5G European Validation platform for Extensive trials

Deliverable D3.1
Interworking Capability Definition and Gap Analysis Document

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List of Acronyms and Abbreviations

Acronym	*Meaning*
3GPP	Third Generation Partnership Project
5G	Fifth Generation
5G-PPP	5G Infrastructure Public Private Partnership
AGV	Automated Guided Vehicle
API	Application Programming Interface
AR	Augmented Reality
BBU	BaseBand Unit
BGP	Border Gateway Protocol
BH	Backhaul
BSS	Business Support System
C-RAN	Cloud Radio Access Network
CAPEX	CAPital EXpenditures
CAT-M	Category M
CBIS	Nokia CloudBand Infrastructure Software
CEE	Ericsson Cloud Execution Environment
CLI	Command Line Interface
COTS	Commercial Off The Shelf
CP	Control Plane
CPRI	Common Public Radio Interface
CU	Central Unit
CUPS	Ericsson Control and User Plane Separation
DC	Dual Connectivity
DG	Distributed Generator
DP	Data Plane
DPDK	Data Plane Development Kit
DRB	Data Radio Bearer
DU	Distributed Unit
DWDM	Dense Wavelength Division Multiplexing
eMBB	Enhanced Mobile BroadBand
EMS	Equipment Management System
eNB	Evolved Node B
ENM	Ericsson Network Manager
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Duplex

FH	Fronthaul
gNodeB	Next generation Node B
GRE	Generic Routing Encapsulation
HARQ	Hybrid automatic repeat request
HCI	Hyper Converged Infrastructure
HD	High Definition
HDR	HD Recording
HMD	Head Mounted Display
HW	Hardware
IoT	Internet of Things
IP	Internet Protocol
IRU	Indoor Radio Unit
IT	Information Technology
I/W	Interworking
KPI	Key Performance Indicator
LAN	Local Area Network
LCT	Local Control Terminal
LTE	Long Term Evolution
M2M	Machine to Machine
M-MIMO	Massive MIMO
MANO	MANagement and Orchestration
ME	Mobile Edge
MEC	Multi-access Edge Computing
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
mMTC	Massive Machine Type Communication
NB-IoT	Narrow Band Internet of Thing
NFVI	Network Function Virtualization Infrastructure
NFVO	Network Function Virtualization Orchestrator
NGC	Next Generation Core
NR	New Radio
NS	Network Service
NSA	Non-Standalone
NSD	Network Service Descriptor
OAI	Open Air Interface
ONAP	Open Network Automation Platform
ONOS	Open Network Operating System

OPEX	OPerating EXpenses
OPNFV	Open Platform for NFV
OSM	Open Source MANO
OSS	Operation Support System
OVS	Open Virtual Switch
P2P	Peer to Peer
PCRF	Policy and Charging Rules Function
PGW	Packet Data Network Gateway
PLC	Programmable Logic Controller
PNF	Physical Network Function
PoP	Point of Presence
QAM	Quadrature Amplitude Modulation
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
REST	Representation State Transfer
RRC	Radio Resource Signaling
RRH	Remote Radio Head
RRU	Remote Radio Unit
RTT	Round Trip Time
SD	Standard Definition
SDN	Software Defined Networking
SGSN	Serving GPRS Support Node
SIM	Subscriber Identity Module
SR-IOV	Single-Root Input / Output Virtualization
SW	Software
TDD	Time Division Duplex
TOSCA	Topology and Orchestration Specification for Cloud Applications
TTI	Transmission Time Interval
UC	Use Case
UE	User Equipment
UHF	Ultra-High Fidelity
UP	User Plane
UPF	User Plane Function
uRLLC	Ultra-Reliable Low Latency Communication
vCPE	Virtual Customer Premise Equipment

vCUDB	Centralized User Database
vEPC	Virtual Evolved Packet Core
vIMS	Virtual IP Multimedia Subsystem
VIM	Virtual Infrastructure Manager
VNF	Virtual Network Function
VNFD	Virtual Network Function Descriptor
VNFM	Virtual Network Function Manager
VNS	Virtual Network Service
VOD	Video On Demand
VPN	Virtual Private Network
VR	Virtual Reality
WAN	Wide Area Network
WIM	Wide Area Network Infrastructure Manager
XHAUL	Fronthaul/Backhaul

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Executive Summary

This deliverable provides a report about the capabilities that have to be supported by a generic site facility operating in the 5G EVE framework, in order to enable its interoperability and interworking with the whole 5G EVE system. The definition of such capabilities is initially driven from the design of the 5G EVE use cases, as specified in Work Package 1, but has the objective to cover a wider and more generalized scope to enable the future porting of further use cases on the 5G EVE platform. This approach will help to open the system towards additional 5G vertical experimenters, beyond those already present in 5G EVE consortium, for example in support of use cases and trials in ICT-19 projects.

This deliverable initially identifies the capabilities offered by the four 5G EVE site facilities in Greece, Spain, France and Italy, in terms of infrastructure resources (for both computing/storage and network connectivity) and control, orchestration, monitoring or management tools deployed in each site. Special attention is also dedicated to the interconnectivity between different site facilities, which enables the delivery of cross-site 5G services. The analysis takes into account not only the current status of the target sites, but also the plans for future deployments and extensions, as documented in deliverable D2.1 and deliverable D2.2, in order to capture a complete and medium-term picture of the capabilities which will support the experiments on 5G services. It is important to note that the survey of the site facilities reported in this document starts from the specification provided from Work Package 2, but provides a different perspective. On one hand Work Package 2 is mostly focused on deployment, installation and configuration issues, with the objective of designing and building the infrastructure. On the other hand, Work Package 3, and thus the analysis performed in this deliverable, is mostly interested in the functionalities, capabilities and interfaces offered by each facility, to define a common and abstract interworking model across the whole platform, regardless of the internal details related to how a given feature is implemented in the particular site.

Following a similar direction, all the 5G EVE target use cases, which have been previously described in deliverable D1.1 from the perspective of the verticals, are analyzed here with the objective of identifying the requirements associated with the deployment, the runtime operation and the monitoring of the associated services. The list of resulting requirements has been elaborated and generalized to produce a comprehensive set of functionalities, features, capabilities and services that are needed to deliver and manage the full variety of 5G services in an end-to-end environment, providing also the required tools for their experimental assessment and performance validation in a realistic 5G environment. This list provides a reference and a guideline for the capabilities that each of the 5G EVE site facilities should provide to enable its integration with the 5G EVE platform. Similarly, it also provides the foundations of the internal functionalities that the 5G EVE Interworking Framework will need to support and implement, identifying the kind of abstract primitives to be adopted in its interaction with all the underlying facilities.

Indeed, the definition of these target “Interworking Capabilities” constitutes one of the main outcomes of this deliverable. Starting from this pillar, the deliverable also derives an initial sketch of the Interworking Framework functional architecture, as well as the technical gaps between the current (or planned) facilities deployment and the target functionalities which should be offered by each 5G EVE site facility. The architectural outcomes are expected to feed Work Package 1 activities, related to the design of the whole 5G EVE platform, and the future activities in Work Package 3 for the definition of reference interworking information model and the implementation of the Interworking Framework. The analysis of the technical gaps will provide inputs to Work Package 2, driving any needed updates in the current deployments of the 5G EVE facilities. Moreover, the target Interworking Capabilities will also provide a sort of template for any potential external facility that may want to join the 5G EVE framework in the context of future collaborations (e.g. to integrate local trial sites made available from ICT-19 projects that would like to interoperate with the 5G EVE platform). In particular, this template identifies the full list of functionalities and capabilities that a generic site facility, independently on its internal infrastructure and specific technologies, should expose towards the 5G EVE Interworking Framework to be compliant with the whole design and principles of the overall system, thus enabling its possible integration with the 5G EVE platform.

1 Introduction

1.1 Motivation and scope clarification

5G EVE aims at building a 5G end-to-end facility composed of four interconnected European sites in Greece, Spain, France and Italy. The main goal is to enable the experimentation and validation of 5G pilots from vertical industries, providing unified and open access to a full set of 5G capabilities. The 5G EVE end-to-end facility will initially host a selection of project use cases to be deployed by verticals participating in the project. These use-cases have been described in deliverable D1.1 [1], in terms of execution scenario, target KPIs and general requirements for each vertical domain. Additionally, these use cases have been grouped around six main categories: i) Smart Transport: Intelligent railway for smart mobility ii) Smart Tourism: Augmented Fair experience, iii) Industry 4.0: Autonomous vehicles in manufacturing environments, iv) Utilities (Smart Energy): Fault management for distributed electricity generation in smart grids, v) Smart cities: Safety and Environment, vi) Media & Entertainment: UHF Media, On-site Live Event Experience and Immersive and Integrated Media. More external vertical industries and related use cases will be involved at later stages in the project, mostly from ICT-19 projects starting from Q2-2019, with the aim of executing more and more 5G experiments over the 5G EVE end-to-end facility and thus strengthen testing and validation of the deployed 5G technologies.

A detailed description of each 5G EVE site facility in terms of deployed 5G technologies and elements, together with the required network control, management and orchestration tools, has been provided in deliverable D2.1 [2]. Moreover, the roadmap for the implementation of each 5G EVE site facility has been also reported in deliverable D2.2 [3], along with the planning of the deployment of 5G enabling technologies, tools and functionalities, aiming to provide the initial access to the vertical partners in the project for use cases experimentation from April 2019.

In summary, these three initial 5G EVE specifications, i.e. D1.1 [1], D2.1 [2] and D2.2 [3], represent the ground to proceed with the 5G EVE end-to-end facility design and development, starting from each site facility implementation, towards the upper layers of the 5G EVE platform, namely, the integrated portal (WP4) for 5G experimentation and validation (WP5), and the interworking framework (WP3). As said, the main goal of 5G EVE is to build a truly integrated end-to-end 5G experimentation facility, where the validation services offered by the four sites are exposed to verticals and their applications as a unified platform service. The interworking framework has thus the role of abstracting the specific logics and tools available in each site, exposing the whole multi-site infrastructure through a unified and site-agnostic information model towards the upper layers of the 5G EVE architecture. This means that the heterogeneous 5G capabilities and orchestration solutions adopted in each site facility are properly abstracted to provide a common and unified end-to-end experimentation and validation facility. Moreover, the 5G EVE platform should enable those vertical use cases and experiments that may have specific requirements for deployment and execution across multiple site facilities, still hiding to verticals the low-level details and the multi-site nature of the infrastructure.

Therefore, the role of 5G EVE interworking framework is crucial to ensure interoperability of validation services offered by the various sites of 5G EVE and to perform tests involving several sites, achieving end-to-end integration of the four site facilities. The interworking framework has therefore two main roles and objectives in the overall 5G EVE platform:

- Provide a common interworking model, to abstract the heterogeneous 5G capabilities and orchestration solutions implemented in each 5G EVE site facility, and expose seamless services, features, interfaces and Application Programming Interfaces (APIs) to the upper layers of the 5GEVE integrated portal for enabling then to deliver unified validation and experimentation of vertical services;
- Provide site facility interconnection means and mechanisms for enabling the deployment of use cases and experiments involving multiple sites (multi-site use cases) in a transparent and seamless way for verticals.

On one hand, the first interworking objective above is valid for any kind of vertical use case experiment to be validated, independently of its single or multi-site nature. This already poses challenging requirements on the interworking framework itself, in terms of functionalities to achieve the common model and the exposure of unified services towards the 5G EVE experimentation portal, as reported later in this document. As a consequence, further requirements are posed on each 5G EVE site to expose a minimum set of capabilities, features and services to enable such common interworking model. On the other hand, the second interworking objective listed above aims to enable the validation of those vertical use case experiments that will be deployed across multiple sites.

Figure 1 provides an overview of how the 5G EVE interworking framework is logically positioned with respect to the four site facilities in Greece, Spain, France and Italy. It can be considered as an overarching layer sitting on top of the site facilities that provides the abstraction, adaptation and cross-site functionalities required to integrate the heterogeneous 5G capabilities, features and services under a common interworking model. This allows providing a transparent and unified end-to-end facility to the 5G EVE integrated portal; thus, keeping the complexity and implementation details within each site.

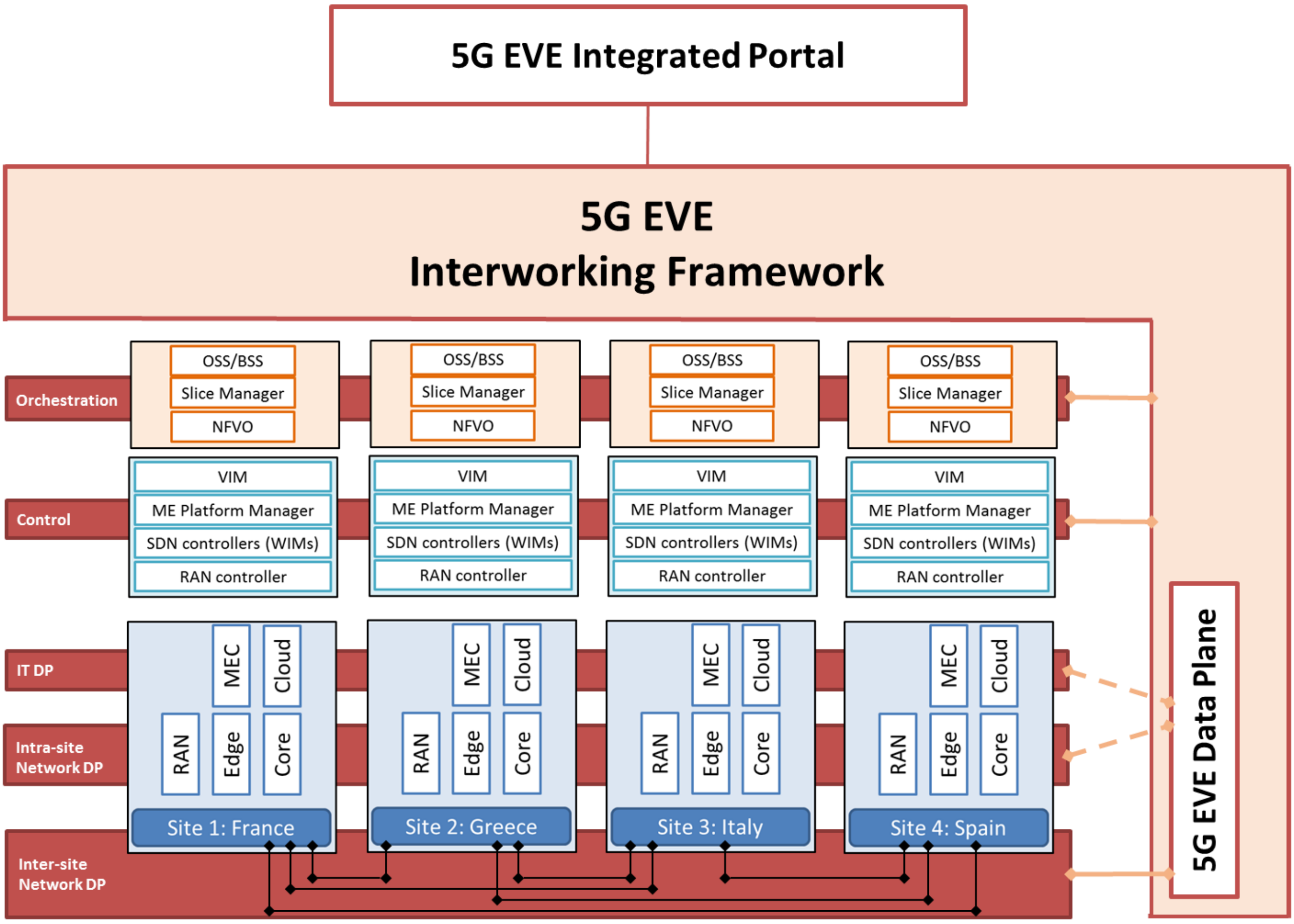

Figure 1: 5G EVE interworking framework overview

Therefore, the interworking framework deals with specific 5G capabilities in each site, and it exposes unified and common APIs to provision end-to-end services and network slices in support of the vertical use case experiments. This means that the interworking framework has to apply its abstraction, adaptation and multi-site interconnection logics at different layers and different segments of 5G networks in each site. As depicted in Figure 1, each site facility can be organized around three main layers: orchestration plane, control plane and physical infrastructure layer (from now on referred as data plane). Starting from the bottom, the data plane within each site is composed of the collection of Radio Access Network (RAN), edge and core network elements that provide the 5G connectivity for a set of IT resources that are deployed in different geographical locations to offer the computing and storage capabilities needed to run virtualized functions and applications. In particular, these resources can be distributed closer to the network edge, following the concept of the Multi-access Edge Computing (MEC), or centralized in a small number of larger deployments, e.g. in Points of Presence (PoPs) implementing a private cloud. In turn, on top of these data plane resources, each site can deploy a wide set of control tools and solutions to properly provision and configure the 5G network connectivity in each of the segments, including the IT part. These control features may include Virtualized Infrastructure Managers (VIM) for the Network Function Virtualization (NFV) part, Mobile Edge Platform Managers for the MEC segment, Software Defined Networking (SDN) controllers for the provisioning of transport networks and RAN controllers for the dynamic configuration and allocation of Radio Access Technology (RAT) resources. Furthermore, for the proper coordination of network services and slices provisioning across the different segments and technologies within each site, dedicated tools and solutions are used at the orchestration plane, including NFV orchestration, slice management and legacy Operation Support System (OSS) products.

For each of these three planes, the 5G EVE interworking framework provides the abstraction and adaptation functionalities mentioned above, taking also into consideration that different sites will potentially provide a different combination of features, functions and tools in each plane. As depicted in Figure 1, the interworking framework also takes care to implement those site interconnection features, thus allowing, if required by vertical use cases and experiments, to build a 5G EVE end-to-end interconnected data plane. However, any interconnection at orchestration and control levels can be mediated by the interworking framework itself following a kind of hierarchical approach.

This deliverable is the first outcome of WP3 and aims at identifying a minimum set of interworking capabilities and features to enable an interoperable use of 5G technologies and services offered by the four 5G EVE site facilities. This is achieved by further analyzing what each site facility offers at each plane (i.e. orchestration, control, and data) in terms of services, features and APIs, beyond the specific technologies and tools reported in D2.1 [2] and D2.2 [3]. Moreover, by establishing vertical oriented functional requirements from a deeper technical analysis of 5G EVE use cases in D1.1, and by defining a preliminary interworking framework architecture scheme, this deliverable also identifies an initial set of interworking technical gaps and recommendations to be considered by each site facility for the implementation of the interworking model and services in WP3.

1.2 Objectives of the document

This document aims at achieving a set of technical objectives related with the 5G EVE interworking framework:

- Collect, for each site facility, the main exposed services, features and APIs that have an impact on the interworking framework capabilities at different layers, from data to control and orchestration planes, as a further and deeper iteration and analysis of site facilities descriptions and implementation roadmaps reported in D2.1 [2] and D2.2 [3];
- Identify the technical requirements to be met by the 5G EVE platform for deploying, operating, monitoring and evaluate the performance of vertical services. These requirements are obtained by analysing, from a technical point of view, the vertical-oriented use cases defined in D1.1 [1], in terms of deployment scenario, service lifecycle workflows and target KPIs;
- Provide a preliminary interworking framework architecture and model scheme, as a collection of services, tools and features aiming at addressing the technical functional requirements associated to the vertical use cases;
- Identify a minimum set of control, management, monitoring, orchestration capabilities and features that each site has to implement and expose towards the interworking framework;
- Identify a preliminary set of technical gaps to be filled at the interworking framework and in each of the site facilities in order to meet the technical functional requirements at the global 5G EVE platform level.

1.3 Document structure

This deliverable is organized as follows:

- Section 2 provides an overview of the services, features and APIs implemented and provided by each 5G EVE site facility that have an impact on the interworking framework. It is the result of a critical analysis of D2.1 [2] and D2.2 [3] outcomes, combined with a technical survey of the site facilities deployment plans, to obtain information about the offered features and technology capabilities, useful for the definition of the preliminary interworking framework architecture;
- Section 3 provides a set of technical interworking requirements derived from the technical analysis of 5G EVE vertical use cases, focused on the deployment, operation and monitoring/data analysis of the associated 5G services;
- Section 4 reports the preliminary interworking framework architecture and identifies a set of target capabilities and features that each 5G EVE site facility shall provide and expose for the realization of the interworking model;
- Section 5 provides a preliminary list of interworking technical gaps and recommendations against the identified target capabilities and functionalities that the site facilities need to implement to deliver the 5G services in support of the reference 5G EVE vertical use cases;
- Section 6 provides some concluding remarks, including highlights on future related work within Task T3.1 and WP3.

2 Site facilities' service capabilities and features

This section aims at providing an overview of the services, features and APIs implemented and provided by each 5G EVE site facility, and that have an impact on the interworking framework. Starting from the site facilities descriptions and roadmaps reported in D2.1 [2] and D2.2 [3], further analysis and investigation have been carried out to identify main services, features and capabilities that each site provides (or plans to provide during the first year of project lifetime) at the three main layers identified and described in Figure 1: orchestration, control and data plane. This analysis is the first step towards the definition of the preliminary interworking framework architecture, and the identification of target capabilities features and services each site has to expose to implement the 5G EVE interworking model, as well.

For each site facility, a brief overview of the site capabilities is reported, and then the main services, features and capabilities at data, control and orchestration planes are summarized in the form of tables. These tables group features, tools and APIs following the logical decomposition depicted in Figure 1 for each site:

- Data plane
    - RAN, Fronthaul (FH)/Backhaul (BH), Core, Mobile Edge (ME) (or edge) hosts, Cloud, Physical Network Functions (PNFs), Inter-site connectivity.
- Control plane
    - RAN controller, SDN controller, ME (or edge) Platform Manager and Orchestrator, VIM.
- Orchestration plane
    - NFV Orchestrator, (NFVO), VNF Manager (VNFM), Slice orchestration or management tools, OSS/BSS tools.

Each of the following subsections focuses on one of the four 5G EVE site facilities.

2.1 Greek site facility

2.1.1 Overview of site capabilities

This section provides the components and technologies of the testbed that is planned to be deployed in OTE premises. The lab will be fully equipped with end-to-end equipment from Ericsson and Nokia that will be capable to show higher bit rates than the ones currently supported. The full Nokia Long Term Evolution (LTE) system has been installed in our labs since 2017 and is regularly upgraded according to new releases. The Ericsson system has started to be installed in the labs' data center and a large room has been selected for the implementation and demonstration of the Industry 4.0 use case which is developed and supported by Ericsson. The lab is equipped with monitoring, testing and assessment tools based on Ixchariot and Spirent commercial products that are used as traffic generators and performance evaluators. It will also be equipped with the Open Air Interface (OAI) [4] and 5G Mosaic platform [5] for testing the performance of network slicing in a lab environment. The RAN system will include equipment from Ericsson and Nokia and will consist of the radio transceiver system that transmits and receives the radio signals located in outdoor environments, while the Base Band Unit (BBU) consists of different nodes for Ericsson and Nokia as explained in following sections. The core network will consist of virtualized Evolved Packet Cores (vEPCs) from Ericsson and Nokia that in a second phase will be interconnected to each other. For the Ericsson setup, a distributed edge cloud infrastructure will be used to advance the service of Automated Guided Vehicle (AGV). The cloud management system will consist of the service and resource orchestrators. The control system will be responsible to control the VNFs' lifecycle and the traffic to the underlying data plane. The monitoring management system will be responsible to collect data on metrics, topology and resources in order to monitor the KPIs and adapt them to the needs of the project.

The Nokia's core solution, such as Cloud Packet Core, is one that combines cloud-native architecture concepts, such as network function software disaggregation, stateless functional software elements with 'state-efficient' processing and a shared data layer with automated cloud networking and dynamic lifecycle management.

Automation tools will be used from both vendors to deal with the massive number of connections and/or with the demanding requirements of 5G. The main services and features offered per vendor at the three different planes (data, control and orchestration planes) are detailed in the following subsections.

2.1.1.1 Data Plane

Table 1: Greek site facility – overview of data plane service capabilities

Category	Vendor	Technology highlights	Main (i/w) features and capabilities
RAN	Ericsson	**Spectrum**: B7 FDD **Technology description**: LTE **Mgt/control/DP interfaces**: Mul/S1c, X2c/S1u,X2u, Uu	• Prescheduling • Instant Uplink Access (Latency Reduction) • Short TTI (Latency Reduction - Candidate) • Intelligent connectivity
		Spectrum: N78 [3400-3800] TDD **Technology description**: NR **Mgt/control/DP interfaces**: Mul/S1c, X2c/S1u,X2u, Uu	• Dual Connectivity (option 3x) • Physical Layer Mid-Band • Scheduler Mid-Band
	Nokia	**Spectrum**: UL: 1760 – 1770 MHz, DL: 1855 – 1865 MHz **Technology description**: LTE **Mgt/control/DP interfaces**: Mul/S1c, X2c/S1u, X2u, Uu	• Prescheduling • Instant Uplink Access (Latency Reduction) • Short TTI (Latency Reduction - Candidate) • Intelligent connectivity
		Spectrum: Spectrum: 3.7GHz-3.8GHz **Technology description**: NR **Mgt/control/DP interfaces**: Mul/S1c, X2c/S1u, X2u, Uu	Dual connectivity (option 3x)
Fronthaul/ Backhaul	Ericsson	**Technology description**: Ericsson proprietary IF-based interface (Radio Dot) / 10G SFP+ **Deployment**: Point to Multipoint LAN and CPRI / Point to Point L3VPN between baseband and vEPC **Mgt/control/DP interfaces**: Outbound-inbound interface	• 4G up to 800 Mbps and 5G NR with peak rate up to 2 Gbps (MIMO 4x4) • FH: CAT 6A LAN cable up to 100m between DOT unit and Indoor Radio Units (IRU), and optical fibre interface between IRU and baseband unit
	Nokia	**Technology description**: IP/Microwave **Deployment**: Point to Multipoint **Mgt/control/DP interfaces**: S1-C, S1-U	4G/5G NR with peak rate up to 10Gbps

Core	Ericsson	**Technology description**: 5G EPC **Mgt/control/DP interfaces**: Si-C', Si-U', S6a'	OpenvSwitch (OVS) DPDK or single-root input/output virtualization (SR-IOV) will be used HW acceleration of User plane
	Nokia	**Technology description**: EPC/5G EPC **Deployment**: R14 vEPC/R15 Core **Mgt/control/DP interfaces**: S1-C/N2, S1-U/N3, S6a/N12, SGi/N6	4G LTE/5GNR Support of Option 3x
ME Hosts	Ericsson	Not planned	Not planned
	Nokia	Will be provided upon need	Cloud
Cloud	Ericsson	**Technology description**: Openstack	Openstack distro for the 5G Core deployment
	Nokia	**Technology description**: Openstack **Capabilities and deployment**: ETSI NFV MANO **Mgt/control/DP interfaces**: Nf-Vi, Or-Vi, Vi-Vnfm, Or-Vnfm	• Openstack for 4G core deployment • Openstack for 5G core deployment
PNFs	Ericsson	No PNFs planned	
	Nokia		
Inter-site connectivity	Ericsson	Standard IP connectivity and IP routing protocols will be used	
	Nokia		

2.1.1.2 Control Plane

Table 2: Greek site facility – overview of control plane service capabilities

Category	Vendor	Technology highlights	Main (i/w) services and features
RAN controller	Ericsson	**Sw tool(s)**: RAN control signalling	• NR long or short PUCCH configuration: Trade-off between fast HARQ feedback and increasing signal quality reception. To be decided during implementation. • Semi-Dynamic NR slot configuration enabled via RRC (Radio Resource Signalling) signalling. • LTE-NR Dual Connectivity (DC) Split-DRB (Data Radio Bearer) flow control mechanism used over the X2 interface (X2-U) to keep buffers in the eNB filled at the right level.

	Nokia	**Sw tool(s)**: RAN control signalling	• NR long or short PUCCH configuration: Trade-off between fast HARQ feedback and increasing signal quality reception. To be decided during implementation. • Semi-Dynamic NR slot configuration enabled via RRC (Radio Resource Signalling) signalling. • LTE-NR Dual Connectivity (DC) Split-DRB (Data Radio Bearer) flow control mechanism used over the X2 interface (X2-U) to keep buffers in the eNB filled at the right level.
SDN controller	Ericsson	Not planned	Not planned
	Nokia		
ME Platform Manager & Orchestrator	Ericsson	Not planned	Management and orchestration solution is embedded in the CEE/VIM solution. No additional layers provided.
	Nokia	Not planned	Management & orchestration solution is embedded in the NOKIA CloudBand solution [8]. No additional layers provided. Use of ONAP orchestrator [10] will have to be agreed for Greek site affected affiliates.
VIM	Ericsson	**Sw tool(s)**: Openstack Queens [6] **APIs**: at least base Openstack APIs and components [6]	Ericsson VIM modules are in CEE
	Nokia	**Sw tool(s)**: CloudBand Infrastructure Software (CBIS) [8] **APIs**: at least base OpenStack APIs and components [6]	Nokia VIM modules are provided by the CBIS product
Additional components (e.g. monitoring platform, inter-domain SDN controller, etc.)	Ericsson	To be further analysed	To be further analysed
	Nokia	No additional components will be provided	No additional components will be provided

2.1.1.3 Orchestration Plane

The Ericsson and Nokia solutions, which will be used to extend the Greek site facility, come with embedded management and orchestration solutions for the control, monitoring and configuration for their local solutions. Upon consent of the Greek partners an overlay Orchestration layer will be integrated on top of the local controllers and orchestrators, hosted at the OTE facilities, in order to hide the complexity of the underlying layers and to offer a single point of entry / communication towards the Greek facility. This common orchestrator will be based on the Open Source MANO (OSM) R4 [9] and will be built on top of the two orchestration platforms of Ericsson and Nokia. This manager will orchestrate the vertical services to the proper infrastructure and will request the necessary resources through the southbound interface with the local Openstack based orchestration platforms [6] of Ericsson and Nokia. The local orchestrators will be responsible to reserve and optimize the resources in the correspondent physical and virtualized infrastructures.

Table 3: Greek site facility – overview of Nokia orchestration plane service capabilities

Category	Technology highlights	Main (i/w) services and features
NFVO	**Sw tool**: ETSI OSM R4 on top of underlying proprietary (embedded) orchestrators **APIs**: ETSI OSM R4 APIs [11]	• NS packaging and on-boarding • NS instantiation, manual scaling, termination • NS monitoring leveraging on OpenStack Telemetry services
VNFM	**Sw tool**: ETSI OSM R4 on top of underlying proprietary (embedded) orchestrators **APIs**: ETSI OSM R4 APIs [11]	• VNF Lifecycle management • VNF Day0[1], Day1[2], Day2[3] configurations
Slice Manager	**Sw tool**: Potentially based ONAP [10] for improved slicing capabilities **APIs**: ONAP APIs [12]	To be further evaluated
OSS/BSS	Not planned	Not planned
Additional components (e.g. service orchestrator, service monitoring platform)	**Sw tools**: Proprietary (OTE, Ericsson, Nokia, WINGS) monitoring platforms and aggregated information monitoring	• Collection and aggregation of infrastructure level metrics • Collection and aggregation of service level metrics • Integration with OpenStack telemetry services

[1] Day0 refers to the cloud-init configuration of a VNF during its instantiation phase

[2] Day1 refers to a VNF configuration after the instantiation phase for its proper functioning in the context of the Network Service

[3] Day2 refers to runtime application-level VNF configurations that can be applied at any time of the VNF lifecycle

2.2 Spanish site facility

2.2.1 Overview of site capabilities

5TONIC Open 5G Lab [13] was created in 2015 by Telefónica I+D and IMDEA Networks Institute with a clear vision to create an open research and innovation ecosystem laboratory in which industry and academia come together to boost technology and business innovative ventures. Currently, the 5TONIC laboratory is composed of 10 members (Telefónica, IMDEA Networks, Ericsson, University Carlos III Madrid, Intel, CommScope, Altran, Cohere Technologies, InterDigital and RedHat) and 5 collaborators (IFEMA, ASTI Robotics, Rohde & Schwarz, Luz Wavelabs and Saguna Networks).

The 5TONIC laboratory includes a solid baseline of facilities, infrastructure and equipment to support advanced experimentation in the 5G Virtual Network Function and Wireless Systems areas. It provides access to a common infrastructure with specific-purpose hardware, to assist in experiments, trials and demonstrations with particular 5G network technologies, as well as to commodity hardware, which allows a cost-effective approach to configure different network topologies of variable size and capacity. The 5TONIC site is located at IMDEA Networks premises in Leganés, in the Madrid metropolitan area, but it has access to other locations for the support of different network functions and use cases.

Because 5TONIC is being composed of different members, it is necessary to distinguish 5TONIC as a whole and the part that will be available to 5G EVE. The specific infrastructure allocated to 5G EVE is provided by Ericsson, Telefónica, UC3M, IMDEA Networks and Nokia, as well as some other general common infrastructure and services existing in the lab. Examples of these include the data centre infrastructure with the racks for each 5TONIC member; the communications infrastructure; a vEPC provided by Ericsson to evolve to Next Generation Core (NGC); LTE Radio Access infrastructure provided by Ericsson and CommScope to be evolved to NR; and virtualization, processing and transport infrastructure.

For April 2019 it is planned to have two non-integrated network infrastructures, one of them based on the network elements provided by Ericsson, UC3M, Telefónica, IMDEA Networks and Telcaria (plus 5TONIC own infrastructure), and the other one based on Nokia provided network elements plus 5TONIC common infrastructure. Specifically, it is planned the incorporation of new network elements and the evolution of the existing ones along the project lifetime. Furthermore, a higher level of integration between the mobile network and the orchestration infrastructure is to be expected.

As the testbed is planned to initially provide 5G services in Non-Standalone (NSA) option 3a fashion with dual connectivity mode, it will be necessary to keep the LTE RAN operating in Band 7 in combination with an 5G NR RAN. The additional improvements, which are expected to be achieved, are the evolution of 5TONIC Communications Infrastructure towards a programmable (SDN-based) architectural framework, the update of the orchestration platform for supporting multi-slicing and the incorporation of Distributed Cloud / Edge capabilities.

The following subsections provide an overview of the main capabilities, in terms of services and features exposed, planned for the Spanish site facility at the three main layers identified as relevant for the 5G EVE interworking framework: data, control and orchestration planes. For each plane, the specific information table is provided.

2.2.2 Main services and features offered

2.2.2.1 Data Plane

Table 4: Spanish site facility – overview of data plane service capabilities

Category	Technology details	Supported features and capabilities
RAN	**Spectrum**: B7, B42 and B43 (potentially also B20). B1 and B2 with LTE. **Technology description**: 4G LTE, 5G NR NSA, NB-IoT and CAT-M under consideration. **Mgt/control/DP interfaces**: S1	• Higher order modulation (256QAM downlink, 64QAM uplink). • Uplink prescheduling for latency reduction • 5G Plug-in Massive MIMO over LTE TDD • 5G NR NSA
FH/BH	**Technology description**: IP routing based BH **Deployment**: concrete Router model still to be determined **Mgt/control/DP interfaces**: CLI (SDN under evaluation)	WAN connectivity for MEC module
Core	**Technology description**: Ericsson and Nokia vEPC including PGW, PCRF and MME **Deployment**: Ericsson vEPC Release 14 and 5G NSA. Nokia vMEC supporting a MCN17 with a MicroCoreNetwork for LTE, plus a second 5G NSA. **Mgt/control/DP interfaces**: CMON	• Supports 5G NSA (R 15) • CUPS (proprietary solution) • IoT (NB-IoT, CAT-M1)
ME Hosts	**Technology description**: Local breakout solution based on distributed cloud **Capabilities and deployment**: includes required hosts for running 5G EVE Madrid's trials. Specific COTS server models still to be determined.	SR-IOV
Cloud	**Technology description**: DELL servers **Capabilities and deployment**: 3 high-profile servers each with 8 cores @2.40 GHz, 128 GB for RAM, 8 10Gbps optical Ethernet ports **Mgt/control/DP interfaces**: management interfaces based on 5TONIC communications infrastructure (optical switches)	SR-IOV

PNFs	Not planned in the first phase. Second phase: **Technology description**: SDN capable routers for Wide Area Network (WAN) emulation. Specific models and capabilities to be determined.	To be further analyzed
Inter-site connectivity	**Technology description**: VPN IPSec Tunnels, GEANT based interconnection available	One VPN Gateway, boundary for control and data plane Networks.

2.2.2.2 Control Plane

Table 5: Spanish site facility – overview of control plane service capabilities

Category	Technology details	Supported services and features
RAN controller	Proprietary per vendor	Vendor specific features and services
SDN controller	Not planned in the first phase. Second phase: **Sw tool(s)**: ONOS [14], Opendaylight [15] **Controlled net technology**: OVS [16], OpenFlow 1.4 [17], YANG models **APIs**: ONOS API, ONOS-intent API, Restconf, Netconf	Intent-based network policies
ME Platform Manager & Orchestrator	**Sw tool(s)**: Nokia ALCM **Underlying VIM**: OpenStack Ocata [6] **APIs**: TOSCA based	Local breakout
VIM	**Sw tool(s)**: OpenStack Ocata [6] **APIs**: base OpenStack APIs	Openstack Telemetry services based on Ceilometer and Gnocchi
Additional components (e.g. monitoring platform, any inter-domain SDN controller, etc.)	**Sw tool(s)**: Prometheus [18], Grafana [19]	Visualization of Openstack infrastructure monitored parameters

2.2.2.3 Orchestration Plane

Table 6: Spanish site facility – overview of orchestration plane service capabilities

Category	Technology details	Supported services and features
NFVO	**Sw tool**: ETSI OSM R4 [9] **APIs**: base OSM APIs [11]	• NS packaging and on-boarding • NS instantiation, manual scaling, termination • Monitoring: module (MON)
VNFM	**Sw tool**: ETSI OSM R4 [9] **APIs**: base OSM APIs [11]	• VNF Lifecycle management • VNF Day0, Day1, Day2 configurations • Monitoring: module MON
Slice Manager	Not planned in the first phase: Second phase: **Sw tool**: integration between OSM and ONOS intent-based API **APIs**: OSM API, ONOS intent-based API	OSM and ONOS integration for multi-slicing support
OSS/BSS	Ericsson proprietary OSS and Telefonica Spain Lab HSS	Provide synchronization signals
Additional components (e.g. any service orchestrator or service monitoring platform)	**Sw tool**: Supervision tools based on OSM Kafka Exporter	Collection and storage of infrastructure and application monitoring metrics
Available VNFs / MEC Apps / NSs	• ASTI PLC for AGVs control • Nokia Multimedia VNF, KPIs VNF and MCN17 VNF.	• ASTI VNF supports Industry 4.0 use case. • Nokia VNFs support UHF media use case

2.3 French site facility

2.3.1 Overview of site capabilities

The French site facility is a federation of platforms that together build a hybrid cluster following TM Forum recommendations. The utilized components are following diverse models: ETSI NFV reference model, Open Platform for NFV (OPNFV) [20] recommendations (i.e. usage of Openstack as VIM, OSM or ONAP as orchestrator, OAI for LTE components) and cloud-native principles [21]. The facility is comprised of two main pillars:

- Pre-commercial Nokia 4G/5G end-to-end network facility, that is called “Nokia 5G innovation platform for Vertical Markets” and is located in Paris-Saclay.
- Open-source building blocks that are distributed on several facilities interconnected by VPN, namely:
  - Plug-in platform located in Paris (operated by Orange)

- Flexible Netlab platform located in Rennes (operated by B-COM)
- OpenAir5G playground located in Sophia Antipolis (operated by Eurecom)
- End-to-end Mobile Networks Virtualization and Verification (Nokia Bell Labs).

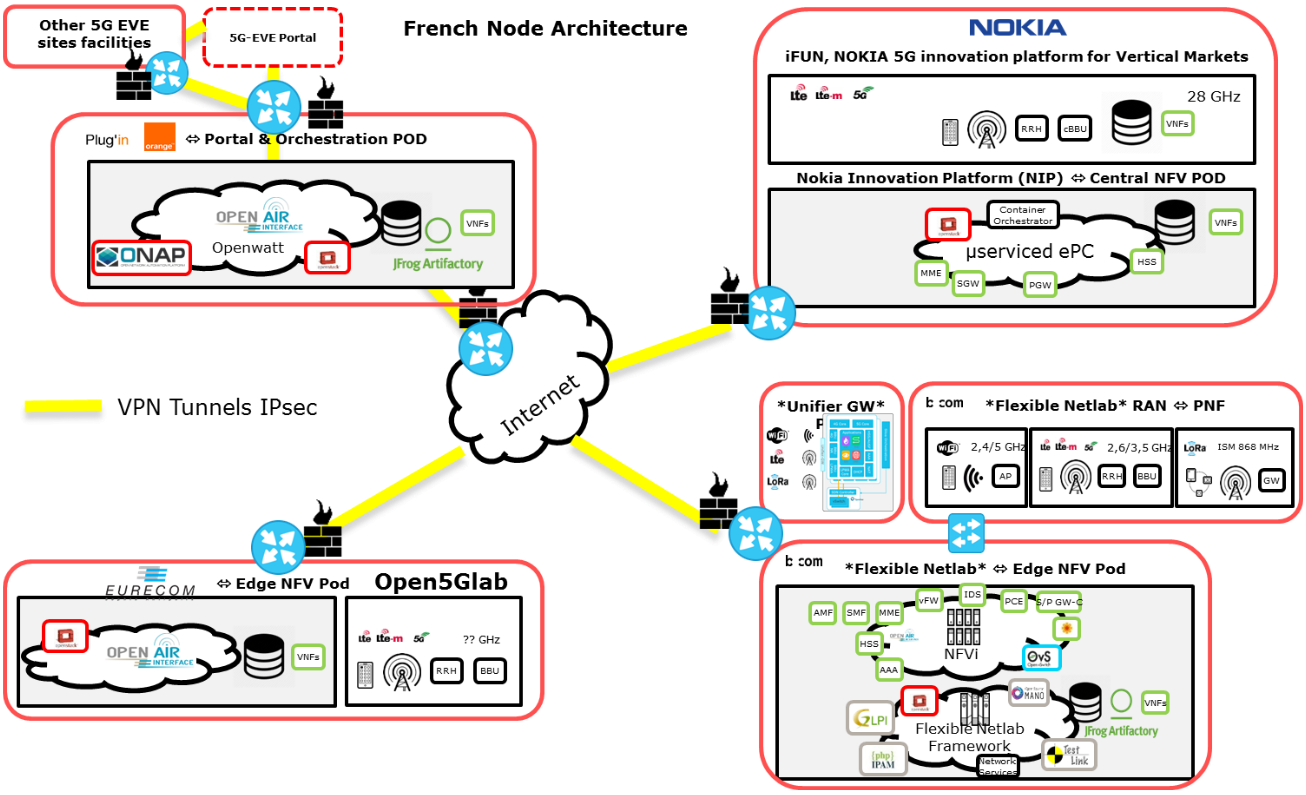

Figure 2: French node architecture

The French facility partners will operate the whole cluster of building blocks as a distributed cloud enabling common deployment and monitoring capabilities, while at the same time presenting a unified, single facility image towards the rest of the 5G EVE facilities and the external third parties (vertical industries), as well. Each cluster is composed of infrastructure pods provided by different facilities. In addition, the various components are issued by the respective cluster partners and deployed in different pods according to their capabilities.

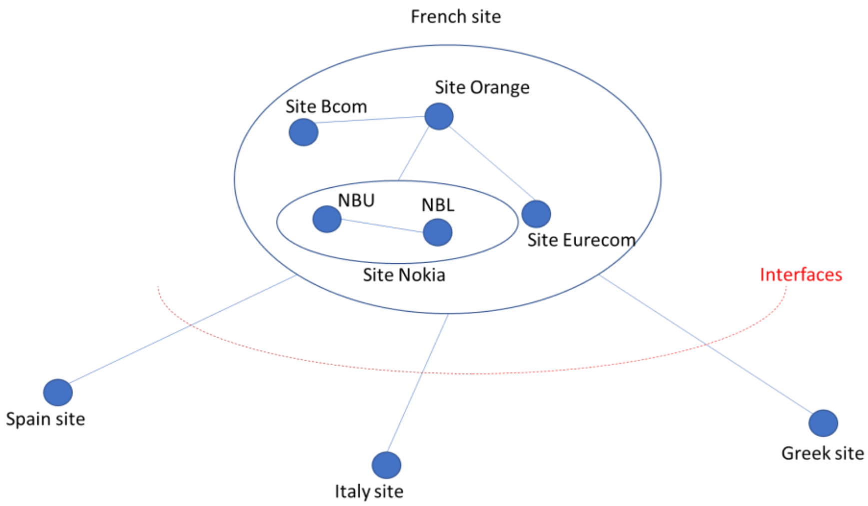

Figure 3: French site as a federation

Some of these components and clusters have been a significant part of previous and ongoing 5G-PPP projects (Superfluidity [22], NGPaaS [23], 5G Ensure [24], etc.) and are expected to be heavily reused in 5G EVE, taking also into account any insights that have or will arise from these projects. As a general practice, DevOps and slicing are key technologies from the aforementioned projects that will be leveraged during the 5G EVE end-to-end facility development.

The focus of the facility development will fall on the following four main directions:

- End-to-end and network KPI validation
- Multi-domain interoperability
- New services on-boarding
- New experimental features and platforms

The aforementioned development goals will be achieved through the adoption and implementation of innovative technologies such as M-MIMO, Cloud RAN (C-RAN) IoT, Cloud RAN 5G, Central Unit (CU)/Distributed Unit (DU) split, SDN, NFV and MEC.

The following subsections summarize the main capabilities, services and features implemented and offered by the French site facility and that are relevant for the 5G EVE interworking framework definition.

2.3.2 Main services and features offered

The French site facility as a federation of several sites, it is not expected to expose the data plane interfaces between sites composing the French site. However, the control plane interfaces will be provided.

2.3.2.1 Data Plane

The data plane is split into the pre-commercial and open-source pillars.

Pre-commercial pillar

Concerning the pre-commercial pillar, the data plane is similar to that one described in D2.1 [2] and summarized in Table 7.

Table 7: French site facility – overview of pre-commercial data plane service capabilities

Category	Technology highlights	Main (i/w) features and capabilities
RAN	**Spectrum**: 28 and 78 **Technology description**: 4G and 5G (R15 3.x) **Mgt/control/DP interfaces**: X2-c and X2-u, S1-U	• 4G & 5G RAN are virtualized using Cloud RAN. • Radio Unit supports all radio access technologies including 4.9G, which provides future service continuity with 5G networks (extreme capacity, massive connectivity and ultra-low latency)
Fronthaul/ Backhaul	**Technology description**: Ethernet **Deployment**: Commercial Switch **Mgt/control/DP interfaces**: F1-c and F1-u	To be further analysed
Core	**Technology description**: R15 3.x **Deployment**: VNF using Nokia VIM **Mgt/control/DP interfaces**: S1-u	• Shared Data Layer • Hyper Converged Infrastructure (HCI) approach

ME Hosts	Not planned	Not planned
Cloud	**Technology description**: Cloud RAN infrastructure VIM **Mgt/control/DP interfaces**: Cloud RAN controller	CU infrastructure is based on Nokia Airframe product using the Nokia Cloud Infrastructure for Radio VNF hosting
PNFs	Not planned	Not planned
Inter-site connectivity	To be further investigated	To be further investigated

Open-source pillar

Concerning the open-source pillar, it is not expected to provide data plane interfaces between the sites within the French cluster.

2.3.2.2 Control Plane

The control plane features in the French cluster are also split into the pre-commercial and open-source pillars.

Pre-commercial pillar

For the pre-commercial pillar, the control plane deployment is still valid according to the plan described in D2.1 [2] and summarized in Table 8.

Table 8: French site facility – overview of pre-commercial control plane service capabilities

Category	Technology highlights	Main (i/w) services and features
RAN controller	**Sw tool(s)**: AirScale Radio Network Controller [25] **APIs:** Nokia proprietary APIs	Support of all features in R15 3.x
SDN controller	**Sw tool(s)**: Nokia Service Platform [26] **APIs:** Nokia proprietary APIs	• Service automation • Network optimization • On-demand network services • Integrated OAM tests • Network adaptation and optimization • Network awareness • Node and Flow monitoring (see monitoring section)
ME Platform Manager & Orchestrator	**Sw tool(s)**: Nokia NetAct [27] **APIs:** Nokia proprietary APIs	• Consolidated network view • Multi-domain, multi-technology • Continuous, real-time monitoring • Manage radio and core networks • Multi-technology management VNF and VNS monitoring (see monitoring section)

VIM	**Sw tool(s)**: Nokia CBIS for virtualized infrastructure management [8] **APIs:** Openstack based APIs [6]	• Management of compute, storage, and network resources • It hosts VNFs and ensures that they meet strict robustness, performance, and security requirements • VNF and VNS monitoring (see monitoring section)

Additional components (e.g. monitoring platform, inter-domain SDN controller, etc.)	Wireless Network Guardian [28]	• End-to-end network analytics and reporting
		• Real time analytics tool
		• Measure performance, detect anomalies and report airtime
		• Components will be monitored, and the following functionalities are provided:
		  ○ statistics collection
		  ○ alarms generation
		  ○ correction mechanisms
		• Multivendor, multi-technology

Open-source pillar

Concerning the open-source pillar, the interfaces between the various sites will follow a service-based architecture, thus where loosely coupled components interacts over service bus with proper discovery functions:

- Each site will offer services that will be operable through REST APIs.
- Each site will offer actionable services with their own capabilities, monitoring and service assurance.

Table 9 summarizes the open-source capabilities offered at the control plane level in the French cluster.

Table 9: French site facility – overview of open-source control plane service capabilities

Category	Technology details	Supported services and features
RAN controller	**Sw tool(s):** FlexRan [5] **APIs**: FlexRan REST APIs [29]	• Software Defined Radio • RAN slicing
SDN controller	**Sw tool(s):** OpenDayLight [15], ONOS [14]	L2 switch, OpenFlow, Netconf, BGP, P4
ME Platform Manager & Orchestrator	Not planned	Not planned
VIM	**Sw tool(s):** Openstack [6] **APIs**: Openstack APIs	Integration with Kubernetes for containerized applications and functions

Additional components (e.g. monitoring platform, inter-domain SDN controller, etc.)	To be further analyzed	To be further analyzed

2.3.2.3 Orchestration plane

The orchestration plane is sub-divided into the pre-commercial and the open-source pillars.

Pre-commercial pillar

Concerning the pre-commercial pillar, the orchestration plane is similar to that one described in D2.1 [2] and summarized in Table 10.

Table 10: French site facility – overview of pre-commercial orchestration plane service capabilities

Category	Technology highlights	Main (i/w) services and features
NFVO	**Sw tool**: Nokia CloudBand Network Director [8] **APIs**: ETSI NFV standards-based APIs	• Network service orchestration, • Resource orchestration and optimization.
VNFM	**Sw tool**: Nokia CloudBand Application Manager [8] **APIs**: ETSI NFV standards-based APIs	• Automated VNF lifecycle management • VNF configuration • Integration with VIM for virtualized resources provisioning
Slice Manager	Not planned	Not planned
OSS/BSS	Not planned	Not planned
Additional components (e.g. service orchestrator, service monitoring platform)	To be further analysed	To be further analysed
Available VNFs / MEC Apps / NSs	To be further analysed	To be further analysed

Open-source pillar

Concerning the pre-commercial pillar, the orchestration plane is similar to that one described in D2.1 [2] and based on the following main assumptions:

- A “root” orchestration will be based on ONAP [10] and will control each elements of the federation.
- Each element will have its own orchestrator, such as Cloudify [30], Nokia CloudBand [8], NGPaaS [23] (based on Kubernetes [31]) or others.
- Each orchestrator shall offer a “northbound” interface to the upper orchestration element.

Table 11: French site facility – overview of open-source orchestration plane service capabilities

Category	Technology details	Supported services and features
NFVO	**Sw tool**: ONAP [10] **APIs**: ONAP REST APIs [12]	• NS lifecycle management (manual and auto-scale) • Fault and performance management, • Catalogue features • Multi cloud platform support (Openstack, Kubernetes)
VNFM	**Sw tool**: ONAP [10] **APIs**: ONAP REST APIs [12]	• VNF lifecycle management, fault and performance management • Internal components: ▪ SDNC – network controller ▪ APPC – VNF controller, ▪ Multi VIM – infrastructure manager
Slice Manager	**Sw tool**: ONAP [10] **APIs**: ONAP REST APIs [12]	Ongoing support for: • slice lifecycle management • multi-domain/multi-site slicing capabilities
OSS/BSS	Not planned	Not planned
Additional components (e.g. any service orchestrator or service monitoring platform)	• ONAP Data Collection Analytics and Events [32] • Prometheus [18], Grafana [19]	Collection and analysis of VNFs events
Available VNFs / MEC Apps / NSs	vCPE, vFirewall, vIMS	

2.4 Italian site facility

2.4.1 Overview of site capabilities

The 5G EVE Italian site facility is hosted in the city of Turin, where all 5G components will be deployed from the radio elements to the distributed cloud PoPs with NFV capabilities, as an integration of lab-based and operational infrastructures. Note that a part of the 5G site facility in Turin is based on existing (and planned) deployments in the context of the "Torino 5G" initiative, where some of the 5G EVE partners are participating.

All of the 5G EVE Italian partners participate with different contributions to the deployment of the Turin site facility infrastructure components, software tools, services and applications that will serve to validate the vertical services and requirements related to at least the following two use cases [1]:

- Smart Transport: Intelligent railway for smart mobility (see section 3.1.1)
- Smart Cities: Safety and Environment - Smart Turin (see section 3.1.5)

The Turin site facility will encompass 5G network elements including NR Access and 5G Core functionalities, provided by Ericsson and deployed into TIM lab testing infrastructures and field operational networks. Additional testing facilities are also planned to be deployed by CNIT in the area of Politecnico di Torino, including 5G radio elements and an NFVI PoP. In summary, mobile radio access in the Italian site facility will range from wireless networks based on 5G standards (3GPP R15_Option 3x, as initial deployment) down to 4G LTE for preliminary validations and benchmarking, as well as local WiFi networks and NB-IoT for indoor deployments and specific connectivity with IoT devices.

On top of this comprehensive physical infrastructure, the Italian site facility will include SDN/NFV based control and orchestration tools aiming at coordinating the deployment of VNFs, Network Services and network slices, thus matching the vertical requirements in terms of performance, availability and reliability. Through these control and orchestration tools, vertical-tailored and application-specific VNFs and functions in general will be deployed in support of the Smart Transport (e.g. for media streaming, traffic flows and user pattern analysis) and Smart Turin (e.g. for integration of IoT sensors and devices with the oneM2M [33] platform by TIM) use-cases.

The following subsections provide an overview of the main capabilities, in terms of services and features exposed, planned for the Italian site facility at the data, control and orchestration planes. For each plane, a dedicated subsection is provided.

2.4.2 Main services and features offered

2.4.2.1 Data Plane

Table 12: Italian site facility – overview of data plane service capabilities

Category	Technology highlights	Main (i/w) features and capabilities
RAN	**Spectrum**: B43 **Technology description**: 5G New radio non-standalone (NSA) **Mgt/control/DP interfaces**: S1/X2	New radio connectivity towards LTE signalling
Fronthaul/ Backhaul	**Technology description**: • FH - Active functionality of Transponders and Power Monitoring Units and built on the DWDM platform • BH – High capacity aggregation router **Deployment**: • FH - High density pizza box for indoor unit (for Baseband or RRU connection) and outdoor equipment unit (for RRU connection) • BH – Provides Radio aware transport for mobile backhaul with high 10GE density and 100GE switching capacity **Mgt/control/DP interfaces**: • FH - IPv4/IPv6 manageability by LCT/CLI and ENM • BH – Managed by CLI, ENM, NETCONF and Yang model	• FH - The Fronthaul active solution provides high capacity and low latency to ensure that even the most stringent transport requirements of LTE, LTE-advanced and 5G are met. • BH - Provides application aware traffic engineering with open and standardized interfaces, enabling network slicing and ability to tailor services for utmost agility

Core	**Technology description**: Distributed cloud (3GPPP) **Mgt/control/DP interfaces**: logical between different VMs and only physical connections will be towards the RAN (eNB and gNB) and towards the backhaul (switch)	SR-IOV accelerator
ME Hosts	**Technology description**: DELL servers **Capabilities and deployment**: Multi-server without external storage **Mgt/control/DP interfaces**: Extreme switch as external host	SR-IOV accelerator
Cloud	**Technology description**: Ericsson Execution environment (CEE) **Capabilities and deployment**: based on Mirantis Openstack **Mgt/control/DP interfaces**: interface with external control and traffic switch	SR-IOV accelerator
PNFs	Not planned	Not planned
inter-site connectivity	**Technology description**: IPSec/GRE VPN tunnelling	Two dedicated VPN gateways at the boundary of the control/orchestration and data plane intra-site networks

2.4.2.2 Control Plane

Table 13: Italian site facility – overview of control plane service capabilities

Category	Technology highlights	Main (i/w) services and features
RAN controller	**Sw tool(s)**: Ericsson Network Manager (ENM) **APIs**: Ericsson's proprietary	• Configuration of radio elements • Seamless integration with configuration and management of other segments (transport, core)
SDN controller	**Sw tool**: OpenDaylight [15] **APIs**: OpenDaylight base APIs	Base Opendaylight Beryllium/Nitrogen version features, applications and services.

	Sw tools: Ericsson ENM/NorthStar [34] **API:** NorthStar REST API	• Network Optimization • Predictable Deterministic Network State • Multiple User-Defined Constraints, Global network view • Ordering and Synchronization of Paths
ME Platform Manager & Orchestrator	**Sw tool(s)**: Ericsson orchestrator as manager of the distributed edge/core cloud deployment **Underlying VIM**: OpenStack Queens **APIs**: Ericsson's API only for network nodes	• Edge breakouts • Redirection of traffic flows to local edge applications
VIM	**Sw tool(s)**: OpenStack Queens; in Ericsson VIM modules are in CEE **APIs**: at least base OpenStack APIs and components	• Management of virtualized infrastructure resources • Integration of network, compute, storage Openstack components
Additional components	**Sw tool(s)**: Openstack Telemetry **APIs**: Openstack APIs	Virtualized infrastructure metrics, resource consumption monitoring and events collection

2.4.2.3 Orchestration Plane

Table 14: Italian site facility – overview of orchestration plane service capabilities

Category	Technology highlights	Main (i/w) services and features
NFVO	**Sw tool**: Ericsson Orchestrator **APIs**: Ericsson proprietary – ETSI NFV SOL002 – SOL005 [35] (planned 2019)	• NS lifecycle management • NS Descriptor-driven orchestration • Tosca support for NS Description
	Sw tool: OSM R4 [11] **APIs**: ETSI NFV SOL005 as northbound APIs [35]	• NS packaging and on-boarding • NS instantiation, manual scaling, termination • NS monitoring leveraging on OpenStack Telemetry services • VNF Day0, Day1, Day2 configurations
VNFM	**Sw tool**: ENM – Ericsson Network Manager for Ericsson PNFs and VNFs **APIs**: Ericsson proprietary	VNF lifecycle management for Ericsson's PNFs and VNFs (instantiate, terminate, scale, heal)

	Sw tool Ericsson Orchestrator for generic VNF **APIs**: Ericsson proprietary	• Generic VNFM for multivendor VNFs • VNF LifeCycle Management • Integration with multi-vendor EMS
Slice Manager	**Sw tool**: Ericsson Service Orchestration **APIs**: Ericsson proprietary	• Network Slice design • (BluePrint Design, BluePrint Validation) • Network Slice instantiation (VNF Instantiation, Network Infrastructure configuration, Network Elements integration) • Network Slice operation (Network Slice re-configuration, Supervision and Performance, Network Slice Scaling and Upgrade) • Network Slice termination (De Activation, Re-set configuration)
	Sw tool: Nextworks' Slicer (open-source) [36] **APIs**: REST APIs (non-standard)	• Vertical services lifecycle management and provisioning • Network slice management functions
OSS/BSS	**Sw tool** ENM- Ericsson network manager	• High capacity and fully scalable • Auto-Provisioning • Enhanced CLI – Scripting for massive automation • Optimized RAN upgrades times
Additional components	**Sw tool**: Ericsson Fault & Performance Management	• Fault and Alarm collection and correlation • Alarm enrichment with tenant data • Performance Management
	Sw tool: Prometheus	• Collection and aggregation of service level metrics • Integration with OpenStack telemetry services
Available VNFs / MEC Apps / NSs	vEPC, vSGSN-MME, vHSS, vCUDB	

3 Technical interworking requirements from vertical use cases

This section aims at providing a set of technical interworking requirements that derive from the vertical use cases of 5G EVE. In particular, starting from the use cases described in deliverable D1.1 [1], and their general and specific requirements, more technical requirements related to their deployment and execution are identified, thus affecting the overall 5G EVE platform, and in the specific case of this document, the 5G EVE interworking framework.

3.1 5G EVE Use Case technical requirements

The whole set of vertical use cases requirements listed in D1.1 [1] have been analysed against each use case scenario, and as a result, a list of functional requirements has been identified.

The following sections provide a set of technical requirements for each of the 5G EVE vertical use cases with the aim of highlighting those related to the interworking framework at different phases of the use case execution, from deployment to operation and monitoring/analysis. It is relevant to highlight that these requirements refer to the current definition and planned roadmap of each use case, as defined in D1.1 [1]. Any further elaboration, improvement or update will depend on each 5G EVE use case evolution and will be reported in future WP3 deliverables, if required and applicable.

The vertical-oriented technical requirements listed in the following sections are grouped as follows:

- *Deployment Requirements*: all those aspects and features needed to deploy and provision the vertical use case in the 5G EVE end-to-end facility;
- *Runtime Requirements*: runtime operations required to be supported in order to execute the vertical use case;
- *Monitoring/Analysis Requirements*: monitoring and data analysis aspects in support of testing and validation of the vertical use case experiments and targeted KPIs.

For each identified requirement, one of the following priorities is assigned:

- *High*: when the requirement is essential to execute and validate the given vertical use case, and therefore it shall be satisfied;
- *Medium*: when the requirement validates a core concept of the vertical use case, and therefore it should be satisfied;
- *Low*: when the requirement is related to nice-to-have features and properties of the given vertical use case, and it does not affect the overall execution and validation of its concepts.

3.1.1 Smart Transport: Intelligent railway for smart mobility

The Smart Transport [1] use-case aims at exploiting the 5G network capabilities for improving railway transportation services in two main directions. First, the use case intends to leverage on the expected 5G performances to allow railway transport operators to provide new enhanced on-board train services for passengers. Second, the use case plans to monitor in real time the passengers' mobility patterns, thus enhancing the railway and train management systems and improving the railway traffic management. This is achieved with prediction of traffic peaks and bottlenecks in the public transportation, possibly by supporting urban multimodality between railway networks and other transportation services.

Therefore, the Smart Transport use case is composed of two highly combined scenarios: i) 5G on-board media content provisioning, to deliver Full HD and 4K media streaming services for entertainment and infotainment of train passengers, and ii) Urban Mobility 5G data flows analysis and monitoring, where mobility data from different transport operations is integrated towards an automatic identification of passengers' mobility patterns, thus enabling enhancements of transportation planning and context-aware provisioning of info-mobility services.

The two scenarios of the Smart Transport use case themselves do not have any specific requirement for being deployed and executed across multiple sites, as they are planned to run and be validated in the Italian site facility. However, the specific nature of both Smart Transport use case scenarios poses a set of technical requirements to be addressed. These requirements are grouped in deployment, runtime and monitoring/analysis requirements, as listed in the following tables.

Table 15: Smart Transport Use Case: deployment technical requirements

Deployment requirements	Priority	Description
Concurrent slices provisioning	High	The Smart Transport use case requires that two concurrent uRLLC (ultra-Reliable Low Latency Communication) and mMTC (massive Machine Type Communication) slices are deployed in parallel to serve the two scenarios for 5G on-board media content provisioning and urban mobility 5G data flows analysis and monitoring.
Slice network domains	High	The Smart Transport use case requires slices that span across RAN, distributed edge and core segments.
Placement of slice vertical VNFs	High	In the 5G on-board media content provisioning scenario, the media related VNFs (e.g. vCaches, video content servers) require to be deployed at specific locations across edge and core sides to fulfil the low latency requirements of the use case.
Placement of slice monitors and data analysis VNFs	High	In the Urban Mobility 5G data flows analysis and monitoring scenario, monitors and data analysis VNFs have to be deployed in specific MEC, edge and core locations to exploit proximity to public transport passengers and apply distributed info mobility data analysis.

Table 16: Smart Transport Use Case: runtime technical requirements

Runtime requirements	Priority	Description
Dynamic re-placement of vertical VNFs	Medium	In the 5G on-board media content provisioning scenario, due to the fast mobility of high-speed train passengers, the vertical media-related VNFs (e.g. vCaches) may need to be dynamically (or predictively) re-located to minimize the effects of the handovers.
RAN configuration	Medium	Runtime RAN configurations are required to maintain video streaming continuity for high speed trains passengers in the 5G on-board media content provisioning scenario, as well as to enable user position measurement and processing at edge locations in the urban mobility 5G data flows analysis and monitoring scenario.

Table 17: Smart Transport Use Case: monitoring/analysis technical requirements

Monitoring/Analysis requirements	Priority	Description
5G network performance monitoring	High	5G network performance measurements, including per-device delivered bandwidth, are required to be collected to validate the requirement fixed to achieve from 5 to 20 Mbps throughput per passenger.
Service performance monitoring	Medium	In the 5G on-board media content provisioning scenario, video streaming metrics and performance measurements have to be collected for estimating per-passenger quality of experience.
User mobility monitoring	Medium	In the Urban Mobility 5G data flows analysis and monitoring scenario, the user position is required to be measured precisely and monitored through 5G/MEC location services possibly integrated with device Global Navigation Satellite Systems.
Emulation of high density train passengers (UEs)	High	In the 5G on-board media content provisioning scenario, the emulation of a realistic scenario with 300 train passengers is required through software tools that are able to emulate the consumption of video Streaming Service in 4K/Full HD and realize active measurements of 5G network performance.

3.1.2 Smart Tourism: Augmented Fair experience

Tourism activity must be considered a vast transversal industry involving a wide range of multiple providers and users which configure and determine its unique idiosyncrasies. This diversity obliges to conscientiously concrete the potential use cases participating in 5G EVE projects to obtain real validation resulting from access to early state-of-the-art 5G features that can transform and improve the tourism sector globally.

The use case proposed for the smart tourism is the Augmented Fair, which aims at transforming the experience of Trade Fair events' users (exhibitors and visitors), with the objective of improving their interactions (information sharing, discussion, networking, negotiations and transactions) by leveraging Virtual Reality (VR)/Augmented Reality (AR) and 5G technologies. The main features encompassed in the Augmented Fair service are interaction with holographic maps, augmented booth and interactive holographic communications. Exhibitors may design virtual booths, with a variety of contents and experiences for interacting with their various types and profiles of visitors over a mixed reality layer, also able to incorporate, whenever needed, 3D volumetric presence of remotely located third persons and objects, as well as real-time translation services for making voice communications more effective between speakers of a variety of languages. All interactions and info exchanged through this platform shall also be available through digital means after the event to both exhibitor and visitor.

Business oriented smart tourism is a large vertical industry which can be greatly enhanced using the 5G capabilities to reduce operating expenses (OPEX) and to increase revenue through innovative services. The following two sub-uses cases, which are described in D1.1 [1], have been identified:

- Sub-use case 1: AR Interaction
- Sub-use case 2: Business Augmented Booth

For demonstrating the Smart Tourism use case, we propose the following architecture:

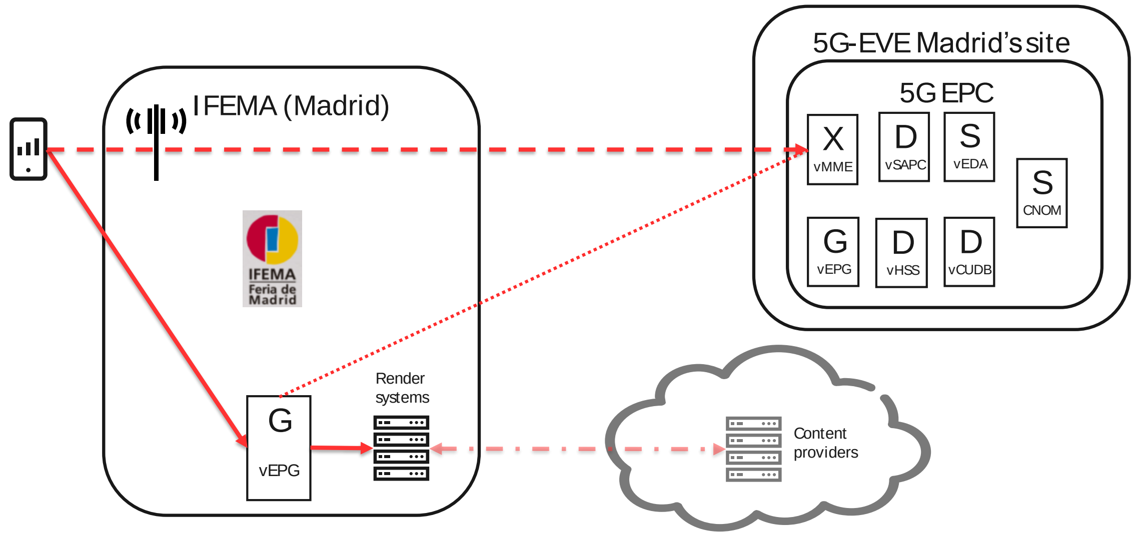

Figure 4 Inter-working architecture

This is a special case of interworking, as part of the infrastructure will be offside of the 5G EVE sites and it requires interconnection capabilities. 5G NR elements will be deployed at IFEMA premises (i.e. the Madrid's fair place), offering coverage to those booths that will be part of the experiment. Also, a user plane is required in IFEMA premises, as part of the distributed cloud that will offer user plane connectivity to the render systems. In addition, all the 5G control traffic need to go to 5G EVE site, for using the 5G EPC core deployed in the Madrid's site.

The overall requirements identified for this Smart Tourism use case are grouped in deployment, operation and monitoring/analysis requirements, as listed in the following tables.

Table 18 Smart Tourism Use Case: deployment technical requirements

Deployment requirements	Priority	Description
Concurrent slices provisioning	High	The Smart Tourism use case requires that two concurrent eMBB (enhanced Mobile BroadBand) and uRLLC slices are deployed in parallel to serve the different use cases.
Slice network domains	High	The Smart Tourism use case requires slices that span across Core segment. At this moment, RAN and Edge computing seem to be ad-hoc deployments for this use case.
Placement of slice vertical VNFs	High	The system in charge of rendering the information will be physically at IFEMA premises, so a UPF (User Plane Function) VNF must be deployed in the same premises. Control plane VNFs will be deployed in 5G EVE site.
Cross-site connectivity	High	It is required a 5G control plane connectivity between IFEMA premises and 5G EVE site

Table 19: Smart Tourism Use Case: monitoring/analysis technical requirements

Monitoring/Analysis requirements	Priority	Description
5G network performance monitoring	High	5G network performance measurements, including per-device delivered bandwidth, are required to be collected to validate the vertical requirements for density and peak throughput per user.

3.1.3 Industry 4.0: Autonomous vehicles in manufacturing environments

The Industry 4.0 use cases regarding the operation of autonomous vehicles in manufacturing environments are among the most challenging ones being realized within the 5G EVE project, since ultra-Reliable Low-Latency Communication (uRLLC) capabilities have to be demonstrated with extreme low latency requirements for AGV. This use case will be demonstrated both in the Greek and the Spanish site facilities and detailed requirements regarding the execution of these use cases have been provided in deliverable D1.1 of 5G EVE [1], including an advanced requirements analysis and providing additional insight into their inherent challenges.

During the pilot execution, various features of autonomous vehicle operation will be demonstrated, with varied levels of difficulty in terms of implementation and with different requirements. The most prominent features based on the scenario description using AGVs [1] of the two sites are:

- Autonomous vehicle navigation based on on-board (and potentially other) sensors;
- Obstacle avoidance and route adjustment based on moving obstacles;
- Transportation of goods between specific points with free movements of the AGV in space;
- Autonomous driving to charging station;
- Remote progress monitoring through mounted High Dynamic Range (HDR) cameras;
- Remote navigation through HD navigation camera & image processing.

All these features will be demonstrated in a local setting by utilizing resources of the respective local testbed (Greek or Spanish facility) and other potential local sources of information, such as facility mounted sensors (at least at a first stage), due to the nature of these pilots (AGV operation in specific manufacturing environments).

Depending on specific interests from verticals, at a later stage, the last two features listed above (i.e. remote monitoring and remote navigation) could also be demonstrated in a multi-site deployment showcasing the interworking capabilities of the 5G EVE end-to-end facility. In such a scenario, a remote user in a different 5G EVE site could monitor the progress of the AGV operations taking place in another facility or even remotely controlling the movements (or giving orders) to the AGV.

Table 20: Industry 4.0 Use Case: deployment technical requirements

Deployment requirements	Priority	Description
Concurrent slices provisioning	N/A	The Industry 4.0 use cases concurrent slices provisioning: URLLC slice for AVG controller and eMBB slice for uninterrupted HD video streaming to be used in the monitoring or remote controlling cases.
Slice network domains	High	The Industry 4.0 use cases require slices that span distributed edge and Core segments.

Placement of slice vertical VNFs	High	The Industry 4.0 use cases deploy a virtual controller for the AGVs with a critical requirement of RTT (less than 10 ms), so it should be deployed at the edge computing environment. Other VNFs can be deployed at core (or in a public cloud).
Placement of slice monitors and data analysis VNFs	High	ASTI use case deploys a monitor VNF near the virtual controller (edge computing environment).
Cross-site connectivity	Medium	ASTI use case can be used for demonstrating the interworking capabilities of 5G EVE. Thus, it requires a control and orchestration interconnectivity between Madrid and Turin sites to enable either remote control or monitoring of AGVs.

Table 21: Industry 4.0 Use Case: operation technical requirements

Runtime requirements	Priority	Description
Background traffic generator	Medium	In order to check the density requirement, Industry 4.0 ASTI use case requires to simulate the traffic of at least 400 AGVs.

Table 22: Industry 4.0 Use Case: monitoring/analysis technical requirements

Monitoring/Analysis requirements	Priority	Description
5G network performance monitoring	High	5G network performance measurements, including service latency, are required to be collected to validate the requirement of 10 ms RTT.
Service performance monitoring	High	Service performance measurements, including service metrics, are required to validate the use cases (correction measurements, AGV power consumption).

3.1.4 Smart Energy: Fault Management for distributed electricity generation in smart grids

The utilities sector comprises multiple society-critical industries such as water, electricity and gas, making the impact of 5G connectivity on their distribution networks, as well as the resulting increased safety, efficiency, reliability and reduced capital expenditures (CAPEX) and OPEX, of extreme societal importance.

The integration of an ever-increasing number of Distributed Generators (DGs), e.g. renewable energy, farms, households, into the electricity grid also introduces greater unpredictability of energy production and an increased risk of failures and section isolations (i.e., islanding). To mitigate these effects, ultra-reliable and ultra-fast fault detection and management is necessary to increase network stability and provide system protection. Currently, fault detection and management in energy grids takes place through fiber connectivity among the centralized electricity generation points (e.g., power plants). The shift towards DG offers great potential, but also makes a fiber communication monitoring solution prohibitive due to its deployment cost. However, 5G can enable ultra-fast and ultra-reliable fault detection and management in high-scale deployments, i.e. with extensive number of DGs. Such a fault management system is a key requirement for modern and next generation smart grids, as it allows to implement immediate automated reaction to changes in the network, while avoiding islanding and isolation of smart grid portions. The use of smart metering and fault detection mechanisms in combination with edge computing features for ultra-fast processing can therefore substantially improve and automate the level of control over the energy grid.

The Smart Energy use case in 5G EVE is implemented in two different scenarios, one in the Greek and the other in the French site facility, as reported in D1.1 [1]. The Greek scenario focuses on fault prediction, fault management and network restoration in a smart grid 5G deployment composed of a network of distributed energy sources equipped with 5G enabled smart sensors to measure the energy level, connected to a network of distributed energy consumers equipped with 5G enabled sensors to measure the energy consumption. The French scenario, on the other hand, focuses on a smart grid protection schemes for remote decoupling of DGs through 5G enabling ultra-low latency communication among the hierarchically distributed primary and secondary protections.

For both use cases, a set of additional requirements have been identified by processing the scenarios and requirements in D1.1 [1]. These requirements have to be addressed by the 5G EVE platform and are grouped in deployment, runtime and monitoring/analysis requirements, as follows:

Table 23: Smart Energy Use Case: deployment technical requirements

Deployment requirements	Priority	Description
Single slice provisioning	High	The Smart Energy use case requires a single uRLLC slice, augmented with mMTC capabilities, to be deployed for its execution.
Slice network domains	High	The Smart Energy use case requires slices that span across RAN, MEC and Core segments.
Device-to-device connectivity	High	The Smart Energy slice requires device-to-device connectivity for enabling communications between the grid protections, the feeders and the substations with ultra-low latency.
Placement of slice vertical VNFs	High	The Smart Energy fault detection, fault management and network restoration VNFs require to be deployed at specific edge locations to fulfil the ultra-low latency requirements of the use case.

Table 24: Smart Energy Use Case: monitoring/analysis technical requirements

Monitoring/Analysis requirements	Priority	Description
5G network performance monitoring	High	5G network performance measurements, including device-to-device latency, are required to be collected to validate the requirement of 5ms maximum latency.

Service performance monitoring	Medium	Smart Grid specific service measures have to be collected to validate the fault prediction and management mechanisms in both the Greek and French use cases. These include energy level at sources' side and energy consumption at consumers' side.

3.1.5 Smart Cities: Safety and Environment

3.1.5.1 Smart Turin

"Safety and Environment - Smart Turin" testbed focuses on the exploitation of 5G services under the areas of uRLLC and mMTC. The communication services provided on top of uRLLC and mMTC are the following:

- Management of critical issues related to urban mobility in the corridor Politecnico/Porta Susa
- Monitoring the flow of people to or from the University and Station. Monitoring with respect to the type of vehicles used. Introducing sensors that allow communication with the users (e.g. beacons) and putting them in communication with the users in the train, at the station, in the Politecnico and in the outdoor.

A set of significant number of sensors will be deployed and connected to the Italian 5G site, thus acquiring ultra-low latencies in the overall communication. In particular, the object of the experimental activities will be focused on the "Urban Safety" scenario, with ad-hoc use cases for the every-day life experience improvement of the Turin inhabitants, as well as the tourists' safety in selected areas of the city.

The Smart Turin use case does not foresee a deployment and execution across different 5G EVE sites. Therefore, for this use case the interworking framework is required to enable a unified access to the (Italian) single-site capabilities and features for validating the KPIs as reported in D1.1 [1]. A set of technical requirements have been anyway identified to achieve the execution of the Smart Turin vertical use case experiments, as listed in the following tables.

Table 25: Smart Turin Use Case scenario: deployment technical requirements

Deployment requirements	Priority	Description
Slice and Beacons deployment	High	The Smart City use case requires a single mMTC slice and the deployment of WiFi/Bluetooth Beacons controlled through the mobile network. The Beacons are used by the User Equipment (UE) (e.g. smartphones) for tracking user mobility and behaviour, while the User Plane (UP) and Control Plane (CP) are delivered through the mobile network.
Slice network domains	High	The Smart City use case requires slices that span across RAN, distributed edge and Core segments.
Placement of slice vertical VNFs	High	In the 5G M2M scenario, the Application Function for the oneM2M platform is deployed in a Cloud platform.
Placement of slice monitors and data analysis VNFs	High	In the Smart City use case, M2M data analysis and monitoring are performed by a specific Application Function deployed in Cloud.

Table 26 Smart Turin Use Case scenario: Runtime technical requirements

Runtime requirements	Priority	Description
WiFi/Bluetooth Beacons	High	WiFi/Bluetooth Beacons and 5G/NB-IoT (Narrow Band IoT) mobile networks have to be coordinated for the user data collection.

Table 27: Smart Turin Use Case scenario: monitoring/analysis technical requirements

Monitoring/Analysis requirements	Priority	Description
Service performance monitoring	Medium	In the 5G/NB-IoT mobile networks, performance measurements have to be collected to estimate the quality of experience.
User mobility monitoring	High	In the Smart City use case, 5G/NB-IoT, Beacon and WiFi/Bluetooth data are analysed by the oneM2M platform. This data will be available via REST APIs, allowing cloud platforms to process data collected in order to monitor the traffic and evaluate parameters and performance.

3.1.5.2 Connected Ambulance

In the Connected Ambulance scenario, the ambulance becomes a connection hub, which enables the transmission of different kinds of data from the emergency location directly to the hospital, in order to facilitate a faster and more accurate diagnosis. In particular, two major types of data need to be streamed in real-time:

- High-resolution video captured in real-time through dedicated wearables.
- A variety of sensor data about vital measurements.

The video traffic requires high data rates, from 200 Mbps up to few Gbps for VR. The sensors' traffic has lower traffic loads, in the order of few kbps, but it should be carried in reliable connections serving several data sources. This IoT-like traffic will be collected and processed through the Nokia IoT platform. Due to the different nature and requirements of these two traffic profiles, it would make sense to serve each type of traffic through a specialized network slice, with HD video served through an eMBB slice and sensors data served through an mMTC slice, respectively.

The main key characteristics of the service, independently of the specific traffic type, are the following:

- The reliability of the service as a whole, in terms of very low outage and failure rates.
- The privacy and the security of the personal data transmitted to the hospital.
- The mobility of the data sources along the ambulance's route, from the emergency location to the hospital.

Taking into account these characteristics and the expected traffic profiles, some technical requirements can be derived, as follows. The service should be instantiated dynamically when a new emergency occurs and it should consist of two concurrent eMBB and mMTC network slices. Moreover, the service should be deployed to cover a well-defined geographical area, which includes the emergency location and the expected route to be taken by the ambulance towards the hospital. Since this route may vary with the traffic condition, the coverage area of the service at runtime may be modified. Moreover, the deployment should include mechanisms to guarantee the high availability and the self-healing of the service, thus meeting the requirement about reliability. The management of IoT data requires the integration with the Nokia IoT platform, also in terms of monitoring functions. The technical requirements, which need to be addressed by the 5G EVE platform, are grouped in deployment, operation and monitoring/analysis requirements, as usual, and summarized in the tables below.

Table 28: Connected Ambulance Use Case scenario: deployment technical requirements

Deployment requirements	Priority	Description
Concurrent slices provisioning	High	The Connected Ambulance use case requires that two concurrent eMBB and MTC slices are deployed in parallel to serve the traffic flows related to HD video streaming and sensors data collection, respectively.
Slice network domains	High	The connected ambulance use case requires slices that span across RAN, XHAUL and Core segments. The service running in the MTC slice should be able to interact with the Nokia IoT Platform.
Geographical coverage of the service	High	The connected ambulance use case requires to deploy the two network slices in a configurable geographical area, guaranteeing a coverage area which includes the emergency location and the route to the hospital.
Dynamic and on-demand instantiation and termination of the service	High	The connected ambulance use case requires to dynamically instantiate and terminate one or more instances of the service on-demand, even in different geographical locations, based on the emergencies occurrence.
Deployment of the service in high-availability mode	Medium	The service should be deployed in high-availability mode (e.g. with some function instances that are replicated, based on the specific application design).
Deployment of functions for data encryption/decryption	Medium	The service should be deployed with integrated functions for data encryption/decryption, to guarantee the privacy of the personal data.

Table 29: Connected Ambulance Use Case scenario: operation technical requirements

Operation requirements	Priority	Description
Dynamic modification of the coverage area of the service	Medium	In order to deal with any unexpected modifications of the ambulance route due to changing traffic conditions, it should be possible to re-configure the coverage area of the service at runtime.
Service self-healing	High	In case of failures, the service should be automatically healed to limit the service disruption and the outage time. In case of failures at the resource level, the service may be re-instantiated over different resources.

Mobility management	High	At runtime, the service should support the mobility of the mobile clients, for both video and sensor data producers. This may include a RAN configuration at runtime to maintain the streaming continuity along the path towards the hospital.

Table 30: Connected Ambulance Use Case scenario: monitoring/analysis technical requirements

Monitoring/Analysis requirements	Priority	Description
5G network performance monitoring	High	The system should be able to provide 5G network performance measurements, including: • Bandwidth provision for video streaming: validation of KPI from 20 Mbps to few Gbps per video flow.
Monitoring of sensor data reception continuity	High	The system should be able to verify the continuity of the received sensors data, with reference to the sampling rate defined for each type of vital sensor.
Monitoring of the QoE in the reception of the HD video	Medium	The system should be able to estimate the QoE perceived for the reception of the HD video transmitted from the ambulance.
Monitoring of service disruption time	Medium	The system should be able to simulate service breaks (possibly related to different causes, e.g. at the application and at the resource level), verify the capability of the recovering the service and measure the service outage time.

3.1.5.3 Health monitoring and forecasting, smart mobility and smart home

This multifaceted use case applies the same type of technologies and architectural concepts to a variety of environments and services, from smart home to eHealth and smart mobility. The overall, unifying idea behind the different scenarios of this use case is to adopt the 5G network connectivity and interact with a wide number of sensors and actuators. This will give the chance to collect data, send notifications and enforce commands, while exploiting the computing and storage resources offered in the cloud or at the edge of the network to run the application logic that processes the collected data and elaborates the resulting actions. The major challenge of the use case is thus the communication with an increasing number of heterogeneous small devices, like an entire smart city (e.g. weather-related sensors, pollution sensors, air quality sensors, etc.). The heterogeneity of the sensors is also associated to different kinds of traffic patterns (e.g. dimension and frequency of the generated messages), different levels of data privacy for the produced measurements (e.g. for health and private home related data) and different mobility profiles (e.g. fixed sensors located at home vs sensors installed alongside heavy-traffic roads but also less congested ones). Another critical aspect is related to the storage and computing resources needed to store, access and process such amount of data, possibly with several different, but concurrently operating algorithms. This may bring requirements in terms of geographical location of such resources, but will guarantee a more efficient and convenient transmission of the data from the pervasive sources. Moreover, it will enable a more distributed and well-balanced processing, also in compliance with the required response time of the different services (e.g. the reaction time to send a command towards one or more actuators as consequence of a particular detected situation). In some cases, the data to be processed may involve video flows, which are characterized by completely different traffic patterns.

Taking into account the requirements described above, we can identify an mMTC network slice as the main enabler of the use case, to deal with the collection of data from a massive number of sensors. Depending on the particular application algorithm, the processing resources may need to be deployed closer to the network edge or not. In parallel, a uRLLC network slice may be needed to guarantee particularly low latencies, e.g. for services requiring a low response time, as happens in the case of health or city emergencies (e.g., related to air quality for instance). In such cases, a uRLLC slice would enable, on the one hand, the immediate sharing of sensor data so as to facilitate emergency monitoring and, on the other hand, ensure the dissemination of the event to all interested stakeholders, such as hospitals and municipalities, with high reliability. In specific situations, e.g., when a health emergency occurs, additional eMBB network slices can be required to support video transmission in the context of remote immediate response to health incidents by medical professionals while the patient is waiting for an ambulance.

The technical requirements, which need to be addressed by the 5G EVE platform, are summarized in the tables below.

Table 31: Health monitoring and forecasting, smart mobility and smart home Use Case scenario: deployment technical requirements

Deployment requirements	Priority	Description
Concurrent slices provisioning	High	The use case requires the creation of one or more concurrent mMTC slices for collection of monitoring data from various sensors (e.g. different slices can be dedicated to elaborate data from different data sources). No specific considerations for the deployment at this point. In parallel, additional URLLC slices may be needed to deal with latency aware services, e.g. to send operational commands. In specific time periods, concurrent eMBB slices are deployed in parallel to serve video traffic flows.
Slice network domains	High	The required slices spans in general across RAN, XHAUL and Core segments. Edge resources may be needed to run particular latency aware algorithms.
Geographical coverage of the service	High	Depending on the specific service, the slices can cover geographical areas with different sizes, with the ultimate vision of covering an entire city. The geographical coverage as well as the specific target location should be configurable.
Dynamic and on-demand instantiation and termination of single services in the whole scenario	Medium	Particular services based on eMBB slices should be dynamically instantiated and terminated on-demand, selecting the specific geographical locations, based on the emergencies occurrence.
Efficient selection of edge/cloud resources for data elaboration	Medium	The system should be able to select the target computing and storage resources, optionally using edge resources, based on the different requirements of specific data elaboration algorithms.

Deployment of functions for data encryption/decryption	Medium	The service should be deployed with integrated functions for data encryption/decryption, optionally applied only to specific traffic profiles (e.g. messages generated from eHealth sensors on wearable devices), to guarantee the privacy of the personal data.

Table 32: Health monitoring and forecasting, smart mobility and smart home Use Case scenario: runtime technical requirements

Runtime requirements	Priority	Description
Dynamic modification of the whole service	High	The component of the service related to emergencies should be dynamically instantiated and terminated on-demand, thus modifying the whole composite service at runtime.
Mobility management	High	At runtime, the service should support the mobility of sensors and video producers. This may include a RAN configuration at runtime to maintain the streaming continuity and the migration of computing resources or context data to keep the continuity of the algorithms' processing.

Table 33: Health monitoring and forecasting, smart mobility and smart home Use Case scenario: monitoring/analysis technical requirements

Monitoring/Analysis requirements	Priority	Description
5G network performance monitoring	High	The system should be able to provide 5G network performance measurements, including: • Delivered bandwidth for video streaming: validation of KPI up to 400 Mbps for total broadband connectivity for aggregated video. • Maximum latency in URLLC slices: less than 5 ms
Monitoring of sensor data reception continuity	High	The system should be able to verify the continuity of the received sensors data, with reference to the sampling rate defined for each type of sensor.
Monitoring of the QoE in the reception of the HD video	Medium	The system should be able to estimate the QoE perceived for the reception of the transmitted HD video.
Emulation of high device density	Medium	The system should be able to emulate a realistic mMTC condition, with up to 60K devices/km^2, some of them moving with a speed up to 200 km/h, for testing the performance of the mMTC slice.

3.1.6 Media & Entertainment

3.1.6.1 UHF Media, On-Site Live Event Experience and Immersive and Integrative Media

The Media & Entertainment's use case consists of three different multimedia over 5G scenarios. On the one side, "Ultra High Fidelity Media" and "Immersive and Integrated Media", which are new very high quality video formats. The use case consists of demonstrating the transmission over 5G of IPTV-like services based on those formats, on urban areas and including a number of concurrent channels. On the other side, "On-site Live Event Experience" is more focused on providing enhanced viewing experience in limited coverage (but very dense) areas, like stadiums, cinemas, etc., also over 5G.

The most critical common requirement for these scenarios is the very high network capacity that is required, in line with the traffic growths that Service Providers are experiencing over the past several years. To optimize its usage, parameters like latency, jitter, bandwidth, etc. should be controlled. In that sense, these 5G services will be demonstrated in this use case: eMBB, to ensure maximum coverage for ultra-high fidelity media and URLLC, to guarantee live events coverage and immersive media.

Each scenario will be deployed in two phases: the first one will include the initial deployments in 2019 and the second one will include the massive deployments in 2020.

The technical requirements to be addressed by the 5G EVE platform for the proper execution of the UHF, on-site Live Event Experience and immersive and integrative media vertical use case experiments are summarized in the tables below.

Table 34: UHF Media, On-Site Live Event Experience and Immersive and Integrative Media Use Case scenario: deployment technical requirements

Deployment requirements	Priority	Description
Slices provisioning	High	The use case requires the instantiation of eMBB slices to support media distribution, for different mixes of live TV and VOD (Video On Demand) and for different types of video quality (SD, HD, 4K), as well as real-time video from connected cameras in uplink. uRLLC slices could be required depending on the performance requirements to be satisfied in situations like immersive and integrated video.
Slice network domains	High	The required slices spans in general across RAN, XHAUL, Edge and Core segments. Edge resources are needed for video caching.
Geographical coverage of the service	High	Depending on the specific scenario, the slices must cover geographical areas with different sizes. The Ultra High-Fidelity Media scenario targets a wide area, while the On-Site Live Event Experience targets a limited geographical area, but with much higher density of mobile clients.
Dynamic and on-demand/advanced instantiation and termination of service	High	The eMBB / uRLLC slices should be dynamically instantiated and terminated on-demand or through advanced reservation, selecting the specific geographical location and the target time periodicity according to the scheduling of the live event.

Table 35: UHF Media, On-Site Live Event Experience and Immersive and Integrative Media Use Case scenario: operation technical requirements

Operation requirements	Priority	Description
Mobility management	High	At runtime, the service should support the mobility of the users guaranteeing the same level of video quality. This may require a RAN configuration at runtime to maintain the video streaming continuity and the migration or new instantiation of video caches based on the position of the user.

Table 36: UHF Media, On-Site Live Event Experience and Immersive and Integrative Media Use Case scenario: monitoring/analysis technical requirements

Monitoring/Analysis requirements	Priority	Description
5G network performance monitoring	High	The system should be able to provide 5G network performance measurements, including: • Bandwidth provision for video streaming in downlink: validation of KPI from 40 up to 250 Mbps per mobile cell, depending on the scenario; • Bandwidth provision for video acquisition in uplink: validation of KPI from 20 up to 60 Mbps total uplink with up to 4 cameras, depending on the scenario; • For more scalable tests, bandwidth up to 50 Mbps for a single video source and up to 20 channels for concurrent video sources and 1 Gbps total bandwidth.
Monitoring of the QoE in the reception of the video with different levels of quality	High	The system should be able to estimate the QoE perceived for the reception of the transmitted video, based on different mixes of the video quality (SD, HD, 4K).

3.1.6.2 Virtual visit over 5G

As already detailed in D1.1 [1], this use case aims at relaxing limitations to some physical places, such as houses and popular touristic places that provide limited access to potential visitors. This use case is described in Figure 5 with a real estate agency example, but even wider examples can be imagined. For instance, the virtual visit of touristic places allows relieving the frequentation by directing interested tourists to a virtual visit either before or instead of a physical one.

Figure 5: 5G PPP scenario: eMBB and URLLC.

Virtual visits should benefit from 360° media delivery in a quality that may allow replacing a physical visit with a virtual one, therefore one general requirement is to support the streaming of 360° video and match the highest quality supported by high-end head mounted displays. This mainly means that a physical network with a good throughput and a very low latency can offer a very reliable connectivity for such high quality contents. In one variant, the content should be accessible to both the widest viewer population and the widest content provider population, thus the service should be supported over eMBB scenario. In a more specialized variant, the viewing terminals are provided by the real estate agency or the smart tourism agency, which requires more controlled performance from its network provider. For the latter variant, the service is supported over uRLLC. The main identified KPIs, which could support such a use case, are:

- Latency: the RTT from the Head Mounted Display (HMD) to video server should be less than 10 ms.
- Speed: Bandwidth between the HMD and the video server on downlink should be around 80 Mbps, for video with compression.

For the Virtual Tourism use case, a deployment across multiple sites is not foreseen by Orange, as the use case is only planned to be executed in a single site facility. However, Orange considers the possibility of supporting a 5G EVE partner willing to implement the use case on its site facility, provided that additional performance metrics would stem from this interworking, such as end-to-end deployment. We identify a total of four scenarios upon which the interworking requirements would depend: two scenarios on the terminal side and two scenarios on the omnidirectional video streaming server side. With reference to these four scenarios and the related figures below, orange coloured boxes are for components provided by Orange (as vertical), blue ones for components provided by other partners or site facility and grey ones either by Orange or other partners.

On the terminal side, we identify the following two scenarios depending on the omnidirectional video terminal (i.e. a HMD, its accompanying PC in case of non-autonomous HMD, the omnidirectional video player and instrumentation software) that would be used:

- **Scenario TO (Terminal Orange):** it covers the case when a clone of Orange's omnidirectional video terminal is used, as depicted in Figure 6
- **Scenario TP (Terminal Partner):** it covers the case when the 5G EVE's partner uses its own terminal.

Figure 6: Video 360° TO scenario deployment

Figure 7: Video 360° TP scenario deployment

Similarly, on the server side, we identify other two interworking scenarios depending on how the 5G EVE partner would use the omnidirectional video streaming server (software and content):

- **Scenario SI (Server Interconnection):** it covers the case where the 5G EVE partner interconnects to the omnidirectional video streaming server hosted on Orange site facility.

- **Scenario SO (Server On-board)**: it covers the case where the 5G EVE partner on-board Orange's omnidirectional video streaming server into its virtualization infrastructure and (optionally) into its management and orchestration infrastructure. This scenario is still to be clearly defined in terms of (performance) requirements (at control and data planes) for cross-site deployment, and its validation is considered in this first phase of the project at lower priority with respect to the single site deployment, The implementation of this scenario will be deeply discussed with other partners during the second phase of the project, i.e. year 2020.

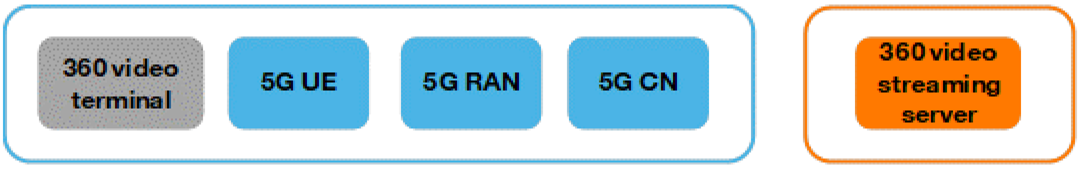

Figure 8: Video 360° SI scenario deployment

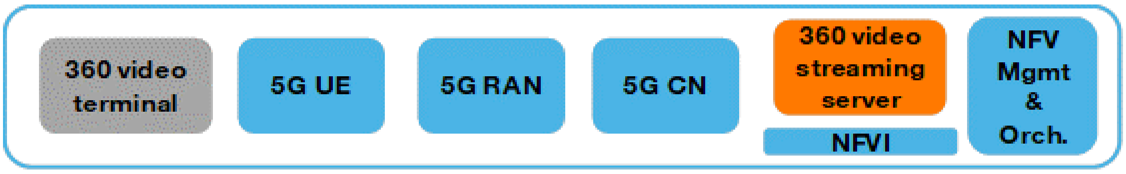

Figure 9: Video 360° SO scenario deployment

In addition to the above four potential interworking scenarios, the Virtual Visit use case experiments execution poses a set of technical requirements to be addressed by the 5G EVE platform, which are summarized in the tables below.

Table 37: Virtual visit over 5G Use Case scenario: deployment technical requirements

Deployment requirements	Priority	Description
Slices provisioning	High	The use case requires the instantiation of eMBB slices to support the 360° video distribution and the instantiation of uRLLC slices, with upper goal to support interactive communications between HMD and video server.
Slice network domains	High	The required slices span in general across RAN, XHAUL, and Core segments. Edge resources may be needed for video caching.
Dynamic and on-demand instantiation and termination of service	High	The eMBB and uRLLC slices should be dynamically instantiated and terminated on-demand.

Table 38: Virtual visit over 5G Use Case scenario: monitoring/analysis technical requirements

Monitoring/Analysis requirements	Priority	Description
5G network performance monitoring	High	The system should be able to provide 5G network performance measurements, including: • Delivered bandwidth for video streaming in downlink: validation of KPI from 40 up to 80 Mbps per mobile user. • Maximum latency from HMD to video server less than 10 ms.
Monitoring of the QoE in the reception of the 360°video	High	The system should be able to estimate the QoE perceived for the reception of the transmitted 360° video.

4 Target interworking capabilities, features and services

This section defines a first proposal of the interworking capabilities, features and services that shall be provided by the 5G EVE platform. We consider, in the scope of the preliminary interworking framework architecture definition, all the features and services required to provide a common interface and model on top of the 5G EVE site facilities. For this scope, a list of target capabilities each 5G EVE site should expose to enable this interworking common model is also defined. In addition, cross-site connectivity aspects and requirements are also considered to enable interworking in executing vertical experiments involving several sites.

4.1 Preliminary interworking framework architecture

Starting from the vertical oriented technical requirements derived from the 5G EVE use cases and reported in section 3, and also considering the heterogeneous services and features offered by each site facility described in section 2, a preliminary interworking framework architecture scheme is proposed. This proposal aims at identifying a minimum set of interworking capabilities functions to be supported by the 5G EVE end-to-end facility.

The 5G EVE interworking framework is a unique selling point of the 5G EVE end-to-end facility, which aims at providing a unified and integrated experimentation platform spanning heterogeneous sites, where diverse 5G capabilities and tools are deployed. Therefore, it is a combination of coordination features for the seamless orchestration and execution of vertical use case experiments over heterogeneous infrastructures.

Therefore, its design and implementation are basically performed from scratch, trying to enhance, combine and integrate, where possible, existing solutions for multi-site orchestration, catalogue and inventory of NFV network services, VNFs and network slices, monitoring of network and service performances. Figure 10 shows the preliminary interworking framework architecture diagram and high-level functional split, as well as its logical positioning with respect to the 5G EVE experiment portal and the four site facilities. In particular, the interworking framework sits between the experiment portal, that is the frontend of the 5G EVE platform and the site facilities where the vertical use case experiments have to be deployed for testing and validation 5G and service specific KPIs.

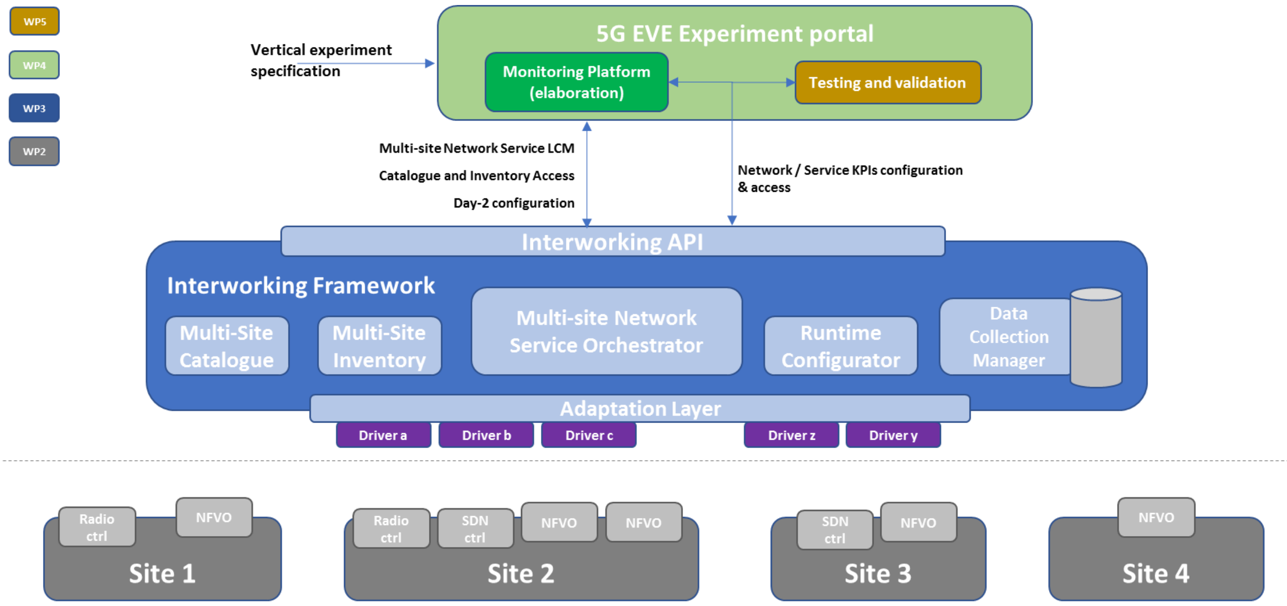

Figure 10: Preliminary interworking framework architecture

The two main reference points exposed and provided by the 5G EVE interworking framework are:

- The *Interworking API* exposed at the northbound towards the 5G EVE experiment portal;

- The *adaptation and abstraction interface* at the southbound for providing a common and unified access to the individual site facilities services and APIs.

As a general reference for modelling and descriptions of end-to-end network services and slices within the interworking framework, the followed approach is the one proposed by ETSI NFV in the Evolution and Ecosystem WG work item EVE012 [37]. In the context of the interworking framework, the most relevant considerations provided by ETSI NFV EVE012 are those related to information models and architectural aspects, specifically targeting 3GPP network slice concepts, described in 3GPP 28.801 [38] and specified in 3GPP 28.530 [39]. Indeed, 3GPP defines a network slice as a combination of zero or more network slice subnets, following a kind of recursive approach, where each subnet can contain zero or more other subnets, as well as zero or more network functions. Network functions in 3GPP are associated to VNFs and PNFs, therefore a direct mapping of an NFV Network Service as a resource-centric view of a network slice is highly appropriate. Moreover, as 3GPP foresees that network slice subnet instances can be shared by multiple network slice instances, and virtualized resources for a slice subnet (including compute, network and storage) can be mapped to nested NFV Network Service concept. In this way, as shown in Figure 11, a correspondence between network slice instances and network slice subnets instances with NFV Network Services exists, following the relationship provided by the dotted arrows.

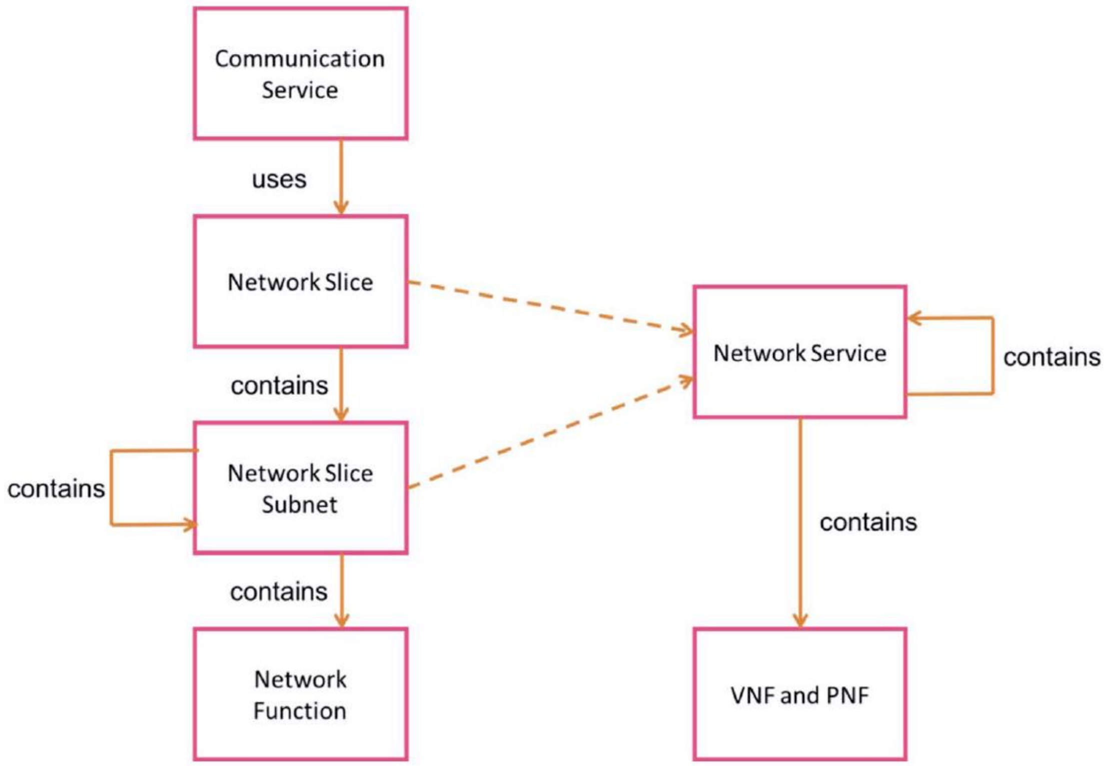

Figure 11: 3GPP and NFV information models potential mapping (source [37])

In this context, the **Interworking API** can be considered as a collection of primitives that aims at exposing a common interface and model for end-to-end Network Services and slices provisioning in support of the vertical use case experiments. It is important to highlight that the interworking API is not only a provisioning interface. Indeed, it is conceived to expose additional features for the operation of the vertical use case experiments, including runtime configuration of the network services and slice elements (e.g. VNFs), and monitoring of network and service performance metrics in support of the validation of targeted KPIs within each experiment.

In summary, the interworking API exposes at least the following services:

- Access to multi-site catalogue to allow the 5G EVE experiment portal to:
    - Retrieve Network Service and VNF Descriptors modelling the network slices that can be provisioned in the end-to-end facility;

  - On-board new Network Service and VNF Descriptors to fulfil the requirements of vertical use case experiments.

- Access to multi-site inventory information to allow the 5G EVE experiment portal to retrieve details of already provisioned Network Services in support of vertical use case experiments;
- Provisioning and lifecycle management of end-to-end Network Services in line with ETSI NFV Management and Orchestration (MANO) principles and operations.;
- Configuration of 5G network and service performance metrics to be monitored and collected during the execution of vertical use case experiments;
- Common and site independent access to collected monitoring information for each vertical use case experiment, for processing and analysis by the 5G EVE experiment testing and validation tools;
- Runtime configuration of Network Services and VNFs, to enable the 5G EVE validation framework to dynamically apply vertical-oriented service logics and configurations (following the vertical's experiment requirements and constraints) with a common approach and interface. It is worth to highlight that this runtime configuration is not intended, at least in this initial phase of the interworking framework definition, to be directly exposed and offered to the verticals

On the other hand, the **Adaptation Layer,** shown in Figure 10, has the main goal to abstract the heterogeneous capabilities and APIs exposed by the 5G EVE site facilities, mostly focusing, in this preliminary interworking framework definition, on orchestration and control features. Therefore, it exposes to the interworking framework components a set of common internal APIs and models for accessing per-site management, control, orchestration and monitoring services, and translates them into the site-specific APIs and models. In particular, the common APIs and models provided by the adaptation layer are intended to provide transparent access to those site features and services listed in section 4.3 as required to fulfil the vertical oriented technical requirements. As depicted in Figure 10, for each of these required per-site features and services, the adaptation layer is equipped with specific drivers providing the required translation from the common interface to the site-specific APIs.

4.1.1 Overview of the interworking framework components

The preliminary interworking framework architecture, presented in Figure 10, is decomposed into the following functional components: Multi-site Network Service Orchestrator, Multi-site Catalogue, Multi-site Inventory, Runtime Configurator, and Data Collection Manager.

The preliminary interworking framework architecture, presented in Figure 10, is decomposed into the following functional components: Multi-site Network Service Orchestrator, Multi-site Catalogue, Multi-site Inventory, Runtime Configurator, and Data Collection Manager.

The **Multi-site Network Service Orchestrator** is the core component within the interworking framework and responsible for coordinating the provisioning and lifecycle of Network Services across the site facilities, as required to deploy end-to-end network slices for the execution of vertical use case experiments. It leverages on the per-site orchestration components and features, as they provide the fundamental logics and coordination within each 5G EVE site facility. Following the ETSI NFV EVE012 [37] approach described above, the Multi-site Network Service Orchestrator allows to provision end-to-end network slices as a combination of NFV Network Services, possibly across different sites when required. For this, the Multi-site Network Service Orchestrator contributes to the interworking API with lifecycle management operations, including on-boarding, based on the ETSI NFV SOL005 APIs [35], which specify the NFV Orchestrator northbound interface. Therefore, it is supposed to operate on top and coordinate, through the Adaptation Layer, the different per-site orchestration and control tools, e.g. at RAN, MEC or edge, transport SDN, NFV segment level. The Multi-site Network Service Orchestrator also provides the logic for selecting where to deploy Network Services and VNFs, according to the specific performance, resource and location constraints received through the interworking API and expressed by the vertical for the execution of its experiment. For this specific selection purpose, the Multi-site Network Service Orchestrator leverages on the information (in terms of running instances and their performances) available from the Multi-site Inventory and the Data Collection Manager. The Multi-site

Network Service Orchestrator owns and manages the Multi-site Catalogue and the Multi-site Inventory, and it is responsible for keeping the information stored consistent and up to date.

The **Multi-site Catalogue** decouples the Network Service Descriptors exposed to the 5G EVE experiment portal, which may span multiple sites and logically represent the actual network slice offers from the Network Service Descriptors collected from each of the site facilities, representing the actual capabilities of the sites. By maintaining both these levels, the Multi-site catalogue can keep track of dependencies and restrictions of each 5G EVE site facilities, as required for deciding where to deploy a given network slice in support of a specific vertical use case experiment. For the time being, in this preliminary interworking architecture definition, verticals will be able to on-board their own VNFs in the Multi-site catalogue, as an automated procedure from the 5G EVE experimental portal. However, the option of having vertical VNFs on-boarding as an offline process in the per-site catalogues is also left open, especially for this first phase of the project. In addition to the legacy NFV-related information, the Multi-site Catalogue is intended to store any per-site additional information required for the vertical use case experiment and that is not dynamically exposed by the sites as described in section 4.3.

The **Multi-site Inventory** is the counterpart of the catalogue component for what concerns the information on provisioned and instantiated network slices in the 5G EVE end-to-end facility. It is fully managed, in terms of information stored, by the Multi-site Network Service Orchestrator, and it maintains detailed information of running. The Multi-site inventory exposes to the 5G EVE experiment portal the end-to-end Network Services instances deployed for a given experiment, augmented with additional service level information (e.g. list of monitored network and service performance metrics, runtime configurations, etc.). At the same time, it keeps the relation with the actual provisioned per-site Network Services, VNF instances and resource configurations (e.g. at RAN, MEC segments) in support of the given vertical use case experiment. The Multi-site Inventory also allows to collect (through the Adaptation Layer or provisioned offline) and store any Network Service and network slice that may be pre-provisioned in each site, and that could be selected by the Multi-site Network Service Orchestrator for deploying and running vertical use case experiments.

The **Data Collection Manager** is a key component within the interworking framework and it coordinates the collection and persistence of all those network and vertical tailored service performance metrics that are required to be monitored during the execution of experiments for testing and validation of the targeted KPIs. On the one hand, through the interworking API, for each experiment, it is allowed to configure the performance metrics that have to be measured for validating the specific use case KPIs. On the other hand, in turn, this monitoring configuration is mapped, through the proper logic provided by the Adaptation Layer, into a request for selective collection of network and service-related metrics to the involved 5G EVE sites. In this way, only the metrics needed to validate the KPIs required by the vertical will be monitored in each of the involved site facilities and collected by the Data Collection Manager (either with explicit queries or through publish/subscribe mechanisms) for their storage in a common database shared with the 5G EVE experiment portal.

The **Runtime Configurator** allows to apply tailored runtime configurations to the provisioned end-to-end Network Services and VNFs in support of the vertical use case experiments**.** While the Multi-site Network Service Orchestrator can handle Day0 and Day1 configurations during the Network Services and VNFs instantiation phases (i.e. by enforcing them through the per-site exposed NFV Orchestration VNF configuration services), experiment specific and vertical oriented Day2 configurations can be applied through the interworking API via a common interface exposed towards the 5G EVE experiment portal. This requires that each site facility, in turn, exposes such capability for Day2 VNF configuration.

4.2 Interworking framework evolution roadmap

We propose a stepwise approach to the final interworking target, based on the complexity and the vertical requirements.

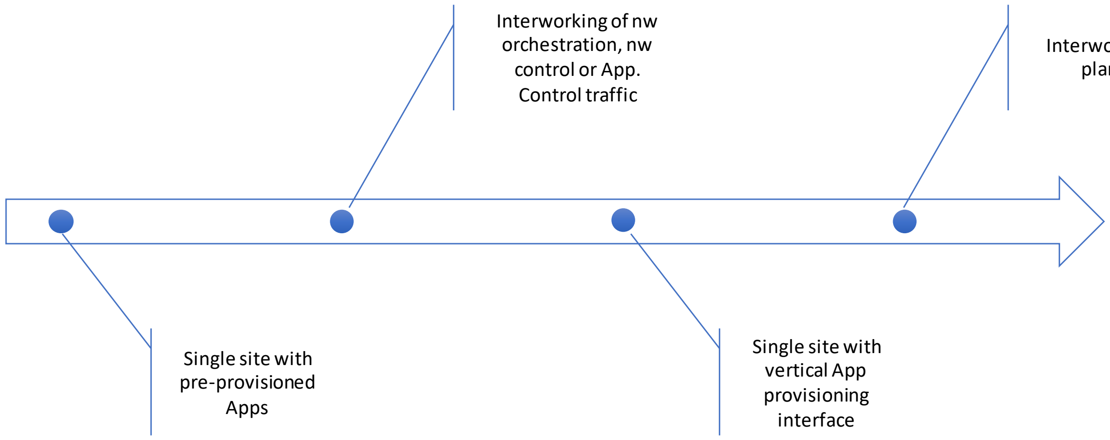

Figure 12: Interworking framework roadmap

In the roadmap, depicted in Figure 12, there are two main dimensions:

Single site. Although the main purpose of the Interworking framework is to allow use cases in several 5G EVE sites, it is also important to verify that a Vertical use case can be deployed in any site. Thus, the first versions of the framework will allow to deploy a Network Service in one site. We differentiate two phases:

- Deploy an NSD (Network Service Descriptor) using pre-provisioned, pre-certified VNFs: Verticals are allowed to define network services that use existing VNFs. Any application required for the Vertical experiment shall be provisioned and certified in each site.
- Deploy full NSD, including VNFs. It is not still clear if this requirement can be fulfilled completely, due to the current state-of-art of cloud technologies and their diversity.

Interworking. The other characteristic included in the roadmap is the capability of interconnecting more than one 5G EVE site. Here, we distinguish among the kinds of cross-site traffic:

- Orchestration should be a basic requirement for all sites;
- Control traffic (both network and application);
- Management traffic, e.g. for monitoring data;
- Data plane traffic.

Data plane traffic is the most demanding one and is more difficult because it depends on physical network in order to be compliant with the requirements (e.g. GEANT network between 5TONIC and France). However, so far, we do not have a clear vertical use case for using it, so we decided to defer the analysis of this interconnection, until we receive the new ICT-19 vertical projects.

Table 39: Requirements per 5G Service Type

	Single site with pre-provisioned Apps	**Single site with vertical Apps provisioning interface**	**Interworking of orchestration and/or control**	**Interworking of data plane**
eMBB	X	X	X	X
mMTC	X		X	
URLLC	X	X		

In Table 39, we show the required phase of the interworking framework per 5G service type. We assume that **uRLLC** services are not going to use inter-site deployments, as their requirement of bandwidth and latency discard any deployment that physically is not near the RAN. Also, we expect that only **eMBB** use cases will require a data plane interconnectivity. However, as **eMBB** and **uRLLC** are demanding in bandwidth and latency respectively, we assume that the provisioning and life-cycle management of the vertical application, most probably deployed at the edge environment, are critical and require one dedicated interface.

4.3 Target site facilities interworking capabilities

In section 3, we have performed a detailed and comprehensive analysis of the technical requirements that the 5G EVE facility has to meet in order to support the set of target use cases considered in the project. Starting from this list of requirements, we have identified a set of capabilities and functionalities that the site facilities need to implement in order, to deliver, to operate and to monitor the 5G services that characterize the reference use cases. On one hand, some of these functionalities (from the control to the orchestration plane) are managed internally and implicitly in each site, without the need to expose their characteristics or programmability towards the upper layer of the architecture through the interworking framework and its APIs. On the other hand, other features and functions should be properly advertised and/or made available through programmable primitives to enable the coordination, orchestration and monitoring of vertical-driven 5G experiments over the end-to-end 5G EVE facility. Thus, the latter category of capabilities and functionalities will be exported from the single sites (where they are defined and accessed through site-specific models and interfaces) towards the 5G EVE interworking framework, where they will be abstracted and translated into the interworking reference information model. If necessary, the functionalities provided by each site facility will be internally coordinated, aggregated or decomposed in more complex or more atomic functions by the interworking framework, in order to expose a unified set of features towards the 5G EVE experiment portal.

The following Table 40 summarizes a list of identified target capabilities and functionalities to be supported by each site facility and, for each of them, indicates if it needs to be exposed towards the interworking layer. It is worth to highlight that these target capabilities are required to be provided by the 5G EVE site facility independently of the single or multi-site nature of the vertical use case experiments.

Table 40: Summary of identified target basic capabilities to be implemented in the site facilities

Capability / Functionality	Description	Exposed to I/W framework
UEs and SIM (Subscriber Identity Module) cards logistic	Intra-site management of mobile user equipment and related SIM cards.	No
Basic subscriber configuration	Intra-site configuration of subscribers.	No
RAN selection and configuration	Dynamic selection and configuration of the Radio Access Network (e.g. for allocation of radio resources).	Yes
Edge Computing	Advertisement of MEC hosts and related capabilities. Management and allocation of virtual resources on MEC hosts.	Yes

NFV / Slice orchestration	Provisioning and management of NFV Network Services and network slices, including: • on-boarding and queries of descriptors, VNF packages and slice templates; • provisioning, termination and query of VNF/NS/slice instances; • explicit management of RAN and EPC/5G Core instances; • Day 0, Day1, Day 2 VNF configuration	Yes (some specific features can be hidden in a given site facility, e.g. RAN configuration and EPC instantiation may be managed internally, on-boarding of vertical's packages may be not permitted, etc.)
SDN-based network control	Programmability of the physical network in the transport and/or the radio domain, as exposed through SDN controllers.	Optional
Monitoring	Tools and platforms for collection of monitoring data related to different kinds of metrics, with mechanisms for monitoring configuration, polling of metrics values, notifications, etc.	Yes
Testing tools	Tools to emulate background traffic or mobile UEs for testing and KPI validation purposes.	Yes

In addition to the above target capabilities, each 5G EVE site is also required to provide specific functionalities to enable cross-site connectivity at the different planes. While the orchestration interconnectivity mostly targets the interaction of each site facility orchestration component with the interworking framework itself, the cross-site connectivity at control and data planes will is a key requirement for the execution of vertical use case experiments spanning multiple sites. In particular, the following Table 41 lists these required cross-site connectivity capabilities and functionalities, together (as for the previous table) with the identification if they have to be directly exposed to the interworking framework.

Table 41 Summary of identified inter-site connectivity requirements

Capability / Functionality	Description	Exposed to I/W framework
Orchestration plane interconnection	A direct communication among per-site orchestration components is not required, as the interworking framework Multi-site Network Service Orchestrator provides the needed cross-site coordination features. However, each site still needs to be interconnected with the interworking framework at the orchestration level. As this orchestration interconnectivity requirement is critical for the execution of any vertical experiment, we require **99.9% of reliability**	Yes

Control plane interconnection	Cross-site connectivity for control plane communications (e.g. among 4G or 5G core control plane components) may be required for the execution of cross-site use cases. The requirement is to have cross-site connection with: • **99.9% of reliability** • **minimum of 20Mbps of bandwidth**	Optional. It may require coordination from the interworking framework
Data plane interconnection	Data plane cross-site connection is not required from the current 5G EVE vertical use case, but it could be needed by one of the future use cases, e.g. from ICT-19 projects. As a recommendation and future requirement, this cross-site connection should have: • **99.9% of reliability,** • **200 Mbps of bandwidth** • **variable latency requirement**, depending on the distance between sites (as detailed in Section 5)	No. This is an inter-site requirement and it is not required at this initial phase of the project

More details about the target capabilities and features to be provided by each 5G EVE site facility (as listed in Table 40 and Table 41 above) and that enable the interworking framework model and approach described in section 4.1, are provided in the following subsections.

4.3.1 UE and SIM cards logistic

The execution of the 5G EVE vertical use case experiments requires the availability of 5G ready UE and SIM cards. It is assumed that their procurement, identification and maintenance will be completely under the responsibility and management of each site and involved verticals. Each site/vertical is free to implement its own procedures and mechanisms for handling UEs and SIM cards.

The availability of UEs and SIM cards, together with their characteristics, will be anyway manually fed and stored in the interworking framework Multi-site Catalogue and exposed to the 5G EVE experiment portal. Thus, they will enable verticals to select and associate them to their use case experiments.

4.3.2 Basic Subscriber configuration

It is not expected that 5G EVE sites will expose the interfaces for configuring the subscribers. 5G EVE sites shall provide a set of subscribers for the experiments, possibly covering the different services provided by the site (eMBB, mMTC, uRLLC). Information about the available subscriber configuration sets will be stored in the interworking framework Multi-site Catalogue.

4.3.3 Radio Access Network selection and configuration

Each 5G EVE site is requested to advertise its RAN capabilities, at least in terms of geographical coverage. Therefore, whenever multiple RAN technologies and coverage options are available, the 5G EVE sites shall expose them to the interworking framework. This is required at the Multi-site Network Service Orchestrator to take appropriate decisions on where to deploy a given vertical use case experiment, either within a single site or across multiple sites. These RAN capabilities and coverage information are thus stored in the Multi-site Catalogue for their usage within the interworking framework.

As an additional consequent RAN-related capability, each 5G EVE site shall give the possibility to select either the geographical area or RAN technology (or both) when provisioning a Network Service or a network slice in a 5G EVE site in support. The exposure of dedicated interfaces for dynamic provisioning and configuration of RAN resources are considered for the time being (i.e. in the context of the preliminary interworking framework definition) as optional, as they are not required in all the use cases. In any case, RAN resources provisioning and configuration can be managed by each site NFV or slice orchestrator and thus being transparent for the interworking framework.

4.3.4 Edge Computing

The availability of edge computing environments is crucial for the execution of most of the 5G EVE vertical use cases. Multiple technology solutions are allowed, including MEC, fog computing and distributed edge cloud. Each 5G EVE site is required to advertise and expose to the interworking framework its availability of edge computing resources and capabilities (hosts, geographical location, network connectivity constraints and characteristics).

Additionally, the 5G EVE sites shall also manage the provisioning and configuration of virtual resources on MEC or edge hosts, according to network and service performance requirements (e.g. latency) and location constraints. This implies the implementation of advanced functionalities for network traffic steering and breakout at MEC/edge hosts and access to location services. However, the exposure of these features and services towards the interworking framework is subject to the specific per-site orchestration approach and paradigm. Indeed, the MEC/edge control and orchestration may be hidden under NFV or slice orchestration services.

4.3.5 NFV / Slice orchestration

Given the network slice modelling and approach followed by the interworking framework and based on the ETSI NFV EVE012 [37]principles (see section 4.1), the support of NFV orchestration services in each 5G EVE site has to be considered as one of the key mandatory features. However, NFV orchestration includes a wide plethora of capabilities, features and functionalities for the provisioning and lifecycle management of network slices, Network Services and VNFs (instantiation, modification, scaling, termination, etc.). In the context of 5G EVE, the per-site NFV orchestration tools have to take into account the interaction with the interworking framework and its Multi-site Network Service Orchestrator, that acts as an overarching coordinator of NFV orchestrators across sites, and if needed within the same site. Indeed, it is assumed that each 5G EVE site shall expose NFV orchestration capabilities, but it is allowed for each site facility to have more than one NFV orchestrator, e.g. to manage different portions of the infrastructure possibly dedicated to deploying different types of service (vertical applications and VNFs vs. 5G mobile network VNFs).

For the sake of their integration with the interworking framework and thus the 5G EVE platform, the site NFV orchestrators shall offer:

- Access to NFV catalogues for querying and on-boarding VNFs and Network Service Descriptors;
- Network Service and VNF lifecycle management, including provisioning, query and termination of instances;
- Network Service and VNF dynamic modification, e.g. through scaling operations;
- Day0, Day1 and Day2 configuration of VNFs.

As optional features, NFV orchestration could provide advanced capabilities for Network Service self-healing and auto-scaling in support of demanding use cases with very stringent requirements in terms of availability and service continuity. Moreover, as further optional and advanced capability, the NFV orchestrator could directly manage and expose RAN and EPC/5G Core instances.

4.3.6 SDN-based network control

Each 5G EVE site facility may make use of SDN-based network control solutions to dynamically program the physical network in the transport or the radio domains, e.g. leveraging on one or more SDN controllers. From a 5G EVE interworking framework perspective, the exposure of SDN network control primitives provisioning of network connectivity in the intra-site 5G infrastructure is not considered as mandatory feature. Such programmable network control capabilities can be considered as hidden under the management of per-site NFV and slice orchestrators.

However, in the case of 5G EVE sites with multiple NFV orchestrators deployed and exposed to the interworking framework, the exposure of SDN-based network control primitives may ease the interconnection and stitching of independent Network Services towards the provisioning of end-to-end intra-site network slices.

4.3.7 Monitoring

The monitoring of 5G network and service performance metrics is a key requirement in 5G EVE to enable testing and validation of the vertical use case targeted KPIs. Indeed, 5G EVE provides an end-to-end experimentation facility, where verticals can deploy their use cases and validate 5G technologies against their application domains to demonstrate the benefits they can achieve. For this reason, each 5G EVE site shall provide advanced monitoring capabilities to measure a wide and complete set of 5G network and service metrics that allow fulfilling the vertical use case requirements, as reported in section 3.

More than that, the dynamic and per-experiment configuration of 5G network and service metrics to be measured and collected is required to be exposed towards the 5G EVE interworking framework by each site facility. This allows the Data Collection Manager in the interworking framework to translate and map the vertical use case experiment target KPIs into lower level metrics to be measured and collected. At the time of writing, given the preliminary nature of the interworking framework definition, 5G EVE sites have two options for exposing monitored data to the Data Collection Manager in the interworking framework:

- Offer an interface for polling 5G network and service performance metrics;
- Push the 5G network and service performance metrics into the common database.

4.3.8 Testing tools

The execution of the 5G EVE vertical use case experiments requires realistic conditions for proper testing and validation of the targeted KPIs. Indeed, to enable 5G EVE (and external users when they will start to use the platform) verticals to validate the 5G technology's expected benefits in terms of network and service performances, the experiments over the project end-to-end facility need to be performed in the appropriate real-time conditions.

This means that at least background traffic generators and emulators of UEs shall be available for their usage in the experiments. Therefore, as a minimum requirement, testing tools need to be known (together with their capabilities) at the interworking framework and stored into the Multi-site Catalogue for their selection and usage in vertical use case experiments. More than the availability, it will be required that each site should expose dedicated interfaces to configure this testing as part of automated experiment execution.

Whether these configuration interfaces will be exposed to the interworking framework or directly to the testing and validation framework within the 5G EVE experiment portal is still under discussion (in WP5 and WP3).

4.3.9 Cross-site connectivity

5G EVE sites shall declare the type of connection available towards Internet or other public networks. Also, they must provide the capability of creating an interconnection with other 5G EVE sites using IP VPNs (in compliance with the plans of each site facility reported in D2.1 [2]), and where possible and available leveraging on the pan-European GEANT research network.

Cross-site orchestration connectivity is required for enabling the communication between the interworking framework and each of the 5G EVE sites. This communication is basic for the execution of any vertical experiment and for that reason we included a basic requirement for this type of cross-site connectivity, which expects a reliability of at least 99.9%.

Cross-site control plane connectivity is required for allowing cross-site execution of a vertical use case experiments, when control plane interworking is required for proper communication among control VNFs or network functions in general. As example, for the Industry 4.0 use case scenario (as reported in section 3.1.3), advanced deployments may require multi-site execution with interconnection at the level of the LTE S6a interface for managing subscriber data in standard roaming. Similarly, considering the Smart Tourism scenario of section 3.1.2, a cross-site control plane interworking at LTE S1-11 interfaces level may be required to radio and edge elements and functions deployed at vertical site (e.g. IFEMA) and core in the 5G EVE 5TONIC site. Taking these two cases as references for expressing some target performances in the case of control plane interworking, we require a cross-site connectivity that guarantees a minimum bandwidth of 20 Mbps, with a reliability of 99.9%.

Cross-site data plane connectivity is not to be considered as a strict requirement at this stage of the project, as none of the 5G EVE vertical use cases need it for its execution. In any case, it is expected that future use case experiments, coming from new verticals using the 5G EVE platform (e.g. from ICT-19 projects) will bring new requirements, including interworking at the data plane level for multi-site deployments. For this, we included a preliminary recommendation for cross-site connection with the following characteristics: 99.9% of reliability, 200 Mbps of guarantee bandwidth and maximum latency that depends on the distance of each site (as listed in the form of interworking recommendations in section 5).

5 Site facilities' technical gaps and interworking recommendations

This section aims at providing for each 5G EVE site facility a preliminary list of technical gaps and interworking recommendations against the identified target capabilities and functionalities (as reported in section 4) that the site facilities need to implement to deliver the 5G services in support of the reference 5G EVE vertical use cases. As a preparatory step towards the identification of per-site technical gaps and interworking recommendations, we have matched the target capabilities and features, listed in section 4.3, against the vertical use cases requirements reported in section 3, and produced as a result matrix in **Error! Reference source not found.** below. In particular, for each vertical use case scenario (i.e. columns in **Error! Reference source not found.**), we have mapped its requirements to the target capabilities and features (i.e. rows in **Error! Reference source not found.**) required to fulfil them. The vertical use cases scenarios are labelled in **Error! Reference source not found.** as following:

- UC#1 - Smart Transport: Intelligent railway for smart mobility
- UC#2 - Smart Tourism: Augmented Fair experience
- UC#3 - Industry 4.0: Autonomous vehicles in manufacturing environments
- UC#4 - Smart Energy: Fault management for distributed electricity generation in smart grids
- UC#5 - Smart Cities: Safety and Environment – Smart Turin
- UC#6 - Smart Cities: Safety and Environment – Connected Ambulance
- UC#7 - Smart Cities: Safety and Environment – Health Monitoring and Forecasting, Smart Mobility and Smart Home
- UC#8 - Media & Entertainment: UHF Media, On-Site Live Event Experience and Immersive and Integrated Media
- UC#9 - Media & Entertainment: Virtual Visit over 5G

Starting from **Error! Reference source not found.** and considering that, for the time being, each of the 5G EVE vertical use case scenario will be executed in a single site facility, the following sub-sections identify a preliminary list of technical gaps and interworking recommendations for each site facility, as a match of **Error! Reference source not found.** against the site facilities service capabilities reported in section 2. However, this initial list has to be considered valid and applicable for any vertical use case experiment (i.e. either it will be deployed in single or multi sites), thus including any potential future scenario coming from new ICT-19 projects' verticals. As a complement, specific additional recommendations are included for each site in support of the cross-site connectivity features defined in 4.3.9.

Table 42: Match between target interworking capabilities/features and 5G EVE vertical use case scenarios

Target I/W Capability / Functionality		UC#1	UC#2	UC#3	UC#4	UC#5	UC#6	UC#7	UC#8	UC#9
RAN selection and configuration		X				X	X			
Edge Computing	Advertisement of MEC/edge hosts and related capabilities	X				X	X	X	X	X
Edge Computing	Management / allocation of virtual resources on MEC/edge hosts			X			X			
NFV / Slice orchestration	Access to catalogues (NSDs, VNFDs)	X	X	X	X	X	X	X	X	X
NFV / Slice orchestration	Network Service / VNF lifecycle management	X	X	X	X	X	X	X	X	X
NFV / Slice orchestration	Dynamic Network Service / VNF modification						X	X		
NFV / Slice orchestration	Runtime VNF configuration	X		X		X				

SDN-based network control				X						
Monitoring	5G network performance metrics	X				X	X	X	X	X
	5G service performance metrics			X		X	X	X	X	
	QoE estimation	X					X	X	X	X
Testing tools		X		X				X		
Cross-site connectivity	Orchestration plane interconnection	X	X	X	X	X	X	X	X	X
	Control plane interconnection		X	X						
	Data plane interconnection		X	X						

5.1 Greek site facility

The Greek site facility will host the following 5G EVE vertical use cases:

- UC#3 - Industry 4.0: Autonomous vehicles in manufacturing environments
- UC#4 – Utilities/Smart Energy: Fault management for distributed electricity generation in smart grids
- UC#6 - Smart Cities: Safety and Environment – Connected Ambulance
- UC#7 - Smart Cities: Safety and Environment – Health Monitoring and Forecasting, Smart Mobility and Smart Home

A preliminary set of interworking technical gaps and recommendations has been identified and is reported separated in two main categories: i) basic requirements for running any vertical use case experiment in Table 43, ii) cross-site connectivity related recommendations for sites interconnection, in Table 44.

Table 43: Preliminary set of basic technical gaps and recommendations for the Greek site facility

Gap/Recommendation	Target I/W Capability / Functionality	Description
5G Devices	User Equipment and SIM cards	5G UEs currently emulated with USRPs. Actual 5G UEs to be on-boarded when available by manufacturers.
RAN dynamic configuration	RAN selection and configuration	To be developed based on the needs of the use case. Exposure to interworking layer to be investigated.
Greek facility Orchestrator	NFV / Slice Orchestration	Hide the complexity of underlying layers and act as single point of entry / communication with the Greek facility.
Component / service catalogue	NFV / Slice Orchestration	A component / service catalogue detailing and exposing the capabilities / configurable components offered by the Greek facility.
API to adaptation layer	NFV / Slice Orchestration	Build an API on the Greek facility side to communicate with the south-bound interface of the interworking layer, i.e. the adaptation layer.

Table 44 Preliminary set of cross-site requirements and recommendations for the Greek site facility

Gap/Recommendation	Target I/W Capability / Functionality	Description
Orchestration interconnection	Cross-site connectivity	Connectivity with the 5G EVE interworking framework shall be established with a minimum reliability of 99.9%

Control plane interconnection	Cross-site connectivity	Connectivity with other 5G EVE sites shall be established with a reliability of at least 99.9% and 20 Mbps of guarantee bandwidth
Data Plane interconnection	Cross-site connectivity	Connectivity with other 5G EVE sites with a reliability of 99,9%, 200 Mbps of guarantee bandwidth and the following maximum latency, per site: • Greece-Spain interconnection: 240 ms • Greece-France interconnection: 210 ms • Greece-Italy interconnection: 160 ms

5.2 Spanish site facility

The Spanish site facility will host the following 5G EVE vertical use cases:

- UC#2 - Smart Tourism: Augmented Fair experience
- UC#3 - Industry 4.0: Autonomous vehicles in manufacturing environments
- UC#8 - Media & Entertainment: UHF Media, On-Site Live Event Experience and Immersive and Integrated Media

A preliminary set of interworking technical gaps and recommendations has been identified and is reported separated in two main categories: i) basic requirements for running any vertical use case experiment in Table 45, ii) cross-site connectivity related recommendations for sites interconnection, in Table 46.

Table 45: Preliminary set of basic technical gaps and recommendations for the Spanish site facility

Gap/Recommendation	Target I/W Capability / Functionality	Description
5G Devices	User Equipment and SIM cards	At this moment, there are not 5G UEs available.
Holographic Devices	User Equipment	Currently, there are no holographic devices with 5G connection. In the meantime, the connection between the 5G network and the device will be made through a MiFi modem, which introduces an additional delay in terms of latency and bandwidth in the end user
CDN Location	NFV / Slice Orchestration	At this moment, work is being done on the creation of a CDN network for the distribution of contents for holographic devices. These content distribution functions be placed as close as possible to the end user, and directly connected to the 5G network.

Edge Computing Orchestration	Edge Computing	Ongoing definition of how distributed cloud solution is integrated with the site orchestrator OSM. in those use cases in which it is required
Exposure of SDN network programmability parameters	SDN-based network control	To define and implement SDN-based control for exposing network parameters for the experiment definition (e.g. S1 latency to main core).
SDN capable BH/WAN	SDN-based network control	Ongoing deployment of an SDN capable transport network including the WAN segment, and potentially the mobile backhaul.
SDN compatibility at the edge of sites	Cross-site connectivity	There may be complications due to the security solutions for protecting the network edge (firewalls) implemented in each site facility, which can be incompatible with the VPN tunnel-termination offered by the SDN solution. This is a gap/recommendation valid for all 5G EVE sites, and the Spanish facility will be used as pilot for its further investigation and implementation.
AGV service performance metrics	Monitoring	Industry 4.0 generates important information for estimating the Use Case KPIs (e.g. Error rate of the AGV and power consumption). This information shall be exposed to the interworking framework.

Table 46 Preliminary set of cross-site requirements and recommendations for the Spanish site facility

Gap/Recommendation	Target I/W Capability / Functionality	Description
Orchestration interconnection	Cross-site connectivity	Connectivity with the 5G EVE interworking framework shall be established with a minimum reliability of 99.9%
Control plane interconnection	Cross-site connectivity	Connectivity with other 5G EVE sites shall be established with a reliability of at least 99.9% and 20 Mbps of guarantee bandwidth

Data Plane interconnection	Cross-site connectivity	Connectivity with other 5G EVE sites with a reliability of 99,9%, 200 Mbps of guarantee bandwidth and the following maximum latency, per site: • Spain-Greece interconnection: 240 ms • Spain-France interconnection: 110 ms • Spain-Italy interconnection: 110 ms

5.3 French site facility

The French site facility will host the following 5G EVE vertical use cases:

- UC#4 – Utilities/Smart Energy: Fault management for distributed electricity generation in smart grids
- UC#9 - Media & Entertainment: Virtual Visit over 5G

A preliminary set of interworking technical gaps and recommendations has been identified and is reported separated in two main categories: i) basic requirements for running any vertical use case experiment in Table 47, ii) cross-site connectivity related recommendations for sites interconnection, in Table 48.

Table 47: Preliminary set of basic technical gaps and recommendations for the French site facility

Gap/Recommendation	Target I/W Capability / Functionality	Description
5G Devices	User Equipment and SIM cards	5G UE modem should be interconnected to the HMD for the video 360° use-case. For UC#4, emulation of the system will be carried out via 5G connectivity.
Edge Computing Orchestration	Edge Computing	Each French nodes will provide its own HW/SW equipment for, at least, RAN deployment.
Integration of ONAP as single top-level orchestrator	NFV / Slice orchestration	The French site facility plans to deploy an orchestrator based on ONAP, overarching four other sub-site facilities as edge nodes. Their roles and integration shall be defined, as a preparatory step for the exposure to the interworking framework. The open-source pillar will expose the VIM API to the French site orchestrator whereas the pre-commercial one will expose the API services.

Exposure of common NFV and slice catalogue	NFV / Slice orchestration	The ONAP Network Service and VNF catalogue shall combine and integrate the catalogues of the other French orchestrators managing the different sub-site facilities. The open-source pillar will use the French site facility generic VxF defined catalogue.
Vertical VNFs runtime configuration	NFV / Slice orchestration	A common interface and model for runtime vertical VNF configurations shall be provided to the interworking framework to expose it to the verticals.
Configuration of monitoring metrics to be collected	Monitoring	A common interface and model for configuring what to monitor for a given use case experiment shall be implemented for its exposure to the interworking framework Data Collection Manager.
Measurement of QoE for 360° video streaming	Monitoring	A dedicated function, monitor or application for measuring QoE of end-users consuming video streams shall be implemented to expose such metrics to the interworking layer common database.
Measurement of latency	Monitoring	Ultra-low latency is a target KPI for both the Smart Energy and the Virtual Visit use case scenarios. Dedicated monitors and functions shall be provided to measure latency at HMD and smart grid protection devices. The latency will be measured at different layers.
Measurement of per-user throughput	Monitoring	The HDM downlink throughput is a target KPI, set to 40-80 Mbps, for the Virtual Visit use case scenario. Dedicated tools and functions for its measure and exposure shall be provided. For both UCs measurements with iPerf tool will be performed.

Table 48: Preliminary set of cross-site requirements and recommendations for the French site facility

Gap/Recommendation	Target I/W Capability / Functionality	Description
Orchestration interconnection	Cross-site connectivity	Connectivity with the 5G EVE interworking framework shall be established with a minimum reliability of 99.9%

Control plane interconnection	Cross-site connectivity	Connectivity with other 5G EVE sites shall be established with a reliability of at least 99.9% and 20 Mbps of guarantee bandwidth
Data Plane interconnection	Cross-site connectivity	Connectivity with other 5G EVE sites with a reliability of 99,9%, 200 Mbps of guarantee bandwidth and the following maximum latency, per site: • France-Greece interconnection: 210 ms • France-Spain interconnection: 110 ms • France-Italy interconnection: 60 ms

5.4 Italian site facility

The Italian site facility will host the following 5G EVE vertical use cases:

- UC#1 - Smart Transport: Intelligent railway for smart mobility
- UC#5 - Smart Cities: Safety and Environment – Smart Turin

A preliminary set of interworking technical gaps and recommendations has been identified and is reported separated in two main categories: i) basic requirements for running any vertical use case experiment in Table 49, ii) cross-site connectivity related recommendations for sites interconnection, in Table 50.

Table 49: Preliminary set of basic technical gaps and recommendations for the Italian site facility

Gap/Recommendation	Target I/W Capability / Functionality	Description
Advertisement of edge computing capabilities	Edge Computing	The capabilities of the distributed cloud platform shall be exposed to make the interworking framework aware of location and availabilities of resources at the edge.
Integration of open-source and commercial NFV orchestrators	NFV / Slice orchestration	Two NFV orchestrators are planned to be deployed and used in the Italian site. Their roles (e.g. managing separated infrastructures) and integration shall be defined, as a preparatory step for their exposure to the interworking framework.
Vertical VNFs runtime configuration	NFV / Slice orchestration	A common interface and model for runtime vertical VNF configurations shall be provided to the interworking framework to expose it to the verticals.
Configuration of monitoring metrics to be collected	Monitoring	A common interface and model for configuring what to monitor for a given use case experiment shall be implemented for its exposure to the interworking framework Data Collection Manager.

Measurement of UE position and location	Monitoring	The exact position and location of UEs is required in the vertical use cases deployed in the Italian site. Dedicated applications or monitors have to be provided to measure and expose this information.
Measurement of QoE for video streaming	Monitoring	A dedicated function, monitor or application for measuring QoE of end-users consuming video streams shall be implemented to expose such metrics to the interworking layer common database.
Measurement of per-device throughput	Monitoring	The per-device throughput is a target KPI for the Smart Transport 5G onboard video streaming use case scenario, and specific tools to measure and expose it are required. This may be provided by end-devices emulators embedding measurement functions (e.g. based on iPerf).
Integration of WiFi/Bluetooth beacons in the 5G network	NFV / Slice Orchestration Monitoring	The provisioned slices have to consider the integration of WiFi/Bluetooth beacons with the 5G mobile network as sensors for tracking user mobility and behavior.

Table 50: Preliminary set of cross-site requirements and recommendations for the Italian site facility

Gap/Recommendation	Target I/W Capability / Functionality	Description
Orchestration interconnection	Cross-site connectivity	Connectivity with the 5G EVE interworking framework shall be established with a minimum reliability of 99.9%
Control plane interconnection	Cross-site connectivity	Connectivity with other 5G EVE sites shall be established with a reliability of at least 99.9% and 20 Mbps of guarantee bandwidth
Data Plane interconnection	Cross-site connectivity	Connectivity with other 5G EVE sites with a reliability of 99,9%, 200 Mbps of guarantee bandwidth and the following maximum latency, per site: • Italy-Greece interconnection: 160 ms • Italy-Spain interconnection: 110 ms • Italy-France interconnection: 60 ms

6 Conclusions

This deliverable identifies the main technical requirements for the 5G EVE end-to-end facility derived from the analysis of the vertical use cases, as defined in WP1. Based on these requirements, we have analyzed the current capabilities and features available in each of the 5G EVE site facilities, as reported so far in WP2. Furthermore, we have also processed the available information towards the identification of more service and features oriented capabilities required for the implementation and validation of the vertical use cases. This enables the definition of the preliminary interworking framework architecture, as a combination of coordination features for the seamless orchestration and execution of vertical use case experiments over heterogeneous infrastructures.

Moreover, by combining and matching the vertical use case requirements with the preliminary interworking framework architecture and principles, we have identified a set of capabilities and functionalities that the site facilities need to implement for provisioning, operating and monitoring the 5G services that enable the reference use cases. Some of these functionalities, spanning from the control to the orchestration plane, are managed internally and implicitly in each site, without the need to expose their characteristics or programmability towards the upper layer of the architecture through the interworking framework and its APIs. On the other hand, other features and functions shall be properly exported from the single sites (where they are defined and accessed through site-specific models and interfaces) towards the 5G EVE interworking framework, where they are abstracted and translated into the interworking reference information model. Once defined these target capabilities and functionalities each site should provide and expose towards the interworking framework, we have identified a preliminary list of technical gaps and interworking recommendations to be filled and followed by each facility to properly deliver the 5G services in support of the reference 5G EVE vertical use cases. These have been clearly split into basic (i.e. for the execution of any vertical use experiment) and cross-site connectivity (i.e. oriented to the deployment of multi-site vertical use case experiments) gaps and interworking recommendations

The release of this document is the first step in WP3 towards the complete design and implementation of the 5G EVE interworking framework. Moreover, the interworking technical gaps and recommendations identified are expected to represent a significant and relevant input to WP2 for the site facilities implementation and evolution towards a smooth integration within the 5G platform and interworking framework.

As part of the next steps, the preliminary interworking framework architecture will be evolved in the context of Task 3.2, taking into account inputs from other WPs (mostly WP1, WP4 and WP5) for an effective integration with the 5G EVE experimental portal and the testing and validation platform. In this context, the detailed definition (and implementation) of the interworking APIs will be the priority, together with the adaptation mechanisms and drivers towards each of the 5G EVE site facility. The sites interconnection, at the three different planes identified (orchestration, control, data planes), will be also implemented taking into account the requirements and recommendations identified in this document. Moreover, considering the expected involvement of external vertical actors with their new use cases (e.g. from ICT-19 projects), and the new related requirements that may emerge for multi-site experiments, the target interworking capabilities and features identified in this document, together with the technical gaps and recommendations, will be updated in subsequent WP3 deliverables (mostly D3.2 and D3.4) as a way to track their evolution.

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