiple crop management activities, e.g. keep an eye on the development of their crop and soil variation issues. For this end, the drone should be equipped with high-resolution camera, GPS and radio technologies. **Key requirements:** high user data rate (UL), moderate area traffic density (UL), low latency, high reliability and availability, low device density, moderate mobility, coverage support: important. **Potential vertical sectors:** Agriculture and farming
Mobile wireless backhaul for in-vehicle entertainment	**Description**: this use case focuses on vehicles providing passengers with high throughput and seamless connectivity under mobile scenarios. This allow passengers to join media applications (e.g. online gaming, video streaming applications) with a high quality of experience that is quite similar to today's MBB scenarios at higher speeds. **Key requirements:** high user data rate (DL), high/low area traffic density (DL), low latency, high reliability and availability, moderate device density, very high mobility, coverage support: important. **Potential vertical industries:** Automotive, Media & Entertainment
Nomadic nodes	**Description**: this use case assumes the presence of vehicles with on-board small cells that can be integrated in the telco network to provide additional capacity and/or coverage. To provide backhaul to these nomadic nodes, vehicle-to-network (V2N) connectivity is required, being the last mile served using cellular or Wi-Fi technologies from these nodes. **Key requirements:** very high/moderate user data rate (DL/UL), very high/high area traffic density (DL/UL), low latency, high reliability and availability, moderate device density, moderate mobility, coverage support: important. **Potential vertical industries:** Automotive

Use Case	Details
Remote processing for vehicles	**Description**: this use case is about applying edge computing to automotive sector, allowing the relocation of certain resource-consuming applications (e.g. generation of dynamic location maps, VR displayed on the windshield) from vehicles to a nearby server, so that vehicles can relieve its own local process units. This approach brings two big benefits: first, it allows any vehicle to access any application regardless of their processing power capabilities; secondly, applications can also be easily and centrally maintained and updated without any user interaction or software updates. **Key requirements:** very high / moderate peak data rate (DL/UL), very high / moderate area traffic density (DL/UL), low latency, high reliability and availability, moderate mobility. **Potential vertical industries:** Automotive
Digital hospital	**Description**: this use case aims at providing inter-campus communication with MBB, reliable and secure connectivity, so hospital workers can exchange a wide variety of sensitive and/or confidential MBB-type information (e.g. ranging from simple documents to resource-consuming videos) as part of their daily activity. **Key requirements:** high/moderate user data rate (DL/UL), high/moderate area traffic density (DL/UL), moderate latency, very high reliability and availability, high device density, low mobility, coverage support: critical. **Potential vertical industries:** Health
Remote healthcare	**Description**: this use case enables individualised consultations, treatment and patient monitoring outside traditional healthcare institutions, including hospitals and clinics. This represents a paradigm change in the health sector, where healthcare has become an in-person, at-the-office experience for most of patients. With this new use case, patients and practitioners could use video conferencing and telepresence facilities for remote consultation and visits. This could be complemented by remote transfer of health-related data from sensors and devices (e.g., in real-time or pre-uploaded to the cloud). **Key requirements:** high peak data rate (DL), high are traffic density (DL), moderate latency, high reliability and availability, high device density, low mobility, high security, coverage support: important. **Potential vertical industries:** Health
Industrial campus	**Description**: this use case allows running multiple industrial applications or public and private networks via common network infrastructure. Support of various deployment options for wireless indoor and outdoor communication as well as the handling of multiple companies residing at the same campus is included. The main innovations of this MBB-type scenario are two. On the one hand, the applicability of better isolation mechanisms to reinforce privacy and security in private and public networks. On the other hand, reliability on simple network management and network sharing options to support even complex campus scenarios with sub-networks, multiple partners and applications. **Key requirements:** high user data rate (DL&UL), very high are traffic density (DL&UL), moderate latency, very high reliability and availability, high device density, low mobility, high isolation, coverage support: important. **Potential vertical industries:** Industry 4.0

Use Case	Details
HMIs and production IT for remote human assistance	**Description**: this use case focuses on the use of Human-machine interfaces (HMIs) to allow interaction between factory's workers and production facilities. Examples of HMIs include panels attached to a machine or production line, but also standard IT devices, including laptops, tablets and smartphones. Scenarios falling within this use case are assisted with Augmented Reality (AR) and Virtual Reality (VR) applications, that are expected to play an increasingly important role in future. **Key requirements:** high/moderate peak data rate (DL/UL), very high are traffic density (DL&UL), low latency, very high reliability and availability, low device density, low mobility, coverage support: critical. **Potential vertical industries:** Industry 4.0
Ultra high fidelity media	**Description**: this use case is focused on providing end-users with an innovative viewing experience, through the displaying of UHD, wide-view pictures and videos with deep contrast and unparalleled multi-channel sound in different types of devices, including large home-centric displays (e.g. 8K TV screens) and portable terminals (e.g. smartphones, tables, VR headsets). These pictures and videos could be on real-time (e.g. live programming, streaming) or on-demand. In any case, to allow this full quality experience, efficient network management, high speed transport capabilities and strategies must be applied (e.g. by means of local and network caching of content). **Key requirements:** very high peak data rate (DL), very high user data rate (DL), low latency, high reliability and availability, low device density, low mobility, coverage support: important. **Potential vertical industries:** Media & Entertainment
Cooperative media production	**Description**: this use case is content-centric and covers the many facets of media production. First, it allows content to be captured and shared immediately from anywhere to anywhere with additional metadata automatically pre-attached (e.g. spatial location date). Secondly, it allows content to be worked upon by different users in multiple locations simultaneously and repurposed for different requirements (e.g. second cameras, interactive games). The immediacy of access to content, as it created, may drastically reduce media production timescales. **Key requirements:** moderate/high user data rate (DL/UL), moderate/high area traffic density (DL/UL), moderate latency, high reliability and availability, moderate device density, no mobility, high security, coverage support: important. **Potential vertical industries:** Media & Entertainment
Collaborative gaming	**Description**: this use case enables moving from a primarily *home-based* gaming experience towards an *anywhere* gaming experience with user collaboration being both simultaneously in the physical world and the AR domain, based on the users' actual location. With this shift, gaming will expand into a full immersive multi-sensorial environment which will result in a more realistic experience, improved ability for users to collaborate within the game and no limitation on the number of simultaneous users. **Key requirements:** high user data rate (DL&UL), high area traffic density (DL&UL), low latency, high reliability and availability, moderate device density, moderate mobility, coverage support: important. **Potential vertical industries:** Media & Entertainment

Use Case	Details
Immersive and integrated media	**Description**: this use case focuses on providing customers with immersive video experiences. This includes the provision of behind-the-scenes content, VR-powered 360-degree views and the retransmission of holographic type video beyond telepresence (2D) closer to a virtual presence experience in 3D. In business environments, immersive video conferencing will simulate the face-to-face experience that present videoconferencing systems do not allow, bringing more efficiency and flexibility to the company. **Key requirements:** very high peak data rate (DL&UL), very high user data rate (DL&UL), low latency, high reliability and availability, no mobility, coverage support: important. **Potential vertical industries:** Media & Entertainment
High resolution media on demand	**Description**: this use case is about the on-demand delivery of media content (video streams) to a wide variety of devices such as smartphones, tablets, laptops and TVs, each of them supporting different screen sizes, resolution and codecs. The main challenge that this use case brings is to provide the wanted content in the shortest possible time, adapted to the end-user device, while optimising bandwidth utilisation and power consumption. In order to reach this goal the media content shall be cached in advance as close as possible to the user and shall be adapted on-demand for the specific user device. **Key requirements:** very high peak data rate (DL), very high area traffic density (DL), low latency, high reliability and availability, moderate mobility, coverage support: important. **Potential vertical industries:** Media & Entertainment
Broadband access in crowded areas	**Description**: this use case aims at providing high data rate services to a large number of concentrated mobile users, including mainly the provision of MBB content at large events (e.g., a football game or a concert) or crowded public areas (e.g. open squares, large metro stations). **Key requirements:** high user data rate (DL), low latency, moderate reliability and availability, very high device density, no-low mobility, coverage support: important. **Potential vertical industries:** Media & Entertainment
Remote area coverage	**Description**: this use case is about providing broadband connectivity to very isolated rural areas, bringing the digital divide to support the economy, education and public services in those areas, where it is difficult or not (yet) possible to deploy terrestrial connections to towers, for example, coverage on lakes, islands, mountains, or other areas that are best or only covered by satellites. **Key requirements:** low user data rate (DL), moderate reliability and availability, low device density, low-moderate mobility, coverage support: critical. **Potential vertical industries:** Public Safety and divide resorption

Use Case	Details
AR/VR for tourism	**Description**: This use case focuses on improving the user experience of tourists visiting major city attractions, using AR/VR technologies for that end. With these technologies, tourists are not only able to benefit from an enhanced visual experience, but also to get more insight about the history and other information of the attractions in an interactive manner. **Key requirements:** very high/medium user data rate (DL/UL), low latency, moderate reliability and availability, moderate device density, low-moderate mobility, coverage support: important. **Potential vertical industries:** Media & Entertainment, Smart Cities
Waste dumping prevention	**Description**: this use case allows monitoring through 24/7 HD video surveillance systems some urban areas under the risk of environmental abuse due to unauthorized dumping of waste materials. For this end, HD video cameras will be installed in the waste collection island that wants to be monitored. Additionally, the use of (quasi) real-time video analytics application will allow smarter control procedures, including the possibility to trigger (quasi) real-time alert procedures to those municipal officers that are closest to the monitored point. **Key requirements:** moderate/high user data rate (DL/UL), low latency, high reliability and availability, moderate device density, no mobility, high isolation, coverage support: critical. **Potential vertical industries:** Smart Cities

Table B-2: Examples of use cases that can be deployed and tested in uRLLC network slices provided by a 5G-VINNI CSP

Use Case	Details
Driver monitoring application	**Description**: the main goal of this use case is to monitor driver's physiological status (e.g. drowsiness, distraction) and use this information to predict in real-time when the driver is not capable of driving, sending him/her a warning when necessary to avoid accidents. **Key requirements:** moderate peak data rate (UL), very low latency, very low packet loss rate, very high reliability and availability, coverage support: critical. **Potential vertical industries:** Automotive
Connected ambulance	**Description**: in this use case, the ambulance will act as a connection hub for the emergency medical equipment and wearables, enabling storing and potential real-time streaming of patient data to the awaiting emergency department team at the destination hospital. The continuous collection and streaming of patient data will begin when the emergency ambulance paramedics arrive at the incident scene right up until the delivery of the patient to the emergency department at the destination hospital. **Key requirements:** moderate/high peak data rate (DL/UL), very low latency, very high reliability and availability, high mobility, coverage support: critical. **Potential vertical industries:** Automotive, Health

Use Case	Details
Distributed automated switching for isolation and service restoration	**Description**: in grid backhaul and backbone, networks provide the necessary mechanisms for electric power distribution automation. In these scenarios, self-healing solutions for automated switching, fault isolation and, service restoration are needed. An example of this solution is FLISR (Fault Location, Isolation & Service Restoration), described in the following lines. FLISR consists of switch controller devices which are especially designed for feeder automation applications that support the self-healing of power distribution grids with overhead lines. They serve as control units for reclosers and disconnectors in overhead line distribution grids. The system is designed for using fully distributed, independent automated devices. The logic resides in each individual feeder automation controller located at the poles in the feeder level. Each feeder section has a controller device. Using peer-to-peer communication among the controller devices, the system operates autonomously without the need of a regional controller or control centre. However, all self-healing steps carried out will be reported immediately to the control centre to keep the grid status up-to-date. The controllers conduct self-healing of the distribution line by isolating the faults. **Key requirements:** moderate user data rate (DL&UL), very low latency and jitter, very low packet loss rate, very high reliability and availability, no mobility, very high isolation, coverage support: critical. **Potential vertical industries:** Energy
Smart grid millisecond-level precise load control	**Description**: this use case focuses on precise load control, the basic application for smart grid, and tries to enhance it, making it work in real-time environments to avoid any type of disruption in energy provisioning. When serious high-voltage direct current transmission fault happens, millisecond-level precise load control is used to quickly remove interruptible less-important load, such as electric vehicle charging piles and non-continuous production power supplies in factories. **Key requirements:** low user data rate (DL&UL), very low latency and zero jitter, low packet size, high reliability and availability, no mobility, high isolation, coverage support: critical. **Potential vertical industries:** Energy, Industry 4.0
Smart central power generation	**Description**: central power generation is about the conversion of any type of energy (e.g. chemical energy, nuclear energy, wind energy) into electrical energy, with electric-power outputs of 100 MW and more. For this end, a wide variety of equipment and plants are used, including large gas turbines, steam turbines, combined-cycle power plants, and wind farms. This use case focused in the operation, monitoring and maintenance pf these equipment and plants, to allow electrical energy generation with reduced footprint and high efficiency. For example, in a wind farm deployed offshore, the use case provides communication in support of closed-loop cyber-physical control in the wind farm. **Key requirements:** low user data rate (DL&UL), low latency and ms-level jitter, low device density, very high reliability and availability, no mobility, high isolation, coverage support: critical. **Potential vertical industries:** Energy

Use Case	Details
Logistics	**Description**: this use case deals with the organization and control of the flow and storage of materials and goods in the context of industrial production, including intra-logistics (e.g. within a factory) and logistics between different locations. One example of intra-logistics is ensuring the uninterrupted supply of raw materials on the shop floor level using fork lifts, etc. **Key requirements:** low user data rate (DL&UL), low latency, moderate reliability and availability, low-moderate mobility, coverage support: critical. **Potential vertical industries:** Industry 4.0, Transport & Logistics
Closed loop motion control for factory automation	**Description**: factory automation deals with automated control, monitoring and optimization of workflows within a factory, with a special focus on complete modular discrete control consisting of sequential, speed control, packaging and batching. This involves many increasingly mobile production assets, for which powerful wireless communication and localization services are required. The main communication components involved in factory automation are a motion control application (e.g. based on programmable logic or motion controllers) and one or more computer-integrated manufacturing actuators (e.g. machine tools, packaging machines, printing machines). A key enabler for factory automation is closed-loop motion control. Unlike in open loop systems, where the controller sends a control command and does not receive a feedback, in closed loop system feedback is provided and used to initiate dependent actions, with cycle times around 1-2 milliseconds. This use case focuses on supporting the stringent requirements on service availability, determinism and availability that upcoming factory automation applications will bring. To support communication with such latency values and high reliability, dedicated optimized uRLLC networks are required. **Key requirements:** low user data rate (UL), very low latency and zero jitter, very high reliability and availability, no mobility, very high isolation, cm-level positioning accuracy, coverage support: critical. **Potential vertical industries:** Industry 4.0
Remote control for process automation	**Description**: Process automation refers to the control of production and handling of substance like chemicals, food & beverage, pulp, etc. Some of the interactions within a plant are conducted by automated control applications. Therefore, sensor output is requested in a cyclic fashion, and actuator commands are sent via the communication network between a controller and the actuator. This use case has similar requirements to the closed-loop motion control for factory automation, but with a bit larger cycle times, around 50 milliseconds. **Key requirements:** low user data rate (UL), low latency, very high reliability and availability, no mobility, high isolation, coverage support: critical. **Potential vertical industries:** Industry 4.0
Mission Critical Push to Talk (MCPTT)	**Description**: this use focuses on granting a given mission-critical organization access to dedicated infrastructure resources on top of which MTPCC services can be built in case of emergency situation, regardless of the state of the underlying infrastructure. **Key requirements:** high peak data rate (DL&UL), moderate user data rate (DL&UL), low latency, very high reliability and availability, high device density, low mobility, very high isolation, coverage support: critical. **Potential vertical industries:** Public Safety and divide resorption

Use Case	Details
Drone-assisted emergency recovery	**Description**: this use aims at using communication capabilities from drones to help people's lives in the context of a natural disaster, e.g. earthquake, tsunami. For example, they can provide and maintain wireless emergency communication services during and after the disaster. Additionally, they can help rescue teams to identify people located in difficult-to-reach areas, providing them with some guidance (or even medical assistance) until the rescue teams' arrival. **Key requirements:** high/moderate user data rate (DL/UL), moderate latency, very high reliability and availability, high mobility, very high isolation, coverage support: critical. **Potential vertical industries:** Public Safety and divide resorption
Smart sea port traffic management	**Description**: this use case focuses on how robotised logistics can provide value in a port environment, enhancing efficiency in the logistic chain in the port and in the infrastructures connecting the port area. A clear example of this value can be seen when a container has just been unloaded from the vessel. Instead of contacting the distribution center by phone and asking them to move the container to a specific destination, an intelligent infrastructure allows the container to communicate directly with both the target destination and all the automated machines and humans along the supply chain, making port management more agile and without more efficient human intervention. For this end, high reliability and low-latency communication among facilities involved is required. **Key requirements:** low user data throughput (UL), low latency, very high reliability and availability, moderate mobility, coverage support: important. **Potential vertical industries:** Transport and Logistics

Table B-3: Examples of use cases that can be deployed and tested in mIoT network slices provided by a 5G-VINNI CSP

Use Case	Details
Smart irrigation	**Description**: This use case is about optimization of irrigation systems based on data collected from remote, non-mobile sensors placed in the field. This data can include information on sensor geolocation coordinates, temperature, humidity level, and type of crop. Once collected, this data is transferred to the farmer's cloud of choice, and after being processed, farmers can use them to analyze where their water resources should be directed, in what kind of volume and for how long, and all from their connected laptop or smartphone. **Key requirements:** very low user data rate (UL), very high device density, very high power efficiency, delay-tolerant, no mobility, coverage support: important. **Potential vertical industries:** Agriculture & Farming
Smart fertigation	**Description**: with IoT-enabled fertigation solutions, farmers can remotely control how many fertilisers are injected and within what volumes. It will also enable them to monitor fertilizer concentrations and other environmental conditions, such as PH, in the soil using remote sensors and adjust to the required levels if necessary. **Key requirements:** very low user data rate (UL), very high device density, very high power efficiency, delay-tolerant, no mobility, coverage support: important. **Potential vertical industries:** Agriculture & Farming

Use Case	Details
Livestock safety and maturity monitoring	**Description**: this use case relies on the use of sensors producing real-time data on livestock, including GPS positioning, body temperature, pulse and even tissue resistivity. The collected data can be accessed by farmers to keep track of the positioning of their animals (to prevent them from wandering off) and their health status (have a direct impact on the quality of the goods that can be extracted from them). **Key requirements:** low user data rate (UL), very high device density, high power efficiency, delay-tolerant, no and low mobility, coverage support: important. **Potential vertical industries:** Agriculture & Farming
Remote sensing and control	**Description**: this use case is about monitoring the status and health of the machinery involved in a given vehicle, demonstrating how IoT can provide value to automotive industry. This includes, on the one hand, the remote control of vehicle functions (e.g. air conditioning and heating, the engine, the headlights, the horn, the locking/unlocking of doors) and, on the other hand, the transmission of vehicle information (battery level, engine's temperature) to a backend server located in the internet. This information can be used by vehicle vendors to perform predictive analytics and unearth any impending faults. **Key requirements:** low user data rate (DL), moderate device density, delay-tolerant high reliability and availability, high mobility, coverage support: important. **Potential vertical industries:** Automotive
Context-aware personal information	**Description**: this use case aims at making a vehicle as much personalized as possible for its driver, based on his/her routines, preferences and actions, thus simplifying his daily travels. The information required for this customization is gathered from a wide variety of sources, thanks to the availability of connected services. **Key requirements:** low user data rate (UL), high device density, delay-tolerant, high mobility, coverage: important. **Potential vertical industries:** Automotive
Grid access communication	**Description**: the access communication systems provide efficient connectivity to a massive number of smart meters with enhanced indoor coverage requirements but relaxed requirements on latency, reliability and bandwidth compared to the grid backhaul and backbone. Forecast generation and consumption can help distribution system operators plan for possible imbalance situations in advance, or to optimize energy generation and distribution. This requires that the operator has detailed information about short and long-term generation and consumption profiles and expected consumer consumption during absence periods. **Key requirements:** low user data rate (UL), high device density, delay-tolerant, no mobility, coverage: important. **Potential vertical industries:** Energy

Use Case	Details
Health and wellness monitoring	**Description**: this use case involves the use of various types of sensors and wearable devices to track health-relevant indicators. Currently, such devices use short range communication technologies such as e.g., PAN (e.g., Bluetooth) and LAN (e.g., Wi-Fi) to connect to a hub (e.g., smartphone, gateway towards the fixed line). The data is used by apps (e.g., on a smartphone) to help the individual to monitor and manage wellness. **Key requirements:** very low user data rate (UL), very high device density, high power efficiency, delay-tolerant, no-low-moderate mobility, coverage: important. **Potential vertical industries:** Health
Smart medication / pharmaceuticals	**Description**: this use case is about allowing individuals to monitor and manage diseases (e.g. blood glucose level management) based on the data collected from sensors deployed as part of the health and well monitoring scenario (see above description). With the ability to upload the data to a third-party (e.g., medical doctor, insurer, data broker) periodically or in real-time, several beneficial interventions that rely on big data analytics and expert knowledge could be envisaged. **Key requirements:** very low user data rate (UL), very high device density, high power efficiency, moderate latency, high reliability and availability, no-low mobility, coverage: critical. **Potential vertical industries:** Health
Additive sensing for process automation	**Description**: this use case focuses on the introduction of a large number of sensors for process quantities (e.g. temperature, pressures, flow, etc.) and equipment conditions (e.g. vibrations, leakages, etc.) to significantly increase the sensory resolution in a plant where process automation take place. These sensors typically transmit bursts of data once per hour, where the data depends on the amount of pre-processing within the sensors. To avoid prohibitively high cabling costs, sensors must be energy-autonomous, and sensor data are transmitting using cellular communication. **Key requirements:** very low user data (UL), very high device density, very high power efficiency, moderate latency, high reliability and availability, low mobility, high isolation, coverage: critical. **Potential vertical industries:** Industry 4.0
Assets tracking and management	**Description**: this use case is based on the development of IoT-enabled solutions that can be used by companies to monitor and keep track of deliveries that are inside their facilities, or in transit from vendors or suppliers to their facilities. These solutions will solve one of the main concerns of today's manufacturing and shipping companies: lost, delayed or misplaced shipments, that dramatically increase manufacturing production times. They will also be very useful for health sector, allowing tagging and tracking of equipment and consumables in the operating theatres, the real-time tracking of value asset and geo-fencing, and the end-to-end monitoring and management of pharmaceuticals along the value and supply chain. **Key requirements:** low user data rate (UL&DL), high device density, high power efficiency, moderate latency, high reliability and availability, low-moderate mobility, coverage: important. **Potential vertical industries:** Industry 4.0, Transport & Logistics, Health

Use Case	Details
Warehousing	**Description**: Warehousing particularly refers to the storage of materials and goods, which is also getting more and more automated, for example based on conveyors, cranes and automated storage and retrieval systems. **Key requirements:** very low user data rate (UL&DL), high device density, high power efficiency, delay-tolerant, no-low mobility, coverage: important. **Potential vertical industries:** Industry 4.0
In-factory monitoring and maintenance	**Description**: this use case is about monitoring of certain processes and/or assets in the context of process automation, without any impact on the processes themselves. This is in contrast to a typical closed-loop control system in factory automation, for example. This particularly includes applications such as condition monitoring and predictive maintenance based on delay-tolerant sensor data, but also big data analytics for optimising future parameter sets of certain processes. **Key requirements:** low user data (UL&DL), high device density, very high power efficiency, moderate latency, high reliability and availability, low-moderate mobility, coverage: important. **Potential vertical industries:** Industry 4.0
Smart buildings	**Description**: this use case deals with the collection and analysis of energy use data to make smarter decisions that can help to reduce energy consumption in any building, including homes, hotels, and commercial offices. Sensing data can come from heating, cooling and lighting systems. For instance, instance, (several) lights could be remotely or locally turned on in a formation based on demand or on motion and estimated trajectory. Maintenance and diagnostics could also be facilitated by regular diagnostic reports (e.g., a few times a day) from light fixtures to a central server. **Key requirements:** very low user data rate (UL), very high device density, very high power efficiency, delay-tolerant, no mobility, coverage: important. **Potential vertical industries:** Smart cities
Environmental information	**Description**: this use case verses on the use of IoT to generate environmental information that can be analyzed by backend servers to detect in advance potential problems of users, that can be informed about areas that should be avoided. For this end, sensors deployed in a city collects information about different parameters (e.g. pollen, a pollution degree) and forwards them to cloud servers for their processing. After detecting high-levels of a given substance, and based on location of users, the proper users would receive an alarm in their devices. **Key requirements:** very low user data rate (UL), very high device density, very high power efficiency, delay-tolerant, no mobility, coverage: important. **Potential vertical industries:** Smart cities, Health

Use Case	Details
Traffic management	**Description**: it consists in monitoring vehicle and pedestrians, traffic lightning to optimize driving and walking roads. Connected sensors for traffic management can be localized in a wide variety of locations to collect a wide variety of data. In-vehicle sensors can monitor their speed and location. Sensors can also be placed on the street or into the road surface, counting the number and type of vehicles. **Key requirements:** low user data rate (UL&DL), high device density, moderate latency, high reliability and availability, no-low mobility (pedestrians) and moderate mobility (vehicles), high isolation, coverage: critical. **Potential vertical industries:** Smart cities, Automotive
Collaborative parking	**Description**: Parking sensors allow detecting on street parking occupancy as well as informing citizens of parking-slots availability. Analytics can be provided to the city, reducing time to search a place as well as pollution. Collected data facilitate the day-to-day monitoring and payment supervision and feed the city parking planning and strategy. **Key requirements:** very low user data rate (UL&DL), delay-tolerant, no-low mobility, coverage: important. **Potential vertical industries:** Smart cities
Smart water management	**Description**: smart water management is one of the main challenges that city authorities must face. Today, up to 50% of the water entering the system lost through facility infrastructure, and with millions of liters wasted in drinking fountains. Activities part of a smart water management include remote control of facility operations, efficient management of facility planning and operation, detection of leaks and incidents in the network, and control of water quality and consumption. For this end, remote reading systems using smart water meters must be deployed, sending collected data to a single management platform for their processing and analysis. **Key requirements:** very low user data rate (UL&DL), very high device density, very high power efficiency, delay-tolerant, no mobility, coverage: important. **Potential vertical industries:** Smart cities
Fleet management	**Description**: this use case is similar to asset tracking and management, but focused on vehicles, allowing a given company to find out where specific drivers are at, monitor the location of their vehicles, and get updates regarding shipment and delivery. **Key requirements:** low user data rate (UL&DL), high device density, high power efficiency, moderate latency, high reliability and availability, moderate-high mobility, coverage: important. **Potential vertical industries:** Transport & Logistics, Automotive
Good sensing	**Description**: perishable or sensitive goods sometimes require precise environmental conditions—for example, a specific temperature during transport—to maintain quality. This use case is about the usage of one or more tracking applications with environmental sensing capability to monitor the shipping conditions and alert the company of any changes to the shipping temperature. **Key requirements:** very low user data rate (UL), delay-tolerant, low-moderate mobility, coverage: important. **Potential vertical industries:** Transport & Logistics

Use Case	Details
Smart airport management	**Description**: in this use case, numerous sensors, big data collection, brokerage, processing and analytics are used to automate different aspects of the operation of a modern airport to improve efficiency while delivering improved customer experience at lower cost. For instance, passenger handling operations such as ticketing, check-in, baggage drop-off, transfer, etc. could all be automated. Additionally, exchange of information between the aircraft and the ground-based operational and maintenance teams could allow for maintenance issues to be handled as soon as the aircraft lands. **Key requirements:** very low user data rate (UL&DL), very high device density, very high power efficiency, delay-tolerant, high reliability and availability, no mobility, coverage: important (for passenger communication) and critical (for aircraft communication). **Potential vertical industries:** Transport & Logistics
Smart sea port pollution control	**Description**: this use case leverages the deployment of mobile sensors on barges for emissions measurement. These sensors provide real-time data on the current air quality in the port area, by sending data streams to a cloud server from which they can be analysed in order to make, if needed, corrective actions (e.g. triggers a new anti-pollution plan). **Key requirements:** very low user data rate (UL), very high device density, very high power efficiency, delay-tolerant, no mobility, coverage: important. **Potential vertical industries:** Transport & Logistics
Smart travel	**Description**: this use case allows the optimization of the flow of commuters and the improvement of the commuting experience by individualized information availability. By aggregating and processing information from various sources (e.g., sensor/ smartphone data from many commuters) proper estimates of travel time, congestion at different facilities, etc. that take into account historical and prevailing real-time conditions could be obtained. This optimization can also be used by airports and other transport hubs to better plan and optimize aspects such as layout and siting of facilities (e.g., shops, bathrooms). **Key requirements:** very low user data rate (UL), very high device density, very high power efficiency, delay-tolerant, no mobility, coverage: important. **Potential vertical industries:** Transport & Logistics

Table B-4: Examples of use cases that can be deployed and tested in customised network slices provided by a 5G-VINNI CSP

Use Case	Details
Automated farm machinery	**Description**: this use case is based on the cooperation of driverless tractors, harvesting machines, and crop loaders to do farming activities such as drilling, seeding and spraying in an agile and optimized manner. With this approach, farm machinery can autonomously drive through farms under close coordination, alleviating the need for a human driver and optimizing trajectories through vast crop fields. The type of communication involves both device-to-device communication, when different machines in the farm communicate with each other to send information, and device-to-network communication, when the data is uploaded to the cloud. **Service types involved:** uRLLC (real-time communication between vehicles and with the network), mIoT (uploading of collected data to a backend server for their processing). **Key requirements:** very low user data rate (UL), very high device density (multiple sensors embedded in farm machinery), very low latency (for communications between vehicles and with the network), very low packet size payloads, very high reliability and availability, low-moderate mobility, coverage support: important. **Potential vertical industries:** Agriculture & Farming.
Intersection collision avoidance	**Description**: the purpose of an intersection collision avoidance system is to alert drivers about the existence of unexpected (or unseen) vehicles or other obstacles (e.g. urban furniture or pedestrian) and eventually activate the emergency braking system. For this end, this use case must allow real-time exchange of data between the involved entities, so the system can activate the brake on time, avoiding the collision or run-over. **Service types involved:** uRLLC with very high mobility support: uRLLC+. **Key requirements:** low user data rate (UL&DL), very low latency, very low packet loss rate, very high reliability and availability, very high mobility, high isolation, cm-level positioning accuracy, coverage support: critical. **Potential vertical industries:** Automotive, Smart cities.
High density platooning	**Description**: this use case is about the creation of closely spaced multiple-vehicle chains on a highway for multiple purposes (e.g. fuel saving, accident prevention, etc.). This requires cooperation among participating vehicles in order to form and maintain the platoon in the face of dynamic road situation, with distances between vehicles reaching down to 1 meter. To keep them in the platoon with such short distances, the vehicles need to constantly exchange their kinematic state information in real-time, so they can implement throttle and brake controls while keeping the distance constant. **Service types involved:** uRLLC with very high mobility support: uRLLC+. **Key requirements:** low user data rate (UL), very low latency, very low packet loss rate, very high reliability and availability, very high mobility, high isolation, cm-level positioning accuracy, coverage support: critical. **Potential vertical industries:** Automotive.

Use Case	Details
Cooperative collision avoidance	**Description**: this use cases highlights the communication challenges faced by self-driving vehicles when trying to prevent collisions (e.g., at intersections in an urban environment) after all other traffic control mechanisms have failed. Collisions between two or more vehicles are prevented by controlling the longitudinal velocity and displacement of each vehicle along its path without creating hazardous driving conditions for other vehicles that are not directly involved. In such a complex and dynamic environment, upon identification of a collision risk, vehicles cannot decide individually and apply the appropriate action without prior coordination. Hence, all involved vehicles should undertake to compute the optimal collision avoidance actions and apply them in a cooperative manner. **Service types involved:** low user data rate (DL&UL), very low latency, very low packet loss rate, very high reliability and availability, very high mobility, high isolation, cm-level positioning accuracy, coverage support: critical. **Key requirements:** low latency, high reliability, high node speed. **Potential vertical industries:** Automotive
Dynamic reserved lane management	**Description**: this use case aims at facilitating mobility of public safety and emergency vehicles (or any other public transportation), by allowing them to circulate in reserved lane. By way of example, when an ambulance is approaching, the rest of vehicles ahead in the same lane would receive a warning message, urging them to clear the line as soon as possible. For this end, connectivity between vehicles, e.g. vehicle-to-vehicle (V2V) communication, and surrounding infrastructure, e.g. vehicle-to-network (V2I) communication, is required. **Service types involved:** uRLLC with very high mobility support: uRLLC+. **Key requirements:** low user data rate (DL&UL), very low latency, very low packet loss rate, very high reliability and availability, very high mobility, high isolation, coverage support: critical. **Potential vertical industries:** Automotive, Public Safety and divide resorption, Health
Lane merge coordination	**Description**: the lane merge coordination demonstration shows a cooperative maneuver for optimizing the process of entering a motorway, for a mixture of vehicles that can and cannot communicate. This is enabled by having a camera system with object recognition capabilities monitoring the lane merge area. Furthermore, the vehicles send information about themselves to a central coordination entity, which first combines this information with the camera output, and then devises a maneuver in real time. Corresponding driving instructions are subsequently communicated to the affected vehicles. **Service types involved:** eMBB (support of high data rates for sending high-quality images), uRLLC (V2V connectivity). **Key requirements:** high/moderate user data rate (DL/UL), very high/high area traffic density (DL/UL), very low latency, very high reliability and availability, moderate device density, high mobility, coverage support: critical. **Potential vertical industries:** Automotive

Use Case	Details
See through for safe driving	**Description**: with the exchange of information among vehicles, it is possible to see through an obstacle. Streaming information should be provided to all the vehicles that want to access to it. This information can be used to identify eventual obstacles that cannot be detected though on-board sensors. **Service types involved:** eMBB (support of high data rates for video streaming), uRLLC (V2V connectivity). **Key requirements:** moderate/high user data rate (DL/UL), high/very high capacity (DL/UL), very low latency, very high reliability and availability, moderate device density, very high mobility, coverage support: critical. **Potential vertical industries:** Automotive
Tele-operated driving	**Description**: tele-operated driving enables operation of a vehicle by a remote driver. This covers both full remote driving as well as limited impasse arbitration cases for autonomous vehicles. Areas where full remote driving could find applications include disaster scenes, unknown/ unexpected terrains and environments where lives could otherwise be put in danger by manual driving, for instance mining, construction, and nuclear plants. **Service types involved:** eMBB (streaming of multiple video feeds with mobility support), uRLLC (zero-ms latency and high reliability in connectivity between remote driver and the vehicle). **Key requirements:** high/low user data rate (DL/UL), very high/moderate area traffic density (DL/UL), very low latency, very high reliability and availability, very low device density, very high mobility, high isolation, cm-level positioning accuracy, coverage support: critical. **Potential vertical industries:** Automotive
Bird's eye view	**Description**: this use case considers a scenario where there is an intersection equipped with cameras and radars that can provide streaming information to approaching vehicles, including video streams and statistics information. The vehicles use this data stream in conjunction with other similar data streams provided by vehicles equipped also with camera and radar sensors, and identify eventual pedestrians or free places, which they could not detect with their on-board sensors, so that they can better plan their future trajectories. The data streams have to be provided with very low latencies in order to allow vehicles to use the data streams similarly to the data streams provided by on-board cameras and radars. **Service types involved:** eMBB (data streaming), uRLLC (V2V connectivity). **Key requirements:** high user data rate (DL&UL), high area traffic density (DL&UL), very low latency, very high reliability and availability, high mobility, high isolation, cm-level positioning accuracy, coverage support: critical. **Potential vertical industries:** Automotive

Use Case	Details
Security and surveillance	**Description**: in this use case, smart video surveillance systems are used to monitor and control different parts of the city, and even to detect dangerous or illegal behaviors (e.g. street fights, thefts). These systems use high-resolution cameras upstreaming real-time video to central servers connected to police dependencies. These cameras are able to perform automatic analysis of video streams, so to relieve the burden of security personnel that cannot effectively monitor a large number of cameras distributed over the city. **Service types involved:** eMBB (uploading video streams), uRLLC (real-time video for prompt alerts and very high reliability) **Key requirements:** very high user data rate (UL), very high area traffic density (UL), very low latency, very high reliability and availability, no mobility, very high isolation, coverage support: critical. **Potential vertical industries:** Smart Cities
Primary frequency control in electric-power distribution	**Description**: the primary frequency control system is responsible for controlling the energy supply injected and withheld to ensure that the frequency is not deviating more than 0,02 % from the nominal value (e.g., 50 Hz in Europe). Frequency control is based on having sensors for measuring the features in all parts of the network at all points where energy generation or storage units are connected to the grid. At these points, electronic power converters, also known as inverters, are equipped with communication units to send measurement values to other points in the grid such as a frequency control unit, or receive control commands to inject more, or less, energy into the local network. This use case foresees a scenario where frequency control shall be supported in the upcoming energy distribution networks, where there will be a widespread deployment of local generation units (e.g. solar power units, or wind turbines, hundreds of thousands of such units, and their inverter) that may have to be connected in a larger power distribution network. **Service types involved:** uRLLC (very low latency values for real-time reaction and very high reliability to avoid service disruption), mIoT (increasing connection density) **Key requirements:** very low user data rate (UL), very high device density, very low latency, low message size payload, no mobility, very high isolation, coverage support: critical. **Potential vertical industries:** Energy

Use Case	Details
Distributed voltage control in electric-power distribution	**Description**: the objective of voltage control is to balance the voltage in future low voltage distribution grids connecting local loads and prosumers, as well as energy storage facilities. The aim is to stabilise the voltage as locally as possible, so that decisions and control commands can be issued as quickly as possible. Distributed voltage control is a challenging and demanding control application, as consumer devices rely on having stable voltage levels to operate successfully. When future energy networks rely on thousands of local energy generation units relying mostly on solar and wind power, then it is crucial to stabilise the voltage levels in all segments of the distribution grid. **Service types involved:** uRLLC (very high reliability to avoid service disruption), mIoT (increasing connection density) **Key requirements:** very low user data rate (UL), very high device density, low message size payload, no mobility, very low loss packet loss rate, very high reliability and availability, very high isolation, coverage support: important. **Service types involved:** uRLLC, mIoT **Potential vertical industries:** Energy
Remote surgery	**Description**: allows a surgeon to remotely operate a surgical robot to perform surgery on a patient. This use case involves the provisioning of the communication link to allow video and audio feeds as well as data to be reliably transferred in real-time between the surgeon and the remote surgical robot. **Service types involved:** eMBB (generation of bandwidth-hungry video streams), uRLLC (provisioning of ultra-high reliable connectivity with zero-jitter latency) **Key requirements:** very high user data rate (UL), very low latency, very low loss packet loss rate, very high reliability and availability, no mobility, very high isolation, coverage support: critical. **Potential vertical industries:** Health
Public Warning Systems (PWS)	**Description**: this use case aims at showcasing the utility of multimedia in public warning alert. Currently, public warning messages mainly contain short text messages. The cellular devices have developed rapidly and more informative warning messages containing for example images, maps and video could be delivered. The messages are to be delivered rapidly only in the area affected by the hazard. This imposes severe amount of data that the network should deliver to many devices simultaneously. **Service types involved:** eMBB (generation of bandwidth-hungry data to multiple devices), uRLLC (extremely high reliability), mIoT (high connection density) **Key requirements:** high user data rate (UL), very high area traffic density (UL), very high device density, very low loss packet loss rate, very high reliability and availability, no-low mobility, very high isolation, coverage support: critical. **Potential vertical industries:** Public Safety and divide resorption

Use Case	Details
Smart street lighting	**Description**: for the case of street lighting, the energy and maintenance savings resulting from an efficient management of lighting poles may not be enough to pay for the connected lighting infrastructure at today's cost, necessitating the need to bundle additional services. Service bundling is particularly appealing to lighting suppliers since the expected longevity of LEDs impacts potential revenues from regular light replacement. Hence, the connected light infrastructure could also find applications in reporting (e.g., traffic information), coordination (e.g., disaster relief), as sites for small cells or as roadside units for V2X services. **Service types involved:** eMBB (use of small cells to provide broadband services), uRLLC (exchange of latency-sensitive information for disaster relief), mIoT (for reporting). **Key requirements:** high user data rate (DL, for broadband; UL, for reporting), high area traffic density (DL, for broadband; UL, for reporting), very high connection density (for reporting), low latency (for disaster relief), very high reliability and availability (for broadband and disaster relief), very high isolation, coverage support: critical. **Potential vertical industries:** Smart cities

Annex C VINNI-SB Modelling

This deliverable has presented the concept of VINNI-SB as key asset to order, deploy and operate network slice services in 5G-VINNI facility. VINNI-SB concept allows CSCS to first provide self-contained network slice service specifications on service orders, and then manage their lifecycle with great agility and in a zero-touch manner. Chapter 4 and 5 have provided a detailed view of the different VINNI-SBs published in 5G-VINNI service catalogue. For each VINNI-SB, the following information has been specified:

- Service type
- Service topology: participant SCs and information on their connectivity (i.e. virtual links, connection points and service access points)
- Service (performance, functionality and network optimisation) parameters: measurement units/selectable options for each parameter, and conditional relationships between them.
- Service exposure, based on a four level-based classification; and monitoring and testing parameters: measurement units/selectable options for each parameter, and conditional relationships between them.

Additionally, some dependencies among parameters of different groups have been presented.

With the above information, we have a conceptual, reference model of how the different VINNI-SBs should look like. With all this information, 5G-VINNI consortium is ready for the start of the next phase: VINNI-SB implementation. For this end, the selection and development of models for VINNI-SB is required.

The aim of this Annex is to providing an overview of pre-existing work on service modelling. This overview identifies existing types of models, their principles and current solutions. This information could be used as starting point for the development activities that need to be undertaken in WP3 with respect to VINNI-SB implementation.

C.1 Principles on service modelling

Service modelling is a prime step towards the achievement of model-driven service management. Model-driven service management is a powerful approach whereby functional blocks taking part in a management system execute their actions (e.g. on-boarding, instantiation, scaling, termination, etc.) over managed services based on the information specified in a given model. In current information technology and networking environments, two types of models can be found, each serving a different purpose:

- Information model
- Data model

There are several ways of describing each of the model and their differences, though one of the primary input, and which gets most of industry consensus, is IETF RFC 3444 [65]. This document makes clarifications around information and data models, including their definition, their differences, and their applicability in different network management model specifications. On the table below, one can find characteristics of the two types of models.

Table C-1: Principles that lay behind information and data modelling

Aspect	Information Model	Data Model
Scope	Provides a conceptual, abstract model for designers and operators. It hides all implementation details	Provides a concrete, detailed model for implementors. It focuses on implementation-specific details
	Protocol-agnostic	Protocol-specific

Aspect	Information Model	Data Model
Content	Includes information of the components of the managed service: their relationships, dependencies, requirements and capabilities.	Includes information on how to map a managed service onto lower-level protocol constructs: data structure, operations, and integrity rules.
Mutual implications	An information model defines the functionality boundaries of a data model.	A data model is the rendering of an information model.

As seen from the above description, information and data models are linked in such a way that the best way to describe is to create an analogy about the *theory behind the experiment*, with information and data models standing for theory and experiments, respectively.

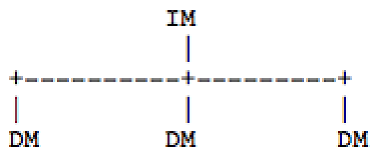

Figure C.1: Information and Data Models (source: [65]).

The relationship between an information and data model is shown in Figure C.1. Since conceptual models can be implemented in different ways, multiple data models can be derived from a single information model.

C.2 Information Modelling

The main purpose of an information model is to provide a high-level description of the managed object, including information (at a conceptual level) on service components and their dependencies, relationships, requirements and capabilities. Any information model shall satisfy a minimum set of requirements; indeed, it shall be:

- Standard
- Modular
- Extensible
- Protocol-/implementation-agnostic.

Information models are primarily useful for designers to describe to describe the managed environment, for operators to understand the modelled services, and for implementors as a guide to the functionality that must be coded in the data models [65].

There are different types of description languages that can be used for developing an information model. This includes natural languages (e.g. human language) and formal languages, such as Unified Modelling Language (UML). The use of UML diagrams has rapidly become a usual practice for the elaboration of information models, due to the language simplicity (i.e. UML diagram is a visual representation), readability, and reusability. Some examples of description languages used by SDOs and industry alliances to elaborate their information model can be seen in the table below.

Table C-2: Examples of information model description languages

SDO / Alliance	Description Language	Examples of information models relevant for 5G-VINNI
3GPP	Formal Language: UML	5G Network Resource Model [66]

SDO / Alliance	Description Language	Examples of information models relevant for 5G-VINNI
IETF	Formal Language: English	Abstraction and Control of Traffing Engineered Networks (ACTN) [67]
NGMN	Natural Language: English	5G Network Slicing Concept [30]
ETSI (NFV)	Formal Language: UML	NFV Info Model [68][69][70], NSD [15], VNF Package [16]
ONF	Formal Language: UML	Core Information Model [71]

From available languages, it seems reasonable to use UML diagrams for VINNI-SB information model.

C.3 Data Modelling

Once VINNI-SB information model is elaborated according to selected description language, the next step is to develop a corresponding data model. Unlike an information model, a data model provides coding details, specifying the data structure used for information model's content representation, and the protocol used for data transport.

Similar to an information model, data model also requires the selection of a description language. Although a wide variety of data modelling languages can be found in the industry today, two of them are mostly used in the context of network softwarisation: Topology and Orchestration Specification for Cloud Applications (TOSCA) [72] and Yet Another Next Generation (YANG) [73]. Since 5G-VINNI main facility sites will make use of on TOSCA (Norway and UK) and YANG (Spain and Greece) in their management and orchestration solutions, these two description languages are very good candidate description languages for service specification data modelling. An overview of the two languages is provided in Table C-3 and a comparative analysis of their features is shown in Table C-4.

Table C-3: Overview on TOSCA and YANG data modelling languages

Area		TOSCA	YANG
Organisation		OASIS	IETF
Roots		IT, Cloud Applications	Networking
Scope		*Orchestration* of applications (and their dependent artifacts) in cloud servers.	*Configuration* of running network devices and applications.
Focus		What needs to be done to make cloud applications operationally ready and keep them running appropriately?	What can be configured in a running deployment?
Operations		Defined in TOSCA Simple Profile: Install, Start, Configure, Scale, Heal, Upgrade, Stop, Uninstall	Defined in YANG Schema: configuration operations starting after Start and ending before Stop
Schemas	Components	Constructs: nodes, relationships, topologies	Statements: container, leaf, list
	Extensions	Derived From	Augment

On the one hand, TOSCA is a data modelling language used to describe the topology of cloud-based services, their components, their relationships/dependencies and their management procedures in a uniform and vendor-independent manner. These components of a web service are virtual applications deployed in virtualized environments. Developed by the Organization for the Advancement of Structured Information Standards (OASIS), the TOSCA standard includes specifications to describe processes aiming at orchestrating cloud-based services throughout their lifecycle (from their instantiation to their termination), with a special focus on their virtual compute requirements rather than network functionalities. This makes TOSCA very appropriate language for web services, but not for network services. To overcome this issue, the TOSCA community created the TOSCA NFV simple profile [74] to adapt the features of TOSCA language for those scenarios where NFV comes into play. The TOSCA NFV profile specifies an NFV specific data model using TOSCA language and following the standardised fields required by the information model of ETSI NFV. The mapping between TOSCA and ETSI NFV is shown in Figure . Figure shows an example of how TOSCA NFV simple profile can be used to model a network service (TOSCA NFV simple profile's view on a web service) and a VNF (TOSCA NFV simple profile's view on a cloud application).

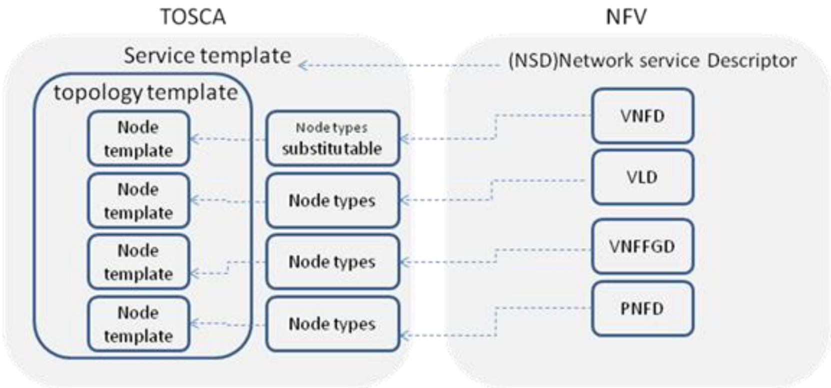

Figure C.2: TOSCA to NFV relationship

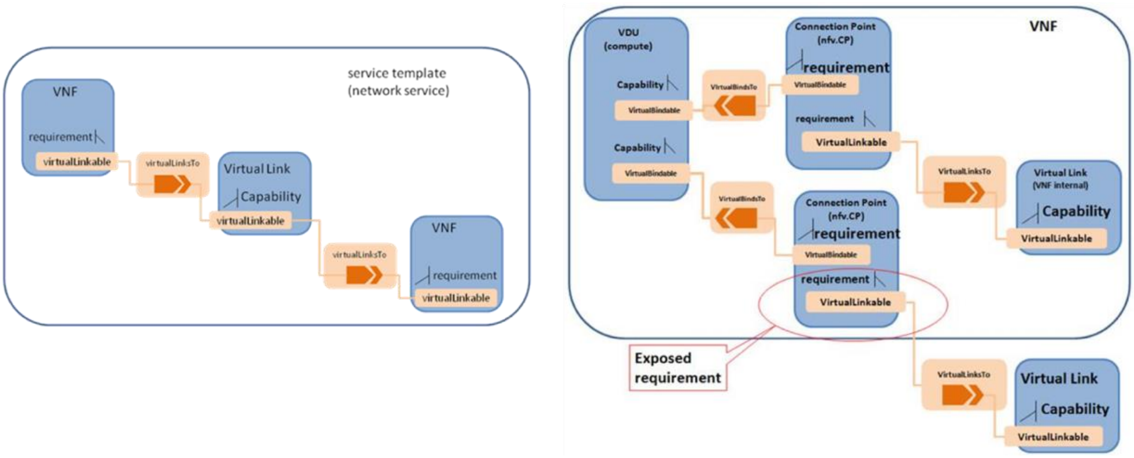

Figure C.3: Use of TOSCA for NSDs and VNFDs.

On the other hand, YANG is an data modelling language for NETCONF protocol used for describing network devices, specifically configuration and state information, in a highly readable and vendor-agnostic manner. Developed by IETF, the YANG language allows data modellers to define the syntax and semantics of device configurations when carried over NETCONF protocol, and supports translations to several schema languages (e.g. XML, JSON, YAML). This allows signification simplification to handle configuration management procedures in network devices. A good overview on YANG language can be found in [75]. While it was originally designed for configuration of appliances, YANG can also be used in NFV environments, particularly for PNF management and VNF/NFV-NS application layer configuration management activities. For example, a networking device such as firewall (that can run as VNF / PNF in NFV environments) can be modelled in YANG, and then configured via the NETCONF protocol. The configuration is plain text and human readable, portable across devices, and easily comparable to other configurations.

Table C-4: Feature comparison between TOSCA and YANG

Feature	TOSCA	YANG
Orchestration	Defined in standard	Custom in orchestrator
Language	Rudimentary	Complete, extensible
Protocols	REST APIs	NETCONF (also RESTCONF)
Syntax	YAML	XML, JSON, YAML
Extensibility	Weak	Good
Composability/Modularity	Good	Weak
Models	TOSCA model (default) and TOSCA NFV Single Profile (for NFV deployments)	Numerous models: IETF models, MEF models, and vendor-specific models
Strengths	• Installation and deployment of distributed cloud applications • Installation and deployment of infrastructure service, e.g. compute, network and storage components • Monitoring on cloud components • Ability to take proactive actions like self-healing and auto-scaling, failover and other remediations • Multi-cloud support	• Configuration of network devices (and services) in a human readable fashion • Portability and reproducibility of configurations across different devices • Ability to separate between configuration and operational data • Support of versioning control • Ability to compare configurations across devices.

Although TOSCA and YANG have different scopes (orchestration vs configuration), they share some similarities in their mechanism to define data models. For this reason, both TOSCA and YANG are used today in the industry for management and orchestration activities in network softwarisation environments, but without any convergence between them. This problem is easy to recognise in NFV orchestration, where there is no generally data model specification based either on TOSCA, YANG (or mix of both) to specify the information models for ETSI NFV descriptors [15][16]. To overcome this issue, SOL working group within ETSI NFV is developing two separation specifications for these descriptors: SOL001 [76] using TOSCA language, and SOL006 [77],based on YANG.

Due to the disjoint use of TOSCA and YANG languages that exist nowadays, current research efforts are going towards the development of a parent data model where both languages are supported, and can coexist. Taking into account the scope of both languages as summarized in Table C-3, their coexistence in 5G-VINNI could be as shown in Figure C.4 with TOSCA focusing on NFV orchestration activities and YANG on application-aware configuration and management activities in the different network domains.

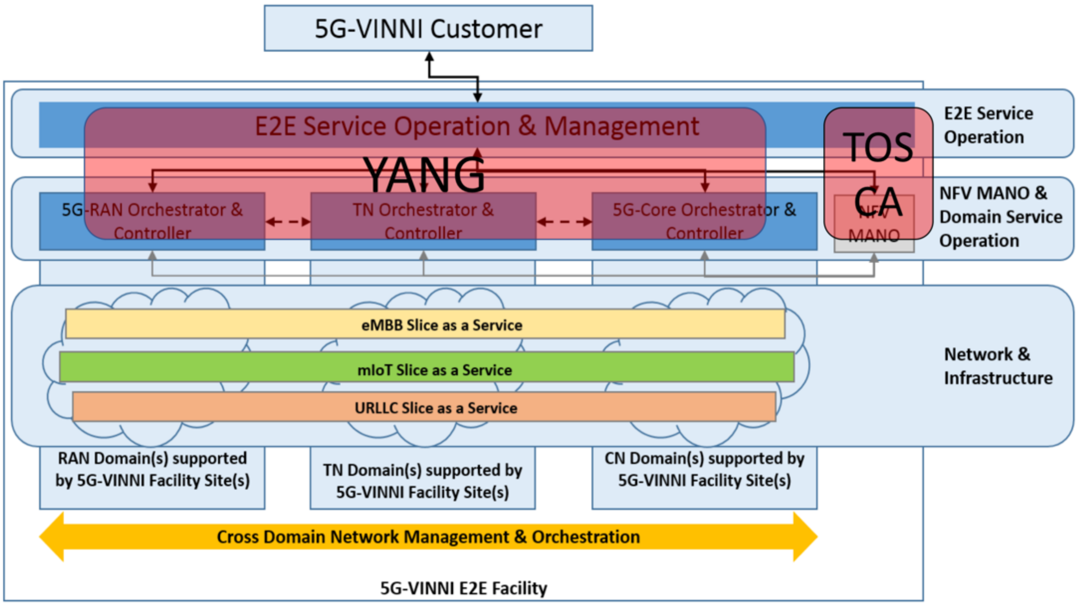

Figure C.4: Tentative applicability of TOSCA and YANG in 5G-VINNI system architecture

Pending the arrival of a converged data model language, each 5G-VINNI facility site shall decide between one or another language for VINNI-SB specification. At the time of writing, this decision has not been taken yet. Although the selection of TOSCA or YANG can be subjected to the assessment of features between the two languages (see Table C-4), the factor that can most strongly condition this decision is the language used for the management and orchestration solutions the facility will use. In this aspect, Norway and UK sites (using Nokia's OneFlow/CloudBand solution) will likely rely on TOSCA, while Spain and Greece (using OSM solution) will likely rely on YANG.

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