Deliverable D2.1

5G-VINNI Solution Facility-sites High Level Design (HLD)

Editor:	Jan Pitter, Ericsson
Deliverable nature:	Report (R)
Dissemination level: (Confidentiality)	Public (PU)
Contractual delivery date:	28th February 2019 (M8)
Actual delivery date:	31th March 2019
Suggested readers:	ICT-19 projects, industry verticals
Version:	1.0
Total number of pages:	104
Keywords:	5G, NFV, VNF, NFVI, MANO, Service Orchestration, 5G RAN, Transport, 5G Core, Solution Design, High Level Design

Abstract

Description of network services for each Facility-site. Includes configuration of Infrastructure, RAN, Core and MANO components and of the interconnections among them. Used as a reference for the orchestration and testing activities. Description of the cross Facility-site services and interconnection requirements and configurations.

[End of abstract]

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 815279.

Impressum

Full project title	5G Verticals Innovation Infrastructure
Project acronym	5G-VINNI
Number and title of work-package	WP2; 5G-VINNI End-to-End Facility Implementation and Infrastructure Integration
Number and title of task(s)	T2.1 Mapping of the Reference Architecture to Facility-sites
Document title	5G-VINNI Solution Facility-sites High Level Design (HLD) - v1
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Executive summary

We are planning to build eight facility sites in the 5G-VINNI end-to-end facility allowing the on-boarding and validation of a wide range of industry use cases and KPIs. The four main facility sites are expected to be interworking. For each facility site, the requirements and reference architectures defined needs to be translated into solution design for the implementation of each specific facility site.

This will involve all the affected 5G domains (Radio, Core, NFVI, MANO, Transmission), the software components for service orchestration and the interfaces for interworking between facility sites.

Each facility site will make its own implementation of Core Network functions according to the reference architecture. The 5G RAN implementation will be aligned with the 3GPP standards to secure that the facility offers a standardized solution supported by developers and end-users of the 5G eco-system. Existing transport network is expected to be reused by most Facility sites.

This document describes the network services and the solution design for the service orchestration and the network domains including RAN, Core, MANO and Transport components for each of the facility sites in addition to interconnections among facility sites. This report shall be used as a reference for the orchestration and testing activities.

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Abbreviations

5G	Fifth Generation (mobile/cellular networks)
5G-VINNI	5G Verticals INNovation Infrastructure
AMF	Access and Mobility Management Function
AUSF	Authentication Server Function
CBND	CloudBand Network Director
CFI	Customer Furnished Item
COTM	Communications-On-The-Move
COTP	Communications-On-The-Pause
CPRI	Common Public Radio Interface
CSR	Cell Site Router
DC-GW	Data Center Gateway
DECOR	Dedicated Core Network (DCN)
E2E	End to End
eMBB	enhanced Mobile Broadband
EMS	Element Management System
eNB, eNodeB	evolved NodeB
ETSI	European Telecommunications Standards Institute
FWA	Fixed Wireless Access
gNB	gNodeB (g=Next Generation)
GPRS	General Packet Radio Service
GPS	Global Positioning System
GRNET	Greek Research and Technology Network
gUE	g User Equipment (g=Next Generation)
GW	Gateway
HAPS	High Altitude Platform Station
HLD	High Level Design

HSS	Home Subscriber Server
ICT	Information and Communication Technologies
IP	Internet Protocol
LLD	Low Level Design
MAC	Media Access Control
MANO	Management and Orchestration
MEC	Multi-access Edge Computing (or else Mobile Edge Computing)
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
mMTC	Massive Machine Type Communications
MNO	Mobile Network Operator
MPLS	Multiprotocol Label Switching
N3IWF	Non-3GPP Interworking Function
NEF	Network Exposure Function
NFV	Network Functions Virtualization
NFVI	Network Functions Virtualization Infrastructure
NKOM	Norwegian spectrum authority
NOC	Network Operation Centre
NR	New Radio
NRF	Network Repository Function
NSA	Non-Standalone
NSMF	Network Slice Management Functions
NSSF	Network Slice Selection Function
NTN	Non-Terrestrial Network
OS	Operating System
OSS	Operation Support Subsystem
PCF	Policy Control Function

PCRF	Policy and Charging Rules Function
PDCP	Packet Data Convergence Protocol
PDN	Packet Data Network
PEP	Performance-Enhancing Proxy
PPDR	Public Protection and Disaster Relief
RAN	Radio Access Network
Rel-0	Release 0
Rel-1	Release 1
RFS	Resource Facing Services
RLC	Radio Link Control
RRC	Radio Resource Control
RRV	Rapid Response Vehicle
SA	Standalone
SDN	Software Defined Networking
SDS	Software Defined Storage
SD-WAN	Software Defined - Wide Area Network
SGSN	Serving GPRS Support Node
SGW/PGW	Serving Gateway / PDN Gateway
SMF	Session Management Function
SNO	Satellite Network Operator
SOM	Service Order Management
TCP	Transmission Control Protocol
TDD	Time Division Duplex
UDM	Unified Data Management
UDR	User Data Repository
UPF	User Plane Function
UTLLC	Ultra-Reliable Low-Latency Communication

VIM	Virtualized Infrastructure Manager
VM	Virtual Machine
VNF	Virtual Network Function
VNFM	Virtual Network Function Manager
VSAT	Very Small Aperture Terminal

1 Introduction

This document together with Annexes provides description of High-Level Design of Infrastructure, RAN, Core, NFVI, MANO and Service Orchestration components and of the interconnections among them. Includes network services for each Facility-site. Used as a reference for the orchestration and testing activities. Description of the cross Facility-site services and interconnection requirements.

Deliverable D2.1 is structured as a main document (this document) with several Annexes. The main document gives an overview of the Solution deployed at each Facility-site and the documents under Annex A focuses on deeper technical details.

The document is structured as follows:

- Chapter 2 - gives an overview of the functional requirements that Facility-sites plan to deliver individually. These are aggregated lists of services and capabilities, which needs to be reflected in the high-level design of each Facility-site.
- Chapter 3 - captures the translation of the architectures principles and recommendations defined in D1.1 [1] to higher level design documentation for the implementation of each Facility-sites.
- Chapter 4 contains the Top-level architectures of 5G-VINNI Facility. Each Facility-site has dedicated one subsection describing main aspects of all domains. These being 5G RAN and Core, MANO and NFVI, Service Orchestration, Edge Site and Security.
- Chapter 5 - describes Facility-sites ambitions and future plans in terms of interconnection and interworking among Facility-sites and their involvement in Management and Orchestration of cross-domain services.
- Chapter 6 - provides an overview of how the unified interfaces are implemented on Facility-site.

This document covers Release 0 and Release 1 scopes provided as a guidance for end-to-end (E2E) architecture. Their definition is as follows:

- Release 0 (Rel-0) of E2E Facility (M12=June 2019) For 5G-VINNI project internal validation of KPIs and specific use cases for E2E Facility validation. Facility will consist of Non-StandAlone (NSA) 5G New Radio (NR) and 5G Core. Virtualization infrastructure, NFV Orchestration and Service Orchestration will be implemented. E2E slicing is implemented supporting basic life-cycle events.

  Note: Rel-0 is for 5G-VINNI internal and test purposes, not relevant for ICT-19.

- Release 1 (Rel-1) of E2E Facility (M18=December 2019) Ready for use by ICT-18-19-22 projects and other external use cases. The main Facility-sites (Norway, UK, Spain and Greece) will be 3GPP Rel-15 compliant. At minimum one of the Facility-sites will include Stand Alone (SA) 5G NR and 5G Core. E2E slicing is implemented supporting all planned life-cycle events. Service orchestration across two interconnected main Facility-sites.

Further Releases scope is covered in document “D2.5 5G-VINNI Solution facilities High Level Design (HLD) - v2” which is updated version (version 2) of this (D2.1) document.

1.1 5G-VINNI Facility

A 5G-VINNI Facility is the deployment of the 5G-VINNI architecture in one administrative domain (e.g. one operator). The 5G-VINNI Facility-sites are classified into two different types:

- *Main Facility-sites*: E2E 5G-VINNI Facility that offers services to ICT-18-19-22 projects with well-defined Service Level Agreements.
- *Experimentation Facility-sites:* 5G-VINNI sites that provide environments for advanced focused experimentation and testing possibilities on elements and combinations of elements of the E2E model.

The 5G-VINNI Facility-sites are illustrated in Figure 1 with the Main Facility-sites (**Norway, UK, Spain, Greece**) and the Experimentation Facility-sites (**Portugal, Germany/Munich, Germany/Berlin, Luxembourg**).

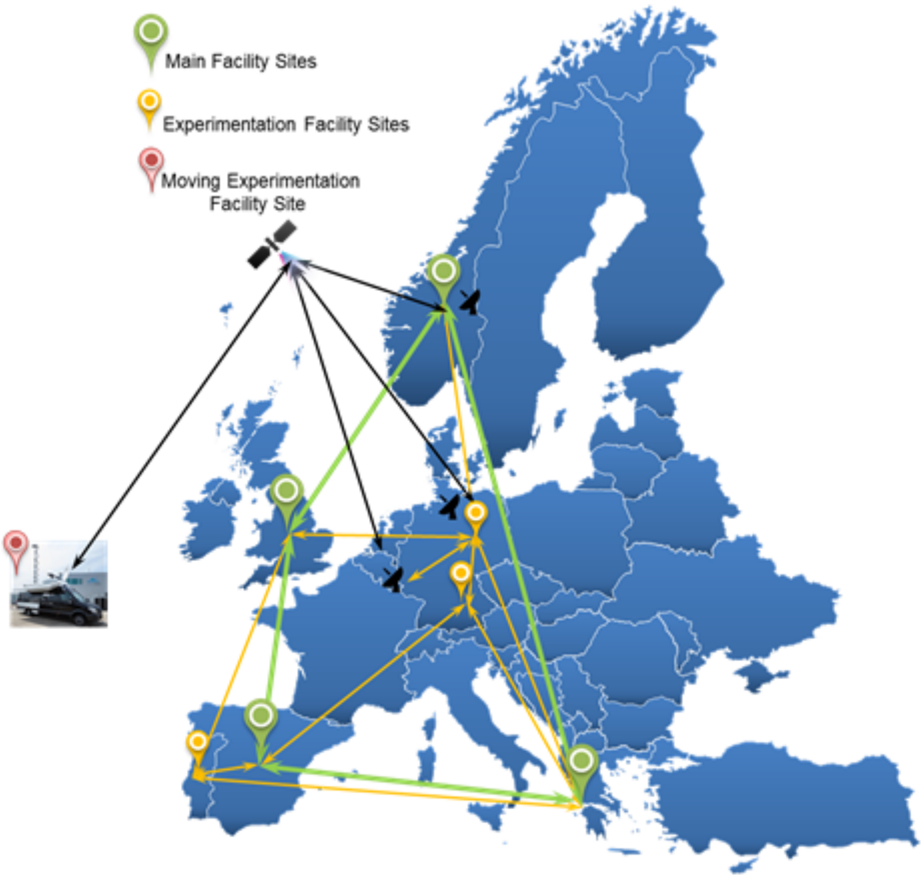

Figure 1: 5G-VINNI Facility

1.2 Facility-sites Actors

5G Network infrastructure for different Facility-sites is provided by different vendors. Table below includes supplies of individual 5G-VINNI Facility-sites.

Table 1: Facility-site actors

Facility-site	***Norway***	***UK***	***Spain***	***Greece***	***Portugal***	***Germany (Berlin)***	***Germany (Munich)***	***Luxemburg***
Operational partner	Telenor	BT	TID	University of Patras	Altice Labs	Fraunhofer FOKUS	Huawei Technologies Dusseldorf GmbH	SES
5G RAN Vendor(s)	Ericsson, Huawei	Samsung	Ericsson, Limemicro, SRS, OAI	Limemicro, SRS	OpenAirInterface Software Alliance	Under NDA	Huawei	N/A
5G EPC/5G Core Vendor(s)	Ericsson	Samsung	Ericsson, OAI, Fraunhofer FOKUS (under consideration)	Fraunhofer FOKUS	Fraunhofer FOKUS	Fraunhofer FOKUS	No EPC, Huawei 5G NFs	Fraunhofer FOKUS
NFVI	Nokia	Samsung	OpenStack	OpenStack	OpenStack	OpenStack	Huawei	Open-Source (OpenStack based)
MANO	Nokia	Samsung	OSM	OSM	SONATA	Open Baton - Fraunhofer FOKUS	Huawei	Open Baton - Fraunhofer FOKUS
Service Orchestration	Nokia	Nokia	5GinFIRE portal	5GinFIRE portal	ONAP	Fraunhofer FOKUS	Huawei	Fraunhofer FOKUS
Transport Network	Telenor	BT	TID (optical mesh)	N/A	N/A	N/A	N/A	SES, VT iDirect

2 Facility-sites Deliverables

2.1 Technical Services provided by 5G-VINNI Facility

In this section, we present the technical services offered by 5G-VINNI where by the *technical services* refer to the *resource facing services* (RFS) offered by 5G-VINNI Facility. Customer facing services are not listed on purpose because they will be agreed and evolved according to the requirements of the verticals/ICT-19 projects. To exemplify, mobile-broad-band-on-demand can be considered as a customer facing service which is composed of eMBB slice which is an RFS. The eMBB slice RFS in turn provides flexible backhaul RFS, autonomous edge RFS leveraging the resources in the access network, transport network and core network.

Table 2: List of technical services from 5G-VINNI which can be exposed to ICT-19 or verticals

No.	***Technical Services offered in Release 1 or beyond Release 1***	***Norway***	***UK***	***Spain***	***Greece***	***Portugal***	***Germany (Berlin)***	***Germany (Munich)***	***Luxemburg***
1	eMBB slice	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, beyond Rel-1	YES, in Rel-1
2	URLLC slice	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, beyond Rel-1	YES, in Rel-1	YES, in Rel-1	NO
3	mMTC slice	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, beyond Rel-1	YES, in Rel-1	NO	YES, in Rel-1
4	Autonomous core in the edge / Self-contained network (a)	YES, beyond Rel-1	NO	NO	NO	NO	YES, beyond Rel-1	NO	YES, beyond Rel-1
5	Fixed wireless access	YES, in Rel-1	YES, in Rel-0	YES, in Rel-1	YES, in Rel-1	NO	NO	NO	NO
6	Firewalling (Layer4-7)	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	NO	NO	NO
7	Flexible backhaul for redundancy (say via satellite) (b)	YES, beyond Rel-1	NO	NO	NO	NO	YES, in Rel-1	NO	YES, in Rel-1
8	Interconnection with Public cloud (c)	YES, beyond Rel-1	NO	NO	YES, Beyond Rel-1	YES, in Rel-1	NO	NO	NO
9	Data fabric service involving correlation, aggregation and analytics (d)	YES, beyond Rel-1	YES, in Rel-1	YES, in Rel-1	NO	Yes, beyond Rel-1	NO	NO	NO
10	Test and KPI validation	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	YES, in Rel-1	NO	NO	NO
11	3rd party VNF hosting	YES, beyond Rel-1	YES, in Rel-1	YES, beyond Rel-1	YES, beyond Rel-1	YES, beyond Rel-1	NO	NO	NO

No.	***Technical Services offered in Release 1 or beyond Release 1***	***Norway***	***UK***	***Spain***	***Greece***	***Portugal***	***Germany (Berlin)***	***Germany (Munich)***	***Luxemburg***
12	Edge cloud	YES, beyond Rel-1	NO	YES, beyond Rel-1	YES, beyond Rel-1	YES, in Rel-1	NO	YES	NO
13	Interconnection with other 5G-VINNI Facility-sites	YES, beyond Rel-1	YES, beyond Rel-1	YES, beyond Rel-1	YES, beyond Rel-1	YES, beyond Rel-1	YES, in Rel-1	NO	YES, in Rel-1
14	Interconnection with non-5G-VINNI Facility-sites (to be offered based on demand)	YES, beyond Rel-1	YES, beyond Rel-1	YES, beyond Rel-1	YES, beyond Rel-1	YES, beyond Rel-1	NO	NO	NO
15	Individual device connectivity (both eMBB and IoT) to 5G-VINNI Facility via default slice	YES, in Rel-1	YES, in Rel-1	YES, beyond Rel-1	YES, beyond Rel-1	YES, beyond Rel-1	NO	NO	NO

Description of the technical services:

(a) Autonomous core in the edge / Self-contained network: This service involves spinning up a mobile core (Both control and data plane) in the edge for example in case the backhaul connection is broken which is essentially a self-contained network

(b) Flexible backhaul for redundancy: This service involves providing redundancy in the backhaul for example via Satellite link.

(c) Interconnection with Public Cloud: The possibility of hosting the network functions in public cloud or extending the network slice in the public cloud.

(d) Data Fabric service: Service to extract, compute/transform and move data across the distributed network Facility (edge, fog, core).

2.2 Capabilities to be supported

Table 3 show from what Release specific capability is supported.

Table 3: Capabilities to be supported

No.	Capability name	Norway	UK	Spain	Greece	Portugal	Germany (Berlin)	Germany (Munich)	Luxemburg
1	5G New radio	Rel-1	Rel-1	Rel-1	Rel-1	Rel-1	Rel-1	Rel-1	No
2	Integrated low power wide area networks	Rel-1	Rel-1	Rel-1	Rel-1	No	No	No	No
3	5G-Core	Beyond Rel-1	Rel-1	Rel-1	Rel-1	Rel-1	Rel-1	Rel-1 non-3gpp compliant	Rel-1
4	Network slicing based on 5G-EPC	Rel-1	Rel-0 (maybe removed by Rel-1	Rel-1	N/A	No	No	No	No
5	Network slicing based on 5G-Core	Beyond Rel-1	Rel-1	Rel-1	Rel-1	Rel-1	Beyond Rel-1	Rel-1 non 3gp	Beyond Rel-1
6	NFVI	Rel-1	Rel-1	Rel-1	Rel-1	Rel-1	Rel-1	Rel-1 In House	Rel-1
7	MANO	Rel-1	Rel-1	Rel-1	Rel-1	Rel-1	Rel-1	Rel-1 In House	Rel-1
8	E2E Service Orchestration	Rel-1	Rel-1	Rel-1	Rel-1	Rel-1	Rel-1	NO	Rel-1
9	Edge computing	Beyond Rel-1	Rel-1	Beyond Rel-1	beyond Rel-1	Rel-1	Rel-1	Rel-1	Rel-1
10	MEC Compliant edge computing	-	-	Beyond Rel-1	beyond Rel-1 (ICT-19 depend)	Beyond Rel-1	Rel-1	No	Rel-1
11	On-boarding containerized workloads	Rel-1	Beyond Rel-1	Rel-1	Rel-1	Rel-1	No	Yes, for internal use	No
12	SD-WAN	-	-	No	-	No	Rel-1	No	Rel-1
13	Control user Plane separation (CUPS) architecture for maximum topology flexibility	Rel-1	Rel-1	Beyond Rel-1	Beyond Rel-1	Rel-1	Rel-1	Beyond Rel-1	Rel-1
14	Secure architecture with infrastructure zoning and with L4-7 Firewalling capabilities	Rel-1	Beyond Rel-1	Beyond Rel-1	Beyond Rel-1	Beyond Rel-1	No	No	No

3 Architecture recommendations vs. Implementation

The global architecture developed in D1.1 [1] of 5G-VINNI and the recommendations therein will be considered while designing and implementing the individual 5G-VINNI Facility-sites. This is reflected in the tables where the 5G-VINNI release (Rel) in which that recommendation will be implemented is also highlighted.

3.1 Domains: 5G Radio and Core

3.1.1 Main Facility-sites

Table 4: Global architecture implementation I

No.	***Architecture recommendations***	***D1.1 Reference***	***Implementation***			
			Norway	***UK***	***Spain***	***Greece***
1	5G Radio: LTE-NR Dual Connectivity for NSA implementations	4.2.1	Ericsson 5G Radio: Rel-1; Option 3x will be implemented; Huawei 5G Radio: Rel-1; Option 3x will be implemented;	Rel-0 Option 3x will be implemented; Rel-1 planned migration to SA	Rel-0: SRS-LTE solution. Rel-1: Ericsson 5G Radio: Option 3a Research purpose deployment of SRS 5G Solution	Facility will have a 5G Core. However, we will try first with SRS-LTE (and AMARISOFT) based nodes and then in parallel we will migrate to SRS 5G software
2	5G Radio: UL/DL Decoupling for NSA implementations	4.2.1	Ericsson 5G Radio: Rel-1; Huawei 5G Radio: Rel-1	Supported in Rel-0	Ericsson 5G Radio: Rel-1	N/A
3	5G Radio: Mobility	4.2.1	Ericsson 5G Radio: Rel-1; Huawei 5G Radio: Rel-1	Rel-1	Ericsson 5G Radio: Rel-1	N/A
4	5G Radio: LTE-NR Aggregation for NSA implementations	4.2.1	Ericsson 5G Radio: Rel-1; Huawei 5G Radio: Rel-1	Supported for Rel-0; SA implementation in Rel-1	Ericsson 5G Radio: Rel-1	N/A
5	5G Radio: RAN support for NR QoS framework	4.2.1	Ericsson 5G Radio: Rel-1; Huawei 5G Radio: Rel-1	Rel-1	Ericsson 5G Radio: Rel-1	N/A
6	Core: NSA support	4.3.1	Rel-1;	Supported for Rel-0; Rel-1 migration to SA	Rel-1	N/A
7	Core: SA support	4.3.2	Beyond Rel-1	Rel-1	Beyond Rel-1	From Rel-1

8	Core: Support of all Options 3/3a/3x	4.3.1.2	Rel-1;	Supported for Rel-0; In Rel-1, SA supported.	Rel-1	From Rel-1
9	Core: User Throughput Enhancement	4.3.1.2	Rel-1; eMBB slice will be deployed	Rel-1	Rel-1	Rel-1
10	Core: NR Access Control	4.3.1.2	Rel-1; Four gNB will be deployed	Rel-1	Rel-1	beyond Rel-1: Three gNBs will be deployed
11	Core: Dual Connectivity LTE/NR	4.3.1.2	Rel-1; eNBs and gNBs will be deployed and integrated into Core	Supported for Rel-0. Rel-1 will be SA-based	Rel-1	From Rel-1
12	Core: CP/UP separation	4.3.1.2	Rel-1; GW-C and GW-UP will be deployed in slice URLLC	Rel-1	Rel-1	From Rel-1
13	Core: NR Volume Reporting	4.3.1.2	Rel-1	Rel-1	Rel-1	From Rel-1
14	Core: GW selection for NR usage	4.3.1.2	Rel-1	Rel-1	Rel-1	From Rel-1
15	Core: DECOR Slicing using NR Capability	4.3.1.2	Rel-1	Rel-0 supported. Rel-1 core will be SBA based	Rel-1	beyond Rel-1
16	Core: QCI support for V2X applications	4.3.1.2	Rel-2	N/A	N/A	N/A
17	Core: Management and Orchestration (NFV-MANO)	4.3.1.2 and 4.6.1	Rel-1	Rel-1	Rel-1	From Rel-1

3.1.2 Experimental Facility-sites

Table 5: Global architecture implementation II

No.	Architecture recommendations	D1.1 Reference	Implementation			
			Portugal	Germany (Berlin)	Germany (Munich)	Luxemburg
1	5G Radio: LTE-NR Dual Connectivity for NSA implementations	4.2.1	N/A	N/A	N/A	N/A - See present D2.1 Section 4.8.2.1
2	5G Radio: UL/DL Decoupling for NSA implementations	4.2.1	N/A	N/A	N/A (Not all sites will support this)	N/A - See present D2.1 Section 4.8.2.1
3	5G Radio: Mobility	4.2.1	Beyond Rel-1: OAI	Rel-1	N/A	N/A - See present D2.1 Section 4.8.2.1
4	5G Radio: LTE-NR Aggregation for NSA implementations	4.2.1	N/A	N/A	N/A (Not all Sites require LTE-NR aggregation to prove the key KPI of 5G)	N/A - See present D2.1 Section 4.8.2.1
5	5G Radio: RAN support for NR QoS framework	4.2.1	Beyond Rel-1: OAI	N/A	N/A	N/A - See present D2.1 Section 4.8.2.1
6	Core: NSA support	4.3.1	N/A	N/A	N/A NSA is not supported	Not Planned - See Berlin D2.1 (Annex A.6)
7	Core: SA support	4.3.2	Rel-1: Open5GCore	Rel-1, updated across releases	Rel-1: non-3gpp Compliant	Supported - See Berlin D2.1 (Annex A.6)
8	Core: Support of all Options 3/3a/3x	4.3.1.2	N/A	Option 3 will not be deployed. Instead an approach to Option 2 was taken	N.A.	Supported - See Berlin D2.1 (Annex A.6). Option 3 will not be deployed.
9	Core: User Throughput Enhancement	4.3.1.2	N/A	Rel-1	N.A.	Supported - See Berlin D2.1 (Annex A.6)
10	Core: NR Access Control	4.3.1.2	N/A	Rel-1, updated across releases, depending on NR acquired	N.A.	Supported - See Berlin D2.1 (Annex A.6)
11	Core: Dual Connectivity LTE/NR	4.3.1.2	N/A	N/A	N.A.	Not Planned - See Berlin D2.1 (Annex A.6)
12	Core: CP/UP separation	4.3.1.2	Rel-1: Open 5G Core	Rel-1	Rel-1: non 3gpp compliant	Supported - See Berlin D2.1 (Annex A.6)

13	Core: NR Volume Reporting	4.3.1.2	N/A	Rel-1	N.A.	Supported - See Berlin D2.1 (Annex A.6)
14	Core: GW selection for NR usage	4.3.1.2	N/A	Rel-1	N.A.	Supported - See Berlin D2.1 (Annex A.6)
15	Core: DECOR Slicing using NR Capability	4.3.1.2	N/A	N/A	N.A.	Not Planned - See Berlin D2.1 (Annex A.6)
16	Core: QCI support for V2X applications	4.3.1.2	N/A	N/A	N.A.	Not Planned- See Berlin D2.1 (Annex A.6)
17	Core: Management and Orchestration (NFV-MANO)	4.3.1.2 and 4.6.1	Beyond Rel-1	Open Baton integration, Rel-1	N.A.	Supported - See Berlin D2.1 (Annex A.6)

3.2 Domains: NFVI and MANO

3.2.1 Main Facility-sites

Table 6: Global architecture implementation III

No.	Architecture recommendation	D1.1 Reference	Implementation			
			Norway	UK	Spain	Greece
1	NFVI Virtual Compute based on ETSI architecture	3.3.2	Supported, Rel-1: This will be based on OpenStack NOVA service (NOKIA NCIR)	Supported Rel-1: OpenStack. This is based on the OpenStack NOVA service	Rel-1: OpenStack	Supported Rel-1: OpenStack
2	NFVI Virtual Network based on ETSI architecture	3.3.2	Supported, Rel-1: Virtual network will be based on an enhanced DPDK solution (Nuage AVRS)	Supported Rel-1: OpenStack, Neutron plugins and OvS-DPDK	Rel-1: OpenStack Neutron	Supported Rel-1: OpenStack, Neutron and Cumulus Linux plugins
3	NFVI Virtual Storage based on ETSI architecture	3.3.2	Supported, Rel-1: Software defined storage will be implemented based on CEPH. OpenStack's Cinder and Nova services could be the clients	Rel-1: OpenStack Cinder	Rel-1: OpenStack Cinder	Rel-1: OpenStack Cinder
4	NFVI Compute	3.3.2	Supported, Rel-1: A hardware platform based Open Rack (OR) solution is used.	Supported Rel-1: TBD - Dell or HPE	Hardware platform (Dell or Intel)	2x 2 x Dual Intel® Xeon® and 2x10GB intel cards
5	NFVI Storage	3.3.2	Supported, Rel-1: For storage OR servers will be used (2OU each)	Supported Rel-1: Dedicated 20TB iSCSI storage		On compute node storage—nonshared file system
6	NFVI Network	3.3.2	Supported, Rel-1: It's a one rack solution using a pair of leaf switches (Nuage WBX 210)	Supported Rel-1: One rack solution using TOR switch (Juniper QFX5110-48S) and Mgt switch (Juniper EX2300-48T)	OpenStack Neutron	OpenStack Neutron and Cumulus Linux plugins
7	VIM based on ETSI architecture	3.3.2.2	Supported, Rel-1: VIM is based on OpenStack with three controllers (NOKIA NCIR)	Supported Rel-1: VIM based on Samsung customised OpenStack controller	VIM based on OpenStack	VIM based on OpenStack

8	VNFM based on ETSI architecture	3.3.2.2, 4.6.1	Supported, Rel-1: There will be two types of VNFM. One specific VNFM (S-VNFM) for Ericsson's VNFs and potentially a generic VNFM (G-VNFM) for future deployments. G-VNFM will not be deployed initially	Supported Rel-1: VNFM is included in Samsung's CMS solution.	OSM	OSM (Juju)
9	NFVO based on ETSI architecture	3.3.2.2	Supported, Rel-1: NFVO is according to ETSI architecture and interfaces. It will act as Service and Resource Orchestrator, with interface to VNFMs, VIM. It will also have interfaces to SDN and firewalls. For NFVO<—>VNFM (Ericsson) interface, a specific plugin was developed.	Supported Rel-1: ETSI compliant NFVO functionality and interfaces are provided through Samsung's CMS solution.	OSM	OSM (Resource Orchestrator (RO) and Drivers for VIMs & VNFMs)
10	NFVO supports multiple VIM support	4.6.1	Supported, Rel-1: This can be supported, but currently there is only one site deployed in Telenor 5G-VINNI, thus NFVO will be integrated to only one VIM	Supported Rel-1: The NFVO solution supports multiple VIMs if required, although this is not in scope and NFVO will be integrated to a single VIM in the UK solution.	OSM	Yes, OSM
11	NFVO to SDN integration	4.6.1	Supported, Rel-1: For on-boarding NFVO will be interact with SDN Orchestrator (Nuage VSP) for external network creation.	Supported Rel-1: The NFVO solution within Samsung's CMS is integrated with an SDN orchestrator, which orchestrates the ONOS based SDN-Controllers within CMS.	OSM	Yes, OSM

3.2.2 Experimental Facility-sites

Table 7: Global architecture implementation VI

No.	***Architecture recommendations***	***D1.1 Reference***	***Implementation***			
			Portugal	***Germany (Berlin)***	***Germany (Munich)***	***Luxemburg***
1	NFVI Virtual Compute based on ETSI architecture	3.3.2	Rel-1: OpenStack	Rel-1: OpenStack	N.A.	Supported - See Berlin D2.1 (Annex A.6). OpenStack selected as the SDN/VIM framework of choice for the satellite ground segment part.
2	NFVI Virtual Network based on ETSI architecture	3.3.2	Rel-1: OpenStack	Rel-1: OpenStack	N.A.	Supported - See Berlin D2.1 (Annex A.6). OpenStack selected as the SDN/VIM framework of choice for the satellite ground segment part.
3	NFVI Virtual Storage based on ETSI architecture	3.3.2	Rel-1: OpenStack	Rel-1: OpenStack	N.A.	Supported - See Berlin D2.1 (Annex A.6). OpenStack selected as the SDN/VIM framework of choice for the satellite ground segment part.
4	NFVI Compute	3.3.2	Rel-1: Dell PowerEdge R730xd	Rel-1: Fraunhofer Server rack	Rel-1: in-house	Supported - See Berlin D2.1 (Annex A.6) (Fraunhofer FOKUS server rack). For the satellite ground segment part, see Luxembourg D2.1 (Annex A.8) Section 4.2 - 4.8.2.1iDirect server rack)

5	NFVI Storage	3.3.2	Rel-1: DISK: 12x 3725GB HDD SATA	Rel-1: Fraunhofer Server rack	Rel-1: in-house	Supported - See Berlin D2.1 (Annex A.6) (Fraunhofer FOKUS server rack). For the satellite ground segment part, see Luxembourg D2.1 (Annex A.8) Section 4.2 - 4.8.2.1iDirect server rack).
6	NFVI Network	3.3.2	Rel-1: OpenStack Neutron	Rel-1: Fraunhofer Server rack, OpenStack Neutron	Rel-1: in-house	Supported - See Berlin D2.1 (Annex A.6 (Fraunhofer FOKUS server rack). For the satellite ground segment part, see Luxembourg D2.1 (Annex A.8) Section 4.2 - 4.8.2.1iDirect server rack).
7	VIM based on ETSI architecture	3.3.2.2	Rel-1: OpenStack	Rel-1: OpenStack	Rel-1: in-house	Supported - See Berlin D2.1 (Annex A.6. OpenStack selected as the SDN/VIM framework of choice for the satellite ground segment part.
8	VNFM based on ETSI architecture	3.3.2.2, 4.6.1	Rel-1: SONATA - FSM (Function Specific Manager)	Rel-1: Open Baton	Rel-1: in-house	Supported - See Berlin D2.1 (Annex A.6 Open Baton VNFM
9	NFVO based on ETSI architecture	3.3.2.2	Rel-1: SONATA	Rel-1: Open Baton	Beyond Rel-1, GUI based	Supported - See Berlin D2.1 (Annex A.6 Open Baton
10	NFVO supports multiple VIM support	4.6.1	Rel-1: SONATA (OpenStack, Kubernetes)	Rel-1: Open Baton	N.A.	Supported - See Berlin D2.1 (Annex A.6 Open Baton feature
11	NFVO to SDN integration	4.6.1	Rel-1: SONATA	Rel-1: Open Baton	N.A.	Supported - See Berlin D2.1 (Annex A.6. SDN used for backhaul. Transparent slice overlay deployed end-to-end using 2 Open Baton orchestrators

3.3 Domains: Service Orchestration

3.3.1 Main Facility-sites

Table 8: Global architecture implementation V

No.	Architecture recommendations	D1.1 Reference	Implementation			
			Norway	UK	Spain	Greece
1	*Catalog-driven orchestration across multiple management domains*	4.6.3	Supported. Using Nokia Flowone Rel-1	Supported. Using Nokia Flowone Rel-1	Supported. Using OSM and 5GinFIRE project Rel-1	Supported. OSM and adoption/implementation of portal solution from 5GinFIRE project Rel-1
2	Onboard component specifications from third party sources (e.g. resource layer)	4.6.3	Supported. Using Nokia Flowone Rel-1	Supported. Using Nokia Flowone Rel-1	Supported. Using OSM Rel-1	Supported. OSM Rel-1
3	E2E Service Catalogue: assembling the design service design (e.g. layout, parameters, transactions, policies, etc.)	4.6.3	Supported. Using Nokia Flowone Rel-1	Supported. Using Nokia Flowone Rel-1	Supported. Using OSM and 5GinFIRE project Rel-1	Supported. OSM and adoption/implementation of portal solution from 5GinFIRE project Rel-1
4	E2E Service Catalogue: publishing service catalog to northbound BSS functions	4.6.3	Supported. Using Nokia Flowone Rel-1	Supported. Using Nokia Flowone Rel-1	Supported. Using OSM and 5GinFIRE project Rel-1	Supported. OSM and adoption/implementation of portal solution from 5GinFIRE project Rel-1
5	E2E Active Inventory: persist service instance representations and pertaining virtual and physical resources	4.6.3	Supported. Using Nokia Flowone Rel-1	Supported. Using Nokia Flowone Rel-1	Supported. Using OSM and 5GinFIRE project Rel-1	Supported. OSM and adoption/implementation of portal solution from 5GinFIRE project Beyond Rel-1
6	E2E Service Process Manager: Scheduling, assigning and coordinating Customer provisioning related activities	4.6.3	Supported. Using Nokia Flowone Rel-1	Supported. Using Nokia Flowone Rel-1	Supported. Using OSM and 5GinFIRE project Rel-1	Supported. OSM and adoption/implementation of portal solution from 5GinFIRE project Beyond Rel-1

7	E2E Service Process Manager: Enriching or modifying request/order information under execution	4.6.3	Supported. Using Nokia Flowone Rel-1	Supported. Using Nokia Flowone Rel-1	Supported. Using OSM and 5GinFIRE project Rel-1	Supported. OSM and adoption/implementation of portal solution from 5GinFIRE project Beyond Rel-1
8	Verifying whether specific Service Request sought by Customers are feasible	4.6.3	Basic support for re-use of slices in Rel-1. Complex qualification scenarios beyond Rel-1 on case-by-case basis	Basic support for re-use of slices in Rel-1. Complex qualification scenarios beyond Rel-1 on case-by-case basis	Supported. Using OSM and 5GinFIRE project Rel-1	Supported. OSM and adoption/implementation of portal solution from 5GinFIRE project Beyond Rel-1
9	E2E Service Process Manager: Decomposition of the Service into Service Components	4.6.3	Supported. Using Nokia Flowone Rel-1	Supported. Using Nokia Flowone Rel-1	Supported. Using OSM and 5GinFIRE project Rel-1	Supported. OSM and adoption/implementation of portal solution from 5GinFIRE project Beyond Rel-1
10	Coordinate execution of the service delivery orchestration plan, delegating Service Component implementation to Network Domain Controllers (e.g., sub-network connectivity), NFV MANO and external providers or partners	4.6.3	Supported. Using Nokia Flowone Re l1	Supported. Using Nokia Flowone Re l1	Supported. Using OSM and 5GinFIRE project Rel-1	Supported. OSM and adoption/implementation of portal solution from 5GinFIRE project Beyond Rel-1

3.3.2 Experimental Facility-sites

Table 9: Global architecture implementation VI

No.	***Architecture recommendations***	***D1.1 Reference***	***Implementation***			
			Portugal	***Germany (Berlin)***	***Germany (Munich)***	***Luxemburg***
1	*Catalog-driven orchestration across multiple management domains*	4.6.3	Rel-1	Not supported - single domain considered	N.A.	Not Supported - See Berlin D2.1 (Annex A.6
2	Onboard component specifications from third party sources (e.g. resource layer)	4.6.3	Rel-1	Supported	Rel-1	Supported - See Berlin D2.1 (Annex A.6)
3	E2E Service Catalogue: assembling the design service design (e.g. layout, parameters, transactions, policies, etc.) and publishing to northbound BSS functions	4.6.3	Rel-1	Partially supported for layout and some parameters. No BSS support	N.A.	Partially Supported - See Berlin D2.1 (Annex A.6)
4	E2E Service Catalogue: publishing service catalog to northbound BSS functions	4.6.3	Rel-1	Not supported. No BSS functionality included	N.A.	Not Supported - See Berlin D2.1 (Annex A.6)
5	E2E Active Inventory: persist service instance representations and pertaining virtual and physical resources	4.6.3	Rel-1	Not supported. Such features are too complex for an experimentation site	N.A.	Not Supported - See Berlin D2.1 (Annex A.6)
6	E2E Service Process Manager: Scheduling, assigning and coordinating Customer provisioning related activities	4.6.3	Beyond Rel-1	Basic support, specific to an experimentation site.	N.A.	Basic Support - See Berlin D2.1 (Annex A.6)
7	E2E Service Process Manager: Enriching or modifying request/order information under execution	4.6.3	Beyond Rel-1	Very limited support - it is assumed that the tenant networks in an experimental Facility can be redeployed when needed.	N.A.	Very Limited Support - See Berlin D2.1 (Annex A.6)

8	Verifying whether specific Service Request sought by Customers are feasible	4.6.3	Beyond Rel-1	Expert verification - through this, a very large number of parameters will be checked. It is assumed that being an experimental site, only a very few and very varied as parameters service requests will be made.	N.A.	Expert verification - See Berlin D2.1 (Annex A.6)
9	E2E Service Process Manager: Decomposition of the Service into Service Components	4.6.3	Beyond Rel-1	Supported	N.A.	Supported - See Berlin D2.1 (Annex A.6)
10	Coordinate execution of the service delivery orchestration plan, delegating Service Component implementation to Network Domain Controllers (e.g., sub-network connectivity), NFV MANO and external providers or partners	4.6.3	Beyond Rel-1	Not supported - self-contained experimentation site.	N.A.	Not Supported - See Berlin D2.1 (Annex A.6)

3.4 Domains: Transport and Inter-site connectivity

3.4.1 Main Facility-sites

Table 10: Global architecture implementation VII

No.	***Architecture recommendations***	***D1.1 Reference***	***Implementation***			
			Norway	***UK***	***Spain***	***Greece***
1	Wireless backhaul	4.5.1	Not considered for initial base station sites.	Not applicable	Not applicable	Supported. ICOM solution
2	Optical Fibre backhaul	4.5.2	Fibre, 10G for each base station	Fibre, 10G	5TONIC optical mesh: Up to 100G	Not Supported
3	Satellite backhaul	4.5.3	Geostationary Orbit (GEO), VSAT terminal.	Not applicable	Not applicable	Not Supported

3.4.2 Experimental *Facility-sites*

Table 11: Global architecture implementation VIII

No.	***Architecture recommendations***	***D1.1 Reference***	***Implementation***			
			Portugal	***Germany (Berlin)***	***Germany (Munich)***	***Luxemburg***
1	Wireless backhaul	4.5.1	Not considered for initial base station sites.	Best effort public-MNO connectivity (currently LTE) between remote and central site	N.A.	Not Supported
2	Wired backhaul	4.5.2	Fibre, 10G for each base station	*Best effort internet connectivity through available public land lines*	Best effort internet connectivity though Ethernet line	Optical Backhaul not supported. Best effort wired Internet connectivity through available public landlines may be possible though.
3	Satellite backhaul	4.5.3	Geostationary Orbit (GEO), VSAT terminal.	*Sporadic usage satellite capacity (subject to use case requirements and Luxemburg node requirements)*	N.A.	Satellite backhaul supported. See Luxembourg D2.1 (Annex A.8) Section 2.2 for capabilities supported: —GEO/MEO satellites —C/X/Ku/Ka-band —Satellite teleport —Satellite backhauling —Satellite-enabled 5G Edge Node with SDN/NFV/MEC capabilities Satellite interconnection with Central Node in Berlin Experimentation Facility-site

4 Facility-sites Solution Description

This section provides High Level Design for the 5G-VINNI Facility. Each Facility site solution is described in separate chapters.

The following domains are covered: Transport Network, 5G RAN and Core, MANO and NFVI, Service Orchestration, Edge Site and Security.

Further details related to each Facility site solution can be find in referred documents in Annex A.

4.1 Facility-site: Norway

There are three main vendors providing 5G Network in the Norway Facility site. 5G Radio network will be provided by Ericsson and Huawei while 5G EPC, VNF-EMS and VNF-M will be provided by Ericsson and finally Nokia will be providing NFVI, NFVO, VIM and Service Orchestration functionality. VNF-M functionality is part of Ericsson's EMS product. Optionally it is also possible to deploy Nokia's VNF-M for 3rd party VNF applications. 5G Core will be provided in later stage beyond Release 1.

Figure 2 shows Norway Facility-site overall network architecture and how it is mapped to ETSI NFV.

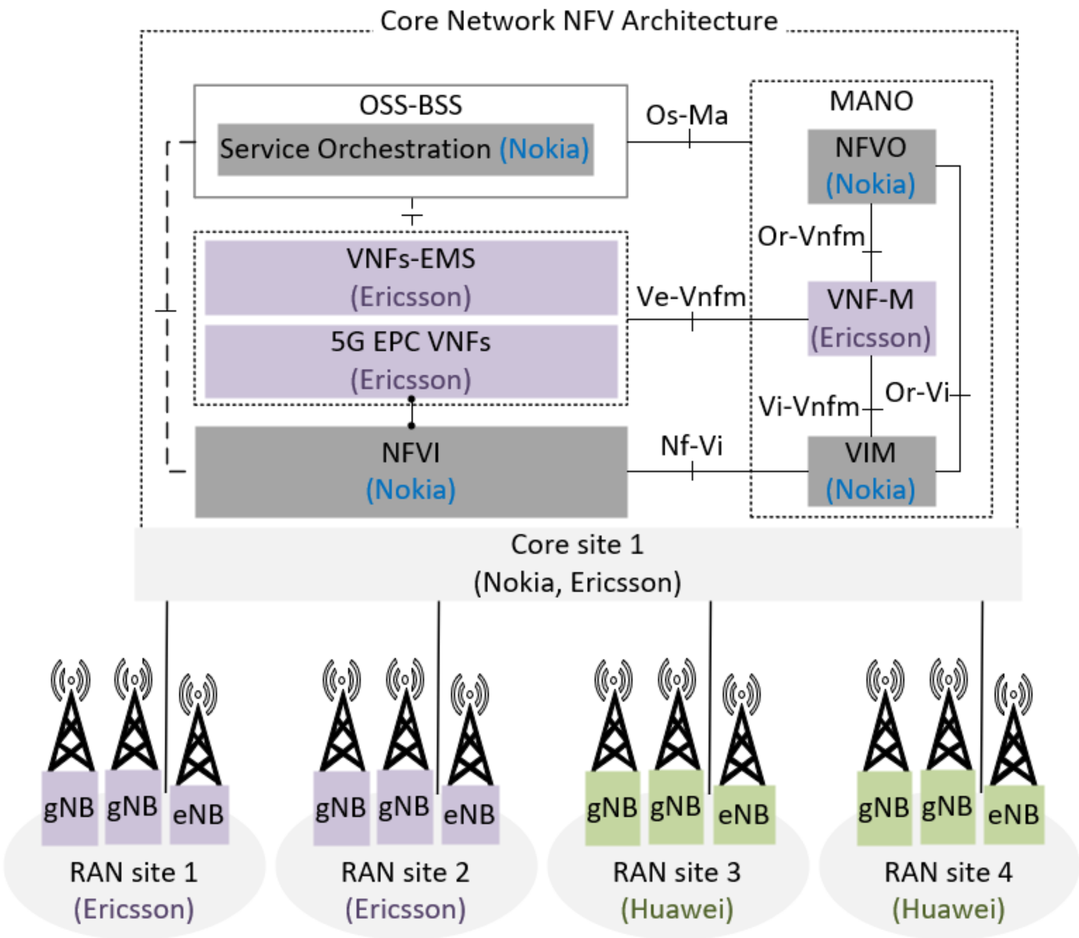

Figure 2: Norway Facility-site overall network architecture

4.1.1 Transport Network

The transport network between RAN and Core/NFV Cloud will use the commercial backhaul network used in operations in Telenor Norway but with a dedicated line. The transport setup which is based on IP/MPLS is illustrated in Figure 3.

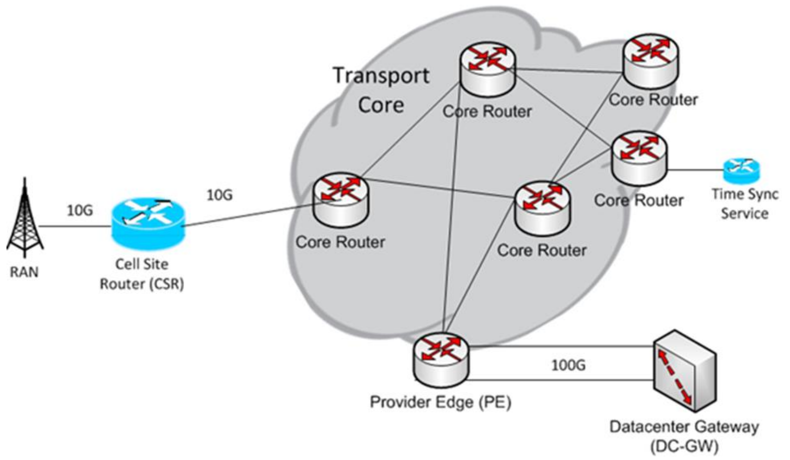

Figure 3: Norway Facility-site Transport network

Cell Site Routers (CSRs) are deployed at the RAN sites for connecting to the transport network. The CSR will use 10G interface. Provider Edge (PE) will connect the datacentre (NFV site) to the transport network. The PE will use 100G interfaces towards the transport Core. Datacentre Gateway (DC-GW) will connect the datacentre (NFV) to the PE using 2x100G interfaces for redundancy. The setup will be the same for both central and edge datacentre. The exception is for edge sites that are co-located with the RAN in which case the edge will connect to the CSR.

Satellite backhaul provided by Telenor Satellite is planned for at least one of the RAN sites. A standardised Very Small Aperture Terminal (VSAT) will be used. Satellite connectivity will be provided either as shared access with DVB-S2 ACM (Digital Video Broadcasting - Second Generation, Adaptive Coding and Modulation) outbound and Advanced TDMA inbound or as Stream Control Transmission Protocol (SCPC) both ways. The shared access profile will typically be limited to 50 Mbps downlink and 5 Mbps uplink. SCPC could be configured with a higher profile.

4.1.2 5G RAN and Core

As illustrated in Figure 2 Norway Facility-site overall network architecture, a total of four (4) 5G radio sites will be built in the Norway Facility with both Ericsson and Huawei providing two (2) each. All the 5G Radios will be deployed as physical network function with no cloud RAN. Later in the project the possibility of Cloud RAN will be explored. The mobile core will be provided by Ericsson and will be hosted in Telenor Headquarters in Fornebu, Norway. Initially 5G EPC in Non-Stand Alone (NSA) mode (Option 3x) will be deployed and later this will be replaced/appended by 5G Core in Stand-alone mode. For Release 0 and 1 of 5G-VINNI, Huawei's radio sites will be connected to Huawei 5G EPC which in subsequent releases will be connected to mobile core by Ericsson.

Network Slicing support

Initial VNFs deployment will support three generic 5G slices: eMBB, mMTC and URLLC. For better NFVI resources utilization some VNFs will be shared by two or three slices. RAN elements will not support slicing so all eNBs/gNBs will be shared by all three slices.

For slice selection DECOR functionality will be used. Figure 4 shows what VNFs will be deployed and how they are shared with slices.

Each of the three slices can be dynamically deployed from NFVO upon Request sent from Service Orchestration and with parameters provided in Network Service Descriptor.

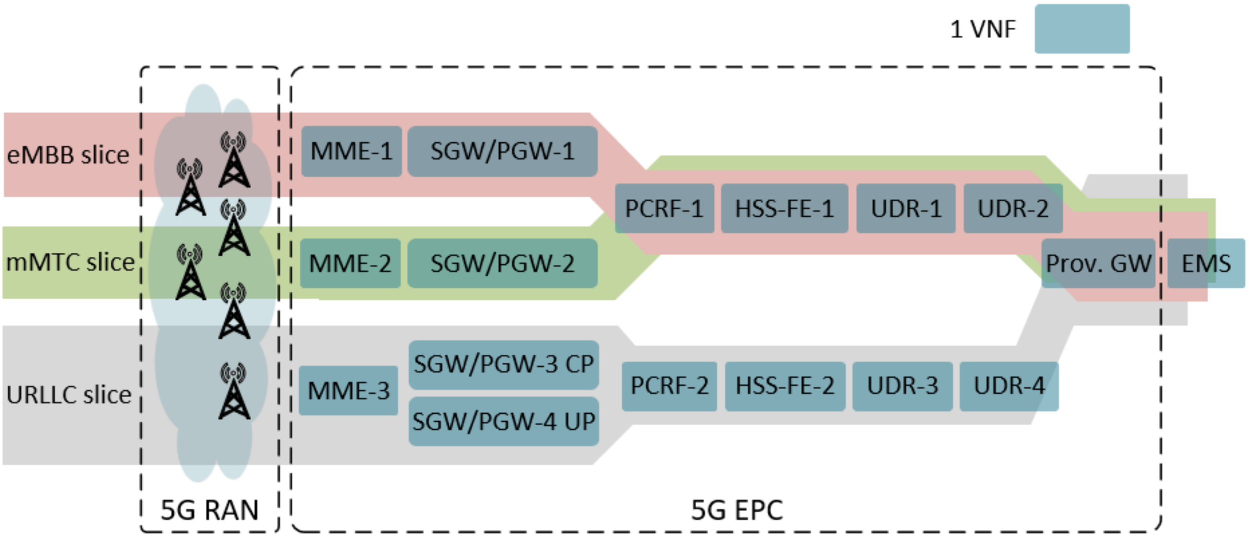

Figure 4: Norway Facility-site VNFs sharing across 5G slices

4.1.2.1 5G RAN Ericsson and Huawei

The 5G RAN will initially use the 3.6 GHz TDD band (80 MHz) and 4G anchor carrier in 2100 MHz FDD band. The initial Radio node will later be expanded with radios that support the 26 GHz frequency band (up to 800 MHz, actual bandwidth used depends on the granted trial license by the Norwegian spectrum authority NKOM). The 4G 2100 MHz radio will be connected to a traditional passive base station antenna and both 3.6 GHz gNB and 26 GHz gNB will use Massive MIMO radios where the radios are integrated with the antenna in one physical unit.

The interface between Radios and Baseband Units will be CPRI for LTE and eCPRI for the Massive MIMO units limiting the required fibre links to a minimum.

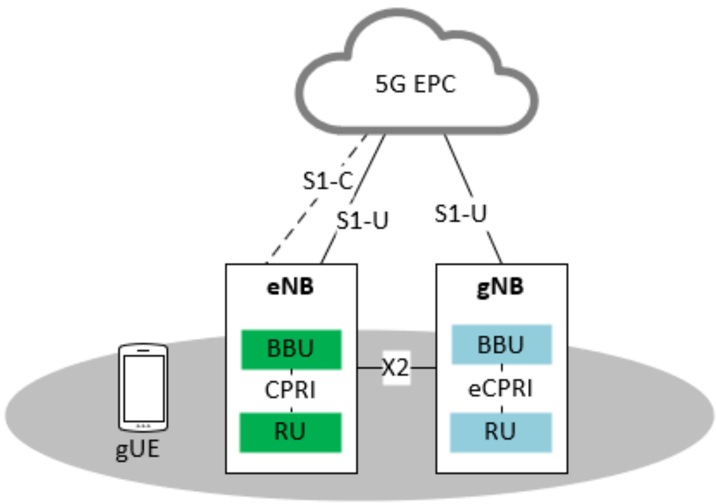

Figure 5: Norway Facility-site 5G RAN

The backhaul towards the Core Network, initially S1 interface, is terminated in a site router that is also connected to a GPS receiver providing accurate synchronization signal required for TDD transmissions. The baseband unit provides the node synchronization based on an external synchronization source provided by GPS or the transport network connection.

Downlink user data is sent over the LTE leg or the NR leg. The selection of a specific leg is based on the NR connection quality that can be set with system configuration. The NR leg is used when the quality is optimal based on the set value. In case the NR quality is below the set value, the LTE leg is used. Downlink Fast Switch enables to switch between the LTE air interface and the NR air interface for the transmission of downlink user plane traffic.

For Downlink Dual Connectivity Aggregation, the downlink user data is sent simultaneously over the LTE and NR legs. A flow control mechanism at the gNodeB guides the traffic over the different legs to minimize the reordering at PDCP layer of the UE.

The radio site parameters for Huawei nodes are 3.5GHz (80 MHz BW) NR, 28 GHz NR (800 MHz BW) and 2100 MHz LTE (20 MHz). Each base station from Huawei will have two sectors with individual radios in every frequency bands i.e. every base station site will have 6 radios. The solutions provided into this project will be based on 3GPP standards and can be integrated towards other 3GPP compliant systems and interfaces. Huawei's RAN solution will support high level CU-DU split with the DU implementing the real-time part (PHY, MAC, RLC) while CU implementing the non-real-time (PDCP, RRC) as shown in Figure 6 Huawei 5G CU-DU Split. For CU-DU separated scenario, a new F1 transmission interface is added for CU-DU transmission.

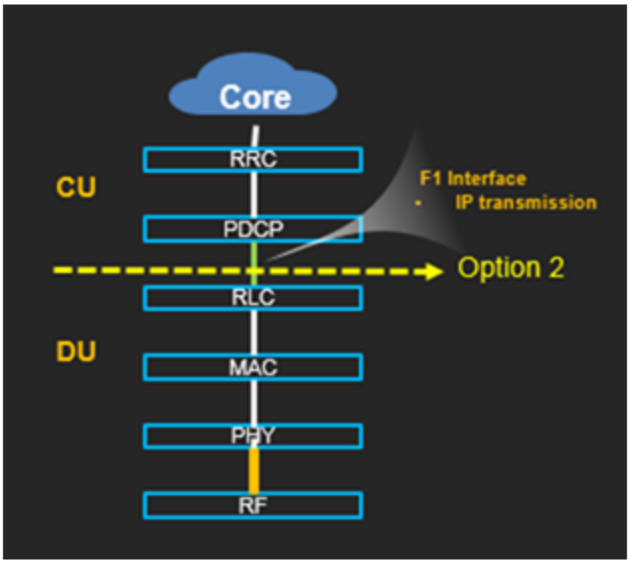

Figure 6: Huawei 5G CU-DU Split

Huawei Norway contribution to 5G-VINNI is mainly related to RAN, however a temporary core solution will be deployed to facilitate early testing of 5G NR. The core network provide by Huawei Norway will be a virtualized EPC+ able to support both 4G and 5G. Huawei E9000 servers will be used to host the core NW software components and will be located at Telenor premises at Fornebu.

Huawei will deploy a virtualized EMS / O&M system to manage both RAN and Core separately. Huawei OSS virtualization structure is build based on E9000 and Fusion sphere as shown in Figure 7 Huawei's OSS Solution. The OSS poses resource consumption and network requirements, and customer design relevant networks.

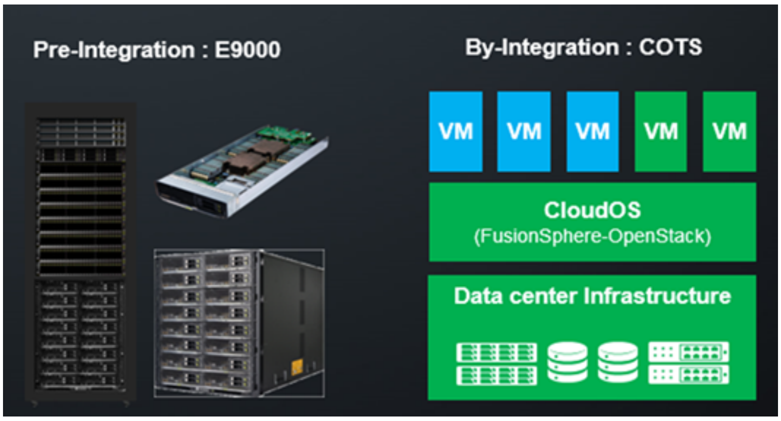

Figure 7: Huawei's OSS Solution

4.1.2.2 5G EPC Ericsson

5G EPC deployed for 5G-VINNI is Ericsson EPC enhanced to support 5G/NR (Opt. 3) according to 3GPP Release 15.

All 5G EPC VNFs will be deployed in Telenor Norway Datacentre and running on the Nokia Open-stack infrastructure. There will be one common NFVI infrastructure hosting all 5G EPC VNFs.

It will be green field deployment and no integration with existing network infrastructure is needed.

Figure 8 shows logical interfaces in target network architecture supporting 3 slices.

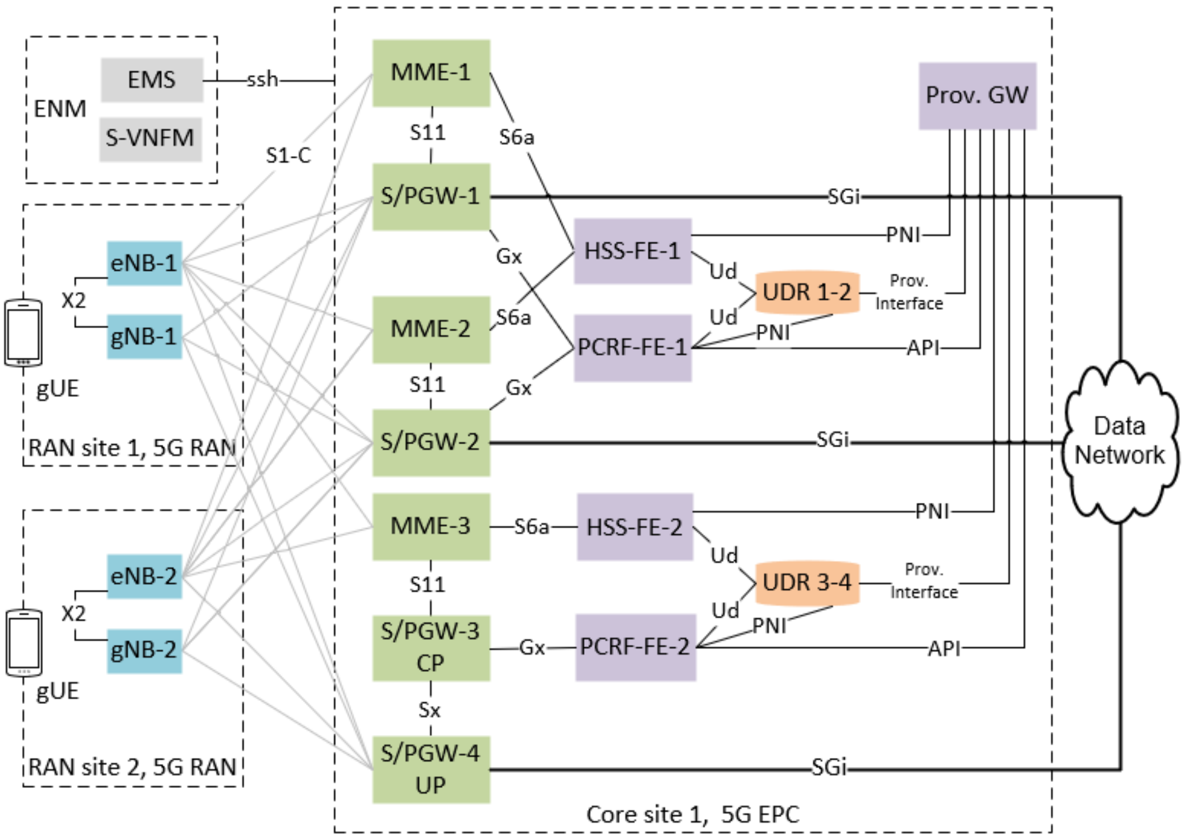

Figure 8: Norway Facility-site 5G Ran & EPC Core network topology

5G EPC VNFs that will be dynamically deployed from NFVO:

- **MME** - 3x VNFs will be deployed and integrated with all eNBs and gNBs. Each MME will serve one 5G slice. All MME will be stand-alone none of them configured in MME pool; All eNBs and gNBs will be shared with all three slices.
- **S/PGW** - 4x VNFs will be deployed. Slice URLLC will be supported with a CUPS thus one S/PGW will be configured as Control Plane GW and one as User Plane GW. S/PGW selection will be preconfigured statically on MMEs no DNS will be used.
- **HSS-FE** - 2x VNFs will be deployed. Two slices will have shared HSS-FE while the URLLC slice will have dedicated HSS-FE. Subscriber profiles will be provided by one of two external UDRs (UDR1-2 and UDR3-4). Both HSS-FE will be stand-alone not back up each other. UE Usage Type parameter used for DCN selection will be part of subscription profile provided by HSS-FE or alternatively could be also statically preconfigured on MME.
- **PCRF-FE** - 2x VNFs will be deployed. Two slices will have shared HSS-FE while the URLLC slice will have dedicated HSS-FE. Data-plans, User Profiles and Policies (Rules) will be stored in internal databases while Subscriber profiles will be provided by one of two external UDRs (UDR1-2 and UDR3-4). Both HSS-FE will be stand-alone not back up each other.
- **UDR** - 2x UDR pairs will be deployed. One UDR pair consist of two VNF. These UDR pairs are independent and does not back up each other.

  Two slices will have shared UDR1-2 while the URLLC slice will have dedicated UDR3-4

- **Provisioning GW** - 1x VNF instance is common across all slices; provides 5G User and Policy Profile provisioning in UDR and PCRF and NW Slicing Profile provisioning.

VNF Element Management System (EMS)

The VNF EMS functionality will be provided by Ericsson Network Manager (ENM). ENM provides centralized operation and maintenance of radio and core. Also provides powerful and unified performance and configuration management, software, hardware and fault management for VNFs, together with security, self-monitoring and system administration for the ENM itself.

4.1.3 MANO and NFVI

The main components that will be deployed in this site are:

- A Virtual Infrastructure Manager (VIM) which is OpenStack based. For this site VIM is provided by NOKIA and its NCIR (NOKIA Cloud Infrastructure Real-time) software
- There will be two Virtual Network Function Managers (VNFM) deployed in this site. Initially it will be the Ericsson ENM (Ericsson Network Management) and later for 3rd party applications, NOKIA's CloudBand Application Manager (CBAM) as generic VNFM.
- For Network Function Virtualization Orchestrator (NFVO), it will be NOKIA's CloudBand Network Director (CBND). It will be connected to VIM, VNFM and SDN Orchestrator (Nuage)
- On top of the NFVO there is a Service Orchestrator provided by NOKIA, FlowOne, which will be responsible for slicing lifecycle management. This is described in more details in the next chapter.
- Software define network (SDN) is accomplished by deploying Nuage SDN platform.

Nokia G-VNFM is an optional VNFM and is intended for 3rd party VNFs when it is requested. In Rel-1 there is no plan to deploy it so far.

For network orchestration and slicing management purposes, integration between the Service Orchestrator (FlowOne), NFVO (CBND) and Ericsson VNFM/EMS will be needed. The interconnection between those components may require specific APIs and plugins, which will be analysed in site's D2.1, chapter 8.

Figure 9 describe Integration of MANO and NFVI.

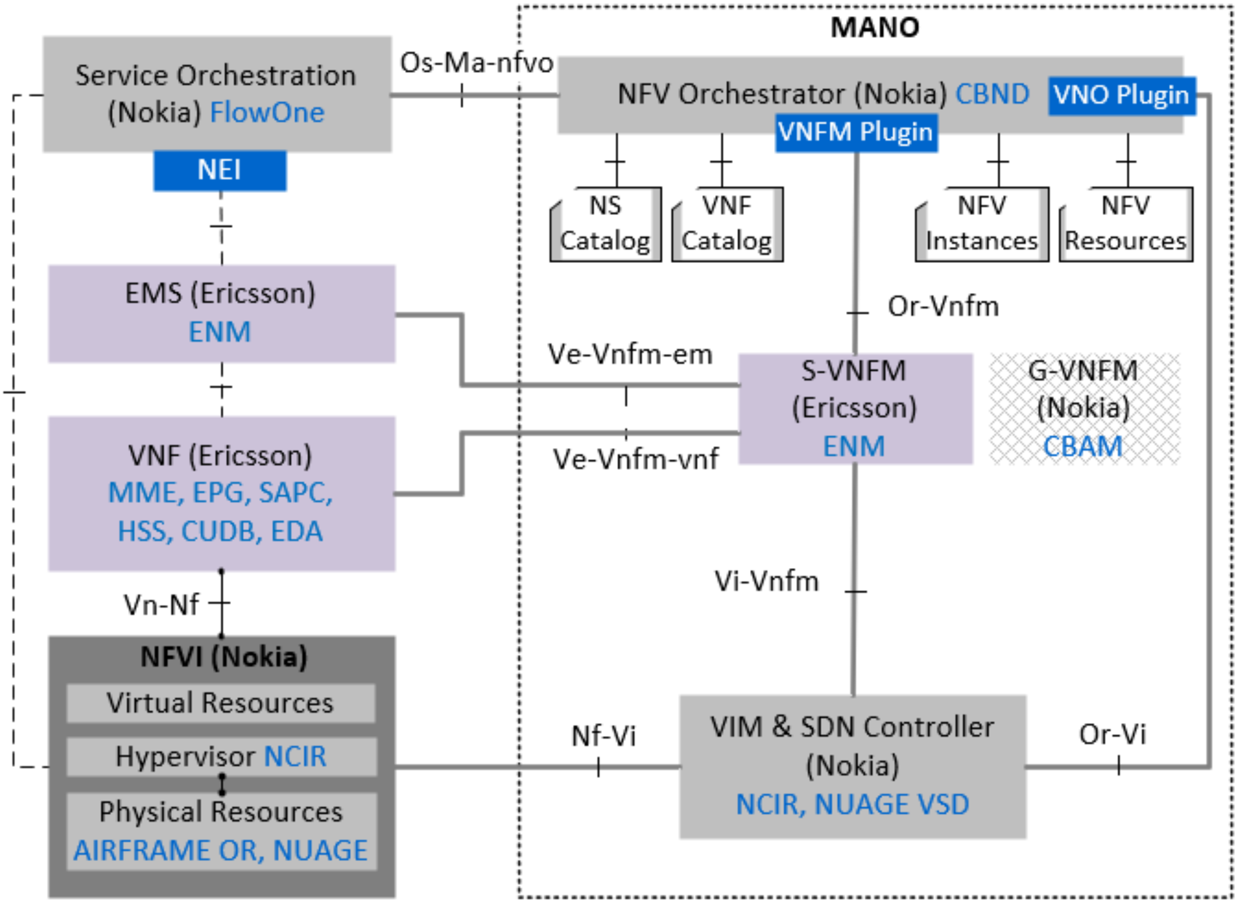

Figure 9: Norway Facility-site MANO and NFVI

NEI (Network Element Interface): A plugin maybe required between SO and EMS.

VNFM Plugin: A plugin for Or-Vnfm will be developed between NFVO and S-VNFM.

VNO Plugin: A plugin for Or-Vi will be developed between NFVO and VIM

The hardware platform for 5G-VINNI is built based on NOKIA Airframe OR (Open Rack) hardware, NOKIA Airframe management switch and Nuage WBX leaf switches.

4.1.4 Service Orchestration

Nokia FlowOne solution is taking care of the E2E service orchestration function. E2E service orchestration is taking responsibility for:

- Centralized SOM, all service delivery is managed in one place.
- Service lifecycle management for network slices and for UE provisioning, taking care of the correct delivery sequence when delivery order contains multiple hybrid services and steps.
- Service Model contains models how different services are delivered and needed resources reserved along different delivery processes. System can expose service model and its detailed information via API to external systems for e.g. enabling product service mapping with versioning.
- Install Base – external or internal and manages existing subscriptions and their services and resources up-to-date information.

The Nokia Flowone architecture for Release 1 is illustrated on Figure 10.

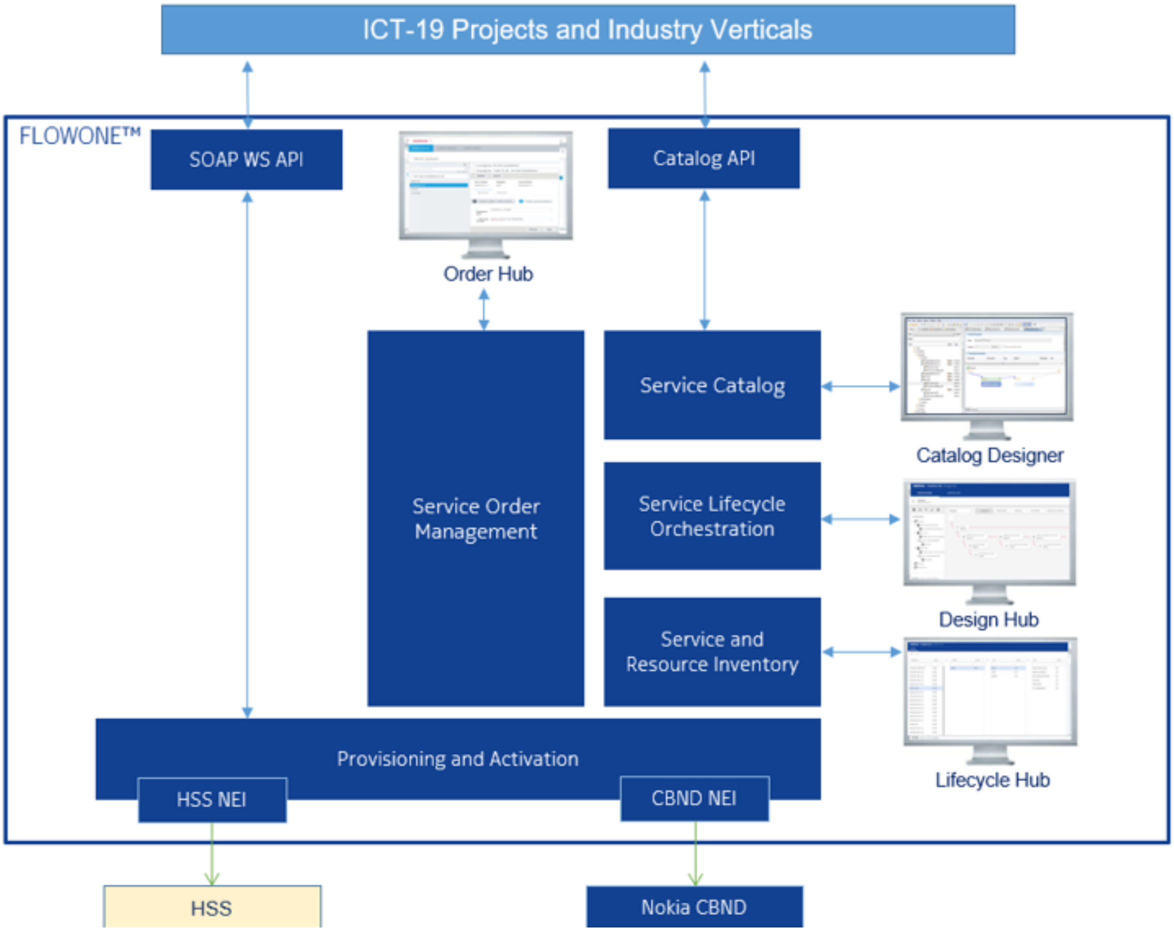

Figure 10: Norway Facility-site e2e Service Orchestration Architecture and Functions

Below is a list of the Flowone modules that will be deployed as part of Release 0.

Table 12: Norway Facility-site Nokia e2e Service Modules for Rel-0

Component	Description
Design Hub	User interface for designing service specification
Lifecycle Hub	User interface for accessing the service inventory
Order Hub	User interface to handle fallouts/error management
Service Lifecycle Orchestrator	Functionality for managing onboarding of network services and VNF's
Service Catalog Designer	User interface for designing service specification
Order Management	Nokia Order Management has the capabilities to control and monitor the progress of the service order from receipt to activation, through all the necessary physical an electronic workflow stage.
Service Catalog	Provides the service definitions and decompositions to more detailed service and resource level specifications

Component	Description
Service and Resource Inventory	In this project, Flowone Service and Resource Inventory will be the master for network slice instances and UE subscriptions
Provisioning and Activation	Provides southbound integration capabilities to CloudBand NFVO and Ericsson HSS

Flowone will support activities in the four 4 phases of the network slice lifecycle described by 3GPP. These phases are,

- Preparation phase
- Instantiation, Configuration and Activation phase
- Modification in the run-time phase
- Decommissioning phase

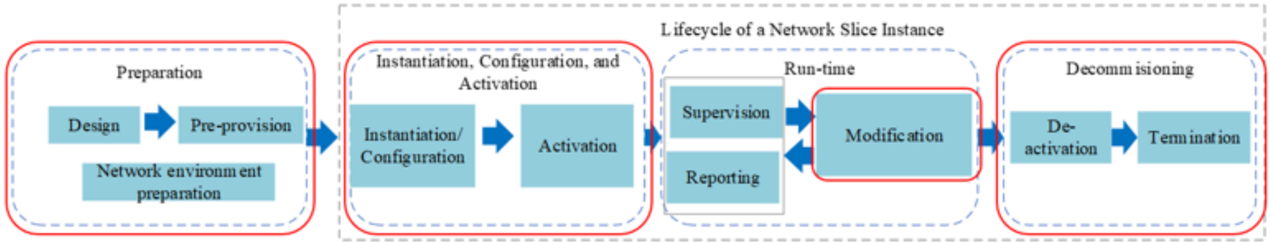

Figure 11: Lifecycle phases of a Network slice instance defined by 3GPP

4.1.5 Edge Site

The virtualized infrastructure design of the edge site will be a scaled down version of the core sites, with lower footprint VIM control plane with relaxed redundancy of only two hot standby VIM instances and one firewall for security zoning.

Edge sites[1] are planned in the Norway Facility-site, but the exact location(s) has not yet been decided and will depend on requirements of the funded ICT-19 projects. The plan is to decide the location considering the capabilities of the transport and RAN network used in addition to the needs of the ICT-19 projects. The edge sites are planned to be implemented in Rel-1.

The plan is to also support autonomous edge sites, meaning that the edge site should be able to operate as full mobile network in case the link breaks down. This is a requirement from multiple verticals (e.g. defence, manufacturing).

There are multiple areas to consider for the design of edge sites including the NFV components (NFVI, VIM, SDN, SDS), the mobile core network whether it is data plane nodes only or fully autonomous edge sites, service chaining, the support for Cloud RAN potentially requiring real-time performance, and support for 3rd party applications potentially demanding high volume storage.

The NFVI platform of Nokia is the Airframe and shown in Figure 12, which scales from centralized datacentres to the far edge datacentres. These are provided as either rack-mounted or open rack,

[1] Note that we use the term edge site and not Multi-Access Edge (MEC). The reason is non-compliance to the ETSI ISG MEC standards at this stage

based on OCP. It's the latter that has been chosen in the 5G-VINNI project as central node, and that is candidate for a deployment of an edge DC in Rel-1 of 5G-VINNI.

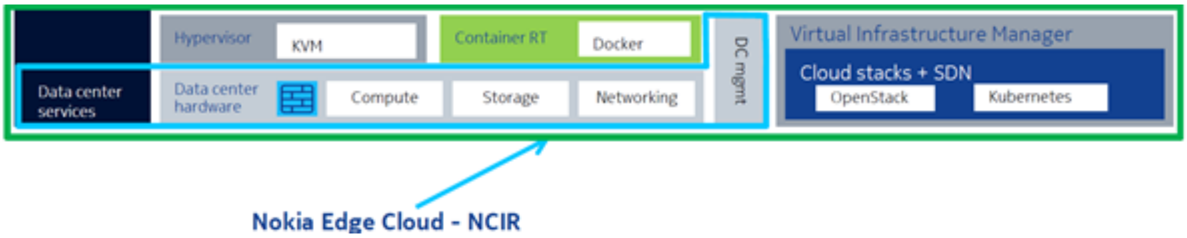

Figure 12: Nokia's edge cloud

4.1.6 Security

Security is a broad topic covering multiple domains including at least RAN, Mobile Core, Transport, NFV, Orchestration and Services. In the following we describe the security domains mostly relevant for the introduction of 5G.

Two important security technologies that will be implemented for the NFV/SDN infrastructure are (i) the infrastructure network zoning model for service classes and management classes and (ii) multi-tenancy across the layers of the NFV architecture and E2E Orchestrator.

Firewalls by PaloAlto will be used to implement the zoning model. Physical firewalls will segregate traffic between security classes and virtual firewalls and/or SDN micro segmentation will be used to segregate traffic between tenants within the same security class. One physical firewall will be used for segregating traffic between security classes, on which four virtual firewalls will be implemented for each of the security classes; three for service classes (exposed, non-exposed, secure) and one for the management class.

Multi-tenancy will be implemented across the modules in the NFV architecture (i.e. NFVO, VNFM, VIM, SDN, SDS) and in the E2E Orchestrator including the network slice management functions defined in 3GPP (i.e. NSMF, NSSMF).

Ericsson 5G EPC security features

- The Ericsson 5G EPC VNFs has functions for internal node security and stability, such as Denial of Service (DoS) attack protection, to prevent payload and signaling overload. It provides mechanisms for perimeter defense i.e. Virtual Network separation based on Virtual Private Networks (VPNs) or User Access Control when only authorized users have access to the VNFs.
- Then there is MS and UE Authentication mechanism, including encryption or ciphering, makes sure that only subscribers with correct identities can access the network.
- Integrity Protection and Encryption secures the signaling control between the UE and the 5G EPC.

4.2 Facility-site: UK

The delivery of the 5G-VINNI UK Facility-site solution will be over two phases, aligned to Release 0 (July 2019) and targeted for Release 1 (January 2020) respectively:

- Phase 1 will deliver a Release 15 Non-StandAlone (NSA) solution for sub-6 GHz 5G NR, alongside a 5G Fixed Wireless Access (FWA) solution based on the TF standard in the 28 GHz band. The solution will be based around a virtualized LTE core.
- Phase 2 will migrate to a Release 15 StandAlone (SA) solution for sub-6 GHz 5G NR, alongside a migrated 5G FWA solution based on the NR standard. This will use a dedicated 5G Core based on NFV.

The overall network architecture for Phase 1 is shown in Figure 13, showing the separate locations 1, 2 and 3 for the various pieces of equipment. These locations are described further in section 5.6.

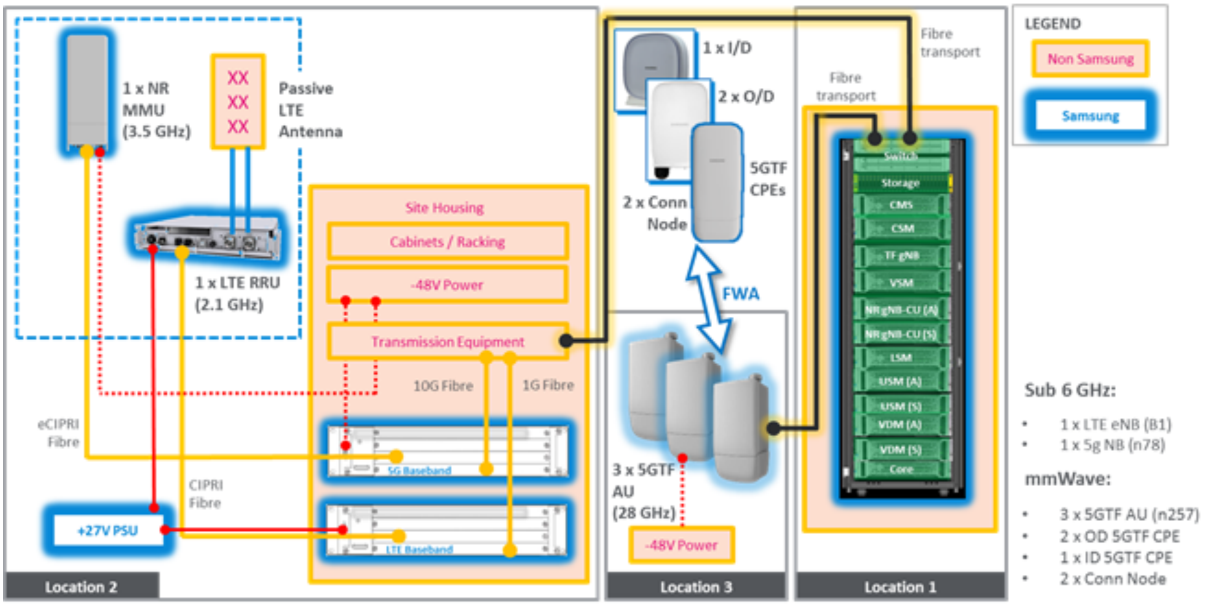

Figure 13: UK Facility-site overall network architecture (Phase 1)

Within Figure 14, three locations are identified. Locations 1 is a Server room within the main buildings of BT's laboratory. Location 2 is the cell site for the sub-6GHz Massive MIMO unit (MMU) and a nearby mounting point housing a small rack for the DU of sub-6GHz RAN equipment. Location 3 is the coverage area for mmWave Access Units (AUs).

The components identified for Phase 1 in Figure 2 are as follows (by location):

Location 1:

- Site 19" rack, comprising:
  - CMS – Cloud Management System
  - Core – All core network VNFs: MME, GW-U/GW-C, HSS
  - CSM – Core System Manager: Element Management of the Core Network (EPC) VNFs
  - TF gNB – 5G TF gNodeB
  - VSM – Virtual System Manager: Management of the 5G TF gNodeB
  - NR gNB-CU – 5G-NR gNodeB Centralised Unit (with redundant Active/Standby)
  - USM – Universal System Manager: Management for the 5G-NR gNodeB (with redundant Active/Standby)
  - LSM – LTE System Manager: Management for the LTE eNodeB

   - VDM – Virtual Device Manager: Management of 5G TF CPEs (with redundant Active/Standby)

<u>Location 2:</u>

- Single LTE baseband unit
- Single LTE SRU – Stackable Radio Unit for the LTE anchor cell, connected to a cross-polar passive antenna supporting band 1
- Single 5G NR DU baseband unit
- Single NR MMU – 5G New Radio Massive MIMO Unit (32T32R)

<u>Location 3:</u>

- Three TF AUs – 5G Task Force (5G TF) specification compliant mmWave Access Unit (AU) incorporating Remote Radio Unit
- TF CPEs – 5GTF specification compliant Customer Premises Equipment, in three variants:
   - Single I/D (Indoor) CPEs
   - Two O/D (Outdoor) CPEs
   - Two Connectivity Nodes – Outdoor mounted device using 5G TF connection as backhaul, and presenting Wi-Fi, Bluetooth and ZigBee interfaces to end devices.

The overall network architecture for Phase 2 is shown in Figure 3, showing the separate locations 1, 2, 3 and 4 for the various pieces of equipment.

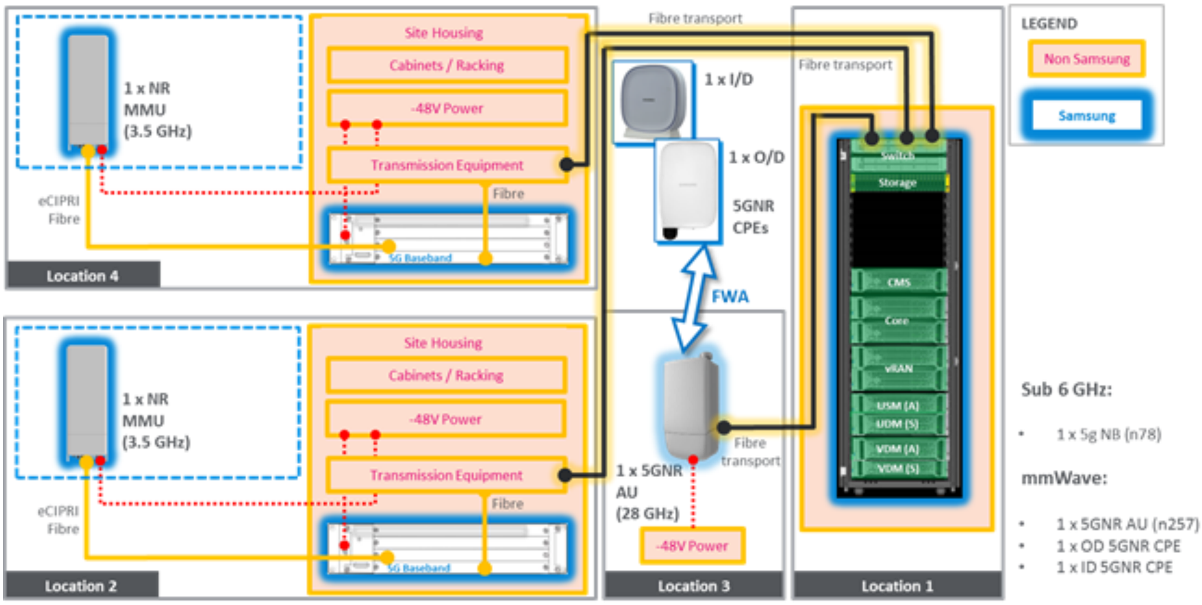

Figure 14: UK Facility-site overall network architecture (Phase 2)

The components identified for Phase 15 in Figure 3 are as follows (by location):

<u>Location 1:</u>

- Site 19" rack, comprising:
   - CMS – Cloud Management System
   - Core – All core network VNFs deployed across two physical servers: AMF/SMF/UPF, UDSF, UDM, UDR, AUSF
   - Two NR gNB-CUs – 5G-NR gNodeB Centralised Units (with redundant active/standby)
   - USM – Universal System Manager: Management for the 5G-NR RAN and Core (with redundant active/standby)

- VDM – Virtual Device Manager: Management of 5G NR CPEs (with redundant active/standby)

Locations 2 & 4:

Configuration is duplicated across these two locations

- Single 5G NR DU baseband unit
- NR MMU – 5G New Radio Massive MIMO Units (32T32R)

Location 3:

- Single NR AU – 5G NR specification compliant mmWave Access Unit (AU) incorporating Remote Radio Unit
- 5G NR CPEs – 5G NR specification compliant Customer Premises Equipment, in two variants:
  - Single I/D (Indoor) CPE
  - Single O/D (Outdoor) CPE

The Transport network, Core and Radio network and MANO and NFVI are illustrated and described further in the following sections.

4.2.1 Transport Network

The transport network between RAN and Core connect using the fibre network across the Adastral Park site and will utilise the on-site layer 3 switching network. Cell Site Routers are deployed at each of the RAN sites for all instances of 3.5GHz NR and mmWave installations, as shown in Figure 15.

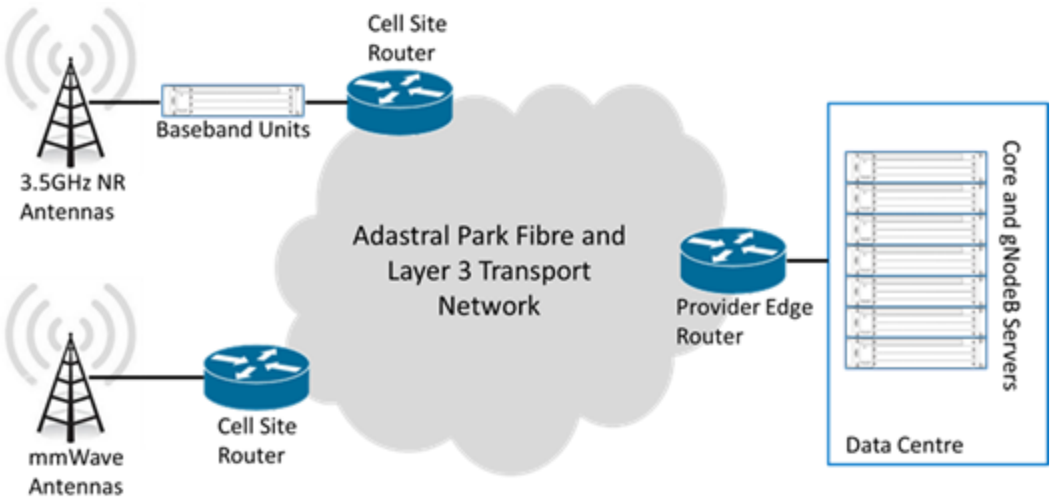

Figure 15: UK Facility-site Transport network

For 3.5GHz NR, the CSRs will connect with the 5G baseband and LTE baseband units which will be co-located with antenna units. Provider Edge Routers will connect the transport links with the Adastral Park data centre containing the 5G Core and 3.5GHz NR gNodeB and mmWave gNodeB.

4.2.2 5G RAN and Core

Figure 16 shows the RAN and Core components to be implement in the UK Facility-site for Release 0.

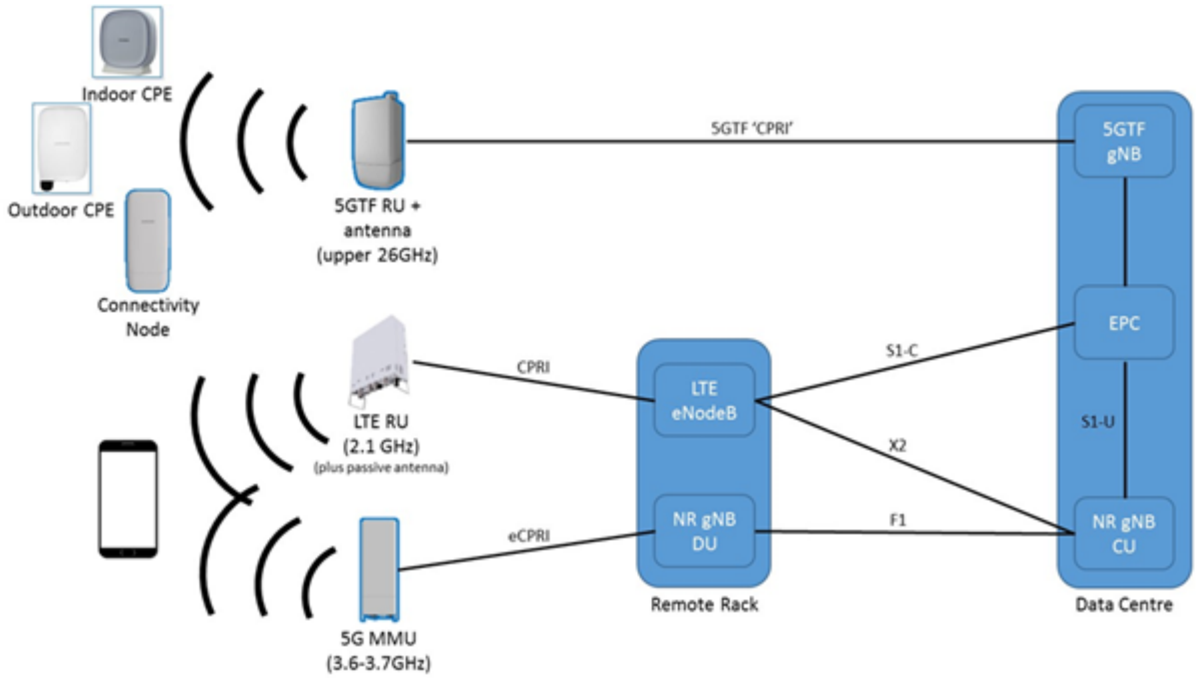

Figure 16: UK Facility-site RAN and Core components

All Core and RAN Components and VNFs are supplied by Samsung.

For 5G-NR implementation in sub-6GHz band, 100MHz of spectrum will be utilized between 3.6GHz and 3.7GHz. The 5G-NR implementation will be in Non-Standalone (NSA) configuration using LTE in Band 1 as the LTE anchor connection.

The 5G-NR gNodeB will operate with MMU-DU-CU split. RU is integrated within the antenna unit in the MMU. The DU will be deployed on dedicated CDU hardware housed in a Remote Rack and the CU will be on servers in the central data centre. The CU function is virtualized. An eCPRI interface is used between the MMU and the gNodeB DU and F1 interface is exposed between gNodeB DU and gNodeB CU.

The LTE eNodeB will be deployed with RU-DU split, and a CPRI interface will connect the RU and DU.

For the mmWave band, 5GTF-based components will be used, operating in the upper part of the 26GHz band. The mmWave Access Unit incorporates the RU, with the 5GTF gNodeB deployed as a virtualized function in the central data centre.

Both eNodeB and 5GTF gNodeB connect to a fully virtualized Core, implemented on servers in the central data centre.

4.2.3 MANO and NFVI

Figure 17 shows the NFVI and MANO architecture for the UK Facility-site.

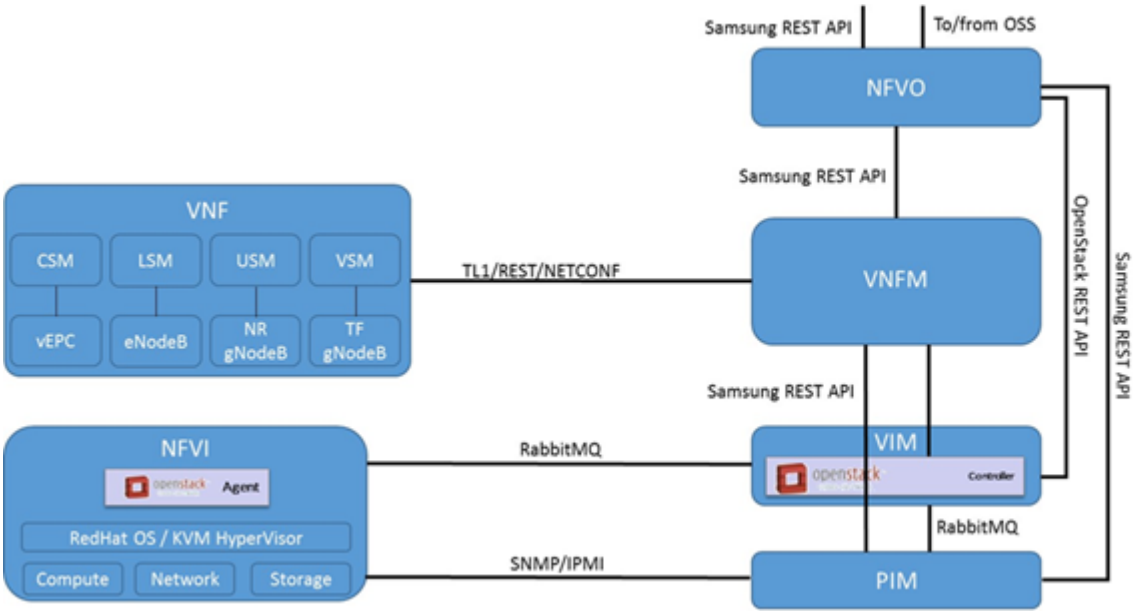

Figure 17: UK Facility-site NFVI and MANO architecture

NFVO and VNFM are provided by Samsung along with VNFs as per the Core and RAN implementation described in sections 5.4.1, 5.4.2 and 5.6 respectively.

Servers, Storage and VIM are provided by HP, and will run RedHat Enterprise Linux.

NFVO will present a REST API towards the Service Orchestration domain.

4.2.4 Service Orchestration

Nokia FlowOne solution is taking care of the E2E service orchestration function. E2E service orchestration is taking responsibility for:

- Centralized SOM, all service delivery is managed in one place.
- Service lifecycle management for network slices and for UE provisioning, taking care of the correct delivery sequence when delivery order contains multiple hybrid services and steps.
- Service Model contains models how different services are delivered and needed resources reserved along different delivery processes. System can expose service model and its detailed information via API to external systems for e.g. enabling product service mapping with versioning.
- Install Base – external or internal and manages existing subscriptions and their services and resources up-to-date information.

The Nokia Flowone architecture for Release 1 is illustrated on Figure 18.

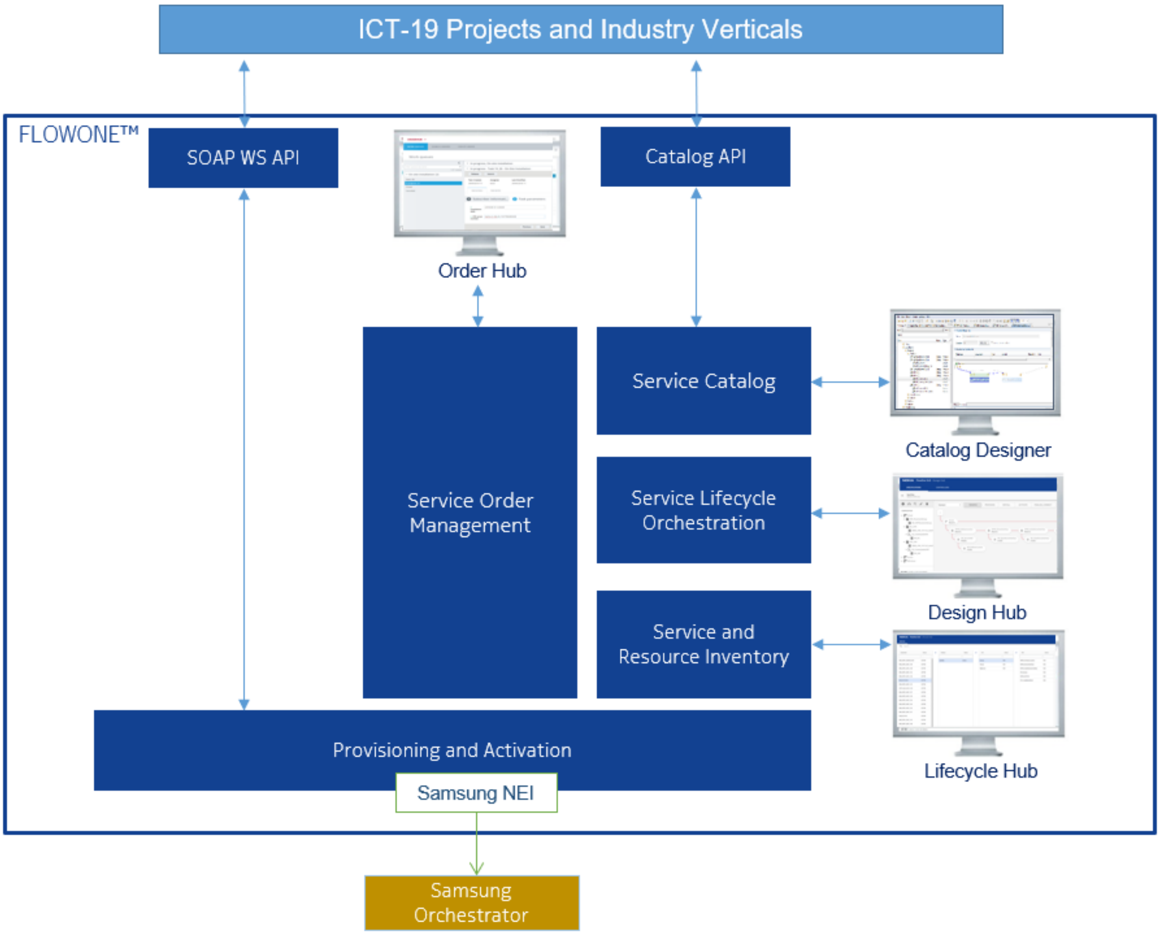

Figure 18: UK Facility-site Nokia e2e Service Orchestration Architecture and Functions

Below is a list of the FlowOne modules that will be deployed as part of Release 0.

Table 13: UK Facility-site Nokia FlowOne e2e Service Modules for Rel-0

Component	Description
Design Hub	User interface for designing service specification
Lifecycle Hub	User interface for accessing the service inventory
Order Hub	User interface to handle fallouts/error management
Service Lifecycle Orchestrator	Functionality for managing on-boarding of network services and VNF's
Service Catalog Designer	User interface for designing service specification
Order Management	Nokia Order Management has the capabilities to control and monitor the progress of the service order from receipt to activation, through all the necessary physical an electronic workflow stage.

Component	Description
Service Catalog	Provides the service definitions and decompositions to more detailed service and resource level specifications
Service and Resource Inventory	In this project, FlowOne Service and Resource Inventory will be the master for network slice instances and UE subscriptions
Provisioning and Activation	Provides southbound integration capabilities to CloudBand NFVO and Ericsson HSS

Flowone will support activities in the four 4 phases of the network slice lifecycle described by 3GPP. These phases are,

- Preparation phase
- Instantiation, Configuration and Activation phase
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- Decommissioning phase

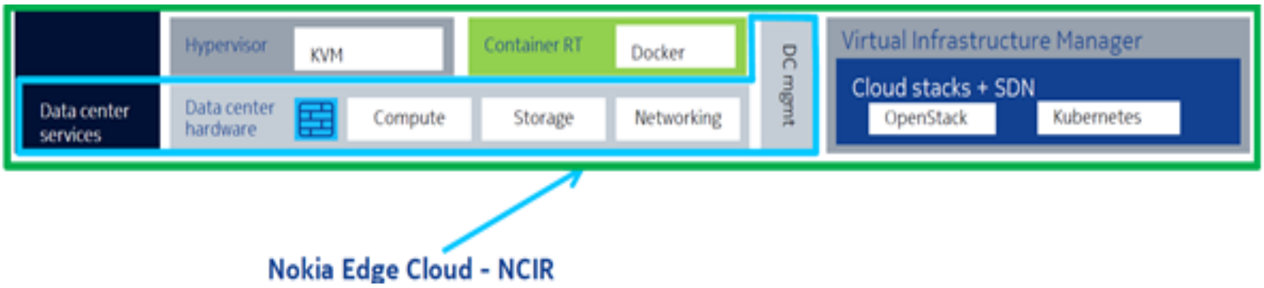

Figure 19: Lifecycle phases of a Network slice instance defined by 3GPP

4.2.5 Edge Site

Not applicable to UK Site Release 1 implementation

4.2.6 Security

UK Test Facility is built entirely within BT Labs facilities and using BT labs privately owned transport networks. It is built using Samsung owned and operated infrastructure. As such, security of the infrastructure and traffic is inherently assured by separation from other networks. Only two points of access exist, these being via the devices attaching to the RAN network, and at the point of ingress/egress at the edge of BT's network.

Devices will be required to register to the RAN using SIM-based credentials as described in 3GPP TS 33.501. As such, subscriptions associated with end users will need to be registered in the HSS (for Rel-0) or AUSF and UDM (for Rel-1), to allow authentication procedures to be completed.

The edge of BT's network, facing towards the internet is secured using a BT managed Firewall. For Samsung's remote access, a VPN will be provided for protected, remote access to the BT Labs-based UK Test facility at Adastral park.

Current plans are for a Cisco FW operating with Cisco AnyConnect VPN. This will be isolated from and provide protection for BT's internal networks. User will be provided with their own credentials that will allow a single user to connect to the UK test facility.

The Firewall at the edge of BT's network, will be managed against a best effort, business hours SLA and any patching, updates or upgrading to the FW will be done without loss of access where possible, but in the event of any planned downtime, advanced warnings will be made. Where possible, all patching will be performed outside UK business hours.

4.3 Facility-site: Spain

The global 5G Telefonica Open Network Innovation Centre (5TONIC) was created in 2015 by Telefonica +D and IMDEA Networks Institute as a leading European hub for knowledge sharing and industry collaboration in the area of 5G technologies. The laboratory provides an open research and innovation ecosystem for industry and academia that will promote joint project development, joint entrepreneurial ventures, discussion fora, and a site for events and conferences, all in an international environment of the highest impact. 5TONIC will also serve to evaluate and demonstrate the capabilities and interoperation of pre-commercial 5G equipment, services and applications. Currently, the 5TONIC laboratory has ten members: Telefonica, Institute IMDEA Networks, Ericsson, Intel, CommScope, Universidad Carlos III de Madrid, Altran, Cohere Technologies, Artesyn Embedded Technologies, and Interdigital and 5 collaborators: IFEMA, ASTI Robotics, Rohde & Schwarz, Luz Wavelabs and Saguna Networks.

The lab has been on the forefront of technological innovation and with an extensive track record in European 5G Research Projects and has also been recognized as a Digital Innovation Hub (DIH) by the European Union. The site already has a deployed network infrastructure for supporting pre-5G trials and a number of use-cases detailed in www.5tonic.org.

The 5TONIC site is located at IMDEA Networks premises in Leganés, but it has access to other locations for the support of different network functions and use-cases: UC3M campus both at Leganés and Madrid City Centre, Telefónica I+D lab at Almagro Central Office, Telefónica headquarters campus Distrito C, 5G IFEMA Lab at Feria de Madrid and connection with Telefónica Spain lab at Alcobendas.

Due to its collaborative nature, 5TONIC is not a conventional site because in terms of available infrastructure, and it is necessary to distinguish 5TONIC as a whole, and the part that will be available to 5G-VINNI. In this sense, 5TONIC infrastructure provided by 5G-VINNI partners, as well as common infrastructure and services (e.g., connectivity), is the one that can be accessed by 5G-VINNI. However, there are network elements that are the property of companies that are not partners of the projects that will require an agreement to be able to access them. Examples of current 5TONIC elements that in principle are not available for 5G-VINNI site are: MEC platforms by Intel and Saguna Networks, OneCell RAN infrastructure by CommScope and mmWave transport infrastructure by InterDigital. Access to these network elements for 5G-VINNI activities should be agreed with 5TONIC members and collaborators in a case by case basis.

Also, it is necessary to distinguish between the infrastructure that is deployed at 5TONIC in a permanent/semi-permanent way (i.e., to be available at least until the end of the 5G-VINNI project), and temporal infrastructure that is deployed to support specific demos by 5TONIC members, associated with EU projects, as well as internal 5TONIC technological trials.

Permanent infrastructure includes:

- Data canter infrastructure including racks for each 5TONIC members and communications infrastructure;
- Virtual EPC provided by Ericsson, to evolve to NGC;
- LTE Radio Access infrastructure, provided by Ericsson and CommScope, to be evolved to NR;
- Virtualization, processing and transport infrastructure.

The 5TONIC laboratory, as a multipurpose environment, counts with multiple racks, which may be flexibly interconnected according to any experimentation requirements, along with a common infrastructure to aid experimentation, trials and demonstrations with 5G products and services. In particular, secure external access may be provided via VPN gateways, allowing different solutions to support management, control and data operations from remote network locations, depending on specific requirements. Due to confidentiality reasons, we cannot disclose all the software and hardware available in the laboratory, which also includes experimental prototypes from the industry and academic members. Consequently, in the following we keep our description concrete, describing the main infrastructure and equipment that currently are available for experimentation to 5G-VINNI. A graphical representation of this infrastructure is schematized in Figure 20, that illustrates the architecture of an initial set-up (to be further extended according to the needs and interests of the Laboratory members).

To support the operation of all the components, the 5TONIC infrastructure provides a common infrastructure of 7 high-performance servers, which are used for different purposes: storage and backup of 5G experimental data, execution of NFV management software, deployment of SDN controllers, performing intensive computing simulations (e.g., using distributed computing or NS-3 simulator) and baseband processing of frequency signals, among others. The testbed is completed with a heterogeneous set of end-user equipment for experimentation purposes, including 20 laptops/workstations (these may also be used as mobile nodes) and a pool of smartphones; a set of VPN gateways, to support the remote access to the 5TONIC laboratory; and different wireless measurement equipment, e.g., supporting equipment to generate baseband signals for transmission in the 60 GHz band, as well as 2 signal analysers to inspect baseband and/or intermediate frequency 60 GHz signals. Additionally, the laboratory incorporates a fleet of 5 programmable Micro Air Vehicles (MAVs), supporting novel experimentation activities related with the use of micro-drones as 5G points of presence as one of the main use cases for the 5TONIC facility in 5G-VINNI.

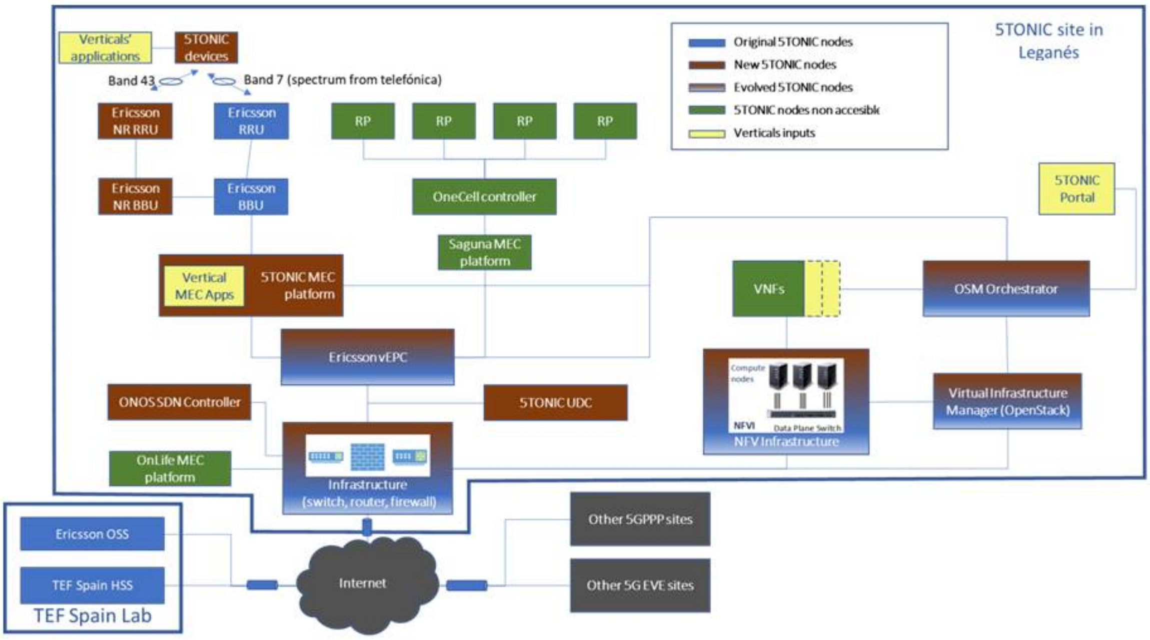

Figure 20: Overview of the 5TONIC site

The 5TONIC site is in continuous evolution due to both the incorporation of new networks elements and the evolution of the existing ones. As the testbed is expected to initially provide 5G services in NSA option 3a fashion with dual connectivity mode, it will be necessary to keep the LTE RAN operation in Band 7 in combination with an 5G NR RAN. Additional improvements that are expected to be achieved are:

- Evolution of 5TONIC Communications Infrastructure towards an SDN architectural framework;
- Updating of the orchestration platform for supporting multi-slicing;
- Updating of the MEC platform.

The 5TONIC data centre includes the basic equipment required for the operation of the 5TONIC site, including racks, power, ventilation, etc. In its current status, the 5TONIC data centre has twelve racks, each one assigned to a 5TONIC member, plus 2 for supporting communications.

Figure 21: 5TONIC data centre

It also has both indoor and outdoor areas where experiments can be carried out.

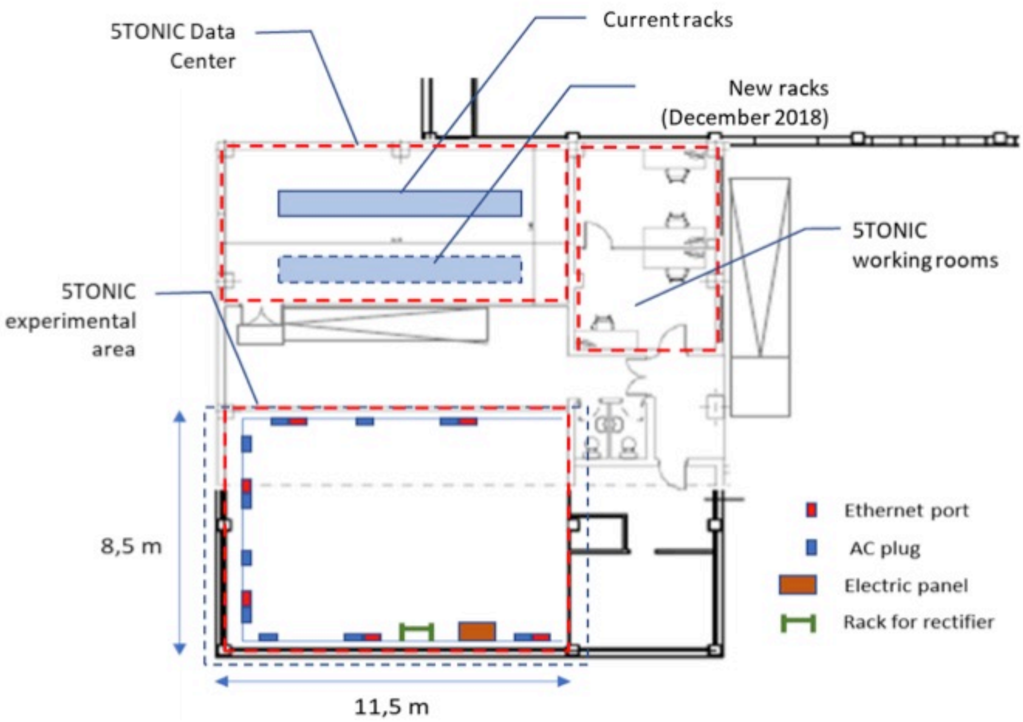

Figure 22: 5TONIC laboratory facilities

Figure 23: 5TONIC indoor experimental area

Additionally, 5TONIC has its own showroom where demos can be shown, located at IMDEA Network premises. This showroom has been used in the review of several European projects.

Figure 24: 5TONIC showroom

4.3.1 Transport Network

The 5TONIC laboratory includes a metro-core network, which can be connected to the components described before in several ways. The metro-core network setup is composed by IP/MPLS and optical devices. The core control plane testbed is confirmed by GMPLS nodes with software developed internally. The experimental setup is built with emulated nodes, which run in an Ubuntu server Linux distribution. Each emulated node implements a GMPLS stack (including RSVP, OSPFv2 and PCEP) and a Flexible Node emulator.

5TONIC has also recently enhanced the capacity and reliability of its connection to RedIRIS, the academic and research network in Spain, which is also part of GÉANT. The capacity has been increased to 10 Gbit/s and reliability has been enhanced by means of a double fibre ring that will connect to UC3M and University Rey Juan Carlos nodes of RedIRIS.

5TONIC is also working on a solution to deploy a high capacity and reliability connection with Telefónica I+D laboratories in Almagro Central Office, and in a L2 VPN based on GÉANT services, connecting with the Greece facility, started under the auspices of the 5GinFIRE project.

4.3.2 5G RAN and Core

Considering research on the 5G air interface and other radio aspects, 5TONIC infrastructure includes different scenarios provided by commercial, opensource or legacy research purpose solutions to support advanced experimentation with Software Defined Radio (SDR) systems.

LTE and 5G NR-capable radio are provided by Ericsson. Currently there is available the LTE coverage from the Ericsson Radio System portfolio. In addition, an 5G NR-capable radio will be deployed at 5TONIC for Rel-1.

The test-bed currently deployed consists of a set of 2 eNodeB with 8 FPGA cards, to run high speed and computationally intensive physical layer operations in WiFi/LTE, 4 radio frequency transceivers and a real-time controller, able to execute MAC and PHY control algorithms with micro-second resolution. Driven by the 5G vision, which considers extending the use of the radio spectrum, the infrastructure also supports communications in the frequency band between 30Ghz and 300Ghz (mmWave), as well as low frequency communications. The testbed includes several scalable SDR platforms, along with a set of 60 GHz down/up-converters, supporting the generation and reception of arbitrary signals in the frequency bands under consideration.

For Release 0, and with the purpose of experimental evaluation, there is an eNB and UE (4G with slicing) deployed within the 5G-MONARCH project that 5G-VINNI is currently using for network slicing experimentation.

In parallel with these experiments, there are several commercial and opensource solutions currently under evaluation (LimeNetSDR and OpenAirInterface).

The same approach of experimenting with commercial and opensource solutions is considered in the case of the core architecture in the 5TONIC site. There is already deployed an Ericsson 5G-EPC and EPC-in-a-box deployment. A legacy core is currently available to be used for Release 0 as result of the evaluation experiments. For future releases, it is under consideration the Fraunhofer FOKUS' Open5GCore as an alternative for comparison experiments.

4.3.3 MANO and NFVI

After an initial study to analyse the different open source solutions for the Management and Orchestration (MANO) of NFV, 5TONIC decided to deploy their MANO based on the ETSI OSM (Open Source MANO). This solution is aligned with the architecture and interfaces proposed by the ETSI NFV team, providing several services and a good performance. The current deployment is based on OSM Release FOUR and will run in a virtual machine using a server computer with 16 cores, 128 GB RAM, 2

TB NLSAS hard drive and a network card with 4 GbE ports and DPDK support. This server computer will also host a VIM instance based on OpenStack Ocata. An additional and independent instance of OpenStack Ocata will be deployed in a separate server computer with six cores, 32GB of memory, 2TB NLSAS and a network card with four GbE ports and DPDK support. This server computer will also host a virtual machine providing a relay functionality (a jump machine) to support the access of experimenters to VNFs. In both VIM instances, the OpenStack networking service was installed to support layer-3 services, and the ML2 plug-in of OpenStack was configured to use Linux bridges.

5TONIC is providing this NFV infrastructure to several projects, like 5GinFIRE and 5G-TRANSFORMER, etc. Due to the necessity to manage and orchestrate network functions in different sites, a very flexible solution is designed to interconnect different sites, using the MANO stack centralized at the 5TONIC premises. This MANO can manage other NFV infrastructures controlled by the local VIM available at each site. The connectivity between the 5TONIC laboratory and other sites require a VPN connection, a service that can be offered by the 5TONIC too depending on the agreements with the other sites. Figure 25 shows a simple diagram explaining how to establish inter-site connections with 5TONIC.

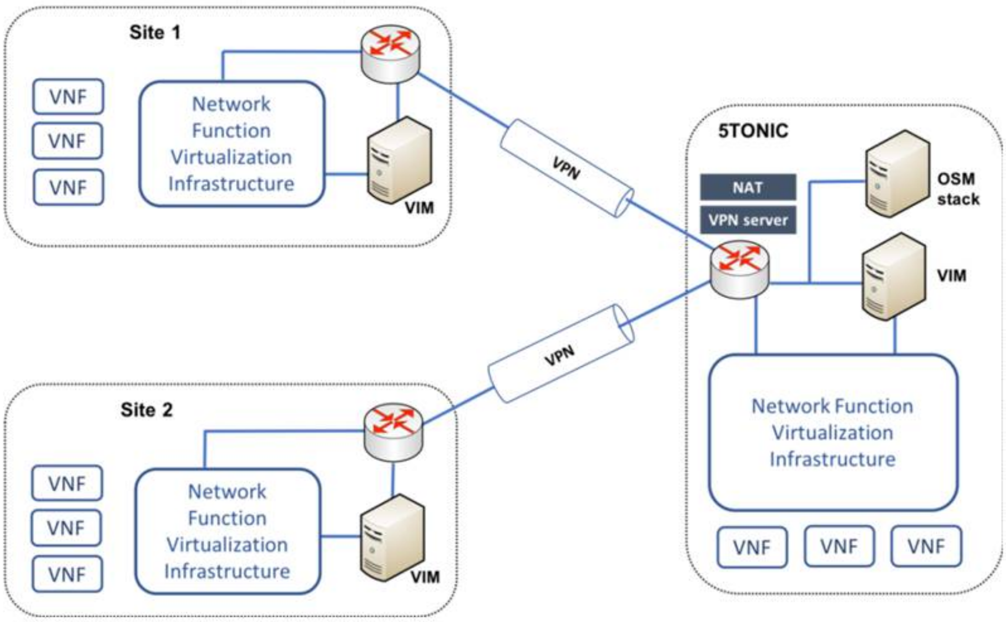

Figure 25: 5TONIC orchestrator managing local and external infrastructures

The utilization of several separate VIMs will allow allocating experiments to different separate NFV infrastructures. On the one hand, the laboratory will include a dedicated NFVI that will be allocated to experimentation activities within 5G-VINNI and based in the current deployment of the 5GinIRE and 5G-TRANSFORMER projects. This infrastructure will consist of a set of three server computers, each with six cores, 32GB of memory, 2TB NLSAS and a network card with four GbE ports and DPDK support. These servers will be interconnected by a GbE data-plane switch. On the other hand, the 5TONIC laboratory will also offer a second NFVI for experimentation, based on two high-profile servers, each equipped with eight cores in a NUMA architecture, 128GB RDIMM RAM, 4TB SAS and eight 10Gbps Ethernet optical transceivers with SR-IOV capabilities. These servers are currently interconnected in the data plane by a 24-port 10Gbps Ethernet switch. This specific infrastructure will be available for experimentation in 5G-VINNI under specific terms and conditions. Finally, the experimentation infrastructure offered to 5G-VINNI includes a number of server computers (not shown in the figure) to support complementary functionalities, such as aiding experimentation (e.g. hosting client applications), deploying a network management system, performing access-control functionalities, storing data (e.g. disk backups, VM images or code), etc.

Last but not least, a relevant feature of the deployed MANO platform is that it would be feasible to extend the experimentation infrastructure offered by 5G-VINNI with the public cloud support available in OSM since Release TWO.

4.3.4 Service Orchestration

5G-VINNI will take benefit of the two current developments on service orchestration already deployed in 5TONIC from the projects 5GinFIRE [21] and 5G-TRANSFORMER [22]

There is currently available for 5G-VINNI a full deployment of the service orchestration solution developed under the 5GinFIRE project.

4.3.5 Edge Site

There are evaluation experiments ongoing for the integration in 5G-VINNI of the Intel/Saguna solutions for Edge/MEC use cases. Saguna is cooperating with 5TONIC members Ericsson, CommScope, and Intel, as well as 5TONIC collaborator ASTI Mobile Robotics, in the implementation of a series of tests demonstrating the use of 5G technology to drive AGVs around large factories. This approach eliminates the need for pre-set routes or tracks.

4.3.6 Security

This setup allows the deployment and/or testing of different NFV/SDN domains, multi-layer control & orchestration, multi-tenancy NFV/SDN and multi-vendor NFV/SDN. Secure external access, both for control and for distributed inter-site connection is also provided via VPN gateways.

5TONIC supports a set of interconnection mechanisms that are used for the management of the internal communications in 5TONIC premises, the secure connectivity with the Internet and the interaction with external sites. The security infrastructure is based on the deployment of IPsec-based VPNs.

This infrastructure has been recently enhanced with the deployment of a firewall FortiGate 501E that provides: Firewall performance for IPv4/IPv6, SCTP and multicast traffic with ultra-low latency down to 2 microseconds; VPN, CAPWAP and IP tunnel acceleration; Anomaly-based intrusion prevention, checksum offload and packet defragmentation; Traffic shaping and priority queuing.

4.4 Facility-site: Greece

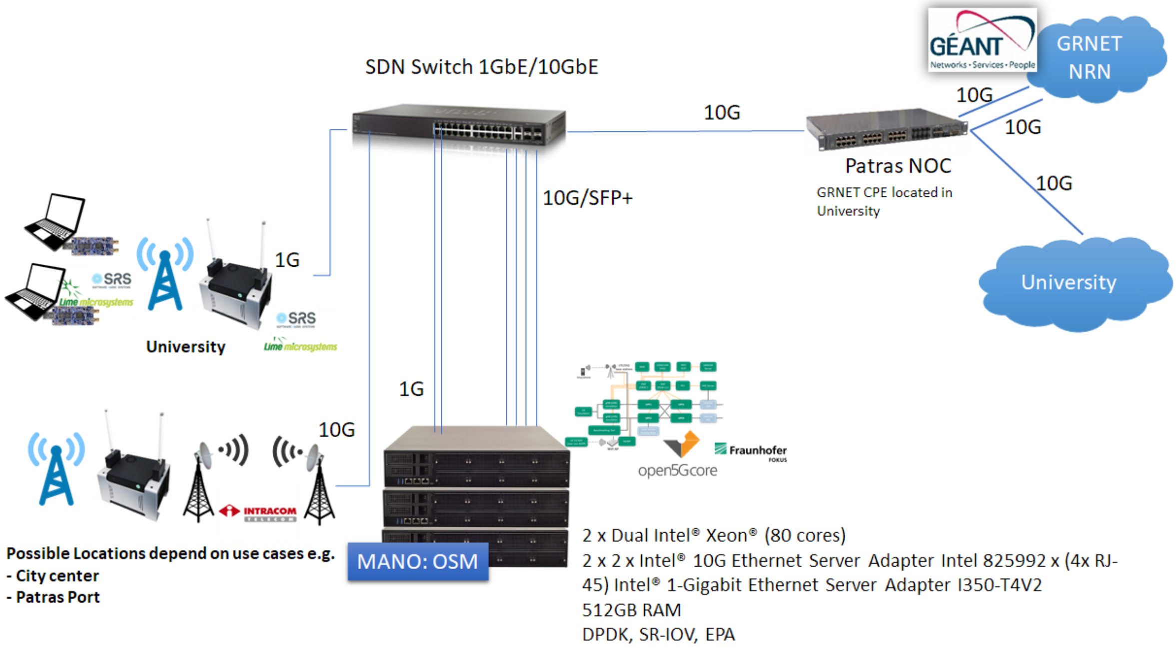

Figure 26: Patras Facility-site end-to-end design

Figure 26 displays a high-level view of the Patras Facility-site end-to-end design including all the necessary components. Next sections provide a description of these components.

4.4.1 Transport Network

The transport network that will connect the RAN with the Core in the Patras Facility-site, will consist of the following connections:

- The Facility will be interconnected via a dedicated 10 Gb link with GRNET NRN in Athens that will allow high speed connectivity to public Internet but also to dedicated GEANT links or VPN connections with other 5G-VINNI sites.
- Point-to-Point mmWave wireless links, operating at 71-76/81-86 GHz and delivering up to 10 Gbps, will interconnect the University campus with selected sites several kilometres away, backhauling the gNBs and FWA that will serve public places in Patras sub-urban area.
- Fixed Wireless Access (FWA) links at 26/28 GHz bands, providing up to 1 Gigabit Ethernet to the subscriber and up to 1.6 Gbps aggregate capacity per sector, will interconnect two buildings of public interest in Patras sub-urban area, providing access to 5G-VINNI core network services.

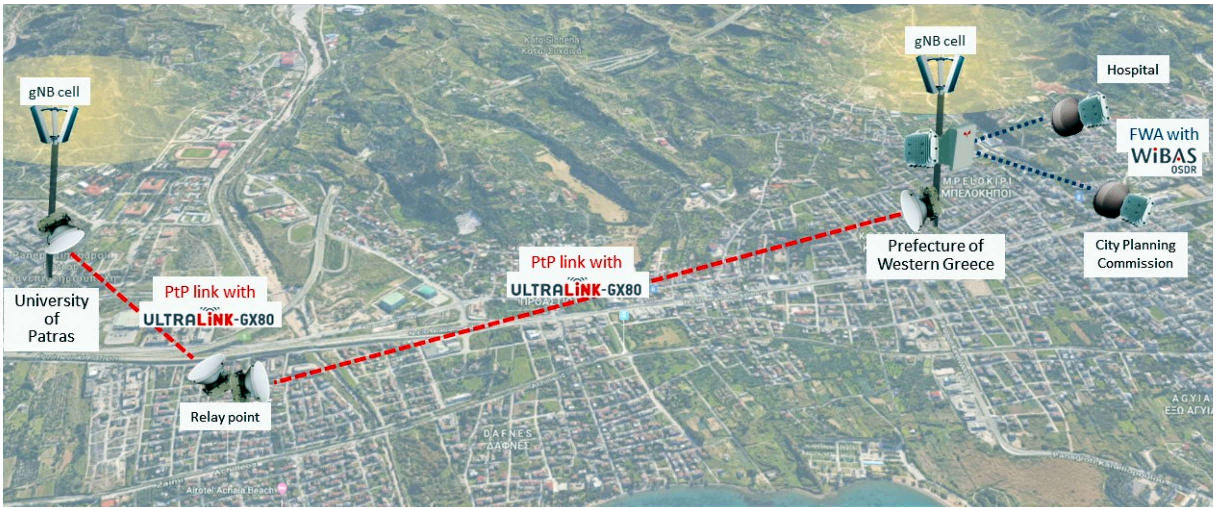

Figure 27: FWA and Backhaul Networks at Patras Facility-site

Figure 28: Illustration from Radio Planning for FWA Network at Patras Facility-site

Detailed radio planning studies has been performed to identify the optimum locations, the appropriate equipment and its configuration, to provide high-speed fixed wireless access to two public services establishments, and to cover this, along with a collocated gNB, with high capacity, low latency, long range backhaul. The results of these studies are listed in the LLD of the Facility.

4.4.2 5G RAN and Core

Figure 26 displays the Facility-site topology. The RAN section of the Patras Facility will comprise both an indoor and outdoor testbed. The indoor testbed will be primarily utilized for short-distance RF link experiments using low power SDRs. This more controlled environment is ideal for prototyping and more preliminary experimentation, before placing the radio nodes in the field. The outdoor testbed will, in turn, be mainly focused on long-distance experiments with network topologies that better match those observed in real-world RANs. The Patras Facility obtained a license for outdoor experimentation in the 3.6 GHz band.

4.4.2.1 5G RAN

LimeNET Mini is based on Mini-PC Barebone (BRIX) platform complete with an integrated LimeSDR USB with added shielding.

The hardware is fully qualified for compatibility with the LimeNET Ubuntu app store. This allows Patras University and project partners to create and deploy applications to configure the system for 5G applications with no system compatibility issues. Below is the picture of the LimeNET Mini.

Figure 29: LimeNET Mini

LimeNET Base station is a software defined radio power house. It is based on top of the line PC fitted with the newly developed LimeSDR QPCIe board. This new board is a much more sophisticated version of the LimeSDR board used in LimeNET Mini. It has two LMS7002 transceiver chips instead of one, which allows for a 4x4 MIMO configuration instead of a 2x2 MIMO configuration.

Figure 30: LimeNET Base station

SRS solution and capabilities

SRS primary role consists of setting up the software side of the Patras RAN Facility. This will include deploying a 4G software-defined network using the currently available open-source srsUE, srseNB and srsEPC products, and designing and implementing new 5G NR solutions. The latter effort will span the duration of the whole project. Next, we list the several solutions SRS plans to make available and accessible in the Patras Facility by the final release of 5G-VINNI:

- srsUEs - software-defined LTE UEs, capable of performing 2x2 MIMO, carrier aggregation, multicast, and handover. The srsUE will be available in the outdoor and indoor testbeds. In the outdoor testbed, it will run on LimeNET mini boards equipped with power amplifiers to sustain long distance connections. In the indoor testbed, the srsUEs will run on LimeSDR minis, with all the baseband processing performed in a laptop.

- srseNB - software-defined LTE eNB. The srseNB is currently capable of performing MIMO, multicast, and different scheduling algorithms. It will run on a LimeNET Base Station in the Patras outdoor testbed, and on a Lime SDR mini connected to a laptop in the indoor testbed.
- srsgUE - software-defined Non-Standalone (NSA) gUE, including the 5G NR PHY and upper layers. It is currently in a stage of early development.
- srsgNB - software-defined Non-Standalone (NSA) gNB, including the 5G NR PHY and upper layers. It is currently in a stage of early development.

4.4.2.2 Core

The 5G Mobile Core is realized by the deployment of Fraunhofer FOKUS' Open5GCore. Open5GCore is a use case-agnostic, standard compliant software-only prototype, implementing the 5G Core components and interfaces, addressing the use cases of seamless mobile broadband connectivity, multimedia and content delivery and massive IoT.

For more details on Open5GCore please refer to the Berlin Facility-site description of this chapter.

4.4.3 MANO and NFVI

4.4.3.1 MANO

The Patras Facility uses currently OSM FOUR but will migrate to Open Source MANO version FIVE with OSM FIVE VNFM support

Open Source MANO (OSM) is an ETSI-hosted open source community delivering a production-quality MANO stack for NFV, capable of consuming openly published information models, available to everyone, suitable for all VNFs, operationally significant and VIM-independent. OSM is aligned to NFV ISG information models while providing first-hand feedback based on its implementation experience.

4.4.3.2 NFVI

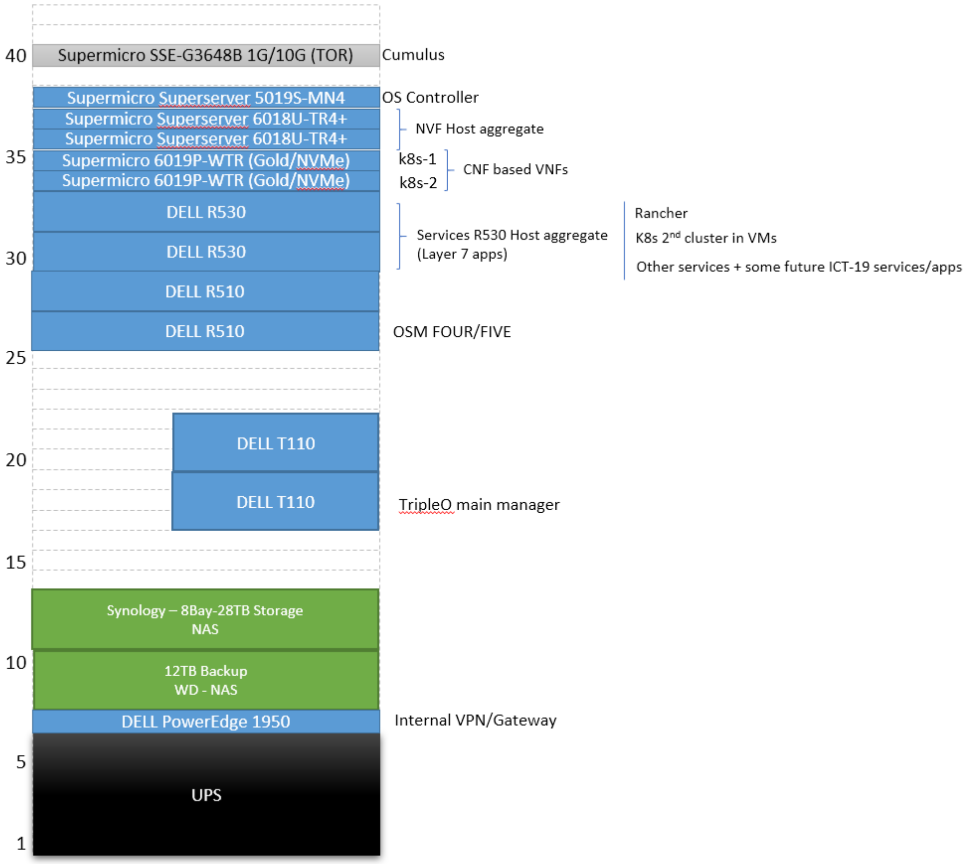

Figure 31: NFVI deployment

The UoP NFVI solution is based on ETSI reference model.

For 5G-VINNI initially 2 SuperMicro super servers Nodes each of 2 x Dual Intel® Xeon® and 2x10GB intel cards will be available

At a later stage 2 more SuperMicro super servers Nodes each with 1 Inter Xeon Gold Scalable processor and 2x10GB intel cards will be available, with NVMe storage dedicated for Cloud Native VNFs.

DELL R530, R510 servers are used for hosting the OpenStack Controller, Kubernetes Master and OSM

White box switches are used with Cumulus Linux installed.

Tungsten Fabric (previous OpenContrail) is planned to be used as virtual networking platform (SDN) that works with a variety of virtual machine and container orchestrators and can integrate with physical networking and compute infrastructure.

NAGIOS is used to monitor the services and nodes status

4.4.4 Service Orchestration

A first approach towards this is to use the existing work from 5GinFIRE project [21] and mainly integrate for the Release 1 the 5GinFIRE portal to deploy NSs.

The approach considers the following high-level requirements and ambitions:

- Adopt and being interoperable with current Cloud/SDN/NFV/MEC standards

- Use open standards and integrate technologically mature, and widespread open source toolsets
- Put effort to enable experimentation and make it effortless for experimenters to deploy experimentation scenarios
- Being interoperable with standards and other 5G facilities
- Adopt Open Source technologies that are embraced also by industry, like Open Source MANO
- Consider the multi domain nature of the Facility
- Scheduling of various Network Service orchestrations
- Automation of all processes that pertain the 5GinFIRe operations
- Consider the Long-term evolution of components

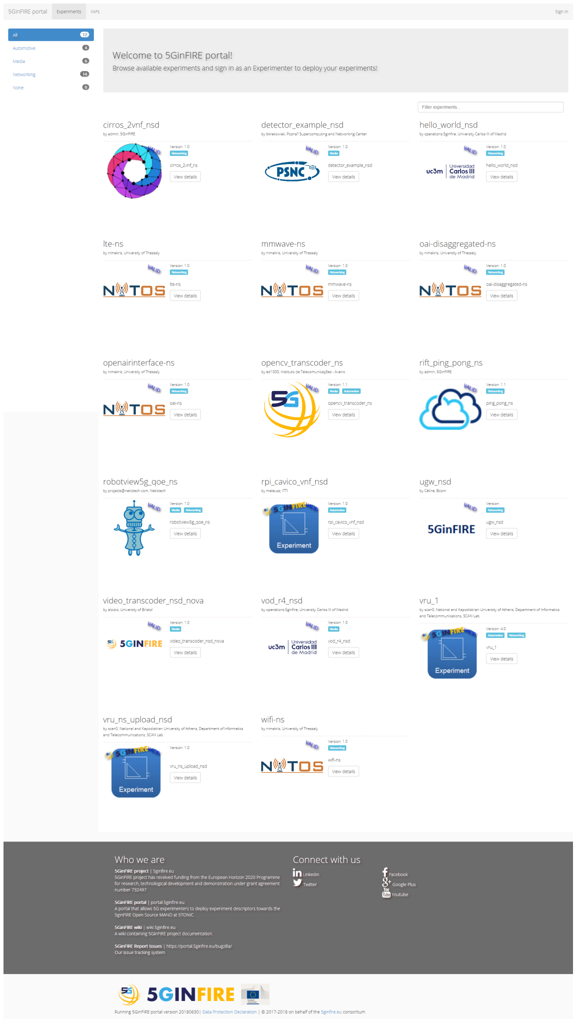

Figure 32: Portal Screenshot of 5GinFIRE of available NSDs adopted for Greek Facility

Figure above displays a screenshot of the portal and potential available NSDs. Some of the supporting Processes of the portal are: VNF Lifecycle managements, NSD/Experiment Lifecycle and Experiment Deployment Requests. It also able to manage artefacts like: Users, VNFs/NSDs catalog, NFVO endpoints via OSM NBI and Deployment requests.

Finally, there are various Integration with several microservices like: Various OSM versions, Issue management System, CI service, Policy Engine, Authentication services and Infrastructure Healthcheck & CentralLog

Within 5GinFIRE some of the core functionalities that facilitate the LCM of various artefacts have been defined. For example:

- Management of VNFs, NSDs, users, infrastructures and experiments in portal
- Maintain a reusable public catalog of VNFs and NSDs together with versioning, licensing, etc
- Description and availability of experimentation resources
- Onboarding/Offboarding VNFs/NSDs to multiple MANOs
- Validation of VNFs, NSDs
- VNFs Images management: These repositories contain the VNF images that need to be deployed in target VIMs
- Experimentation scheduling and deployment requests as well VNF placement to multiple VIMs for distributed Network Services

Next figure displays the architecture of the portal solution that will be used in the Facility.

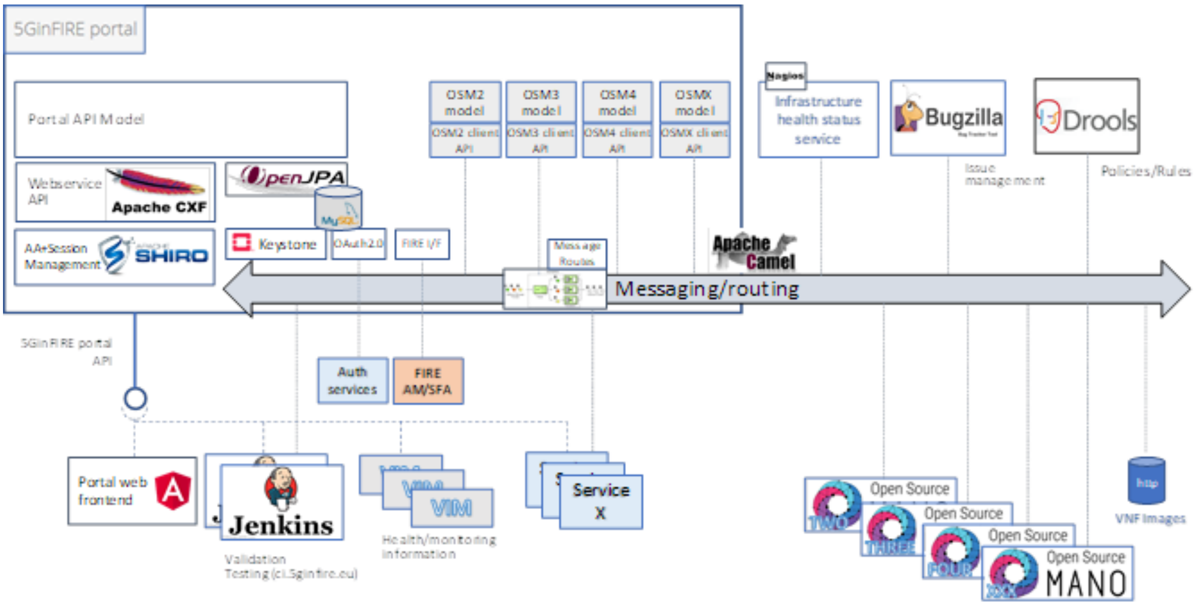

Figure 33: Portal architecture

4.4.5 Edge Site

Edge site is planned for Rel-1. The decision on location is not yet decided and will depend on requirements of the funded ICT-19 projects.

Nevertheless, the Edge site will be included with one of the solutions presented in next figure: Either the Edge site compute nodes will be managed by OpenStack, or the Edge site will be seen as its own VIM, handled as a multiVIM scenario by OSM deployed at Patras Facility-site

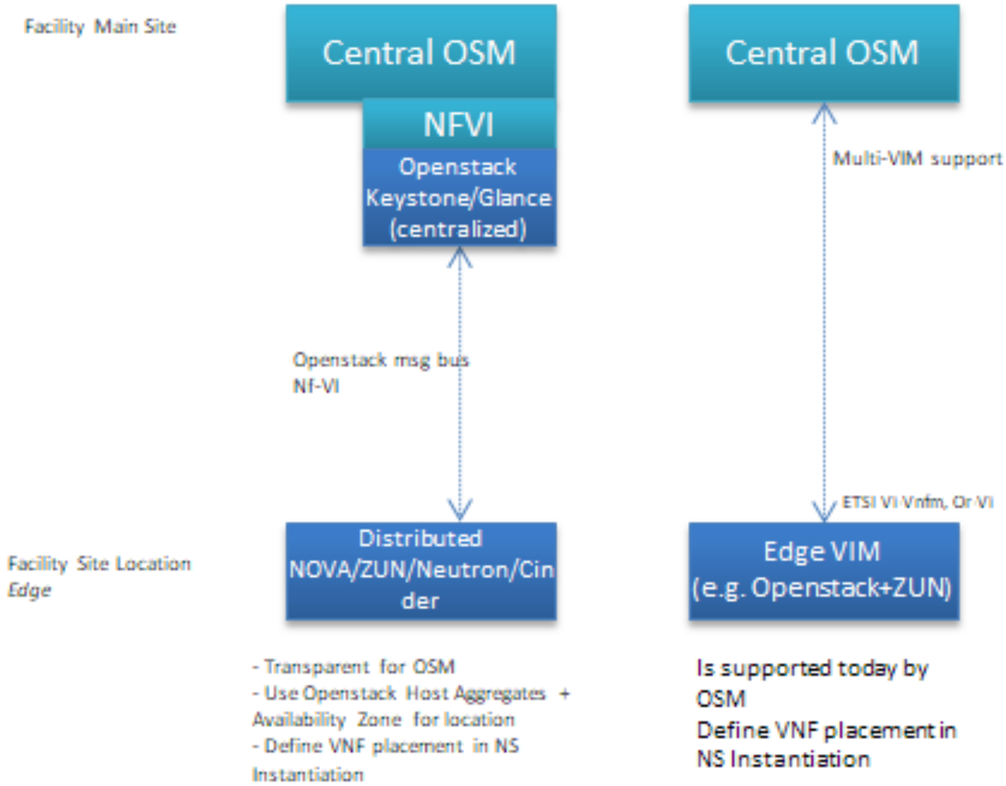

Figure 34: Edge Compute site in Patras Facility

4.4.6 Security

All Patras Facility infrastructure will have its own private network. The NFVI infrastructure is behind a firewall with restricted access to Internet allowed only to specific services.

4.5 Facility-site: Portugal

The Portugal experimental Facility-site will be hosted by Altice Labs in Aveiro. The figure below provides an overview of the Portugal Facility-site and the main technology components used in each segment. A detailed description of individual components is provided in the following sub-sections.

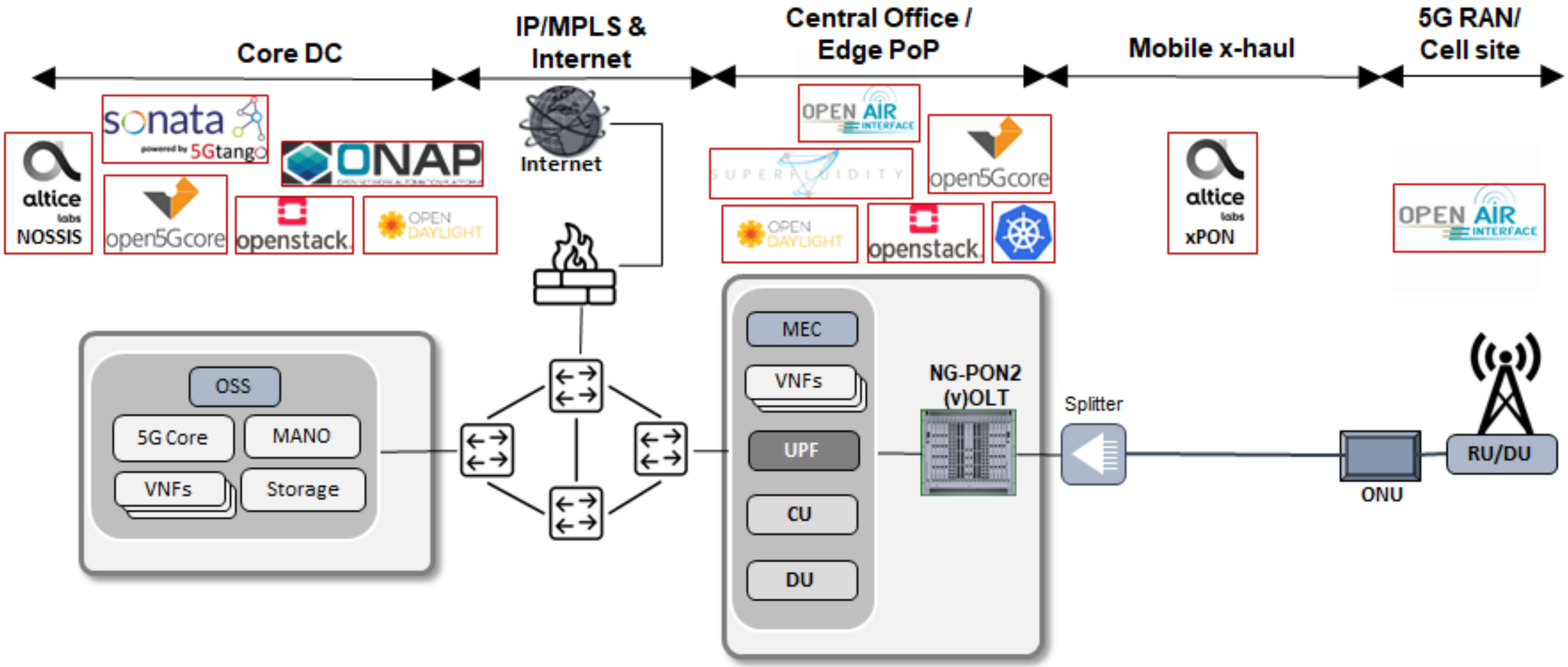

Figure 35: Portugal Facility-site components and supporting technologies

From a physical perspective, the Facility-site infrastructure will be hosted in two sites - Altice Labs and Institute of Telecommunications (IT) [11], both located in the city of Aveiro and both involved in other 5G-related initiatives. The figure below illustrates the physical location of the edge, core, MANO and OSS components of the site. Both Altice Labs and IT-Aveiro will host edge PoPs. Altice Labs will host the 5G core, as well as the MANO and OSS components. IT -Aveiro will host a second instance of the 5G core if required for specific scenarios or to address specific use case requirements (e.g. multi-domain, redundancy, resource migration).

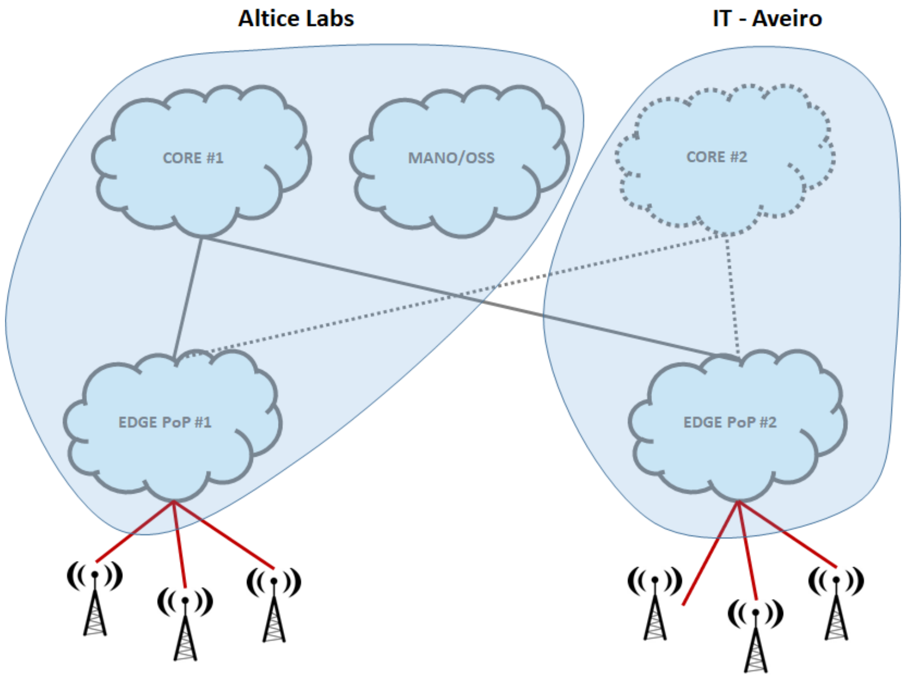

Figure 36: Portugal Facility-site physical location

4.5.1 Transport Network

The fronthaul, midhaul and backhaul infrastructure of the Aveiro Facility-site will be based on a FFTx network, composed of Altice Labs NG-PON2 OLTs and ONUs.

The next figure depicts the overall network architecture, including the transport network. Altice Labs NG-PON2 solutions will enable several distinct scenarios. As depicted on the figure, the NG-PON2 systems support Backhaul, Midhaul and Fronthaul use cases.

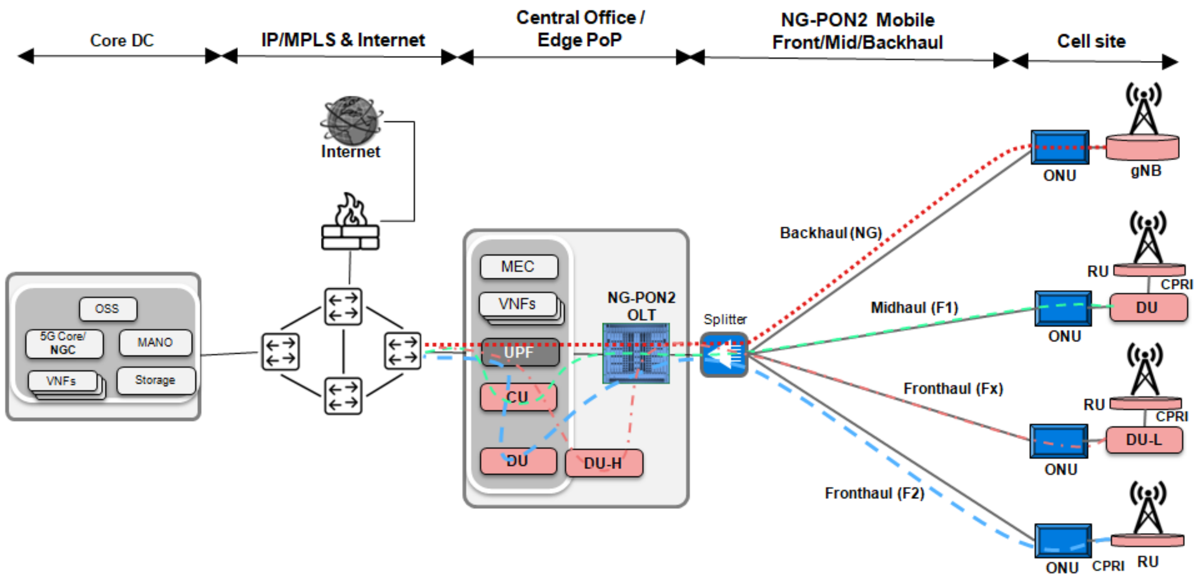

Figure 37: Portugal Facility-site transport network options

The backhaul scenario, the simplest and the least demanding scenario, will be available for Rel-1. In this scenario, the complete gNodeB is connected to the NGPON2 ONU and the PON provides connectivity towards the 5G Core.

In addition to Backhaul, two other scenarios, Midhaul and Fronthaul, are planned to be available beyond Rel-1.

On the Midhaul scenario, the CU (Central Unit) is located on the OLT uplink and the DU (Distributed Unit) and RU (Remote/Radio Unit) are connected on the ONU side. On this scenario, the NGPON2 is used for the F1 interface between CU and DU. Altice Labs is developing a hardware and software solution to support this use case, based on OAI (Open Air Interface), which is planned to be integrated with the 5G-VINNI test site.

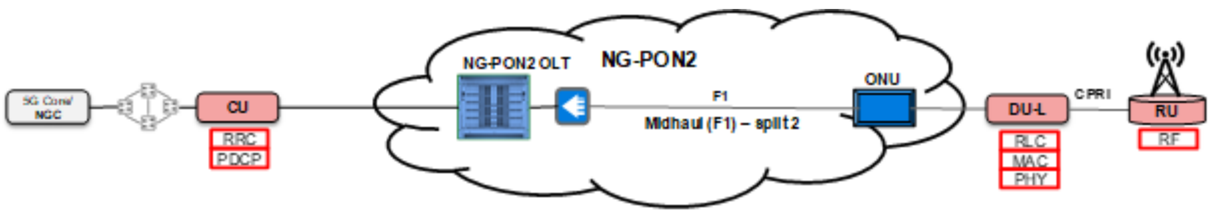

Figure 38: Midhaul scenario

The midhaul transport, obtained with split 2, exposes the F1 interface, whose traffic is transported over the NG-PON2 infrastructure. This solution puts the CU on the OLT side and the DU on the ONU side of the NG-PON2 network. The F1 interface is a standardized interface, which potentially allows interworking between solutions from different vendors.

Within this option, Altice Labs is seeking the development of two different access elements. One that combines the ONU, the DU and the RU, making it an all-in-one 5G Small Cell ONU and another that binds the ONU with the DU, exposing a CPRI interface to other vendors RUs.

Finally, Fronthaul support over NGPON2 infrastructure is also possible. In this case, the CU is located on the OLT side, the RU is located on the ONU side and the DU is split into DU-H (DU High) and DU-L (DU Low). DU-H is collocated with the CU and DU-L is collocated with the RU. Several options exist to do this split of the DU. Altice Labs is evaluating the possibility to develop such a solution (out of the scope of 5G-VINNI). If available on time, this solution will also be tested and validated on the 5G-VINNI infrastructure.

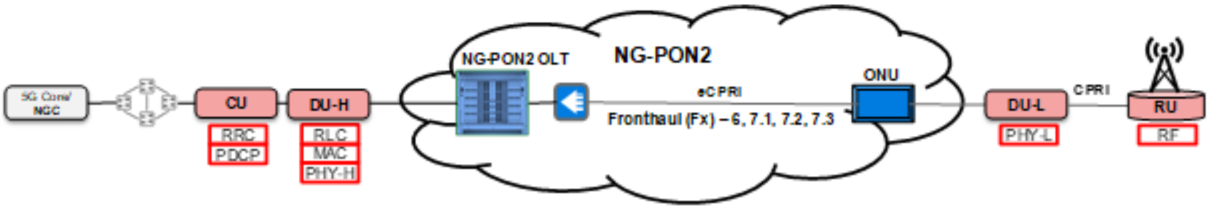

Figure 39: Fronthaul scenario

With respect to Fronthaul, there are still some doubts on what the most viable split in order is to achieve the best compromise between radio characteristics (CoMP, MIMO, Digital Beam Forming) and network features demand (delay, synchronization, used bandwidth). Nowadays, there is a trend between some vendors to go for Split 6. Altice Labs is developing hardware solutions (out of the scope of 5G-VINNI), combining DU-L with the NG-PON2 ONU that will allow any of most promising splitting options (6, 7.1, 7.2 and 7.3).

4.5.2 5G RAN and Core

4.5.3 5G RAN

The starting point of the RAN component of the Aveiro experimental Facility-site is based on OpenAirInterface (OAI) and leverages on the local 4G-based infrastructure currently being used in the framework of the H2020 Slicenet project [4], already in place at Altice Labs. Currently supporting 4G radio, the OAI roadmap includes the support of 5G in the near future. OAI is designed to be agnostic to the hardware radio frequency (RF) platforms. It can be interfaced with 3rd party Software-Defined Radio (SDR) RF platforms without significant effort. At present, OAI officially supports the following hardware platforms [5]:

- EURECOM EXMIMO2: This board, developed by Eurecom, features four high-quality RF chipsets from Lime Micro Systems (LMS6002), which are LTE-grade MIMO RF front-ends for small cell eNBs. It supports stand-alone operation at low-power levels (maximum 0 dBm transmit power per channel without any power amplifier) simply by connecting an antenna to the board. RF equipment can be configured for both TDD and FDD operation with channel bandwidths up to 20 MHz covering a very large part of the available RF spectrum (250 MHz-3.8 GHz) and a subset of LTE MIMO transmission modes.
- USRP X-series/B-Series: Ettus USRP B-series and X-series products, supported by OAI via Ettus UHD Driver (USB3 and Ethernet).
- LIMESDR: Lime Micro Systems SDR board that is supported by OAI via the Lime USB3 driver.
- BladeRF: Nuand SDR board that is also supported by OAI via the bladeRF USB3 driver.

The USRP model deployed in the lab is the Ettus B210 [6], which provides a fully integrated, single-board USRP platform with continuous frequency coverage from 70 MHz – 6 GHz. The figure below provides an overview of the hardware currently used in the lab, including the eNB, the USRP and the antenna. The Moxa OnCell G3150A-LTE serial/Ethernet-to-cellular gateway [7] is currently used to provide 4G cellular connectivity to local Ethernet networks.

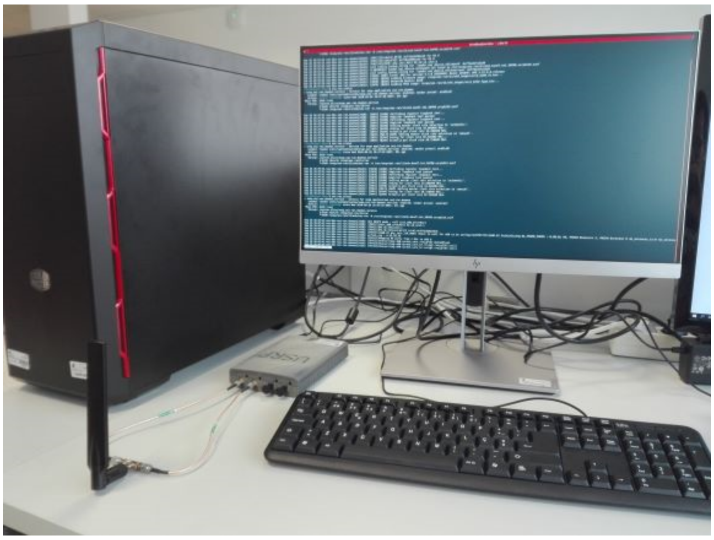

Figure 40: OAI lab hardware components (eNB, USRP, antenna)

The OAI evolution roadmap towards 5G NR, both for gNB and the UE, is described in [8] and provided in Annex A.5.

The 5G RAN component of the Aveiro Facility-site will initially use the 3.6 GHz band (100 MHz) and later will be expanded to other frequency bands, depending on the outcome of the 5G spectrum auction (not expected before June/2020), or temporary availability of spectrum for testing and demonstration purposes.

4.5.4 5G Core

The 5G Core component of the Portugal Facility-site will be based on Fraunhofer FOKUS Open5GCore toolkit [20]. The target for Facility release 1 will be the deployment of the 5G Core compliant with 3GPP release 15, integrated with 5G NR and support for 5G interfaces (e.g. N1, N2, N3, N4) and the fundamental 5G core network components (e.g. AMF, SMF, UPF).

For more details on Open5GCore please refer to the Berlin Facility-site description.

4.5.5 MANO and NFVI

4.5.5.1 NFVI

The ALB site can offer the following infrastructure resources:

- an OpenStack VIM running on one Controller Node and two Compute Nodes, appropriate to act as the Core site
- an OpenStack VIM running on a single machine, aka ‘all-in-one’ configuration, appropriate to act as an Edge site. A second Edge site is available at ‘IT Aveiro’
- a Kubernetes VIM running on five bare metal blade servers, two master nodes and three worker nodes
- one Opendaylight SDN Controller running on a dedicated bare metal blade server

The generic ALB’s NFVI can be used by any MANO framework if the connectivity is established, and the right credentials are provided.

The NFV Orchestrator part of the MANO, based on SONATA as described in the following section, contains built-in plugins to connect to an OpenStack and Kubernetes VIM. Considering its modular architecture, other plugins can be developed to add other VIM types.

Figure 41 shows the SONATA coverage of ETSI Reference Model.

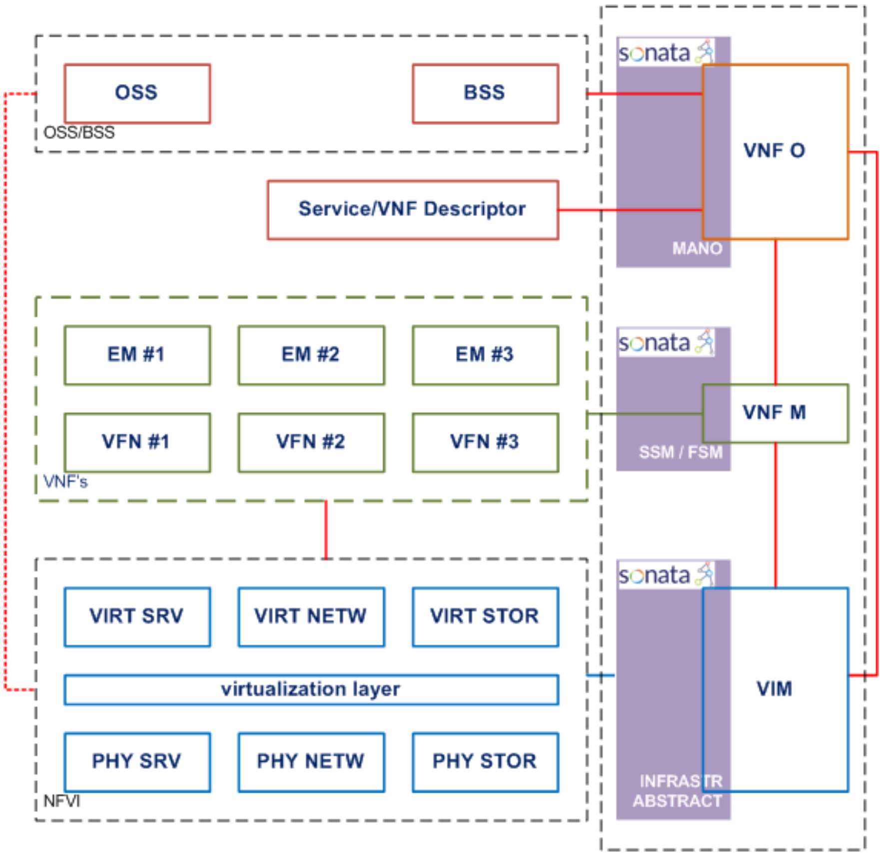

Figure 41: SONATA relationship with the ETSI NFV reference model

4.5.5.2 MANO

The Management and Orchestration (MANO) will be provided by SONATA open source platform [9]. This tool was initially developed by the H2020 5G-PPP Phase 1 project with the same name - SONATA - and is currently under development in a Phase 2 project, 5GTANGO [10]. This tool compares very well with other well-known open source, such as ONAP or OSM in terms of supported features.

Figure 42 provides a high-level view of the SONATA MANO architecture and its components.

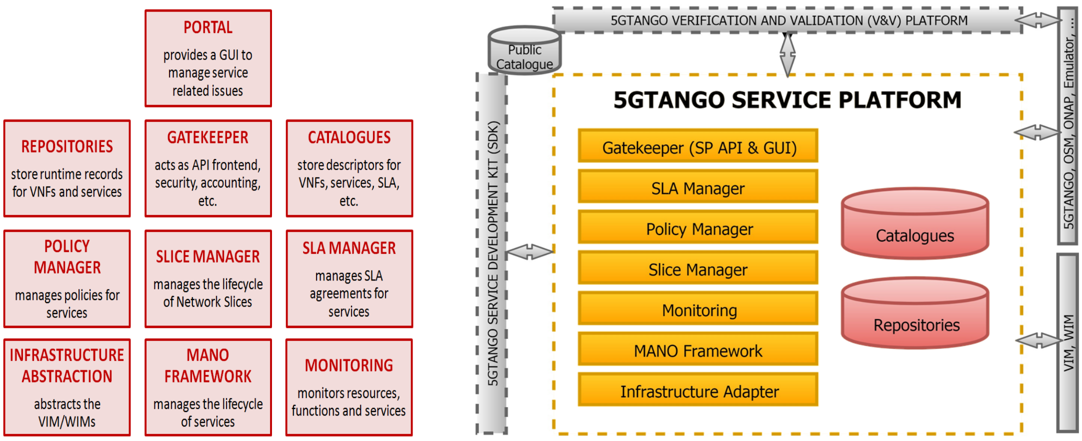

Figure 42: SONATA MANO Functional Description

Externally, the SONATA MANO may interact with VIMs/WIMs, with other orchestrators (hierarchical perspective), as well as with the V&V (Verification and Validation) platform, also part of SONATA. Internally, it composed by the components indicated in Figure 38, namely: MANO Framework, Infrastructure Abstraction, Monitoring, Policy Manager, SLA Manager, Catalogue, Repositories, Slice Manager, Gatekeeper and Portal. The former is the component responsible to provide a User Interface (UI) for SONATA. This UI allows the users to manage, in a simple manner, most of the assets available, like NSs, VNFs, Policies, SLAs, Slices, etc. Some other detailed features can be done via API, via Gatekeeper.

Further details on SONATA functionalities and internal components can be found in [16].

4.5.6 Service Orchestration

The Service Orchestration function will be performed by using the ONAP open source tool. For that, the ongoing work under development in the scope of the SLICENET project (5G-PPP Phase II) will be reused and further evolved. ONAP will be responsible for the end-to-end orchestration, namely:

- Receive customer service orders coming from BSS (business perspective), e.g. Order Management, and trigger the execution of specific processes, sequencing activities for the creation, modification and removal of a customer service;
- Manage the lifecycle of network slices, enabling the design, creation, modification and removal of slices on top of a cloud infrastructure, ensuring the proper customer isolation;
- Expose service orchestration capabilities to BSSs by using an API;
- Use NFV Orchestration (NFVO) APIs to manage the lifecycle of NFV artifacts (VNFs and NSs), as a way to build end-to-end network slices;

The ONAP high-level architecture (version Casablanca) is depicted in the Figure below. In particular, it shows the *Service Orchestration Project* box, which takes care of orchestration issues. The *Service Orchestration Project* implements the *Master Service Orchestration (MSO)* component, which is a general-purpose tool that can be used for orchestration functions at several levels (in this case, it will only be used for end-to-end service orchestration).

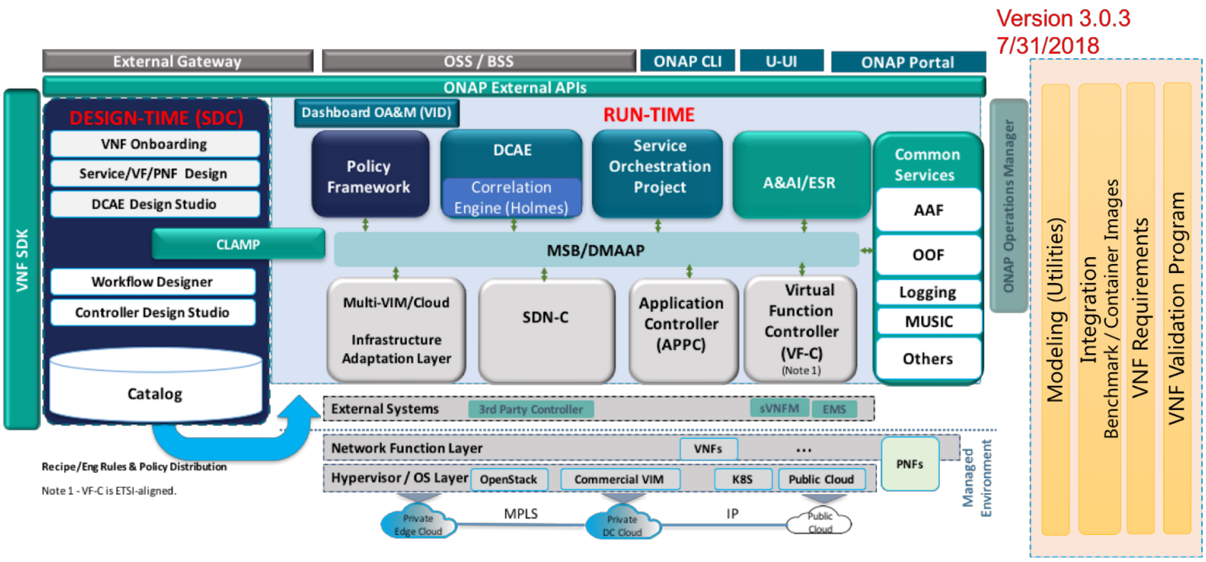

Figure 43: ONAP Casablanca (v3) Architecture

4.5.7 Edge Site

From Rel-1, two edge sites will be setup, located at IT-Aveiro and Altice Labs. Depending on use cases to be supported and requirements imposed by availability of infrastructure (e.g. location of the

NGPON-2 OLT), one of the edge sites may need to be deployed at the Altice Aveiro Central Office, but a decision has not been made yet.

The edge site will support the experimentation activities in the framework of the Edge Computing research item. This includes the evolution of current platform based on 4G “bump in the wire” approach and the integration with 5G architecture and components.

A detailed description of the edge site characteristics can be found in [16].

4.5.8 Security

Security should be seen on a holistic and integrated perspective. To cover this matter the following topics will be addressed: facilities access control, network security, platform security.

4.5.8.1 Infrastructure Security

The Core and Edge PoP are accommodated on premise at Altice Labs datacentre. These facilities are equipped with fire door, extinguishing system in case of fire, HAVAC with free-cooling system, two groups of UPS, two power transformation station and two independent fibre paths for WAN connectivity. These resources are supposed to provide enough resilience against physical or natural incidents.

The access to the datacentre interiors is controlled by a card reader that opens the door to a reduced group of authorized technicians.

4.5.8.2 Network Security

Being part of the corporate resources, both Pops are integrated on the corporate network security policies, namely at the firewall, IDS/IPS, Remote Access service and VLAN segregation level.

5G-VINNI partners are allowed to remotely connect to the Altice Labs PoP’s by establishing a VPN Remote Access session using a client that supports an SSL connection. Example of VPN Remote Access clients are:

- OpenVPN client – for Windows and Linux users
- Cisco AnyConnect VPN client – for Windows and Linux users

The partners are authenticated by Username and Password credentials on a specific URL.

This VPN group is authorized to access only the four provider subnets assigned to the 5G-VINNI project.

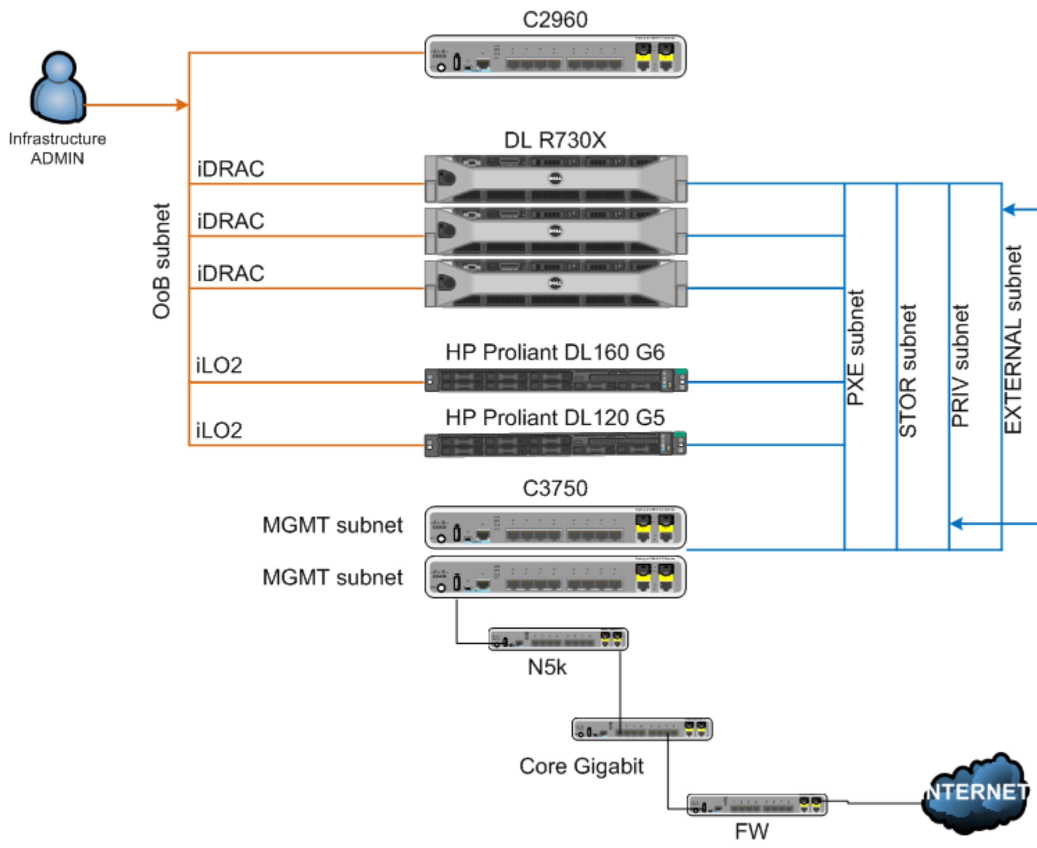

Figure 44: Altice Labs OpenStack Core network

4.5.8.3 Management and Orchestration Security

From the Management and Orchestration (MANO) perspective, security is an important aspect to consider, to ensure that the different artifacts (NSs, VNFs, Policies, SLAs, etc.) can only be managed by users allowed to that. For that purpose, SONATA supports the following security features:

- **APIs**: In SONATA, all operations can be invoked via APIs. APIs have mechanisms based on token technologies to ensure that only users authenticated and authorized can invoke a particular operation.
- **Packages:** In SONATA, NSs and VNFs are on-boarded (via APIs) by using single-file zipped packages, holding descriptors, images or other files inside. Packages are secured by using checksum integrity mechanisms, to ensure that a package is immutable and cannot be changed by any third party.
- **Portal**: In SONATA, the main operations can be performed using an intuitive Management Portal. This Portal is protected by a username/password-based login, supporting multiple roles (Developer, Operator and Customer) and tailoring the UI menus and options according to the provided credentials, enforcing the respective authentication and authorization rules. In addition, it runs over SSL/TLS (HTTPS) protocols, to ensure confidentiality.

4.6 Facility-site: Germany (Berlin)

The Berlin experimental Facility-site concentrates on the deployment of an end-to-end architecture comprising of a central node and potentially multiple nomadic/edge/remote nodes. A high-level overview of the Berlin Facility-site (Release 1) is shown in Figure 45 including only the main core components for the sake of simplicity. Both the central and edge nodes of the Berlin Facility-site are located at the Fraunhofer FOKUS premises and use FOCUS-developed software. A deployment of Open5GCore provides the 5G Core network functions. NF orchestration is achieved using Open Baton and service orchestration is done with the E2E Orchestrator. RAN components are either simulated or obtained from external sources (Release 1).

The deployment of edge nodes to physically remote locations is possible if the following conditions are met:

- availability of the deployment site - all permissions to deploy the nodes are acquired
- availability of the spectrum - a spectrum lease for experimental purposes is acquired
- electric power availability - the remote location requires a minimum of ~400W
- backhaul availability - any type of internet connectivity including satellite, best effort fixed networks or mobile subscriptions.

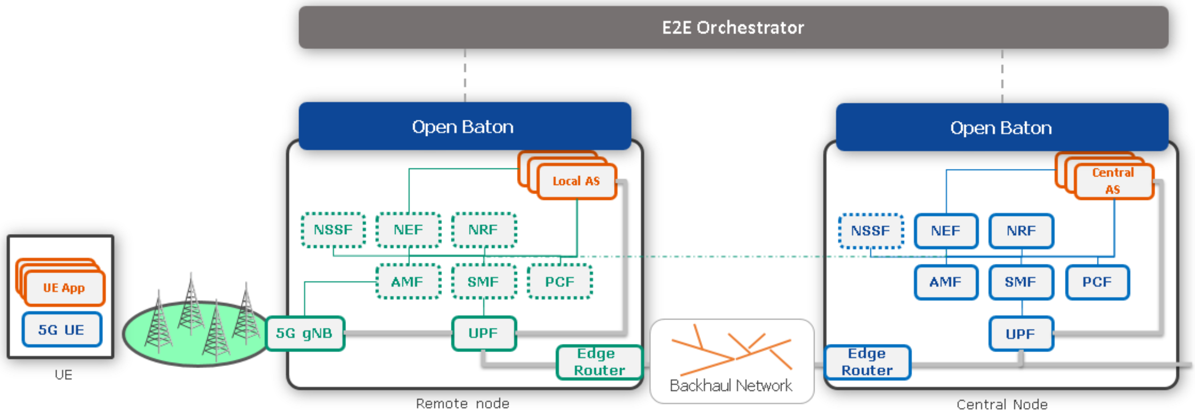

Figure 45: Overview of Berlin Facility-site (Rel-1)

4.6.1 Transport network

Internally, the central as well as the remote node, deployed on the Berlin Facility-site, are built over in-house physical networks together with virtualized network technologies and include an edge router, developed by Fraunhofer FOKUS, that enables backhaul selection. In this Facility-site, the transport networks experimented on between the central and edge nodes are best-effort internet and Over-the-Top wireless networks over German mobile network operator LTE. Experiments with satellite backhaul are described in the documents detailing the Luxemburg site.

4.6.2 5G RAN and Core

4.6.2.1 5G RAN

Simulated gNodeBs and 5G UEs will be used for testing the standard-conformance and performance of the 5G Core. In addition, macro-gNB base stations will provide RAN functionality. The acquisition process of these base stations is still ongoing and hence specifications are not included in this deliverable. The base stations are expected to be available for Release 1.

4.6.2.2 5G Core

The 5G Mobile Core (Figure 46) is realized by the deployment of Fraunhofer FOKUS' Open5GCore. Open5GCore is a use case-agnostic, standard compliant software-only prototype, implementing the 5G Core components and interfaces, addressing the use cases of seamless mobile broadband connectivity, multimedia and content delivery and massive IoT. In order to assure the connectivity to the 5G terrestrial network though the different backhauls, the core components are distributed between the central and edge nodes, the experimentation with different deployment models (examples in Figure 47) being one of the main purposes of the Berlin Facility-site.

The Open5GCore deployment in the Berlin Facility-site will include:

- A simulated gNB and a macro-gNB base station will be used on the central and/or the edge node depending on the core separation template.
- Simulated 5G UEs connecting to the simulated gNBs and UE devices capable of connecting to the macro-gNB base station.
- One AMF on the central node and depending on the core separation template and other AMF on the edge nodes.
- One SMF on the central node and depending on the core separation template and other SMF on the edge nodes.
- One AUSF on the central node and depending on the core separation template and other AUSFon the edge nodes.
- One UDM on the central node and depending on the core separation template and other UDM on the edge nodes.
- One NRF on the central node and depending on the core separation template and other NRF on the edge nodes.
- One PCF on the central node and depending on the core separation template and other PCF on the edge nodes.
- One NEF on the central node and depending on the core separation template and other NEF on the edge nodes.
- One NSSF on the central node and depending on the core separation template and other NSSF on the edge nodes.
- One to four UPFs on the central node and one on the edge nodes.

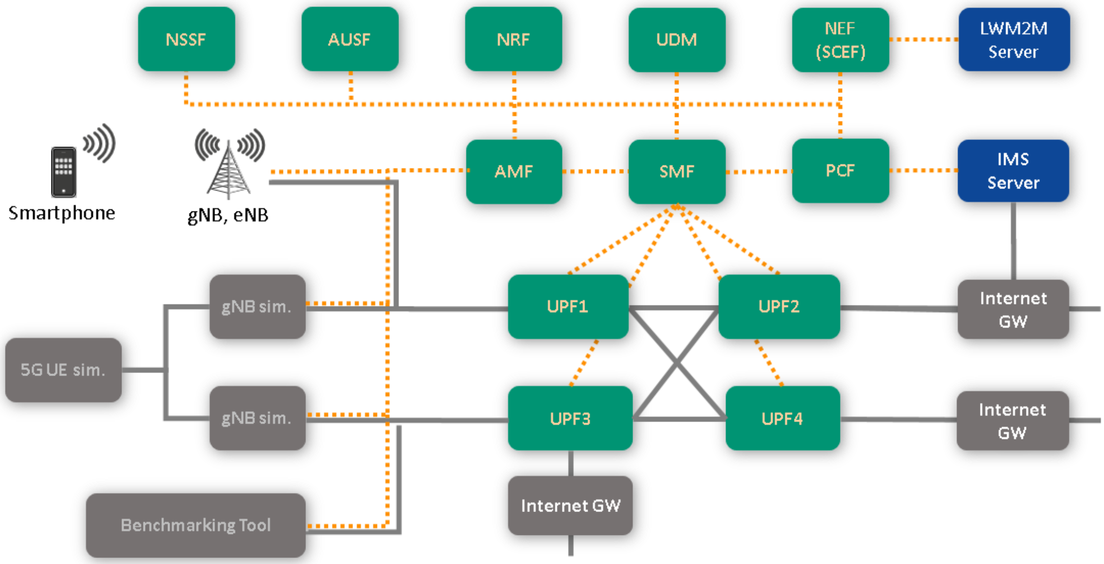

Figure 46: Release 1 core architecture

Open5GCore was designed to integrate 5G radio prototypes. With this, common devices may be used as well as new device prototypes as part of the validation process.

Open5GCore is designed for cloud and NFV deployments. It can be deployed using Open Baton as VMs on top of virtually any type of Linux OS and Linux-based VIMs (e.g. VMs, containers, namespaces, x64 or ARM based).

Furthermore, the Open5GCore is highly customizable for deployment of dedicated/private networks.

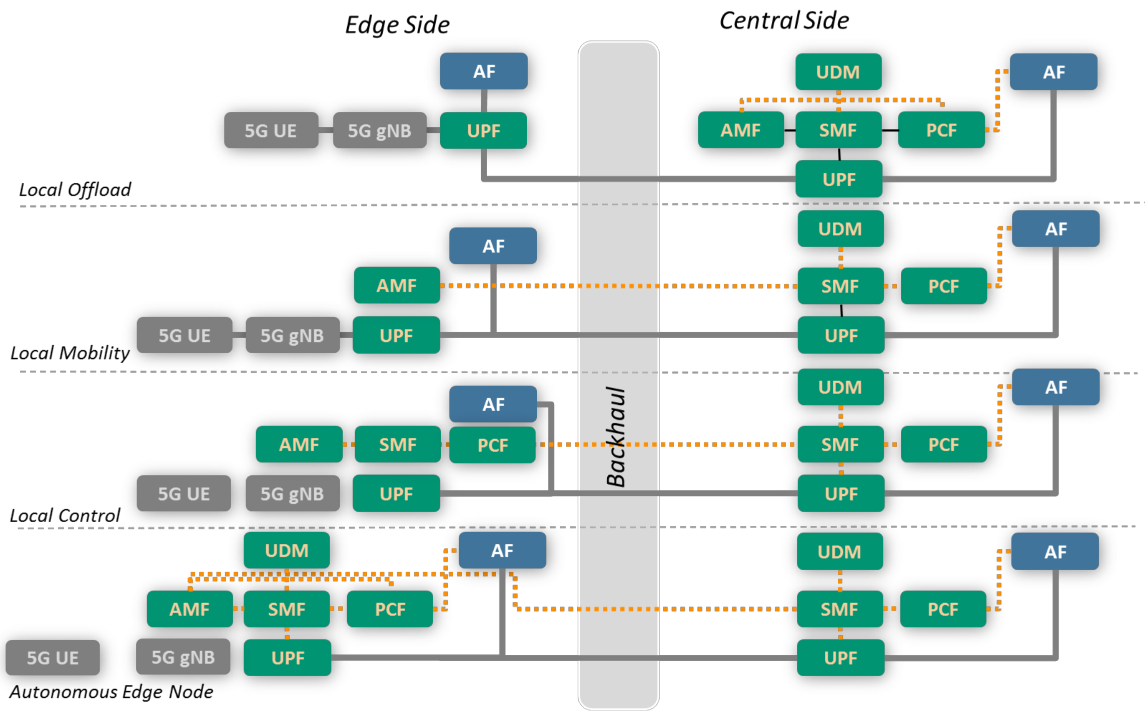

Figure 47: Example core separation models

4.6.3 MANO and NFVI

Open5GCore VNFs will be deployed using a mix of containers and virtual machines using OpenStack, orchestrated by Open Baton.

The main components that will be deployed in this site are:

- The Virtual Infrastructure Manager (VIM) will be OpenStack based, utilized by Open Baton (detailed below) through a VIM driver mechanism.
- The Virtual Network Function Managers (VNFM) deployed in this site is part of Open Baton.
- The Network Function Virtualization Orchestrator (NFVO) is the core of Open Baton
- On top of the NFVO there will be a Service Orchestrator provided by Fraunhofer.

Integration with orchestrators of other vendors is not planned as Berlin hosts an experimental Facility-site.

The hardware platform for 5G-VINNI is a server-chassis equipped with 3 blade-servers of:

- 2 x 2666 MHz 16-Core
- 256 GB DDR4-2133 MHz RDIMM RAM

4.6.3.1 Open Baton

Open Baton is an ETSI compliant opensource NFV MANO framework implemented and maintained by Fraunhofer FOKUS and TU Berlin. The main objective is to provide an extendible, opensource and standard framework capable of orchestrating VNFs on top of heterogeneous infrastructures. The main reason for an NFV-MANO platform to be designed accordingly to open and standard technologies is the possibility to facilitate the integration with other standard-based systems.

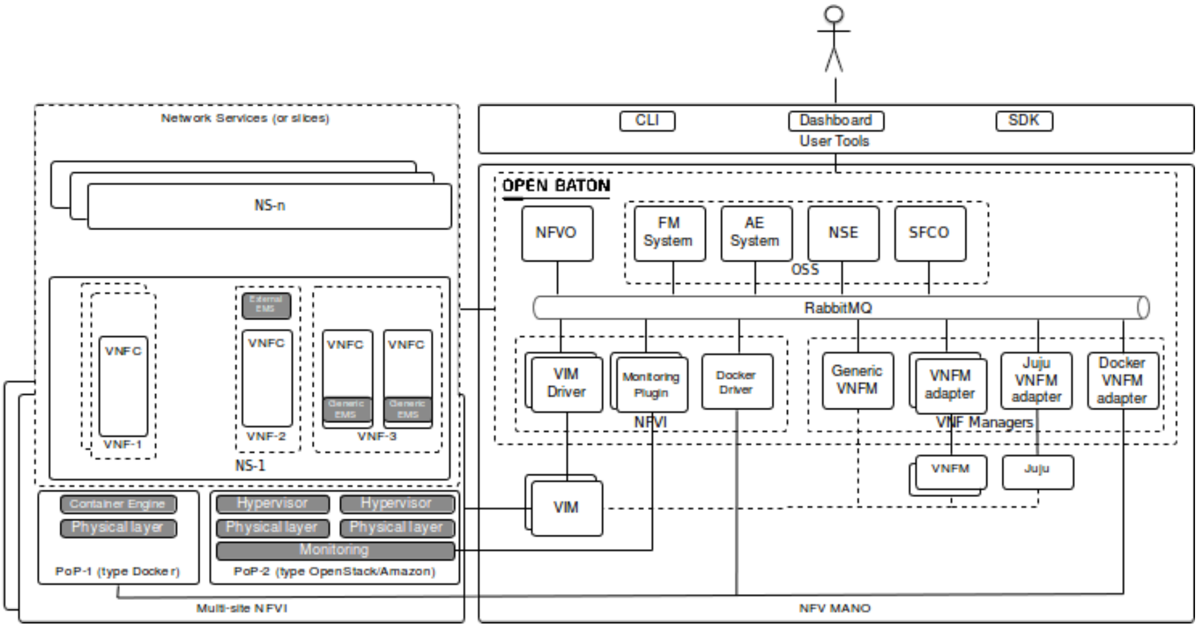

Figure 48: Open Baton Architecture

The implementation (figure above) follows the architecture defined by ETSI, which is included in the NFV specifications.

Open Baton provides a modular and extendible architecture where functionalities can be plugged in and out. Such modular architecture allows extending and customizing the framework for supporting any kind of use cases. Additionally, SDKs are provided in order to allow developers to focus on their business logic requirements without caring about the complexity of the communication, security or registration procedures.

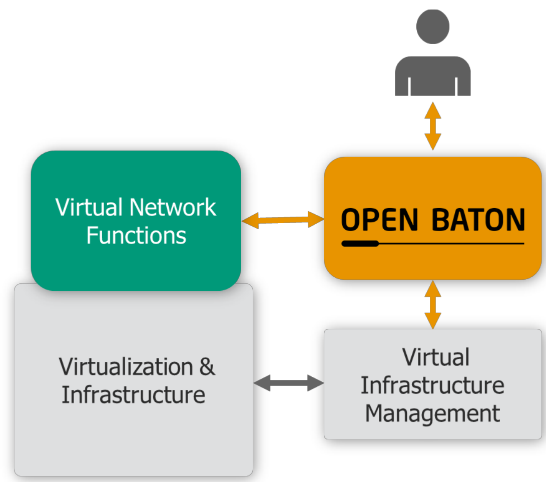

Figure 49: Open Baton interactions overview

The Open Baton framework is comprised by several components which communicate with a message bus. The Network Function Virtualization Orchestrator (NFVO) is the core component which maintains the overall overview of the entire system, running network services or available resources. In addition, the NFVO make use of the VNF Manager for the VNF lifecycle operations. The VNF Manager provided is called Generic VNFM because enables the management of any kind of VNFs using a lightweight Element Management System (EMS).

4.6.4 Service Orchestration

The service orchestration is handled by instances of the Open Baton NFVO. To encapsulate the deployments of the NFVOs to one common place and to provide the capability of deploying network services over multiple NFVO instances, the Fraunhofer FOKUS-developed End-to-end orchestrator is acting on a meta-orchestration level. It provides a northbound REST API so that users can upload and deploy network services and retrieve information about the deployment status. The E2E Orchestrator is connected to adapter components (e.g. the Open Baton adapter) via an interface that defines the possible remote procedure calls that the E2E Orchestrator can call on an adapter.

Note that the 5G-VINNI Standard Services refer only to the 5G-VINNI **Main** Facility-sites (Norway, UK, Spain, Greece), whereas the present Facility-site corresponds to a 5G-VINNI **Experimentation** Facility-site.

4.6.5 Edge Site

In the Berlin experimental Facility-site an edge node will be deployed internally, connecting to a central node, likewise deployed in-house for the purpose of local experimentation. The connection between the edge and central nodes will be realized through reliable in-house network, best-effort internet and over German MNO networks.

4.6.6 Security

For reliable tunneling mechanism that provides encryption and authentication OpenVPN with a testbed-specific PKI is used, as it provides adequate security, is open source, and is supported on many platforms. Additionally, it is less likely to run into problems with firewalls or other middleboxes in public or private networks compared to, for example, some IPsec implementations.

It may additionally be necessary to run secure tunnels through sites local networks without terminating them. This may be due to the security policies of the sites' networks or because deploying a tunnel endpoint is not logistically possible at a site. This may result in tunnels on top of tunnels and come at the cost of performance.

Given that the management of OpenVPN or similar security solution is done in an experimental context, it is additionally recommended that the testbed components run in DMZ-like isolated networks at the sites wherever possible.

4.7 Facility-site: Germany (Munich)

4.7.1 Transport Network

The RAN as well as the core networks are located within the same building at the Riesstr. 25 in Munich. Both networks will be connected via a wired Ethernet connection transport connection. Alternative connectivity using Fibre might be considered. The Core network will be running on top of virtualized infrastructure in the server room in E6. The use of a wired connection for layer 1 and 2 allows to run different virtual links and protocols for the higher layers. Therefore, it will be possible to create different virtual LANs on top of the transport network to deliver traffic for different use-cases or slices. Details of the architecture are presented in the next section.

4.7.2 5G RAN and Core

In this section we will explain the high-level design of the RAN and Core networks.

4.7.2.1 RAN

The RAN of the Munich Facility-site geographical structure is depicted in the map of the Figure below. The RAN site is located in the Riesstrasse 25 in Munich Germany and will be providing connectivity to the nearby streets and alleys. This will be a challenging surrounding due to the nature of the environment (due to trees/buildings, etc..).

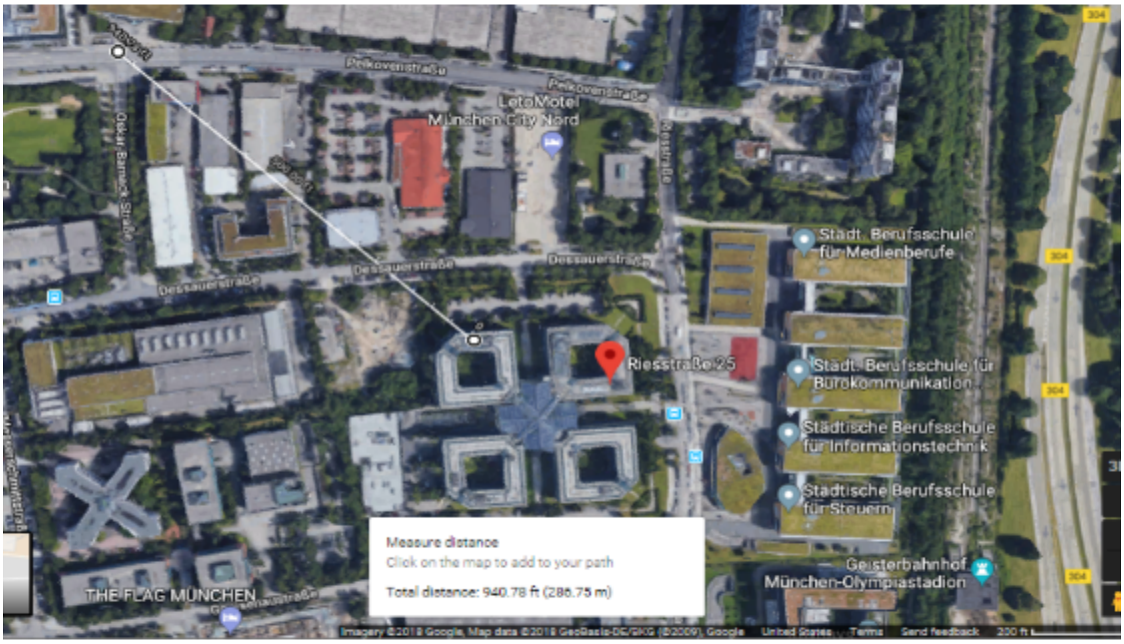

Figure 50: 5G Munich Facility-site

The setup of the RAN site and the interconnections are depicted in the above figure.

Moe technical details about the radio characteristics:

- Carrier Frequency: 3.4 GHz
- Bandwidth: 20 MHz
- Maximum UEs: 3
- Antenna gain: 12dBi
- TX power per antenna: 28dBm

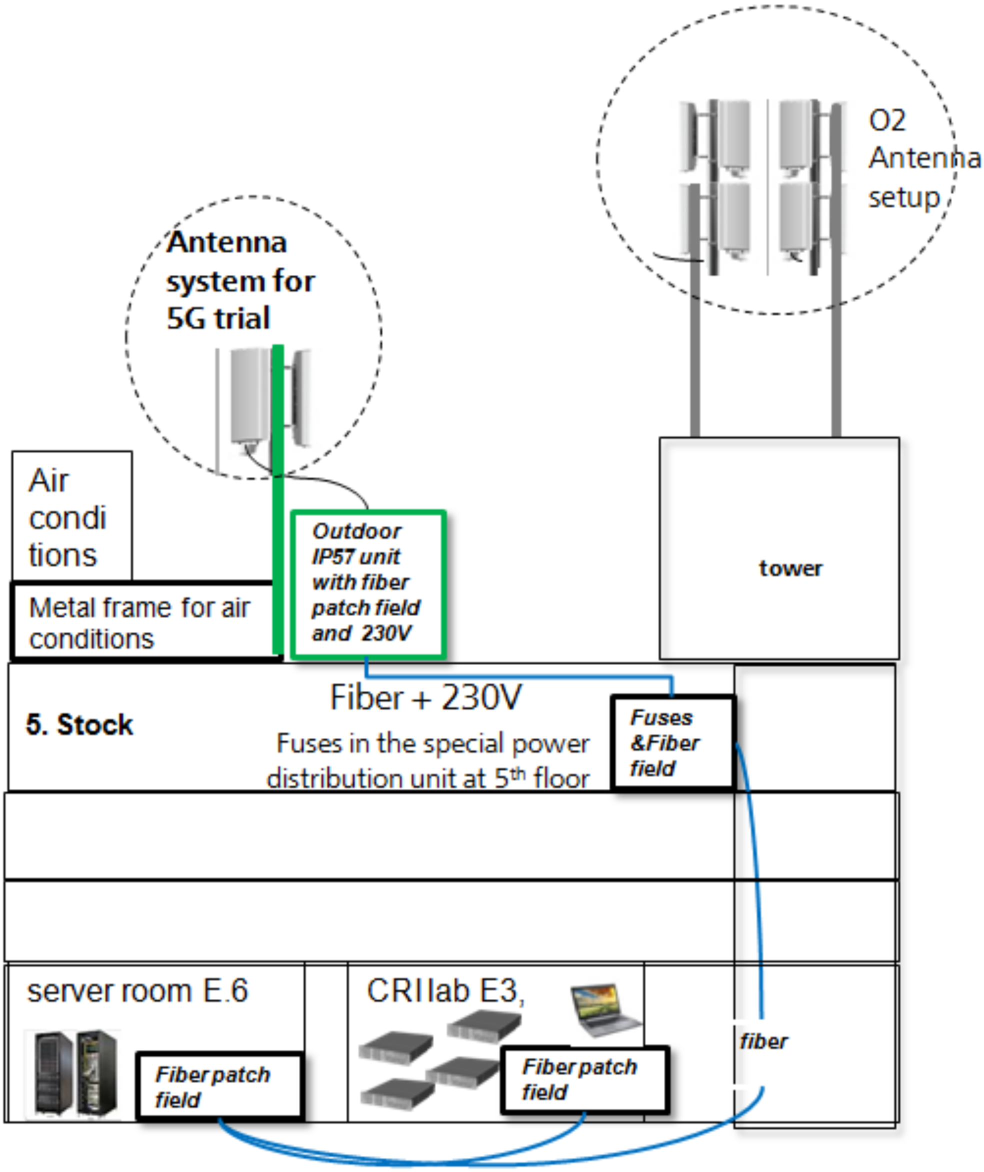

Figure 51: 5G Munich setup/configuration

4.7.2.2 Core Network

The core network will be composed of different network functions running on top of virtualised infrastructure. The core network is responsible for typical functions required to setup and manage the end to end connectivity. The core network does implement a certain number of 5G functions, however, it is not strictly 3gpp compliant. The core network at our site relies on the Docker and Mininet technologies. The core network may launch, and setup data paths as required by the UE requirements and use-cases. Details on how the VNFs are created and managed are presented in the next section.

Physically, the core network platform consists of a dedicated server farm composed of COTS servers in racks, patch panels and DC switches.

- **CPU and Memory**: Every COTS server has 48 *Intel(R) Xeon(R) E5-2697 v2 @ 2.70GHz* CPUs and each CPU has 12 cores. Every server has 80GB RAM.
- **Ethernet:** Every server has 8 Ethernet ports.
- **Networking**: All servers are interconnected with a maximum bandwidth of 10Gb/s.

4.7.3 MANO and NFVI

The Figure below presents the basic MANO/NFVI architecture at our site. The Figure depicts an end to end connectivity created between a UE (lower left and right sides of the figure) and an application server (upper right side) or to another UE. The end to end path is created dynamically to accommodate for the QoS/requirements of the data path. The black boxes represent entities that manage traffic (e.g. routers or virtual network devices) and are able to steer the traffic based on the congestion and/or requirements of the data path created.

Docker container and Mininet are utilized together to realize our NFVI multi-host platform on top of our hardware installation. Docker containers provide a virtualized environment, where different NFs can share the same hardware resource from the server machine isolated from each other.

Mininet provides software-defined networking capability to customize the interconnectivity of the virtualized NFs running in Docker containers through Open Virtual Switch (OVS). Mininet also provides capability to connect to one or multiple software-defined network controllers. Network control application logic can operate the network via the interfaces provided by the controller.

At HWDU experimental Facility-site, we use a multiple-host capable, mobility-supporting extended Mininet testbed. In this testbed, nodes are Docker containers with an OVS instance inside (as opposed to OVS, as in standard Mininet). Besides, such nodes can be deployed across different physical hosts; our system guarantees that regardless of the virtual node to physical machine assignment, the desired virtual topology constraints are always respected. Finally, nodes can be reattached within the network, therefore emulating mobility events.

At HWDU experimental Facility-site, we do not have a formal MANO system in the sense of ETSI NFV definition. However, we have full control over both the physical platform and the deployed virtual network, including runtime control. We use a special Network Control Graphical User Interface (GUI) developed in house for these purposes.

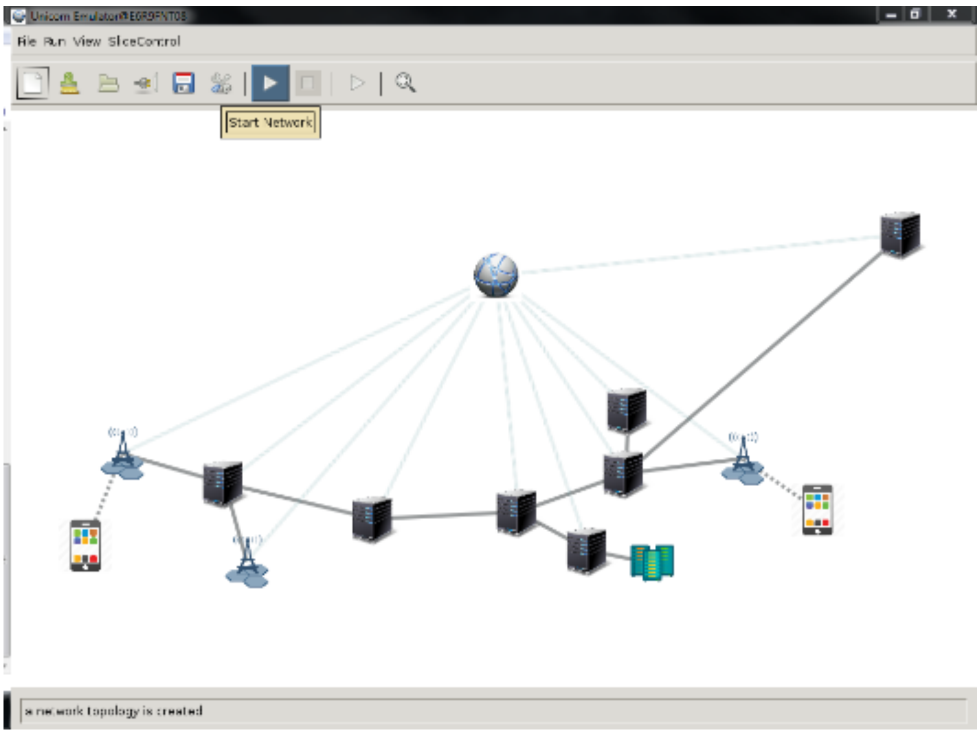

Figure 52: A GUI being developed by HWDU Munich to operate NFVI

4.7.4 Service Orchestration

Not applicable at our experimental Facility-site

4.7.5 Edge Site

As our experimental Facility-site, no full compliant ETSI MEC implementation is available. However, it is possible to deploy Docker containers and virtualization at the edge of network in order to provide low latency communication.

4.7.6 Security

Not applicable at the experimental Munich Facility-site.

4.8 Facility-site: Luxembourg

4.8.1 Transport Network

The 5G-VINNI moving experimentation Facility-site (satellite connected vehicle) will mainly provide satellite backhaul capabilities. The 5G Edge Node corresponds to the SES's Rapid Response Vehicle (RRV) which will be equipped with an SDN/NFV/MEC-enabled 5G testbed node and satellite communication equipment (modem and antenna) in order to be interconnected through satellite to the Satellite Hub platform located in SES's teleport in Betzdorf, Luxembourg. The 5G Core Network will be located at Fraunhofer FOKUS's premises in Berlin which is interconnected to the Satellite Hub platform. The satellite link between the 5G Edge Node and the 5G Core Network corresponds to the satellite backhaul transport network, whose high-level design is shown in Figure 53.

In this system, satellite can be used as a transport network within the 5G network in order to provide connectivity between areas. With the adoption of edge nodes as the means to offload computation close to the UEs, the network is split between this functionality at the border and the one in the central entities and the two parts being connected over a backhaul network.

The backhaul is seen as a transport layer for the messages between the edge node and the central (core) network. Because of this, the backhaul should be as transparent as possible, while at the same time being able to assure a guaranteed communication quality. This can be configured statically or dynamically through specific management interfaces.

A solution design of this satellite backhaul transport network is presented in Figure 54Figure 54 and is further elaborated in Section 3.1 of Luxembourg Experimentation Facility-site (Annex A.8).

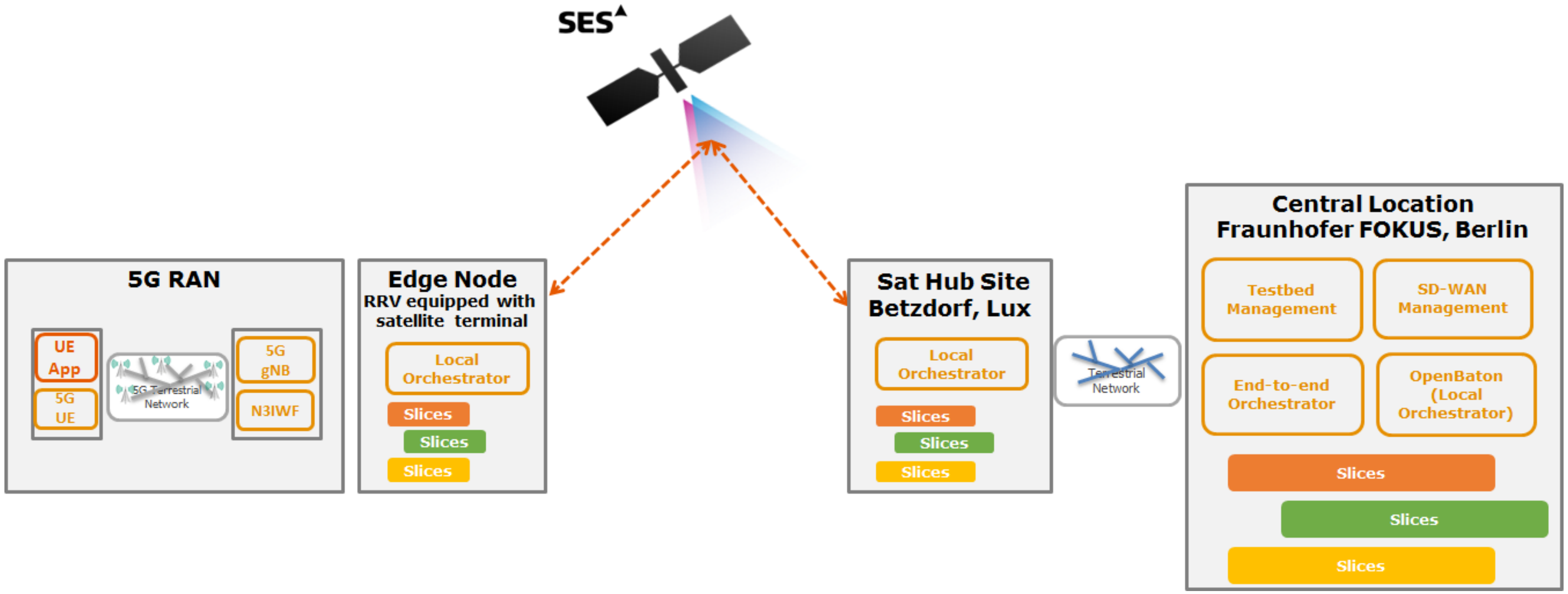

Figure 53: Backhaul Connectivity Architecture – High level

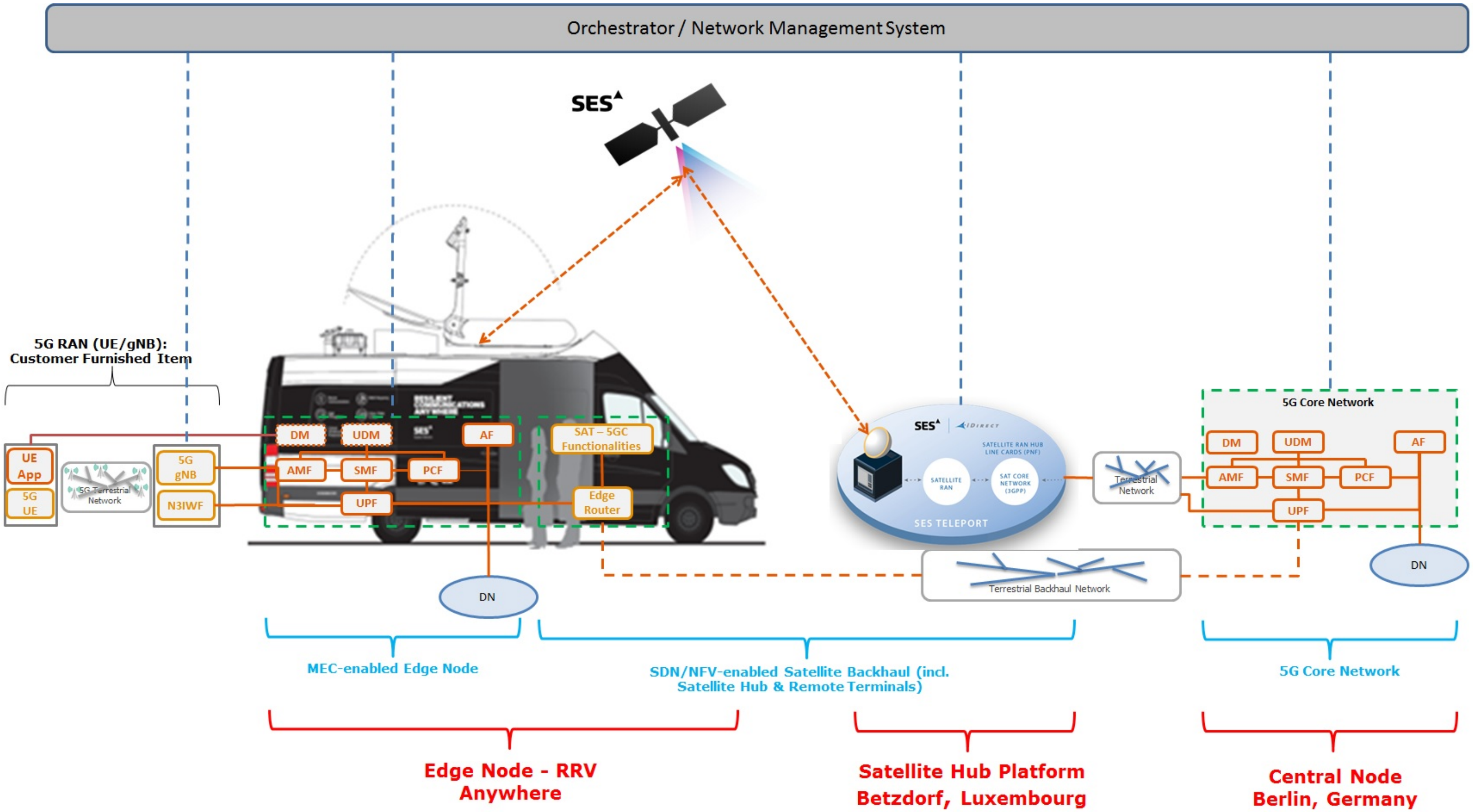

Figure 54: Satellite Backhaul Connectivity Architecture – Solution design

4.8.2 5G RAN and Core

4.8.2.1 5G RAN [Out of Scope]

Note that the 5G RAN (gNB and UE) is provided by a TBD third party as a CFI, which can be integrated with the RRV infrastructure. As such, the 5G RAN is not applicable for the 5G-VINNI moving experimentation Facility-site (satellite connected vehicle).

4.8.2.2 5G Core

The 5G Core Network of the 5G-VINNI moving experimentation Facility-site (satellite connected vehicle) corresponds to Fraunhofer FOKUS' Open5GCore (www.open5gcore.org), which is compliant with the 3GPP Release 15 and is located at Fraunhofer FOKUS's premises.

For further details, see Section 4.6.2.2 of the present document.

4.8.3 MANO and NFVI

4.8.3.1 MANO

The management and network orchestration of the 5G-VINNI moving experimentation Facility-site will be based on Fraunhofer FOKUS' Open Baton (https://github.com/opeNBaton). For further details about the Open Baton see Section 4.6.3.1 of the present document.

The MANO solution is split into two sub-categories:

1. MANO for 5G Edge Node and 5G Central Node.
2. MANO for Satellite Ground Segment (satellite hub platform and remote VSAT satellite terminal).

4.8.3.1.1 MANO for 5G Edge Node and 5G Central Node

Open Baton is an implementation of the ETSI NFV MANO specification. It is an open source project developed at Fraunhofer FOKUS and TU Berlin under the Apache Public License 2.0. It follows a modular approach with the main components being an NFV orchestrator, a generic VNF manager and VIM drivers to support different types of VIMs (e.g. OpenStack and Docker).

For further details see Section 4.6.3.1 of the present document.

4.8.3.1.2 MANO for Satellite Ground Segment

The Network Function Virtualization Orchestrator (NFVO) is the core of Open Baton. Satellite VNFs include the SatRAN software element, the satellite 3GPP Core Network function, and additional auxiliary VNFs deployed on the same system using the OpenStack VIM, which is selected as the SDN/VIM framework of choice for the satellite transport network.

For further details see Section 3.3.2 of Luxembourg Experimentation Facility-site (Annex A.8).

4.8.3.2 NFVI

The NFVI solution is split into two sub-categories:

1. NFVI for 5G Edge Node and 5G Central Node.
2. NFVI for Satellite Ground Segment (satellite hub platform and remote VSAT satellite terminal).

4.8.3.2.1 NFVI for 5G Edge Node and 5G Central Node

Open5GCore VNFs will be deployed using a mix of containers and virtual machines using OpenStack, orchestrated by Open Baton. For further details see Section 4.6.3 of the present document.

4.8.3.2.2 NFVI for Satellite Ground Segment

One of the fundamental goals of NFV is to reduce the hardware footprint of network equipment by "softwarizing" (i.e. virtualizing) network services, and subsequently consolidating numerous virtualized network functions on a single COTS platform. To this direction, the satellite ground segment equipment vendor iDirect has virtualized the network functions in the satellite network by transferring the execution environment of a satellite function from a dedicated server to a Virtual Machine (VM) using the OpenStack Pike VIM. Satellite VNFs include the SatRAN software element, the satellite 3GPP Core Network function, and additional auxiliary VNFs deployed on the same system using the OpenStack VIM.

4.8.4 Service Orchestration

The service orchestration is handled by instances of the Open Baton NFVO. To encapsulate the deployments of the NFVOs to one common place and to provide the capability of deploying network services over multiple NFVO instances, the Fraunhofer FOKUS-developed End-to-end orchestrator is acting on a meta-orchestration level. For further details see Section 4.6.4 of the present document.

Note that the 5G-VINNI Standard Services refer only to the 5G-VINNI **Main** Facility-sites (Norway, UK, Spain, Greece), whereas the present Facility-site corresponds to a 5G-VINNI **Experimentation** Facility-site.

4.8.5 Edge Site

The Edge Site of the 5G-VINNI moving experimentation Facility-site is portable (nomadic) and can be located anywhere, provided that there is satellite connectivity to SES's satellites.

The SES's RRV can be rapidly deployed and provide satellite backhaul capabilities (either as a primary or backup connectivity) enabling local terrestrial communications. The RRV is already equipped with a variety of capabilities, including Wi-Fi technology, licensed VHF radios for push to talk ("PTT") applications as well as with high-definition video surveillance cameras and autonomous power supply. Other local terrestrial communications systems which can be integrated with the RRV infrastructure correspond to CFIs and include systems such as e.g., 4G/5G RAN, TETRA, and M2M/IoT.

The Edge Site of the 5G-VINNI moving experimentation Facility-site corresponds to the SES's RRV which will be equipped with a satellite-enabled 5G Edge Node currently under development in cooperation with Fraunhofer FOKUS as part of the ESA ARTES funded project SATis5 [3]. This satellite-enabled 5G Edge Node will provide SDN/NFV/MEC capabilities and enable both eMBB and mMTC use cases over satellite.

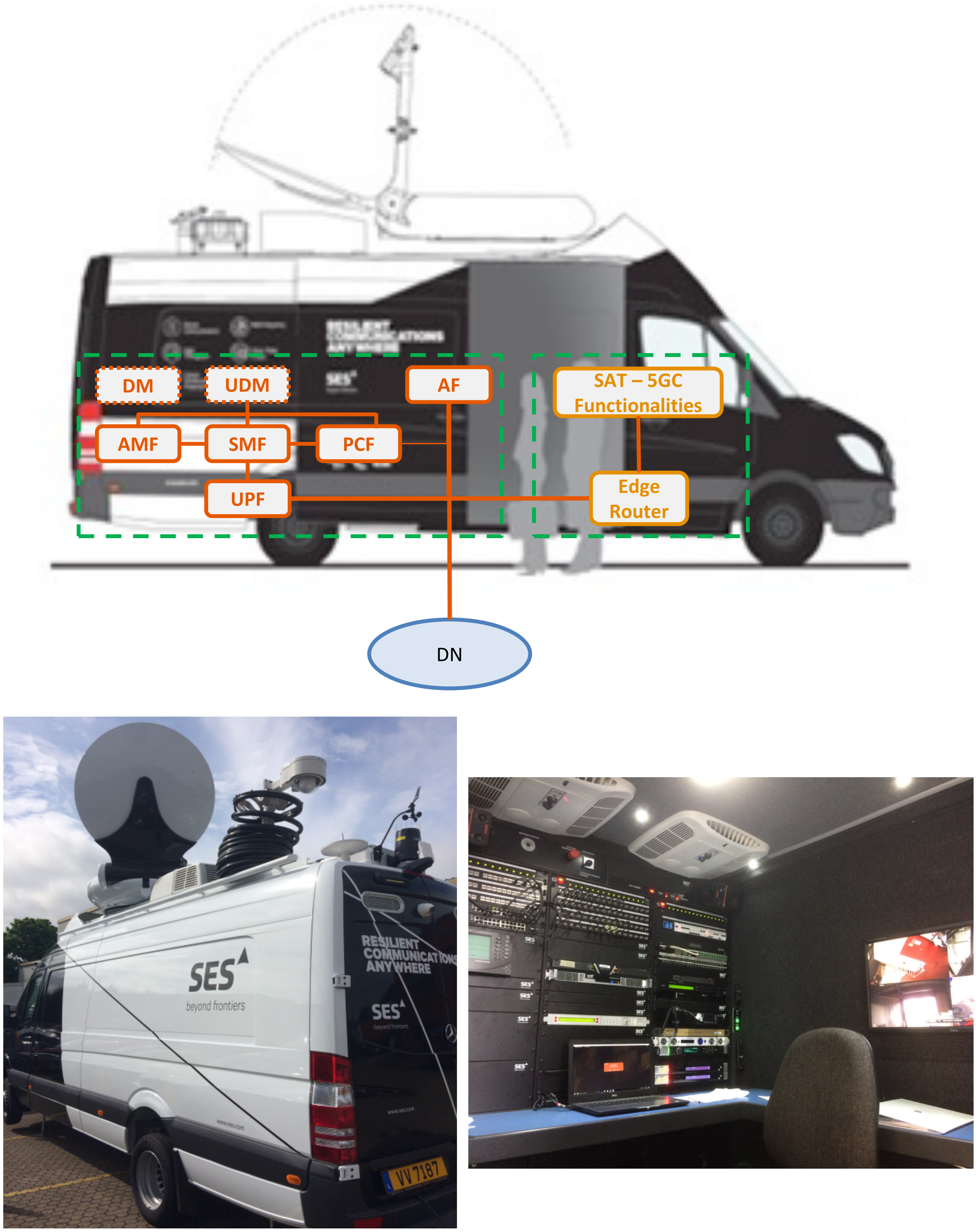

Figure 55: Edge Site: SES's Rapid Response Vehicle (RRV)

Edge-Central Network Split

The edge networks are considered as the best option to compensate specific limitation in the backhaul connectivity. This includes specifically delay and capacity limitations which are also considered the weakest points in having satellite in a convergent architecture. Additionally, having a wide distribution of edge nodes potent the strong characteristics of the satellite networks such as secure communication, global coverage, broadcasting capabilities as well as the limited need of distributed terrestrial infrastructure. Because of the wide connectivity, the communications-on-the-move (COTM) scenarios are easier to deploy with satellite then with terrestrial.

The edge-central network split is expressed as the split of the 5G system between edge and central network, this being considered the most important item into establishing satellite as a reference technology within the 5G systems.

In this context, in order to assure the connectivity to the 5G terrestrial network though the different backhauls, the 5G Core Network is deployed with a functional split between the edge and the core network (see Figure 55Figure 54).

Further details on the Edge-Central Network Split are provided in Section 5.3.2 of the present document.

4.8.6 Security

For reliable tunneling mechanism that provides encryption and authentication OpenVPN with a testbed-specific PKI is used, as it provides adequate security, is open source, and is supported on many platforms. Additionally, it is less likely to run into problems with firewalls or other middleboxes in public or private networks compared to, for example, some IPsec implementations.

For further details, see Section 4.6.6 of the present document.

5 Cross Facility-sites end-to-end Solution Description

In time of writing this section not all information has been fully specified and available. This section describes Facility-site(s) ambitions and future plans in terms of interconnection and interworking among Facility-sites and their involvement in Management and Orchestration of cross-domain services.

5.1 Facility-sites Norway and UK

Norway and UK Facility-sites plan to be interconnected beyond Release 1.

5.1.1 Deliverables to be supported

Inter-working between the UK Facility-site and the Norway Facility-site will be implemented at the E2E Service Operations layer in the 5G-VINNI reference architecture. This will involve delivering function support for the four API's defined for the INTERLUDE (SOF:SOF) Management Interface Reference Point in the reference architecture. These interfaces are:

- Service Ordering API
- Activation and Configuration API
- Service Inventory API
- Service Catalogue API

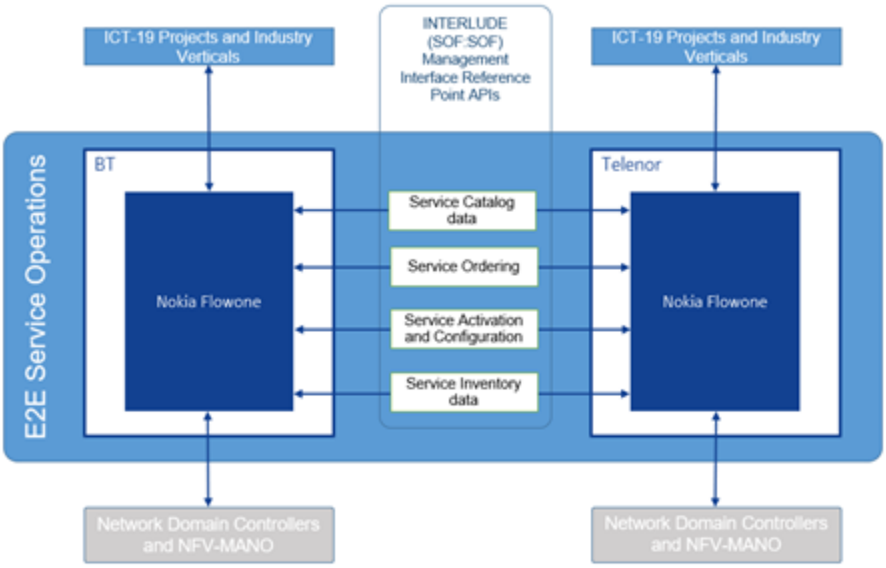

Figure 56: Cross Facility-sites Norway and UK

5.1.2 Interworking requirements

Table 14: Cross Facility-sites Norway and UK

No.	***Architecture recommendations***	***D1.1 Reference***	***Implementation***	
			Norway	*UK*
1	Expose Service Ordering API	4.7.4	Beyond Rel-1. Supported using Nokia Flowone	Beyond Rel-1. Supported using Nokia Flowone
2	Expose Activation and Configuration API	4.7.4	Beyond Rel-1. Supported using Nokia Flowone	Beyond Rel-1. Supported using Nokia Flowone
3	Expose Service Inventory API	4.7.4	Beyond Rel-1. Supported using Nokia Flowone	Beyond Rel-1. Supported using Nokia Flowone
4	Expose Service Catalogue API	4.7.4	Beyond Rel-1. Supported using Nokia Flowone	Beyond Rel-1. Supported using Nokia Flowone
5	Consume Service Ordering API for requesting instantiation of Network Slice Instances	4.7.4	Beyond Rel-1. Supported using Nokia Flowone	Beyond Rel-1. Supported using Nokia Flowone
6	Consume Activation and Configuration API for configuration and activation of network slice instances	4.7.4	Beyond Rel-1. Supported using Nokia Flowone	Beyond Rel-1. Supported using Nokia Flowone
7	Consume Service Inventory API for requesting service instance information	4.7.4	Beyond Rel-1. Supported using Nokia Flowone	Beyond Rel-1. Supported using Nokia Flowone
8	Consume Service Catalogue API for onboarding service specifications	4.7.4	Beyond Rel-1. Supported using Nokia Flowone	Beyond Rel-1. Supported using Nokia Flowone

5.2 Facility-sites Greece and Spain

There will be an interconnection between the two facilities provided by GEANT beyond Rel-1 using the expertise and infrastructure already deployed in 5TONIC by the three common partners (TID, UoP and UC3M) in both the 5GinFIRE [21] and 5G-VINNI projects.

5.2.1 Deliverables to be supported

The potential interconnection towards the outside is mainly managed by the 5TONIC Communications Infrastructure module that encompasses a number of elements that allows the management of the internal communications in 5TONIC premises, the secure connectivity with Internet and other sites. The security infrastructure deployed allows for the implementation of VPNs with IPSec.

5TONIC infrastructure has been already used for the support of several multisite trials associated to H2020 projects. The following figure depicts the inter-site connectivity that supports remote orchestration. In this case, Site 1 was located in Portugal and Site 2 in UK.

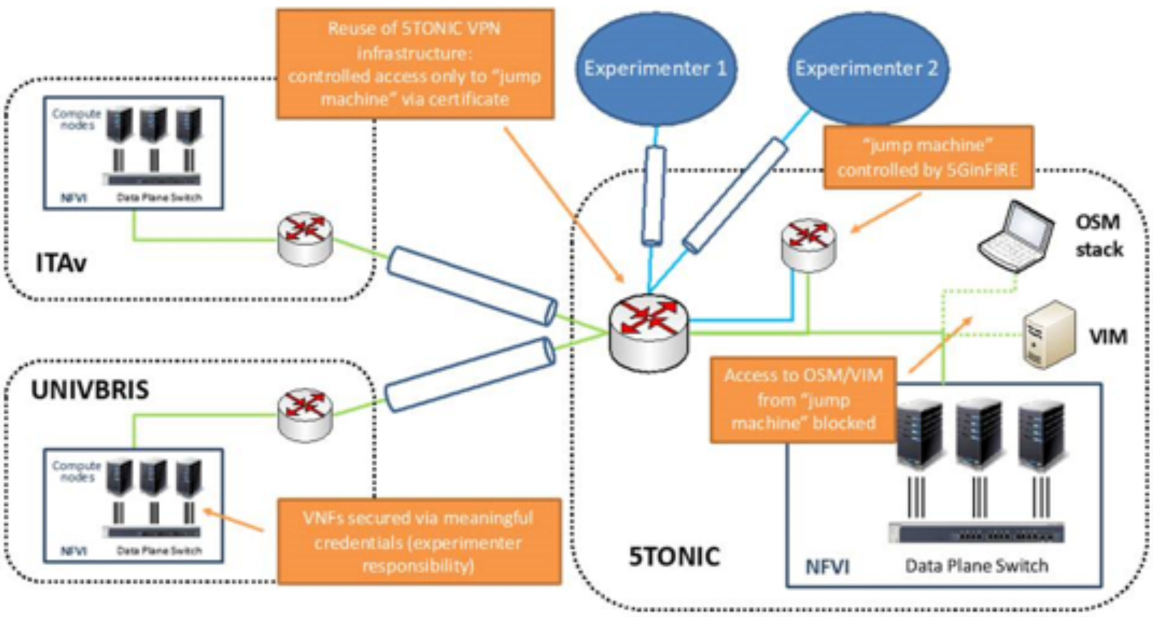

Figure 57: Intra-site connectivity in 5GinFIRE

5.2.2 Interworking requirements

Table 15: Cross Facility-sites Greece and Spain

No.	***Architecture recommendations***	***D1.1 Reference***	***Implementation***	
			Greece	***Spain***
1	Expose Service Ordering API	4.7.4	Beyond Rel-1. OSM	Beyond Rel-1. OSM
2	Expose Activation and Configuration API	4.7.4	Beyond Rel-1.OSM	Beyond Rel-1. OSM
3	Expose Service Inventory API	4.7.4	Beyond Rel-1. OSM	Beyond Rel-1. OSM
4	Expose Service Catalogue API	4.7.4	Beyond Rel-1. OSM	Beyond Rel-1. OSM
5	Consume Service Ordering API for requesting instantiation of Network Slice Instances	4.7.4	Beyond Rel-1.OSM	Beyond Rel-1. OSM
6	Consume Activation and Configuration API for configuration and activation of network slice instances	4.7.4	Beyond Rel-1.OSM	Beyond Rel-1. OSM
7	Consume Service Inventory API for requesting service instance information	4.7.4	Beyond Rel-1. OSM	Beyond Rel-1. OSM

8	Consume Service Catalogue API for on-boarding service specifications	4.7.4	Beyond Rel-1.OSM	Beyond Rel-1. OSM

5.3 Moving Experimentation Facility-site and Berlin Experimentation Facility-site

The 5G-VINNI moving experimentation Facility-site will be satellite interconnected with the 5G-VINNI Berlin experimentation Facility-site (located at Fraunhofer FOKUS's premises in Berlin) and the SES's teleport Facility-site located in Betzdorf (Luxembourg) as depicted in Figure 58.

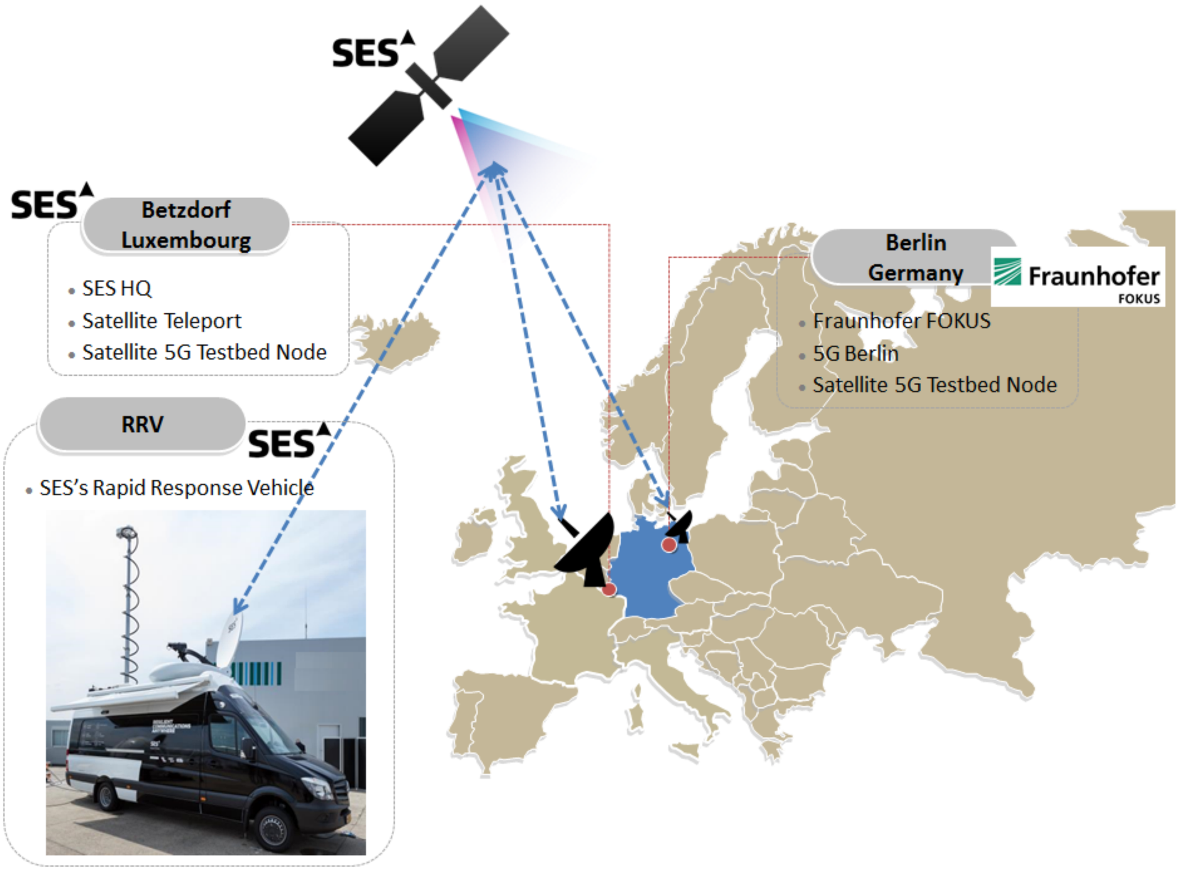

Figure 58: Satellite interconnection between 5G-VINNI moving experimentation Facility-site and 5G-VINNI Berlin experimentation Facility-site

5.3.1 Provided services

In relation to Berlin experimentation Facility-site, the moving experimentation Facility-site will provide satellite backhaul capabilities enabling local terrestrial communications with main focus on both eMBB and mMTC usage scenarios.

5.3.2 Interconnection requirements

As mentioned in Section 4.8.1, the network functions can be placed either at the Edge Node or at the Central Node. In order to make the appropriate split, a set of considerations have to be made on the opportunity of such a placement and several considerations on the communication.

- Edge placement will reduce the communication needs with the central location – the main reason to place functions at the edge is to reduce the communication needs to the central location.
- Edge placement will incur the deployment of more network functions – when the function is placed at the edge, this function has to be managed in order to assure that the same service quality is offered to the subscribers.
- Placement at the edge will require trust into the edge node for the specific functionality – a remote node is very easy to tamper with including man-in-the-middle attacks. Sensitive information for the functioning of the system such as user profiles or user credentials should not be placed at the edge.
- Placement at the edge requires available compute and storage – a function will consume a set of resources when placed at the edge, especially important in case of mobile edge nodes which cannot connect to a fixed power supply.
- Placement at the edge will require backhaul resource consumption – when a function is placed at the edge node, it has to communicate with the central location. It may require a continuous connection to the central location or a temporary one. In case the connection is temporary, the edge node should be able to function even when the connectivity to the central node is lost or terminated, at least for the support of local services.
- The state in the edge nodes has to be synchronized – for a robust system, the state available in the edge nodes regarding the subscribers has to be synchronized with the central location as to avoid accidental or intended miss use of the network (such as the same device connected twice).
- The state within the edge node will have to be handed over to a new edge node in case of a handover – this would require in most of the cases the passing of the state information through the central node.

For the different elements, the following considerations have to be made:

- AMF placement at the edge will provide local access and mobility management, giving the possibility for the remote node to control the mobility within the local area.

  During a handover to a terrestrial network not using the same backhaul or self-backhaul (in proxy mode), an AMF-to-AMF handover should be made. This is similar to terrestrial-only edge nodes.

  Placement of AMF at the end will require that the network provider trusts the remote node with security credentials and information on the subscribers, as this may create man-in-the middle attacks.

  A placement of AMF at the edge is beneficial in some of the backhaul cases where the remote node is trusted and has enough compute capacity (and battery).

- SMF placement at the edge will provide the local control of the data path, independent of the central locations. The SMF cannot be placed at the edge without an AMF placement (due to the procedures of data path establishment which follow the UE-AMF-SMF signalling path). The SMF can be placed at the edge when:
  - The edge SMF establishes the edge data path (the local node can be independent)
  - The edge SMF can communicate with the central SMF for an end-to-end data path including the edge and the central node. For this, the scope of the N21 interface between SMFs has to be extended to include not only the roaming cases, as today.
- PCF placement at the edge – PCF can be placed at the edge only when the AMF and SMF are placed at the edge. Edge PCF is useful in all the situations when an edge SMF is involved for the local communication. Otherwise, a central PCF would be connected to the central location, thus not requiring an additional control network element.

- UPF placement at the edge – in any situation when an application function is placed at the edge, a UPF is required to enable the local offload. As the UPFs can be dynamically chained, a second one can be placed at the central location for the end-to-end connectivity without incurring any standard modifications.
  A UPF placement at the edge in case of proxy mode is highly recommended for a satellite connected node, as it will enable the local offload of the data traffic while maintaining the dynamicity provided by the self-backhauling. However, for this solution to be accepted by 3GPP, it is required to support dynamic addition of UPFs to the network (i.e. adding the UPF in the proxy node) and the change of UPF network location (i.e. when changing the self-backhaul connection to another node, then the UPF in the proxy changes the location).
- UDM placement at the edge – this is not recommended as the UDM includes private information on the subscriber. A temporary UDM partially synchronized can be added to be able to maintain the functioning of the edge node in case the backhaul connectivity completely fails.
- DM placement at the edge – the device management considerations are the same as for UDM.

Based on these considerations, the following slice models are most promising for enabling the various use cases.

1. **Centralized slice** – all the network functions are placed at the central location. This solution relies on the advantage of the optimized satellite direct connectivity (and on the foreseen integration of the satellite specific protocols with the 5G ones) to establish a large scale gNB at the hub side.
2. **Local offload with centralized control plane** – the edge node is able to offload the data traffic to the edge; however, the control is done from the central location. As the control remain centralized, in this situation a larger end-to-end procedure delay for establishing the offloading is required.
3. **Local mobility** – placing the AMF on the edge side will enable the optimized authentication and authorization (less as the UDM remains in the central side) and especially mobility management in the local coverage area. One aspect is the efficient reachability of the devices as the paging procedure is executed only in the coverage area. Furthermore, the control plane signalling is optimized and can be implemented using the Service Based Architecture, as there are no interfaces between edge and central location directly related to the radio technologies. The establishment of the data path is the same as in the previous model, as the SMF remains centralized.
4. **Local session** – placing an additional SMF on the remote side provides the means to locally control the local data path, with a minimal signalling to the core network towards the PCF. This solution requires the chaining of SMFs as well as the interaction with the PCF only at the last SMF. Because of this interaction with a centralized PCF, this solution is mainly optimized for the end-to-end connection and less for the local offload, where the control plane signalling will have to reach the central PCF for establishing the communication rules.
5. **Local control** – placing the comprehensive control plane elements at the edge will enable the system to act as an autonomous connectivity island which takes decisions on its own functioning. However, for the end-to-end communication the edge side will have to interact with the central SMF as in the local session case and with the local PCF.
6. **Autonomous Edge Node** – the edge node may include an additional front-end for device management and for user data subscription, using information stored in the local cache and default subscription profiles. In this case the edge side can function in a complete manner when the backhaul connectivity is lost. However, with passing the subscription profiles to the edge node, an increase security of these nodes has to be established. This solution should be considered only when the trust in these edge nodes is large.

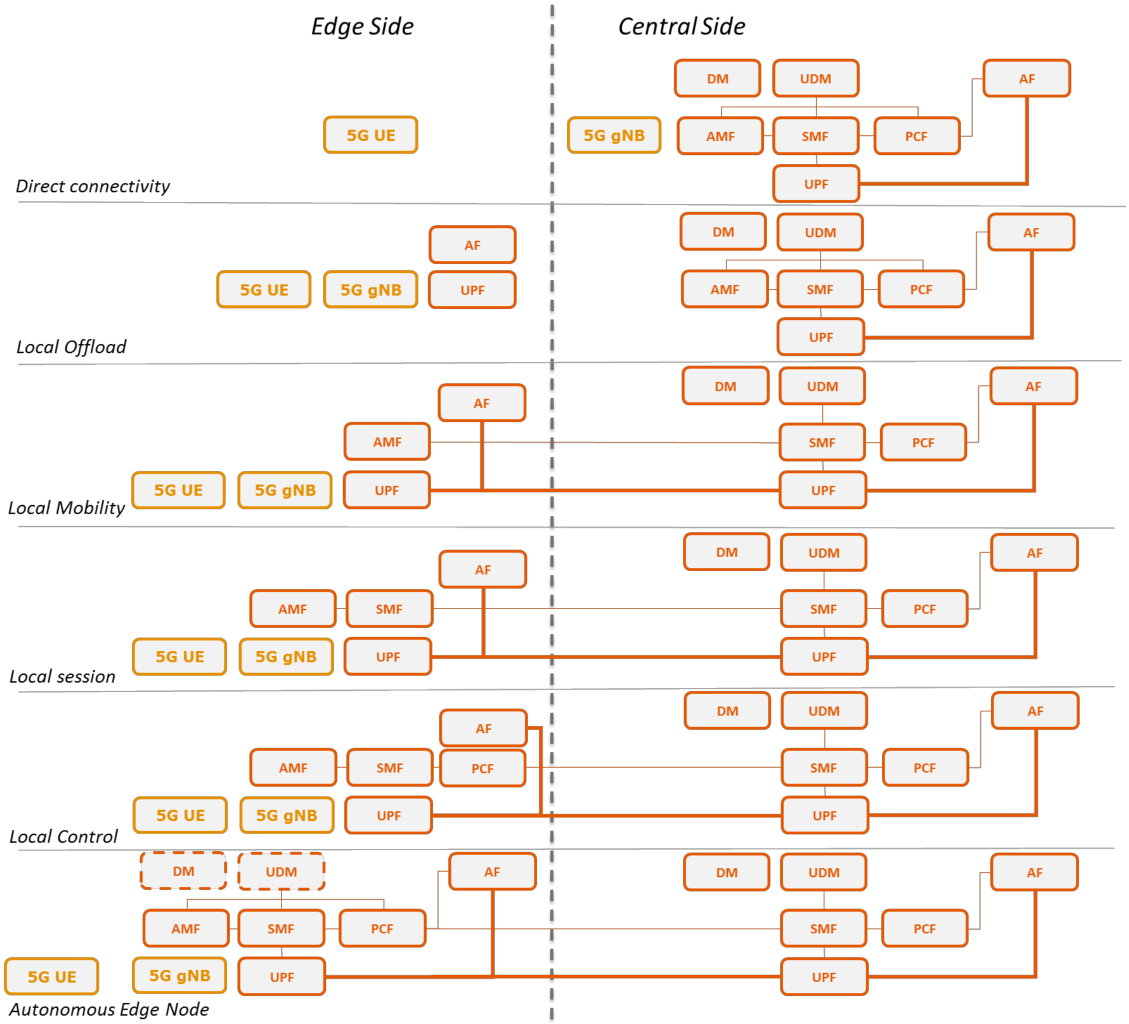

Figure 59: Slice Models

5.3.3 Moving Experimentation Facility-site and TBD 3rd party site

As mentioned above, the 5G RAN (gNB and UE) is provided by a TBD third party as a CFI which can be integrated with the RRV infrastructure. As such, the 5G-VINNI moving experimentation Facility-site (satellite connected vehicle) can be interconnected with other TBD 3rd site which includes the 5G RAN part.

6 API

This section provides an overview of the Interfaces/API's that are being designed to be implemented in all facility sites across different nodes & domains. This section seems to be vital as it offers to reader a wholesome overview of the different integration points; such knowledge can be useful in different ways i.e.

a) Support other WPs to develop and create testing framework in line with the interfaces implemented
b) Will accelerate the troubleshooting and issue isolation during the integration and testing phase.
c) ICT 19's/ESB members with their technical understanding, would be able to analyse and suggest application use case integration with the network
d) Testing and verification of standard 3GPP/ETSI interfaces across multivendor/opensource solutions

To be noted that this is not an exhaustive list, there could be deviation and possibly additional interfaces that will be introduced in different facility site with different releases which shall be captured in the updated design document

Table 15: 5G-VINNI Common API

No.	Interface	Interconnection points	Norway	UK	Spain	Greece	Portugal	Germany (Berlin)	Germany (Munich)	Luxembourg
1	Or-Vnfm	NFVO<->VNFM	Https/Rest	HTTP(S)-ReSTful	Https/Rest	Https/Rest	Https/Rest	AMQP (Rel-1)	N.A.	See Berlin
2	Vi-Vnfm	VNFM<->VIM	Https/Rest	HTTP(S)-ReSTful	Https/Rest	Https/Rest	Https/Rest	HTTPS/Rest (Rel-1)	N.A.	See Berlin
3	Ve-Vnfm-em/vnf	VNFM <-> EMS/VNF	SSH/SFTP, IIOP/TCP	NETCONF or ReSTful	SSH, OSM API	SSH, (OSM based/Juju)	SSH/Others	AMQP (Rel-1)	N.A.	See Berlin
4	Or-Vi	NFVO<->VIM	Http/Rest	HTTP(S)-ReSTful	Https/Rest	Https/Rest	Https/Rest	HTTPS/Rest (Rel-1)	N.A.	See Berlin
5	Os-Nfvo	E2E SO<-> NFVO	Http/Rest	Https/Rest	Https/Rest	Https/Rest	Https/Rest	N.A.	N.A.	See Berlin
6	S1-C	gNodeB<->MME	SCTP, A1AP		N.A.	N.A. (5GCORE)	N.A.	N.A.	N.A.	See Berlin
7	S1-U	gNodeB<->SGW/PGW	GTP, 3GPP Rel-15	GTP, 3GPP Rel-15	N.A.	N.A. (5GCORE)	N.A.	N.A.	N.A.	See Berlin
8	S6a	MME<->HSS	Diameter, 3GPP Rel-15	Diameter, 3GPP Rel-15	N.A.	N.A. (5GCORE)	N.A.	N.A.	N.A.	See Berlin
9	Mun	gNodeB<->ENM	Http/Rest	HTTP(S)-ReSTful	N.A.	N.A. (5GCORE)	N.A.	N.A.	N.A.	See Berlin
10	S5/S8	SGW<->PGW	GTP-C/U, 3GPP Rel-15	GTP-C/U, 3GPP Rel-15	N.A.		N.A.	N.A.	N.A.	See Berlin

11	S11	MME<->SGW	GTP-C, 3GPP Rel-15	GTP-C, 3GPP Rel-15	N.A.	N.A. (5GCORE)	N.A.	N.A.	N.A.	See Berlin
12	SGI	PGW<->External connections	3GPP Rel-15	3GPP Rel-15	N.A.	N.A. (5GCORE)	N.A.	N.A.	N.A.	See Berlin
13	Gx	PGW<->PCRF	Diameter, 3GPP Rel-15	Diameter, 3GPP Rel-15	N.A.	N.A. (5GCORE)	N.A.	N.A.	N.A.	See Berlin
14	Prov 1	Provisioning GW<->E2E SO	Cai3g (over SOAP)	Https/Rest	Https/Rest	Https/Rest	Https/Rest	N.A.	N.A.	See Berlin
15	Ud	CUDB<->HSS	LDAP	LDAP	N.A.	N.A. (5GCORE)	N.A.	N.A.	N.A.	See Berlin
16	Sp/Ud	PCRF<->SPR PCRF<->CUDB	LDAP	N.A.	N.A.	N.A. (5GCORE)	N.A.	N.A.	N.A.	See Berlin
17	Counters / alarms	ENM<->Core VNFs	sftp, snmp		N.A	NRPE, Nagios Plugins	N.A.	N.A.	N.A.	See Berlin
18	ALLEGRO	E2E SO<->Customer	SOAP (https/Rest in future releases)	SOAP (https/Rest in future releases)	Https/Rest	Https/Rest	N.A.	N.A.	N.A.	See Berlin
19	PRESTO	E2E SO<->Core EMS	TBD in future Releases	Https/Rest	Https/Rest	Https/Rest	N.A.	N.A.	N.A.	See Berlin
20	PRESTO	E2E SO<->RAN EMS	TBD in future Releases	TBD in future Releases	Https/Rest	Https/Rest	N.A.	N.A.	N.A.	See Berlin
21	PRESTO	E2E SO<->Transport EMS	TBD in future Releases	TBD in future Releases	Https/Rest	Https/Rest	N.A.	N.A.	N.A.	See Berlin

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[12] 5G-VINNI_D2.1_Annex_A1_Norway, see Annex A

[13] 5G-VINNI_D2.1_Annex_A2_UK, see Annex A

[14] 5G-VINNI_D2.1_Annex_A3_Spain, see Annex A

[15] 5G-VINNI_D2.1_Annex_A4_Greece, see Annex A

[16] 5G-VINNI_D2.1_Annex_A5_Portugal, see Annex A

[17] 5G-VINNI_D2.1_Annex_A6_Berlin, see Annex A

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Annex A Individual facility design documents

For each Facility-site there are available documents describing detailed design aspects.

5G-VINNI_D2.1_Annex_A1_Norway

https://www.5g-vinni.eu/wp-content/uploads/2019/02/5g-vinni_d2.1_annex_a1_norway.pdf

5G-VINNI_D2.1_Annex_A2_UK

https://www.5g-vinni.eu/wp-content/uploads/2019/02/5g-vinni_d2.1_annex_a2_uk.pdf

5G-VINNI_D2.1_Annex_A3_Spain

https://www.5g-vinni.eu/wp-content/uploads/2019/02/5g-vinni_d2.1_annex_a3_spain.pdf

5G-VINNI_D2.1_Annex_A4_Greece

https://www.5g-vinni.eu/wp-content/uploads/2019/02/5g-vinni_d2.1_annex_a4_greece.pdf

5G-VINNI_D2.1_Annex_A5_Portugal

https://www.5g-vinni.eu/wp-content/uploads/2019/02/5g-vinni_d2.1_annex_a5_portugal.pdf

5G-VINNI_D2.1_Annex_A6_Berlin

https://www.5g-vinni.eu/wp-content/uploads/2019/02/5g-vinni_d2.1_annex_a6_berlin.pdf

5G-VINNI_D2.1_Annex_A7_Munich

https://www.5g-vinni.eu/wp-content/uploads/2019/02/5g-vinni_d2.1_annex_a7_munich.pdf

5G-VINNI_D2.1_Annex_A8_Luxembourg

https://www.5g-vinni.eu/wp-content/uploads/2019/02/5g-vinni_d2.1_annex_a8_luxembourg.pdf

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