Intent-driven **N**a**T**ive AI architectur**E** supporting Compute-**N**etwork abstraction and **S**ensing at the Deep **E**dge

D2.1 Report on Requirements and PoC scenarios definition

Document Summary Information

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Glossary of terms and abbreviations used

Abbreviation / Term	Description
5G NSA	5G Non-Standalone
5G QI	5G Quality Indicator
5G SA	5G Standalone
ANT	AI-Native Toolkit
AP	Access Point
AppD	Application Descriptor
AMF	Authentication Management Function
APC	Authentication and Policy Control
AR/XR	Augmented Reality/eXtended Reality
BSS	Business Support Systems
BWP	Bandwidth Part
CAPEX	Capital Expenditure
CDN	Content Delivery Network
CIC	Compute Interconnection
CMG	Cloud Mobile Gateway
CMM	Cloud Mobility Manager
CMU	Cloud Mobility Unit
CN	Core Network
CNF	Container Network Function
CSI	Channel State Information
CSP	Communication Service Providers
CU	Central Unit
DRB	Data Radio Bearer
DU	Distributed Unit
DIMO	Distributed Intent-Driven Management and Orchestration
DMO	Domain Manager and Orchestrator
DVR	Digital Video Recorder
eMBB	enhanced Mobile Broadband
EPG	Electronic Programming Guide
ES	Experiment Scenario
FCAPS	Fault, Configuration, Accounting, Performance and Security
FaaS	Function as a Service

FINRA	Financial Industry Regulatory Authority
FTM	Fine Timing Measurement
GA	Grant Agreement
gNB	gNodeB
GNSS	Global Navigation Satellite System
HRL	Hierarchical Reinforcement Learning
IoT	Internet of Things
IP	Intellectual Property
IP	Internet Protocol
IPTV	Internet Protocol Television
JCS	Joint Communication and Sensing
KPI	Key Performance Indicator
KVI	Key Value Indicator
LC	Life Cycle
LCM	Lifecycle Management
LMO	Local Managers and Orchestrators
mMTC	massive Machine Type Communication
MANO	ETSI NFV Management and Orchestration
MEC	ETSI Multi-Access Edge Computing
MLaaS	Machine Learning as a Service
MLO	Multi-Link Operations
MlOps	Machine Learning Operations
MNO	Mobile Network Operator
MPLS	Multiprotocol Label Switching
NCF	Network-Compute Fabric
NF	Network Function
NFVO	Network Function Virtualization Orchestrator
NG-C	New Generation Control Plane
NG-U	New Generation User Plane
NR	New Radio
NSD	Network Service Descriptor
NSSAI	Network Signal Selection Assistance Information
OAI	OpenAirInterface
OPEX	Operating Expenses

OSS	Operation Support System
PaaS	Platform as a Service
PoC	Proof of Concept
PoP	Point of Presence
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
HIPAA	Health Insurance Portability and Accountability Act
RIC	Real-Time Intelligent Controller
RU	Radio Unit
SD	Slice Differentiator
SDN	Software Defined Networking
SD-WAN	Software Defined – Wide Area Network
SEC	U.S. Securities and Exchange Commission
SLA	Service Level Agreement
SoTA	State of The Art
SST	Slice Service Type
ToF	Time of Flight
UCs	Use Cases
UE	User Equipment
URLLC	Ultra-Reliable Low Latency Communications
VNF	Virtual Network Function

Executive Summary

D2.1 *("Report on Requirements and PoC scenarios definition")* is the result of the works of T2.1 *("Business requirements analysis and PoC scenario definition").* The vision of 6G-INTENSE is a new business model that separates service management from resource management. This vision creates a unique opportunity to disrupt the market in order to allow the entrance of new actors, such as those owning extreme-edge nodes. To this aim, a refinement of two Proof-of-Concepts (PoCs) is elaborated, focusing on the technological gaps which are filled by 6G technologies developed in the project. The societal impact of 6G-INTENSE on the vertical sector applications and on European industrial competitiveness is also a major concern investigated in this document.

6G-INTENSE technologies will be demonstrated in two PoCs. PoC#1("Distributed Continuum towards Pervasive computing") aims at validating the abstraction framework which will be developed in 6G-INTENSE addressing the deployment and integration with the southbound Compute and Communication platforms provided by ICOM, EUR and ORO. Content consumption and gaming are most critical use cases (UCs) which depend on Content Delivery Networks (CDNs). The CDNs are installed at various Points of Presence (PoPs) in order to reduce the latency for mobile devices. PoC#1 will support two different experiments towards the validation of the 6G Network-Compute Fabric (NCF) abstraction Framework leveraging on the Media Vertical. The CDNs will be deployed in the form of micro-services on various heterogeneous resources unified under the Cloud Edge Continuum. The first experiment, denoted as Experiment Scenario (ES)#1.1 ("Pervasive computing in a distributed continuum") aims to provide benefit to Telecom Operators in terms of joint allocation of network and computational resources. Additionally, the dynamic interconnection of Compute Continuum Domains across different access technologies exploits the computational and storage capabilities of the Deep Edge. The second experiment, denoted as ES#1.2("Edge intelligence and compute interconnection") aims to demonstrate the usage of SD-WAN to facilitate CDN PoP interconnection. Furthermore, it targets to guarantee an SLA by employing intent monitoring techniques and the Edge intelligence for training distributed ML models. PoC#2 ("Metaverse") is an emerging use case aiming to drive the transition to 6G systems, as it requires KPI improvements by an order of magnitude. Extended Reality (XR) requirements are already exceeding the capabilities of 5G Networks, due to their demands in extremely high downlink capacity (>100Mbps per device) and low latency below 5ms, for immersive operation. The Metaverse evolutions aligns with the digitalization of our societies and presents a massive opportunity for telecom operators to pursue the upgrade of their systems from 5G to 6G. This deliverable describes two experiments under the Metaverse. The first one, denoted as ES#2.1 ("Joint Communication and Sensing for optimal user tracking in the Metaverse") showcases the huge potential of JCS by unlocking innovation towards pervasive location awareness. The second experiment, denoted as ES#2.2 ("Fully autonomous Metaverse FCAPS, sensing and continuum abstraction") showcases all the DIMO components by demonstrating an end-to-end deployment of Metaverse service. This includes: (i) Business Intents definition, translation and propagation through NCF and (ii) zero-touch configuration and management of the Intent Life Cycle (LC) using Native AI toolkit.

Three well-defined experimentation platforms will host the two PoCs: (i) ORO's testbed facility is physically hosted in Romania in a distributed context between Bucharest (full 5G SA) and Iasi (5G SA RAN) DataCenters. The two sites are interconnected through high-capacity IP/MPLS links, (ii) ISI/ATH's experimental platform located in Greece, Patras which comprises an independent and private 6G ecosystem, and (iii) EUR's experimental platform which provides 5G services including eMBB, uRLLC, mMTC based on open-source tools and open-architecture design, located in France. It also caters a WebPortal specifically designed to allow vertical use-case deployment. For each testbed facility a detailed description of the hardware capabilities is provided.

This deliverable also outlines the definitions of Key Performance Indicators (KPIs) and Key Value Indicators (KVIs) to evaluate the project's success and effectiveness. It provides the baseline and target values that must be validated within the PoCs for KPIs, along with identifying which KVIs are relevant for each application. Since 6G networks are not yet fully defined, the 6G KPI values referenced have been derived from previous experimental trials of 5G-PPP ICT-52-2020 projects, various 6G-related white papers and technical journals, as well as the expertise and experiences of consortium members involved in flagship 6G projects such as the Finnish 6G Flagship and Hexa-X.

Key Value Indicators (KVIs) is an important topic in 6G networks and 6G-INTENSE has well defined solutions from the proposal phase. The Relevance of the defined KVIs is examined, as stated in the SNS R&I Work Program 2021-2022. Furthermore, it is aimed to split the KVIs per application demonstrated. *Table 10: Mapping of 6G-INTENSE KVIs per* Based on that, a more detailed description of the measurement method of each KVI will be presented in subsequent deliverables. Throughout the works of T2.1, a literature survey was performed from other projects such as HEXA-X, FIDAL, TARGET-X, TRIALS-NET and CENTRIC analyzing the different approaches towards the various Evaluation Methodologies developed.

Finally, a Market Analysis and the impact to verticals is performed, highlighting: (i) the advancements that Native AI with the fusion of 6G Networks may deliver across multiple sectors and (ii) the NCF's benefits for Communication Service Providers (CSPs). The Business Model Proposal of "6G as a Smart Service Execution Platform" is also described indicating the value proposition, key resources as well as with the legal and regulatory considerations. Furthermore, a business model canvas is created showcasing 6G-INTENSE's value proposition with the associated value chain components. In the last part of the deliverable, 6G-INTENSE's stakeholders are clearly illustrated with the business interactions between them. The innovative concept of tenant-DMO (Domain Management and Orchestrator) is introduced here, highlighting on the benefits it brings to the vertical service owners. The business benefits of 6G-INTENSE are discussed in terms of the benefits it brings: (i) by separating the service and resource management and orchestration, (ii) to the native AI toolkit and (iii) by supporting the "network of networks" vision.

1 Introduction

While 5G has revolutionized mobile networks with enhanced capacity and efficiency, the growing demand from data-intensive applications like the Metaverse is pushing the need for 6G. Both academia and industry are developing 6G as the next-generation communication network to enable the digital transformation of society. 6G will provide energy-efficient, high-performance infrastructure for future internet services, supporting innovations like autonomous systems and smart healthcare. To achieve these advancements, new collaborative approaches are necessary, involving multiple stakeholders to manage the complexity and cost of upgrading from 5G. Central to 6G will be AI-driven automation, aiming for pervasive intelligence across networks.

In this context 6G-INTENSE proposes a new system architecture for 6G that introduces the "Smart Service Execution Platform". This approach comes into parallel with the vision of sustainable infrastructure sharing, aiming to reduce space and energy costs while fostering collaboration across the entire value chain through a unified NCF. A key innovation is the introduction of a novel automation architecture featuring a native AI toolkit that enables intent declaration, negotiation and decision making across autonomous domains, referred to as Distributed Intent Driven Management and Orchestration (DIMO).

WP2 will provide detailed requirements and specifications of the technologies, algorithms and systems that will be developed under the 6G-INTENSE framework. It will also deliver low-level modular architectural design of all sub-components. To this end, this deliverable offers a concise summary of the outcomes of the activities of the first task of WP2, T2.1. More specifically it:

- presents every experiment associated with each PoC. For all experiments the associated narrative, User Requirements and indicative KPIs targeted are displayed. A detailed review for each experimental testbed is also illustrated in this deliverable. The detailed PoC definitions and requirements defined here will act as blueprints for their implementation.
- Demonstrates two PoCs: (i)PoC#1 ("Distributed Continuum towards pervasive computing") is concerned with two different experiments towards the validation of the 6G NCF abstraction framework that will be developed through the project. It focuses on the Media Vertical to demonstrate the deployment and operation of Content Delivery Networks (CDNs) in the form of micro-services on a variety of resources and infrastructures, (ii)PoC#2 ("Metaverse") demonstrates in two scenarios the 6G-INTENSE component's ability to support and enrich metaverse experience in the context of multi-technological domain deployment. In this Deliverable both PoC's are presented in detail, highlighting on their User Requirements and the Mapping of the deployments in the 6G-INTENSE architecture for each Experimental Setup.
- Elaborates a list of KVIs associated with each application developed in this project. Towards this aim, firstly an analytical review of the different methods for various SNS-JU projects was studied. Then, in collaboration with the PoC leaders a 'splitting' between which KVI could be presented in the course of each application developed was identified.
- Presents a current state of the Market Analysis focusing on the fusion of AI with 6G technologies in various market verticals such as transportation, Industry 4.0 and Entertainment. The objective is to identify a clear Business Model Proposal and the Value Proposition that 6G-INTENSE brings through the Distributed Intent-driven Management and Orchestration (DIMO). To this end the 6G-INTENSE actors are identified and displayed, as well as with the associated to the actors value chain components of the architecture and the value proposition they provide to them.

1.1 6G-INTENSE Outputs

The purpose of this section is to map 6G-INTENSE Grant Agreement commitments, both within the formal Deliverable and Task description, against the project's respective outputs and work performed.

Table 1: Adherence to 6G-INTENSE GA Deliverable & Tasks Descriptions

6G-INTENSE Task No. and Title	6G-INTENSE GA Task Description	Respective Document Section(s)	Justification
DELIVERABLE			
D2.1 - Report on Requirements and PoC scenarios definition			
T2.1 - Business requirements analysis and PoC scenario definition	Testbeds descriptions	6G-INTENSE Testbeds	Detailed description of the three experimental testbeds provided by ORO, ISI/ATH and EUR
	PoC requirements and objectives Components, applications and KPIs	2.2 PoC #1 - Distributed Continuum towards pervasive computing 2.3 PoC#2 - Metaverse	Technical description of each PoC's experiment is provided in Sections 2.2 and 2.3. This section includes also the KPIs to be demonstrated
	Respective KVIs addressing their target	2 Definition of KVIs to be evaluated	A complete list of the KVIs is described in this Section and the feasibility to be measured for each application developed
	Market and business analysis	3.2 Market Analysis and Impact	A thorough Market analysis is performed in this Section for the Native AI and NCF
	Separation of service from resource management	3.3.1.1Business benefits of separation between service and resource management and orchestration	Detailed analysis highlighting on the benefits that 6G-INTENSE brings to Edge and Cloud vendors
	Service providers that may not own resources	3.3.2 Value chain components and actors	The benefits for involved 6G-INTENSE actors are displayed in Table 11: Benefits of 6G-INTENSE architecture for Actors

1.2 Deliverable Overview and Report Structure

A brief overview of the report structure is highlighted in this part.

- ***Section 1 - Testbeds and PoCs enabled by 6G-INTENSE*** provides all the technical details of the demonstrated PoCs including the relevant KPIs to be targeted with the corresponding values.

- ***Section 2 - Definition of KVIs to be evaluated*** investigates the works of other SNS-JU projects towards the evaluation of the KVIs addressed. In the context of 6G-INTENSE, a list of KVIs is displayed according to the relevance to the works of this project. Furthermore, it is attempted to map each KVI with the applications developed for each PoC.

- ***Section 3 - Market analysis and business model*** performs a market analysis for the Native AI and NCF. Additionally, it describes in a clear manner the different stakeholders of the 6G-INTENSE architecture and the benefits this project provides to each one.

- ***Section 4 - Conclusions*** this part summarizes the outputs of the works of the deliverable and highlights on the business impact that 6G-INTENSE aims to deliver.

1 Testbeds and PoCs enabled by 6G-INTENSE

This section presents the narratives of each PoC, the associated user requirements and the indicative KPIs to be demonstrated.

1.1 6G-INTENSE Testbeds

All testbeds that will be used for the demonstration purposes of the PoCs are explained in detail; specifically, the experimentation platforms belonging to ORO, ISI/ATH and EUR in Romania, Greece and France, respectively.

2.1.1 ORO Experimental Platform (Romania)

ORO's testbed is based on the 5G Laboratory testbed infrastructure[1] deployed in a distributed context in Bucharest and Iasi Laboratories Data Centers. They provide the infrastructure for ORO's 5G-enabled research activities and support the 6G-INTENSE proofs-of-concept and use cases. The Bucharest 5G Lab, showcased in *Figure 1* and currently implements a full 5G SA infrastructure, comprising 5G RAN, Core, Edge Computing, and advanced Software Defined Networking (SDN) and IPFABRIC elements in the associated Data Centre. ORO has implemented high-capacity IP/MPLS enabled links, with Traffic Engineering rules, assuring end-to-end services QoS, key testbed 5G and beyond 5G technology availability for RAN, Core, programable transport network, Edge computing, Virtualization, Orchestration, Monitoring, Security and associated platforms.

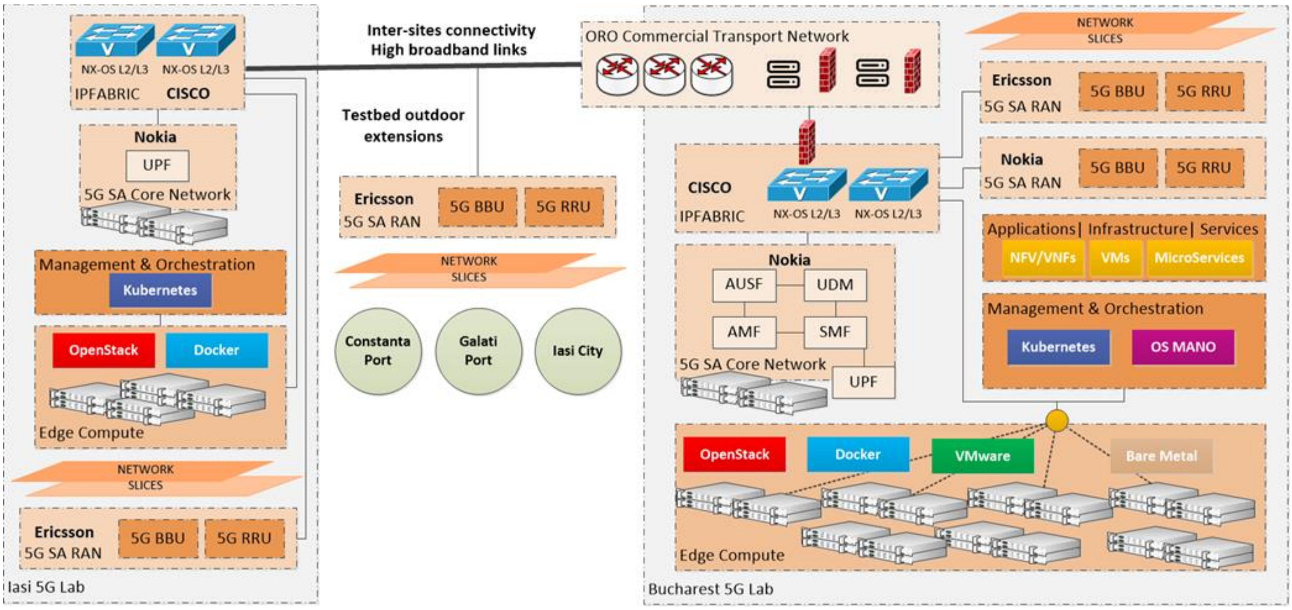

Figure 1: ORO experimental testbed facility

Testbed features and capabilities are summarized in *Table 2* and will be further developed in the following sections. The testbed offers a full set of APIs (standard and testbed specific) available for the upper 6G-INTENSE architectural layer components.

[1] https://5glab.orange.ro/en

Table 2: ORO testbed capabilities overview

5G infra \ testbed	RAN NSA/SA	5GCN NSA/SA	IP Transport	IaaS	MANO & Monitoring	Security	MEC	Slicing
Bucharest	EricssonSRA N18 NSA/SA O-RAN AW2S RRU OAI / srsRAN	Ericsson 2.15 vEPC Nokia CMU23.10 5GC OAI / Open5GS	CISCO NXOS IPFABRIC	OpenStack Ussuri VMware ESXi K8s	OSM v12 Prometheus Grafana	Fortinet 1000D FW, LMT, WAF	Collocated IaaS with 5G Core	SNSSAI based APN based
Iasi	Ericsson DOTs NSA/SA OAI / srsRAN	Nokia CMU23.10 UPF OAI / Open5GS	CISCO NXOS IPFABRIC	OpenStack Ussuri K8s	-	-	Collocated IaaS w 5G UPF	SNSSAI based APN based

ORO's 5G testbed is based on virtualized network infrastructure. 6G-INTENSE will use only features and capabilities related to 5G SA 3GPP Rel.16 and beyond. The SA Core architecture uses the 5G SA Compact Mobility Unit (CMU) Core Network solution from Nokia, which is running on a virtualized infrastructure in the Bucharest 5G Lab datacenter, as seen in *Figure 2*. Three main components are integrated, the Cloud Mobile Gateway (CMG), the Cloud Mobility Manager (CMM), and the Authentication and Policy Control (APC). 5G SA RAN architecture follows the 3GPP Option 2, N78 100MHz available spectrum; in this approach, the RAN consists of only gNBs that are connected to the 5G Core network. The gNBs connect to AMF over the NG-C interface for control plane signaling and to UPF over the NG-U interface for user plane data transfer. gNBs provide the NR (New Radio) air interface access for the UEs. The deployed 5G SA RAN components also include support for network slicing, leveraging on priority management with differentiated 5G QoS flows, prioritized UE TCP sessions and 5G QoS flows to DRB mapping – in this approach the network maps different IP flows with the same QoS requirements into the same QoS Flow.

Figure 2: ORO Network infrastructure deployment

The testbed implements end-to-end network slices based on 3GPP NSSAIs parameters, as eMBB, URLLC and mMTC, at the RAN level the slicing performance is ensured by leveraging gNB-specific 5G Quality Indicators (5GQIs) functionality for proper slice implementation (Uplink Preallocation, SR Period Configuration), based on 3GPP-defined parameters; the S-NSSAI identifies network slices in NG-RAN and 5GC and is composed of a Slice Service Type (SST) and Slice Differentiator (SD), SST identifying a type of network slice with specific capabilities and characteristics, while SD pointing out different network slices belonging to the same type, as described in *Figure 3*.

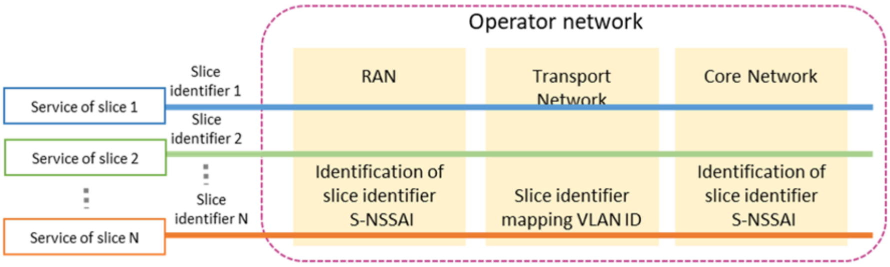

Figure 3: ORO testbed E2E slicing availability

Development and deployment tools implemented in ORO testbed infrastructure:

OpenStack is the cloud operating system that controls large pools of compute, storage, and networking resources throughout a datacenter, providing standard IaaS functionality, orchestration, service management.

Docker is the open platform for developing, shipping, and running applications, by separating the applications from the infrastructure so the software can be quickly delivered; an application is running in a loosely isolated environment called a container, for a fast-consistent app deployment.

Kubernetes is an open-source system for automating deployment, scaling and management of containerized applications; Kubernetes is the cloud native applications orchestrator.

OSM is the open source ETSI NFV Management and Orchestration (MANO) stack for E2E network service orchestration for telco services.

CI/CD or Continuous Integration and Continuous Delivery is the framework for creating, building and running automated software application tests.

Prometheus is an open-source monitoring and alerting system that collects metrics as series data; the data is stored on a single server node; the data collection is pulled/pushed and multiple modes of graph are supported.

Grafana is the open-source multi-platform analytics and interactive visualization web application, allowing dynamic dashboard creation for centralized data analysis, visualization, and alerting.

Monitoring network and services monitoring capabilities, the process of data collection of a variety of metrics, benefitting by different open software tools, framework described in *Figure 4*.

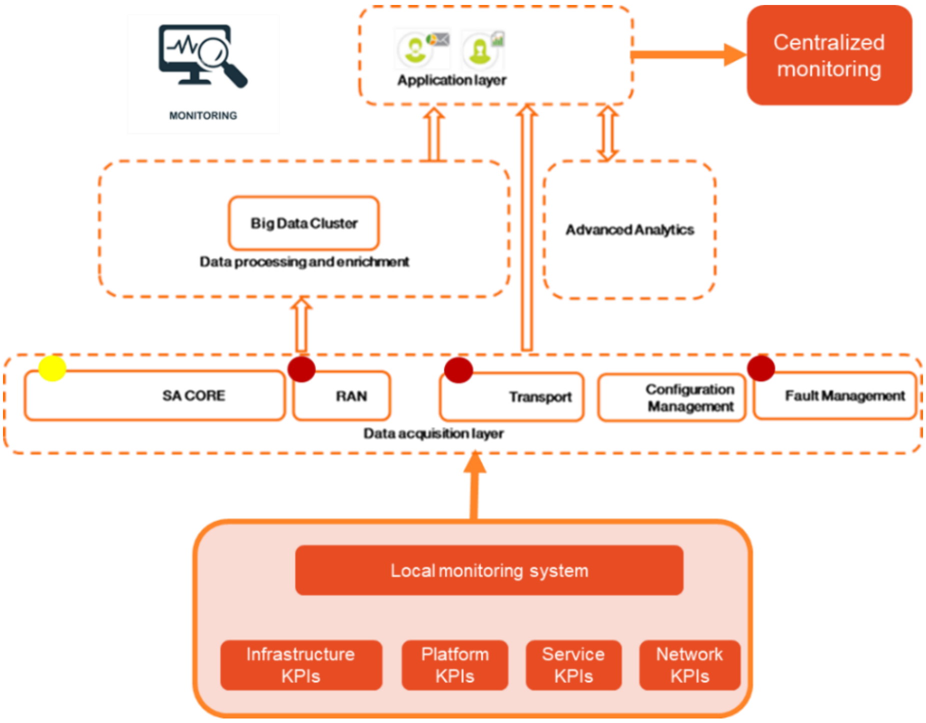

Figure 4: ORO testbed E2E monitoring framework

2.1.2 ISI/ATH Experimental Platform (Greece)

The ISI/ATH testbed serves as a virtual experimentation environment that comprises an independent and private 6G ecosystem. It is located at the ISI/ATH premises in Greece, Patras and is illustrated pictorially in *Figure 5*. It implements a full stack 5G system, encompassing Core, Edge and RAN tiers as well as advanced 5G UE emulation capabilities. The ISI/ATH testbed is based on open-source frameworks and software stacks, including an Amarisoft 5G RAN and Core Network, Kubernetes/ OpenStack based Multi-access Edge Computing (MEC) nodes and ETSI OSM based Orchestration components. It is currently being upgraded with O-RAN compliance.

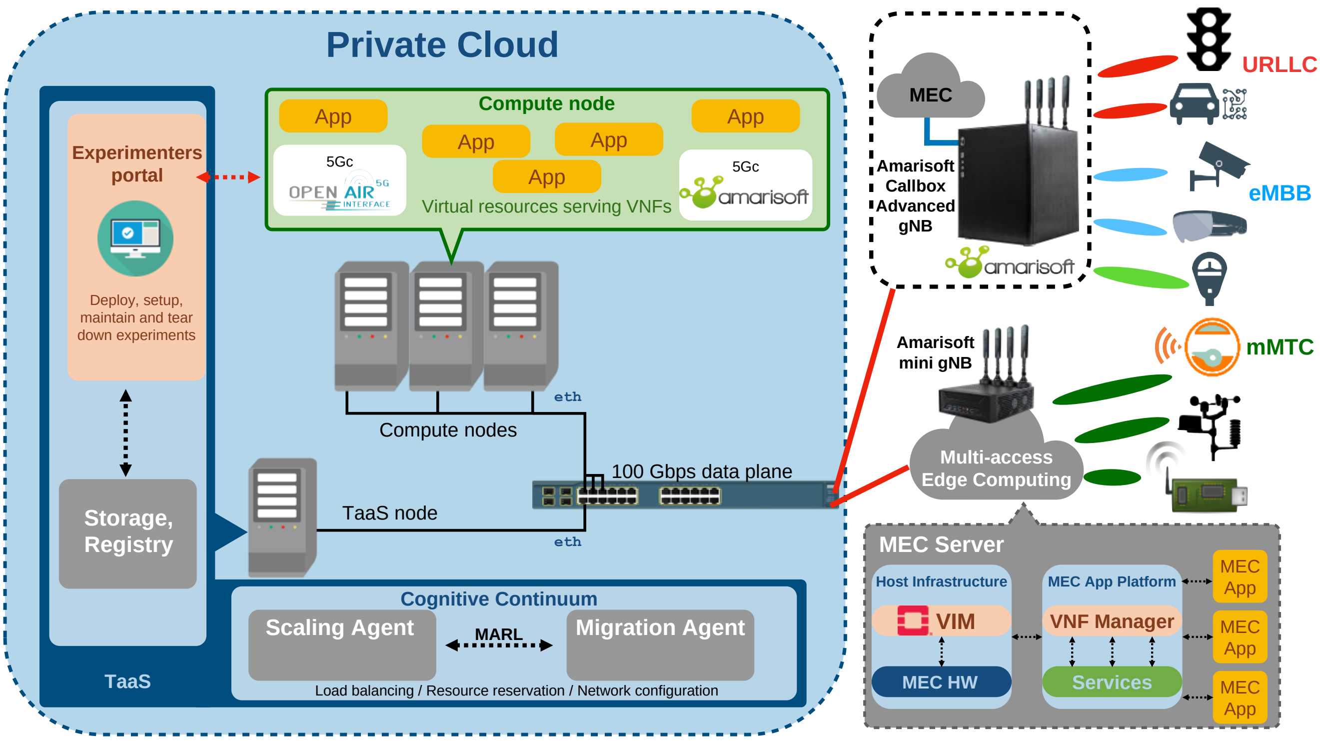

Figure 5: ISI/ATH testbed overview

Hardware details: The typical resources available in a Testbed Instance include:

- Computing: 3 physical servers, based on Intel Xeon Gold processors, with 24/48 cores running at 3 GHz with 192GB of RAM memory. The storage devices include SATA SSD and NVMe (Non-Volatile Memory Express) storage.
- Platform as a Service/Management and Orchestration: Kubernetes
- Monitoring Systems: Prometheus
- 5G capabilities:
  - 5G Core: Amarisoft Callbox 5GC, and Open5GS.
  - 5G RAN: Amarisoft Callbox gNBs

The testbed architecture is shown in *Figure 6* and consists of a 5G network with the following elements:

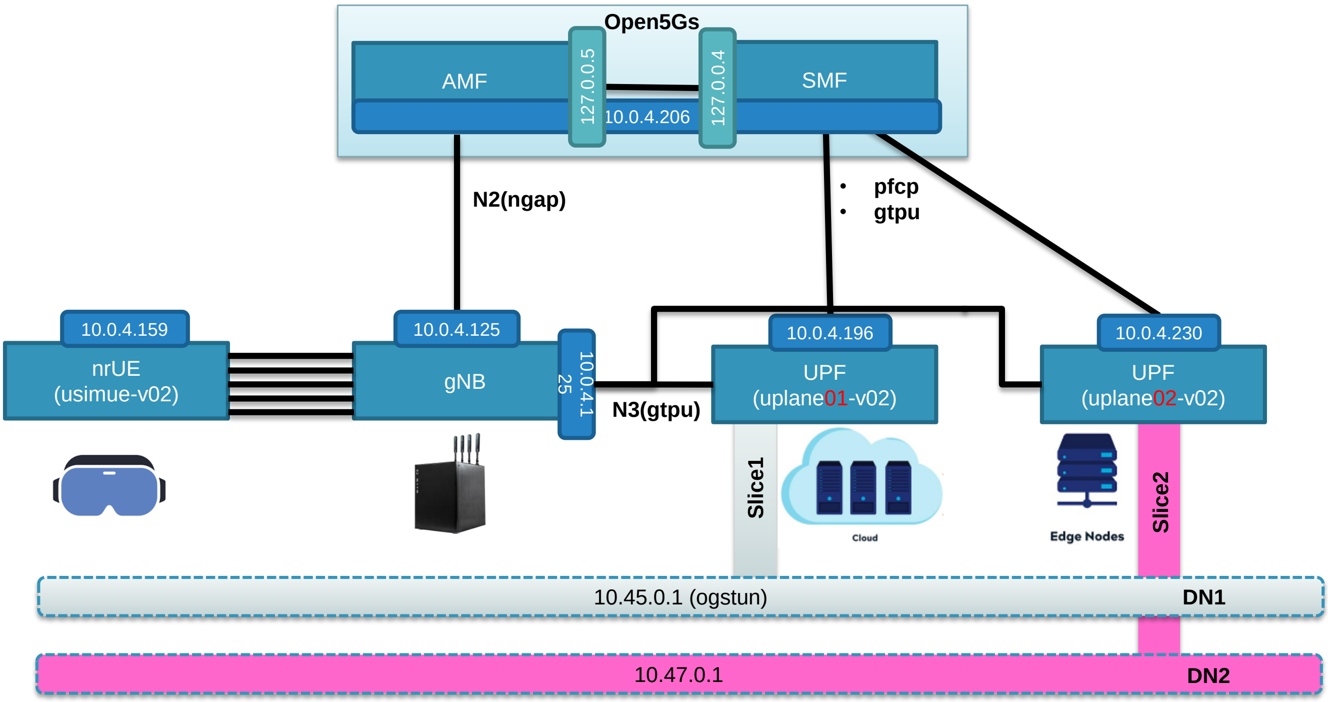

Figure 6: ISI/ATH testbed architecture

- Core Cloud (5GC) Domain: 3 high-performance servers are deployed in a Private Cloud, running Open5GS, which is an open source 5G Mobile Core. The current deployment works in Stand Alone (SA) mode.
- RAN Domain: the RAN Domain consists of 5G-compliant gNBs and MEC nodes. The gNBs currently in use is an Amarisoft Callbox Mini and an Amarisoft Callbox Advanced, both suitable for experimentation environments and lab-scale UC validation. Extending the RAN domain with O-RAN capabilities is currently under consideration. The gNB is currently deployed as MEC nodes enabled, which represent the Edge Cloud domain.
- UE domain: in this part, our testbed offers a selection of Smartphones compatible with 5G SA, including 2 OnePlus 8T 5G phones, 2 Samsung Galaxy S23+ phones, 1 Teltonika TRB500 CPE, as well as RPIs enabled with SIM8200EA-M2 5G HATs.

2.1.3 EUR Experimental Platform (France)

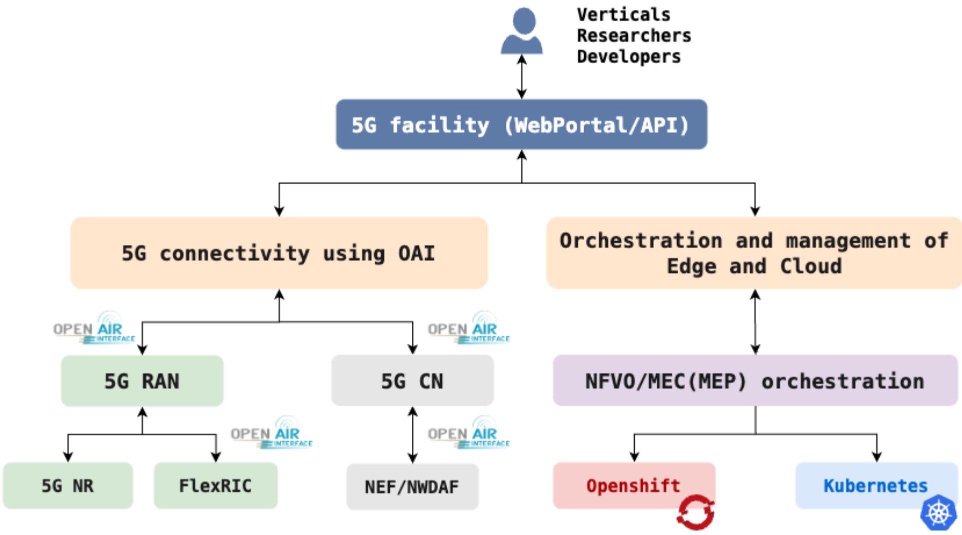

Figure 7: EURECOM 5G Facility

The 5G facility of EURECOM, as illustrated in *Figure 7*, provides experimental 5G services, including eMBB, URLLC, and mMTC. Based on fully open-source tools and open-architecture design, it provides the means to on-board new network functions to the running 5G infrastructure and test them in both a controlled laboratory setting and in a deployed live network. As shown in the figure above, the facility is accessible through a WebPortal or exposed API. The WebPortal is specifically designed to allow vertical use-case deployment, while the API can be used by an external component or orchestrator. Indeed, the facility is connected to EU federation of testbeds in the context of the SLICE-PP, 6G-BRICKS and SUNRISE-6G projects. In terms of technical components, the facility provides 5G connectivity using OpenAirInterface (OAI). It permits the deployment of cloud-native applications and services in the forms of Virtual Network Function (VNF) or Container Network Function (CNF). The management and orchestration components are compliant with the ETSI NFV and MEC specifications to manage virtual resources for cloud and edge. The network function virtualization orchestrator (NFVO) and MEC Orchestrators are homemade software that allows to manage the Life-Cycle of Network Services via Network Service Descriptor (NSD), which in turn is composed of a set of cloud-native functions (i.e., CNF) described using an Application Descriptor (AppD). The cloud-native functions are deployed on two container-management platforms, i.e., OpenShift and Kubernetes, and supports cloud-edge continuum over multiple clusters (including public cloud).

The 5G NR connectivity is fully supported by OpenAirInterface (OAI) RAN and CN. The RAN supports both FR1 and FR2 deployments. Regarding FR1 deployment, the RAN platform is split into CU, DU, and RU, following two different functional splits:

- Split 7.2: OAI CU and DU using commercial RUs from VVDN (indoor), LiteON (indoor), Benetel (indoor and outdoor)
- Split 8: OAI CU and DU using USRPs (B210, N300, X310, indoor) and commercial RUs from AW2S (indoor and outdoor).

The FR1 RAN setup operates at bands 38 (2.6 GHz) and 78 (3.4 GHz) supporting two subcarrier-spacing (15 and 30kHz), six different bandwidth sizes (10, 20, 40, 50, 80 and 100MHz) with multiple BWPs support (initial BWP and dedicated BWPs), different TDD configurations enabling asymmetric assignment of uplink and downlink resources with shorter TDD periods (down to 2.5 ms). It also includes the Procedures for 4-layer DL and 2-layer UL MIMO with the support of 256 QAM modulation. For FR2, the current implementation supports FR2 RU from a commercial company, LiteON, operating at 27 GHz. Completing the O-RAN setup, the facility includes a Real-time Intelligent Controller (RIC) (OAI FlexRIC) to run xApp for RAN management and optimization. Regarding the 5G CN, it is based on OAI CN. It is a partial 3GPP 5GC service-based architecture including the following Network Functions (NFs): NRF, AMF, SMF, UPF, UDM, UDR, AUSF, NSSF, PCF, NEF, NWDAF and CAPIF. NEF and CAPIF are used to expose CN functions to verticals. All the CN functions are managed and orchestrated using the NFVO of the facilities.

2.2 PoC #1 - Distributed Continuum towards pervasive computing

The first PoC concerns the Distributed Continuum towards pervasive computing. It aims at validating the Abstraction Framework that will be developed in the context of 6G-INTENSE and will address the deployment, model training and integration with the southbound Compute and Communication platforms provided by different partners, namely the πEdge platform from ICOM**,** the OAI Open RAN by EUR and the MPLS from ORO**.**

PoC#1 will support two different experiments validating the 6G NCF abstraction framework that will be developed in the project, leveraging on the Media Vertical to showcase the deployment and operation of Content Delivery Networks in the form of micro-services on a variety of heterogeneous resources and infrastructures, unified under the umbrella of Cloud Edge Continuum.

2.2.1 PoC#1 – ES#1.1 Pervasive computing in a distributed continuum

This subsection presents in detail the first experiment of PoC#1, denoted as *ES#1.1 Pervasive computing in a distributed continuum*, the challenges that it deals with, the respective objectives, and the requirements that occur from them. It is also mapped according to the high-level 6G-INTENSE architecture, and a set of KPIs is defined for the experiment.

2.2.1.1 Narrative

This experiment concerns scenarios about the smart and efficient distribution of media content (video streaming, gaming, AR/XR, etc.) across a multi-domain, multi-cluster Core/Cloud to Edge to Deep Edge Continuum.

Content consumption and gaming represent the most critical use-cases that drive internet traffic and are rapidly shifting towards mobile devices. Mobile applications have a strong dependence on user location and typically depend on Content Delivery Networks (CDNs), which are being used to reduce the delivery latency of content requested by subscribers. A CDN typically has infrastructure in multiple geographical locations, known as Points of Presence (PoPs). Each PoP contains a number of storage, caching and streaming servers responsible for content delivery of the live and on-demand content to users within its proximity. Therefore, a subscriber of a CDN service can receive content from the corresponding serving PoP, depending on their location.

To this end, we consider a resource layer of converged networking and compute infrastructure via the NCF capable of hosting a hierarchical, dynamic set of Edge Cache instances to support the reliable and efficient streaming of content over a geographically distributed customer base. The scenario will utilize ICOM's fs|cdn™ Anywhere commercial solution, its own-developed and future-proof IPTV & multi-play services platform, shown in *Figure 8*. ICOM's end-to-end fs|cdn® Anywhere platform enables service providers to deliver high-quality video to any television, computer, smartphone, or tablet by smoothly bundling middleware and conditional access, offering a complete portfolio of value-added service packages (e.g. live TV, video on demand, restart TV, network DVR and TV) anywhere over any managed or unmanaged network. It combines a fully customizable EPG and advanced TV features to build an engaging, locally-branded TV service and makes access to services ubiquitous across any device. fs|cdn® Anywhere products work together seamlessly, so subscribers can move between home TV service, mobile viewing and on-demand/DVR services with ease.

Figure 8: *fs|cdn™ Anywhere*

During the execution of the experiment, we will showcase the instrumental role of the 6G-INTENSE NCF Abstraction framework, homogenizing in an abstracted view all underlying resources and allowing for the hierarchical, intent-driven automation. Thanks to that the optimal Edge Cache services' instantiation, configuration, operation, and adaptation (auto-scaling, auto-healing, migration etc.) will be able to respond to the sensed context of evolving environments and users. Moreover, this experiment targets the lifecycle management of micro-service deployment as an Orchestration Continuum undertaken by the NCF abstraction framework after appropriate training of its Generative AI models. The JCS of the Deep Edge infrastructure (e.g. towards the monitoring of the network links and performance) will be another outcome of the experiment.

2.2.1.2 Objectives

The NCF aims to provide an advantage to telecom operators in terms of increased efficiency through joint optimization and allocation of network and computational resources. At the same time, network infrastructures can act as hosting environments for application tasks and (micro-)services, allowing ubiquitous computing and extreme proximity of user-centric processes to end user environments as well as localized inference and learning, calibrated by converged sensing features of the (Deep) Edge. Furthermore, the dynamic interconnection of Compute Continuum domains across all access technologies aims to help exploit the computational and storage capabilities of the Deep Edge. This is achieved via the deployment of micro-service chains that can span across multi-stakeholder resource pools and heterogeneous domains, down to the deep edge.

2.2.1.3 Challenges

Content consumption and gaming represent the most critical use-cases that drive internet traffic (e.g., Netflix uses up 15% of all Internet downstream traffic worldwide) and are rapidly shifting towards mobile devices. Mobile applications have a strong dependence on user location and typically depend on CDNs with global PoP deployments. This market is currently dominated by US-based hyperscalers and is difficult to disrupt by EU companies due to the global nature of CDNs.

2.2.1.4 User Requirement Analysis

Table 3: PoC#1-ES#1.1 User Requirements

ID	**P1–ES1.1-UR01**
Name	fs|CDN Service Instantiation
Description	The user must be able to request instantiation of the fs|CDN service.
ID	**P1–ES1.1-UR02**
Name	Requirements specification
Description	The user must be able to specify service-related constraints and requirements/targets that need to be met.
ID	**P1–ES1.1-UR03**
Name	Service update
Description	The user should be able to update their service request.
ID	**P1-ES1.1-UR04**
Name	Service termination
Description	The user should be able to terminate their instantiated service.

2.2.1.5 Mapping with the Architecture and associated components

ES#1.1 will make use of the DMO component, which will receive *fs|cdn® Anywhere* service instantiation requests from tenants and translate them to lower-level intents that will be provided as input to the NCF, another architectural layer that will be used. The NCF will utilize its AI-Native intent handler to translate the intents received from the DMO to network-level resource instantiation requests, targeting a subset of the underlying homogenized abstracted resources. The resource instantiation requests will be propagated to the appropriate πEdge LMOs (Local Managers and Orchestrators), handling the various homogenized resource pools geographically distributed among multiple testbeds. This flow will enable the hierarchical, intent-driven, and optimal deployment of a set of cloud-native fs|cdn® Anywhere Edge Cache services, exploiting a multi-domain, multi-cluster Core/Cloud to Edge to Deep Edge Continuum of networking and compute resources to achieve smart and efficient streaming of media content to a geographically distributed customer base. The mapping of the ES#1.1 architecture is depicted in *Figure 9* below.

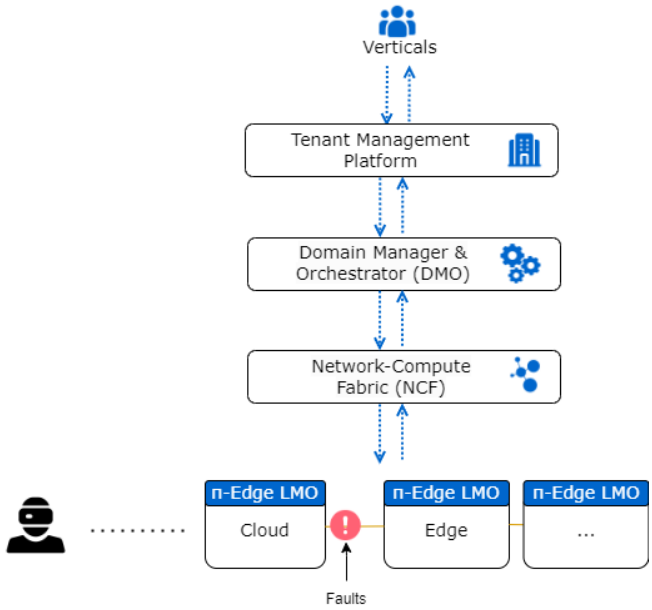

Figure 9: High-Level mapping of Metaverse PoC with 6G-INTENSE architecture

2.2.1.6 KPI definitions for ES#1.1

- Meeting dependability targets with <90% SLA breaches even on best-effort networks leveraging on JCS for infrastructure sensing.
- Autonomous mitigation of at least 90% of conflicts due to multi-domain deployment
- Service Instantiation Time < 50msec
- Time for translation of business intents and mapping to network resources < 30 sec
- Accuracy of ML models for the translation (i.e. what was instantiated VS what was requested) ~> 85%
- E2E Latency (from the moment that subscriber requests for content until they receive it) < 10 ms
- Time to adapt (from the moment an adaptation action has been triggered, until it has been fully applied) < 50msec.

2.2.2 PoC#1 – ES#1.2 Edge intelligence and compute interconnection

This subsection presents in detail the second experiment of PoC#1, denoted *as ES#1.2 Edge intelligence and compute interconnection*, the challenges that it deals with, the respective objectives and the requirements that occur from them. It is also mapped according to the high-level 6G-INTENSE architecture and a set of KPIs is defined for the experiment.

2.2.2.1 Narrative

6G systems approach for the increasing importance CDNs for high-quality video streaming is based on the distributed and scalable architecture of DIMO and NCF techniques. The aim is to ensure Service Level Agreements (SLAs) for CDN-based video streaming services deployed over different domains, validated through a CDN-based video service experiment, where a high-level defined intent is translated and propagated across the NCF, connecting computing and RAN domains. The experiment focuses on the Composable AI and learning capabilities of the 6G-INTENSE system, utilizing Machine Learning as a Service (MLaaS) to automate objective setting and adjustment across domains and resources, as in *Figure 10*.

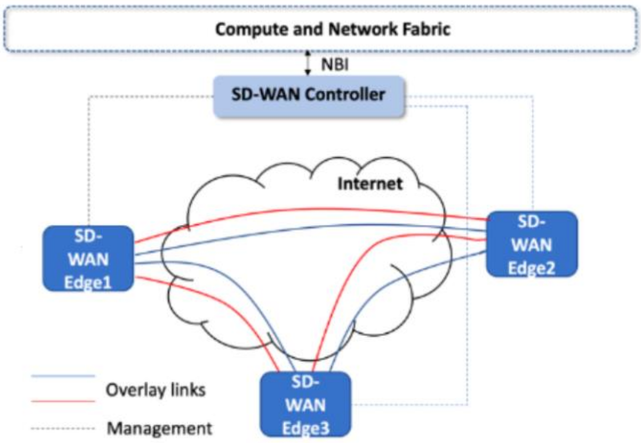

Figure 10: NCF and programmable SD-WAN

The goal is to optimize streaming services by transferring learning assets between domains and conducting domain adaptation.

2.2.2.2 Objectives

The experiment aims to demonstrate the usage of SD-WAN to facilitate CDN PoPs interconnection as well as the dynamic resource integration to the NCF abstraction framework. Another goal is the SLA guarantee by employing intent monitoring techniques and the Edge intelligence for training distributed ML models. The PoC objectives are also related to the chaining concepts under a unified entity, the NCF. More specifically, to facilitate intent declaration, negotiation and decision automation across Edges domains, as described in *Figure 10*, in relation to the end-user (PoCs experiments) requirements, dynamic service and resources are orchestrated with the support of the SD-WAN.

2.2.2.3 Challenges

Identified challenges are related to the DIMOs and NCF integrated technologies, adapted to the 6G Telco Infrastructures, in order to provide relevant SLAs for deployed services in the envisioned different domains, intent defined instantiation and infrastructure network translated to the NCF, for RAN and Edge domains, on top of existing technologies within testbeds. Another challenge is related to the AI and learning capabilities of the system (MLaaS), for cognitive enablement of domains, SD-WAN interconnection with dynamic resources integration. In the end, it will also be challenging to ensure reliable operation and inter-operation of resources and services with respect to KPIs in terms of SLA, as described previously and applied to the Edge intelligence and compute interconnection PoC experiments. From a business perspective, a new service model could emerge from the proposed PoC results, and this should be further evaluated in terms of economic/financial impact vs technological investments for a positive business plan. Other challenges of the PoC#1 – ES#1.2 are the following:

- The validation of resource utilization efficiency for SLA, supported by unified Intent APIs (NBIs and SBIs),
- The interface towards/from tenants and NCF to the SD-WAN Controller for dynamic aspects as autonomous self-configuration, self-healing and self-optimization of the envisioned network.
- The proper network integration of the SD-WAN controllers within the NCF, in order to provide zero-touch management and configuration between edges,
- The validation of the QoS enforcement,
- The deployment of seamlessly services in the network.

2.2.2.4 User Requirement Analysis

Table 4:PoC#1-ES#1.2 User Requirements

ID	**P1–ES1.2-FR01**
Name	CDN Service subscription
Description	Request of CDN-based video service instantiation
ID	**P1–ES1.2-FR02**
Name	Service requirements
Description	CDN-based video services optimization for the users(automated)
ID	**P1–ES1.2-FR03**
Name	Service Termination
Description	CDN-based video service termination

2.2.2.5 Mapping with the Architecture and associated components

The second experiment of PoC#1, as shown in *Figure 11*, intends to deliver Edge intelligence and compute interconnection with support of SD-WAN usage for PoPs interconnection. The dynamic resources of NCF for Cloud-Edge and RAN serves the applications requirements (e.g. video) to deliver low-latency and high-quality video through a scalable architecture. Two major components are used per tenant deployment (tDMO): the DIMO and the NCF. These are further using the defined Intents propagated to the NCF, within two domains: the Computing and the RAN, interconnected through SD-WAN and controlled by NCFs mapped in *Figure 11*:

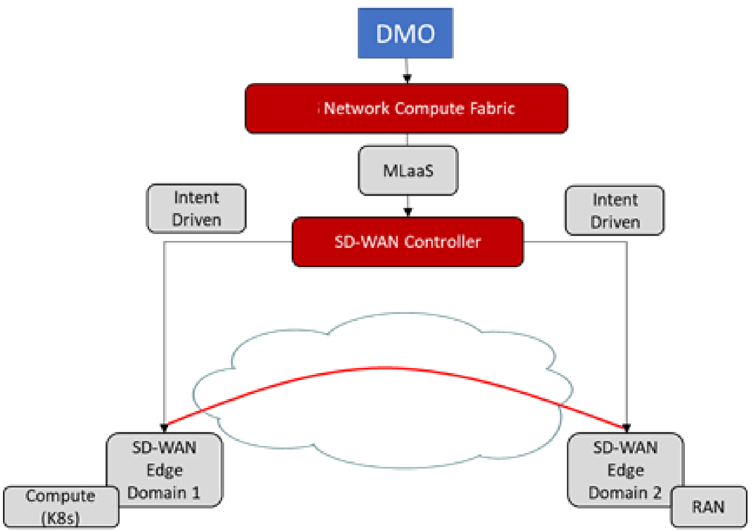

Figure 11: PoC#1-ES#1.2 6G Compute Fabric design

2.2.2.6 KPI definitions for ES#1.2

The envisioned KPIs of this experiment are related to reducing SLA degradation by a factor of 2, achieving equivalent accuracy of ML when using a distributed solution compared to a centralized solution without disclosing data, and reducing the time to discover new resources by a factor of 5.

6G network KPIs are measured in interaction to the Edge intelligence and compute interconnection to provide CDN services, technology support of the DIMO, NCF, SD-WAN:

Network/technical KPIs:

- Achievement of round-trip time for data transmission between edges and the CDN servers to ensure latency for real-time applications.
- Monitoring of data transfer rate/throughput between the edge and the CDN servers to ensure sufficient bandwidth for delivering content seamlessly.
- Edge Node Utilization to optimize resource allocation and ensure efficient utilization of compute resources.

KPIs:

- Reduce SLA degradation by a factor of 2.
- Reduce the time to discover new resources by a factor of 5.
- Reduce service instantiation between Edges by 20%
- Improve Edge Node utilization through efficient resource allocation by 10%
- Network latency between edges (Edge Intelligence) by 10%
- Reduce energy consumption due to sensing by 30%

2.3 PoC#2 - Metaverse

The Metaverse blends physical and digital worlds into one where XR users, content, and digital entities interact. It is one of the emerging use cases, which is expected to drive the transition to 6G systems, as it requires KPI improvements by at least an order of magnitude. Extended Reality requirements are already at the limit of 5G network capabilities, requiring extremely high downlink capacity (>100Mbps per device) and low latency (<5ms) to achieve immersive operation. The Metaverse further pushes the limits, allowing users to freely navigate and interact in virtual worlds. One of the key features of the Metaverse is its fully immersive and interactive environment. Users will be able to interact with each other in real-time, which means that the network infrastructure will need to be able to handle a massive amount of data in real-time. This trend is well aligned with the ongoing digitalization of our societies and presents opportunities for telecom operators to pursue the future generation upgrade of their systems (from 5G to 6G). Recent advancements in the volumetric video domain allow to capture the user's volume in real time and insert the resulting hologram into these VEs, enabling multiple users to be co-present, together with others, in a 3D space while embodied in their own self-representation. This PoC will demonstrate the 6G-INTENSE components' ability to support and enrich metaverse experience in the context of multi-technological domain deployment.

- The first UC scenario aims to showcase the huge potential of JCS to improve Metaverse experience by unlocking innovation toward pervasive location awareness. To achieve this, JCS-oriented Intent will be translated to JCS requirements and enforced by the NCF using Deep Edge JCS capable nodes.
- The second UC aims to demonstrate an end-to-end deployment of Metaverse service showcasing all the DIMO components. This includes: (i) Business Intents definition, translation, and propagation (including resource reservation) up to LMOs through NCF; (ii) zero-touch configuration and management of the Intent LC using Native AI toolkit to guarantee SLA, showcasing FCAPS and mitigation decisions using HRL.

2.3.1 PoC#2 – ES#2.1 Joint Communication and Sensing for optimal user tracking in the Metaverse

This section introduces the first experiment of the Metaverse PoC, denoted as *ES#2.1 Joint Communication and Sensing for optimal user tracking in the Metaverse*. It will be led by CNIT with contributions from IQU, ICOM and EUR that will provide the testbed facilities.

2.3.1.1 Narrative

Future 6G systems will utilize intelligent algorithms for Joint Communication and Sensing (JCS) to facilitate User Equipment (UE) localization and tracking. Integrating the ability to sense user location and movement patterns into the communication network will enable many innovative use cases, ranging from those aimed at enhancing the performance of the network itself to those targeted at offering spatial sensing capabilities as a feature to external users or applications in order to support pervasive location awareness. While these algorithms perform well in outdoor environments, their accuracy and precision are inadequate for indoor settings. In such scenarios, users often connect to Deep Edge devices using non-3GPP, best-effort protocols due to weak cellular signals. This connection helps offload computations and conserve battery power.

In this experiment we consider a scenario of users connected through WiFi to a Metaverse service deployed using the 6G-INTENSE DIMO framework. The experiment will focus on showcasing user localization and tracking capabilities based on JCS, exposed as a micro-service by an LMO (an edge or extreme edge node). The experiment will start with devices implementing the Fine Time Measurement (FTM) protocol introduced in IEEE 802.11-2016, which enables precise indoor ranging and positioning thanks to precise time-of-flight estimation, and will evaluate the ranging precision as a function of the number of FTM-capable devices and other relevant parameters, as well as exploring the possibility to enhance the ranging through novel techniques, as the exploitation of additional information carried by the signals and extracted through Channel State Information (CSI) analysis.

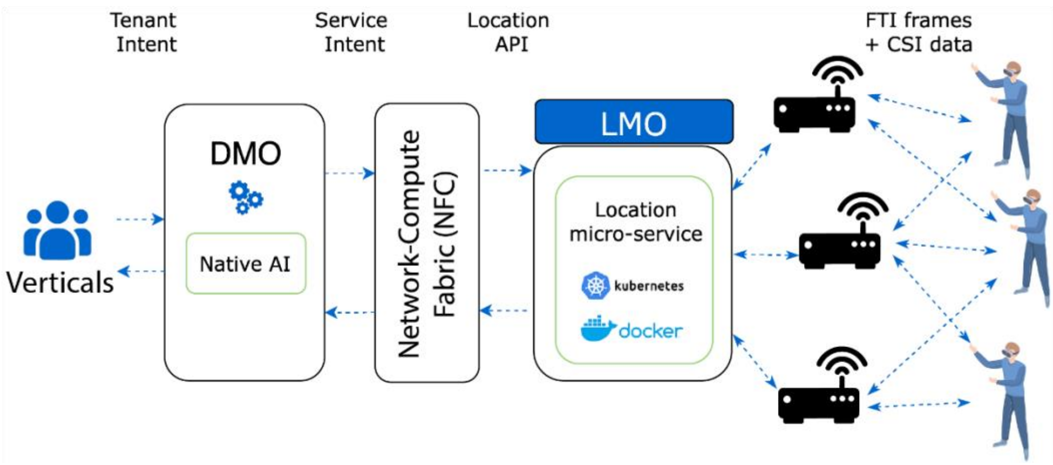

Figure 12: Architecture of ES# 2.1

The experiment comprises the following main building blocks, as depicted in *Figure 12*:

- On the end-user side, FTM-capable UEs are connected through non-3GPP access to a Metaverse service.
- At the deep edge, FTM-capable Wi-Fi APs perform multilateration of UEs to provide user location and tracking capabilities based on JCS. Multilateration of user devices will leverage the FTM protocol; location accuracy enhancement through the use of Channel State Information (CSI) will be explored.
- A location micro-service, deployed at the edge on the LMO, will expose the spatial sensing capabilities by means of a Location API both to the NCF and applications running on user devices.

For the initial phase of the experiment, a Google Pixel 6 smartphone with Android 13 onboard will be used as the FTM-capable UE. For the FTM-capable APs, we decided to employ two different devices: the

Aruba 505 AP and the Celer onboard automotive router, developed by Teldat. Both devices are dual radio, 5 GHz and 2.4 GHz 802.11ax 2x2 MIMO. Additional devices might be considered in the future.

The experiment will consist of two main phases:

1. Evaluating the performance of each UE-AP pair individually.
2. Evaluating the effectiveness of multilateration using FTM-derived distance estimations.

All measurements will be executed both indoors and outdoors for performance comparison.

2.2.1.2 Objectives

- Demonstrate that JCS functions provide enough accuracy for pervasive location awareness to be leveraged by Metaverse.
- Explore trade-offs on sensing accuracy vs. energy efficiency at the Deep Edge, including multiple APs (the more the APs to achieve a given precision, the more energy consumed) and CSI analysis.
- Compare results with indoor/outdoor alternative localization techniques, including GNSS (outdoor) and camera-based analysis.

2.3.1.3 Challenges

Accuracy of FTM Depends on the Environment

The accuracy of Fine Timing Measurement (FTM) is significantly influenced by the surrounding environment. One of the primary environmental factors that affect FTM accuracy is multipath propagation. In scenarios where multipath effects are prominent, the Time of Flight (ToF) measurements obtained through FTM can become increasingly noisy and unreliable. Multipath occurs when signals reflect off various surfaces before reaching the receiver, causing multiple signal paths that interfere with one another and distort the true ToF.

To mitigate these issues and restore accuracy, several strategies can be implemented:

- Utilizing Channel State Information (CSI). By incorporating CSI at both the APs and client devices, it is possible to better detect the time-of-first arrivals. CSI provides detailed information about the signal's propagation characteristics, enabling the system to differentiate between direct paths and reflected paths. This allows for more precise identification of the first arrival time, thereby improving the accuracy of ToF measurements.
- Collecting Measurements on Multiple Channels. Accuracy can be enhanced by gathering measurements across multiple channels. By dynamically switching both the client device and all APs or anchors to different channels, the system can average out the noise and errors introduced by any single channel. This multi-channel approach helps to mitigate the effects of frequency-specific interference and multipath, leading to more reliable FTM readings.
- Utilizing Multiple Frequency Bands. Modern wireless networks can exploit multiple frequency bands, including the traditional 2.4GHz and 5GHz bands, as well as the newer 6GHz band. Collecting measurements across these different bands can further improve accuracy. Each band has distinct propagation characteristics and multipath behaviors; combining measurements from all these bands provides a more comprehensive dataset, reducing the impact of noise and improving overall accuracy.
- Exploiting Multi-Link Operations (MLO). MLO enables simultaneous use of multiple frequency bands, facilitating continuous and coherent measurement collection across 2.4GHz, 5GHz, and 6GHz bands. This capability allows for better management of band-specific challenges and leverages the strengths of each band to enhance the reliability and precision of FTM measurements.

By addressing these challenges through advanced techniques such as CSI integration, multi-channel measurements, and multi-band operations, it is possible to significantly improve the accuracy and reliability of FTM in diverse and complex environments.

Accuracy of FTM Depends on the Specific Device/Chipset

The accuracy of Fine Timing Measurement (FTM) can be highly dependent on the specific device or chipset being used. Different devices and chipsets may have varying levels of precision and may introduce unique biases or errors into the measurements. This variability often necessitates a calibration step to ensure consistent and accurate results across different hardware. To address this challenge, several methods can be employed:

- Oversampling Approach: One effective method to mitigate device-specific inaccuracies is to use an oversampling approach. By increasing the number of Access Points (APs) or anchors involved in the measurement process, a larger dataset can be collected. This abundance of data allows for better statistical analysis, smoothing out any anomalies or errors introduced by individual devices. The additional measurements help to resolve ambiguities and compensate for any lack of calibration in the client devices.
- Increasing Number of APs/Anchors: Adding more APs or anchors into the network infrastructure enhances the spatial diversity of the measurements. This increased density of measurement points helps to provide more robust data, reducing the reliance on any single device or chipset. The diverse sources of measurement can be used to cross-verify and correct the ToF data, leading to more reliable and accurate FTM results.
- Self-Measurements by Anchors: Another approach to address device-specific inaccuracies is to implement self-measurements by the anchors themselves. Since the positions and locations of the anchors are known in advance, they can perform self-calibration procedures to correct any mis-calibration or biases in their own measurements. By regularly conducting self-measurements, the anchors can maintain a high level of accuracy and ensure that their ToF data remains reliable.
- Resolving Ambiguity and Mis-Calibration: The self-measurement process helps to resolve any ambiguity or mis-calibration issues that might arise from environmental changes or hardware drift over time. Anchors can use their known positions to calibrate their internal clocks and measurement algorithms, ensuring that their ToF readings are as accurate as possible. This proactive calibration step enhances the overall reliability of the FTM system.

By employing these methods, it is possible to address the challenges posed by device and chipset variability in FTM accuracy. The combination of oversampling, increasing the number of APs/anchors, and implementing self-measurements by the anchors helps to ensure that the FTM system remains accurate and reliable, regardless of the specific hardware in use.

2.3.1.4 User Requirement Analysis

Table 5: PoC#2-ES#2.1 User Requirements

ID	**P2–ES2.1-FR01**
Name	User localization query
Description	Services can request the location of target UEs by querying the Location API.

ID	**P2–ES2.1-FR02**
Name	User tracking subscription
Description	Services can subscribe to receive periodic updates about the location of target UEs.

ID	P2–ES2.1-FR03
Name	User tracking cancellation
Description	Services can cancel their tracking subscription to target UEs.

ID	P2–ES2.1-FR04
Name	Energy/accuracy management
Description	According to the tenant's intent, different trade-offs between location accuracy / tracking frequency and energy consumption can be enforced through the Location API. For instance, location accuracy may be lowered by decreasing the number of FTM frames that are sent by UEs for a single localization event in order to preserve battery power, while in tracking the tracking period can be adjusted (e.g., from 0.5s to 10s).

2.3.1.5 Mapping with the Architecture and associated components

Figure 12 provides a high-level illustration of the experiment's integration within the 6G-INTENSE framework. The tenant requests an intent that can be realized using JSC functions. The DMO translates this intent into a service intent using the JSC capability of nodes as exposed by the NCF. The latter enforces this request using the API exposed by the location microservice deployed at an LMO and triggers intent monitoring using the Native AI plane. The location microservice interacts with deep-edge devices and UEs to enable user localization and tracking.

2.3.1.6 KPI definitions for ES#2.1

- Increase the Metaverse Quality of Experience (QoE) by at least 20% compared to the case where no JCS solution is used.
- Reduce energy consumption due to sensing by 30% while still meeting the minimum required sensing precision.

2.3.2 PoC#2 – ES#2.2 Fully autonomous Metaverse FCAPS, sensing and continuum abstraction

2.3.2.1 Narrative

The second experiment of PoC#2, denoted as *ES#2.2 Fully autonomous Metaverse FCAPS, sensing and continuum abstraction,* demonstrates the DIMO components from an end-to-end point of view while showcasing intent translation, and propagation up to the infrastructure. The ORO and EUR testbeds represent the resource pools, interconnected via SD-WAN, which are onboarded via the 6G-INTENSE DMO, indicating their preferences and constraints (e.g., pricing, SLOs, Coverage) via the intent mechanism. Moreover, we consider a Metaverse Service Mesh adopting the 6G-INTENSE generalized paradigm, for the packaging of cloud-native NFs (e.g., UPF), the Metaverse Application micro-services, as well as a Cyber-Physical Systems (CPS) service for Sensing. The generalized Metaverse Service Mesh is onboarded via the DMO, with Tenants indicating their preferences and constraints in terms of Service-Level Objectives (SLOs) of individual functions, main objectives and hard constraints with the vertical Tenant intent. The DMO intent handler loop is then responsible for the topological mapping of the Service Mesh, via an intent (re-)negotiation process between the Tenant and the Resource owner, via fully autonomous actions driven by the Native AI toolkit. Service deployment at the Southbound Resource Pools (as represented by testbeds) is facilitated by their respective NCF abstraction frameworks, which have already been trained/finetuned to abstract the respective LMOs in the framework of PoC#1. The LMOs considered are the EUR O-RAN LMO for the orchestration of the Network resources and the ICOM pi-Edge for Compute Continuum orchestration on both sites. During experiment execution, users are connected to the network via O-RAN gNBs, and roaming with their UEs (e.g., in the form of VR headsets) and tracked via a Sensing service. Faults and workload variations are created to test the system's adaptability and the system's intra- and inter-domain coordination and conflict resolution among the DMO and NCF, showcasing the respective HRL capabilities of the Native AI toolkit. The UC will show several FCAPS decisions with O-RAN and pi-Edge LMOs cooperating as an orchestration continuum, via intent adaptations, service migrations between nodes following users' movement patterns, updating network link configuration, and scaling computing resources and radio resources.

2.3.2.2 Objectives

- Showcase how Native AI mechanisms drive intent (re-) negotiation at the Tenant domain.
- Deliver the Orchestration Continuum vision at the Service domain.
- Demonstrate adaptation based on the inputs of a Sensing service that is part of the generalized Service Mesh.

2.3.2.3 Challenges

The challenges of this scenario are related to the DIMO architecture and its main components, namely, the NCF and DMO. The first challenge will be regarding the intent definition, an intent model should be designed for different levels of architecture (business, service, resource). Native AI machine learning models should be trained, especially models that operate in the intent translation loop, these models should be trained and tested against typical intents that can be received. Models related to FCAPS should also be trained to respond to the introduced faults (network faults, compute resources faults, node faults ...). Additionally, it will be challenging to ensure reliable operation and inter-operation of resources and services with respect to KPIs in terms of SLA, as described previously and applied to the Edge intelligence and compute interconnection PoC experiments.

2.3.2.4 User Requirement Analysis

Table 6: PoC#2-ES#2.2 User Requirements

ID	**P2–ES2.2-FR01**
Name	Metaverse Service Mesh onboarding
Description	A Metaverse Service Mesh is onboarded at multiple resource pools via the 6G-INTENSE DMO; preferences and constraints (e.g., pricing, SLOs, Coverage) expressed via the intent mechanism
ID	**P2–ES2.2-FR02**
Name	Metaverse Service Mesh instantiation
Description	The DMO intent handler loop is responsible for the topological mapping of the Service Mesh, via an intent (re-)negotiation process between the Tenant and the Resource owner, via fully autonomous actions driven by the Native AI toolkit

ID	**P2–ES2.2-FR03**
Name	User Tracking
Description	During experiment execution, users are connected to the network via O-RAN gNBs, and roaming with their UEs (e.g., in the form of VR headsets) and tracked via a Sensing service.

ID	P2–ES2.2-FR04
Name	Automated Fault Management
Description	Faults and workload variations are created to test the system's adaptability and the system's intra- and inter- domain coordination and conflict resolution

2.3.2.5 Mapping with the Architecture and associated components

A high-level overview of the experiment's integration with the 6G-INTENSE architecture is depicted in *Figure 13*. In this scenario, the tenant's verticals request a Metaverse service, accompanied by constraints such as pricing and SLA (coverage, latency, etc.). The Tenant Management Platform processes this request and sends a service intent to the DMO, detailing all requirements and the microservices to be provisioned. The DMO is responsible for designing the service mesh and making decisions about topological scheduling and service placement. The NCF then generates the necessary policies, including SD-WAN overlay configurations. This PoC will simulate network degradation and resource over-usage, triggering assurance mechanisms in both the NCF and the DMO. These mechanisms use Native AI models to make FCAPS decisions and resolve the issues.

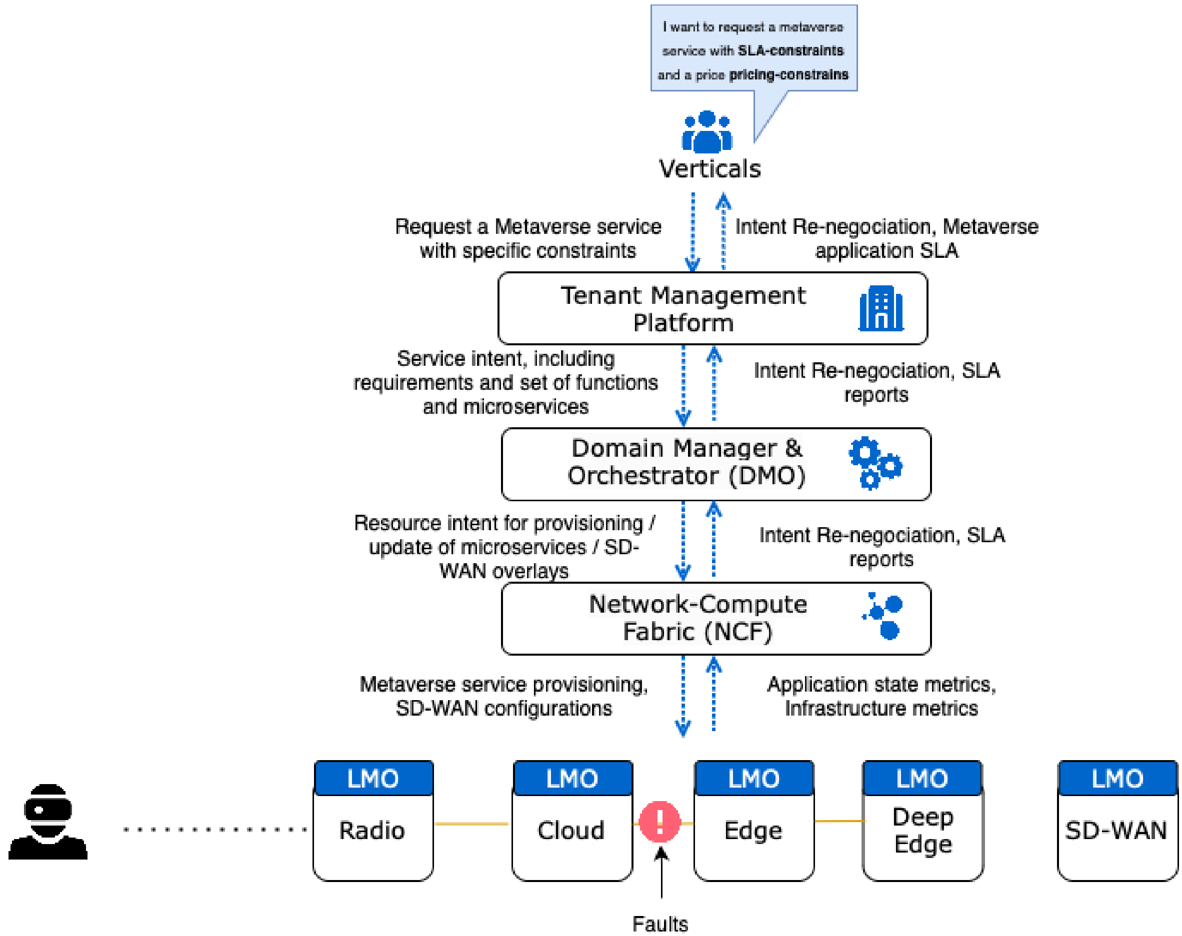

Figure 13: High-Level mapping of Metaverse PoC with 6G-INTENSE architecture

2.3.2.6 KPI definitions for ES#2.2

- Increase user experience by at least 20% when no Native AI plane is used.
- Reduce the time to react to service degradation by at least 20% when no Native AI plane is used.
- Improve service resiliency by at least 20% when no SD-WAN solution is used.

2 Definition of KVIs to be evaluated

This Section investigates the current state of significant projects within the context of measuring their societal impact. Furthermore, the relevance for 6G-INTENSE of the KVIs measured in each application developed and the indicated measurement method are described.

2.1 Analysis of other projects

In this section the progress of other SNS-JU projects relatively to 6G-INTENSE KVIs is described. More specifically the projects: (i) HEXA-X [2], (ii) FIDAL[3], (iii) TARGET-X[4], (iv) TRIALS-NET[5] and (v) CENTRIC[6] are getting under the loupe. The latter project is the only use case agnostic whereas all the other are based on use cases.

2.1.1 HEXA-X methodology

HEXA-X elaborates on the fundamental network design from being performance-oriented towards being both performance as well as value-oriented in order to embrace the 6G vision. In the context of HEXA-X, value entails important human and societal needs such as growth, sustainability, trustworthiness and inclusion. The core values of 6G are embedded in HEXA-X's use cases and subsequently mapped to UN SDG targets.

This introduces a new category of evaluation criteria, specifically KVIs for each target, which must be understood, developed, and integrated into network design for 6G. HEXA-X will therefore define value indicators relevant to 6G for both SDG targets and other objectives. In some cases, these KVIs may be directly measurable, but they are typically linked to a set of Key Performance Indicators (KPIs) that act as proxies for the corresponding KVI [1] .

According to the project's use case E-Health for all, using 6G connectivity it should be possible to reach a very high fraction of the world's population and provide E-health services, resulting in enormous public and personal health benefits. To this aim, HEXA-X deals with E-Health for all as a step towards digital inclusion and a sustainable development of society where trustworthiness is both a prerequisite for and products of improved health. From the perspective of UN SDG, this use case could contribute positively to several SDG targets, such as below:

- Target 3.8: Achieve universal health coverage (for inclusion and sustainability).
- Target 3C: Increase health financing and support the health workforce in developing countries (for inclusion and sustainability).
- Target 5.6: Ensure universal access to reproductive health and rights (for inclusion and sustainability).
- Target 16.6: Build effective, accountable, and transparent institutions at all levels (for trustworthiness, inclusion, and sustainability).

[2] https://hexa-x.eu/
[3] https://fidal-he.eu/
[4] https://target-x.eu/
[5] https://trialsnet.eu/
[6] https://centric-sns.eu/

2.1.2 FIDAL methodology

FIDAL's proposition of a high-level framework for Key Values (KVs) and the example indicators are shown in *Table 7* below. FIDAL aims to adopt a common methodology to investigate the parameters to maximise 5G evolution service impact on the community. KVIs sit supplementary to the KPIs in order to balance the business and social performance indicators. FIDAL envisages engaging relevant stakeholders in all trial phases as well as the open-call trials. Additional large scale electronic surveys throughout all EU countries and workshops with industry, academia and societal stakeholders will be performed in order to assist in the evaluation of the KVIs. Not all KVIs are relevant to all the use cases; therefore, a consultation process with the stakeholders is essential to establish the goals [2] .

Table 7: FIDAL's Key Values and Indicator Framework

FIDAL's Key Values and Indicator Framework	
Democracy	
Fairness	Just treatment without discrimination; what is right for a group might conceal unfairness for individuals
Inclusiveness/Equal Opportunity	Consider broader demographics in a community, giving access to the widest possible range
Trustworthy	Regarding infrastructures and networks; trust towards fellow users/governance; public trust in systems and authorities
Economic Ecosystem (part of 6G for sustainability)	
Sustainability	Competitive and resilient EU economy; investing in jobs, skills, education and digital transformation
Business value	New value chains; inclusive commercial benefit
Tackling economic inequality	New business opportunities
Innovation	
Flexibility	Ability to work in multiple situations, configurations
Responsibility	Accountability over 6G systems
Environmental Ecosystem (part of 6G for sustainability)	
Environmental sustainability	To reduce its footprint on energy, resources and emissions; improve sustainability in other parts of society and industry
Waste management	Recycle and re-use of materials; emissions
Mitigation Strategies	Awareness of environmental impact with a strategy to minimize it
Safety and Security	
Safety	Protection of humans; safer communities

Security	Protection of data and socio-technical systems
Data protection	Appropriate use of personal data
Societal Ecosystem (part of 6G for sustainability)	
Societal sustainability	Support of convergence of physical, human and digital worlds
Healthier community	Improve the mental health of individuals
Knowledge	Training to new digital skills

2.1.3 TARGET-X methodology

TARGET-X proposes a KPI/KVI-based methodological assessment framework (MAF) which is supposed to enable the quantification of the value proposition of its use cases after their implementation and application. It focuses on technical and economic as well as societal benefits.

Figure 14 illustrates the basic concept of the applied methodology for each use case [3] :

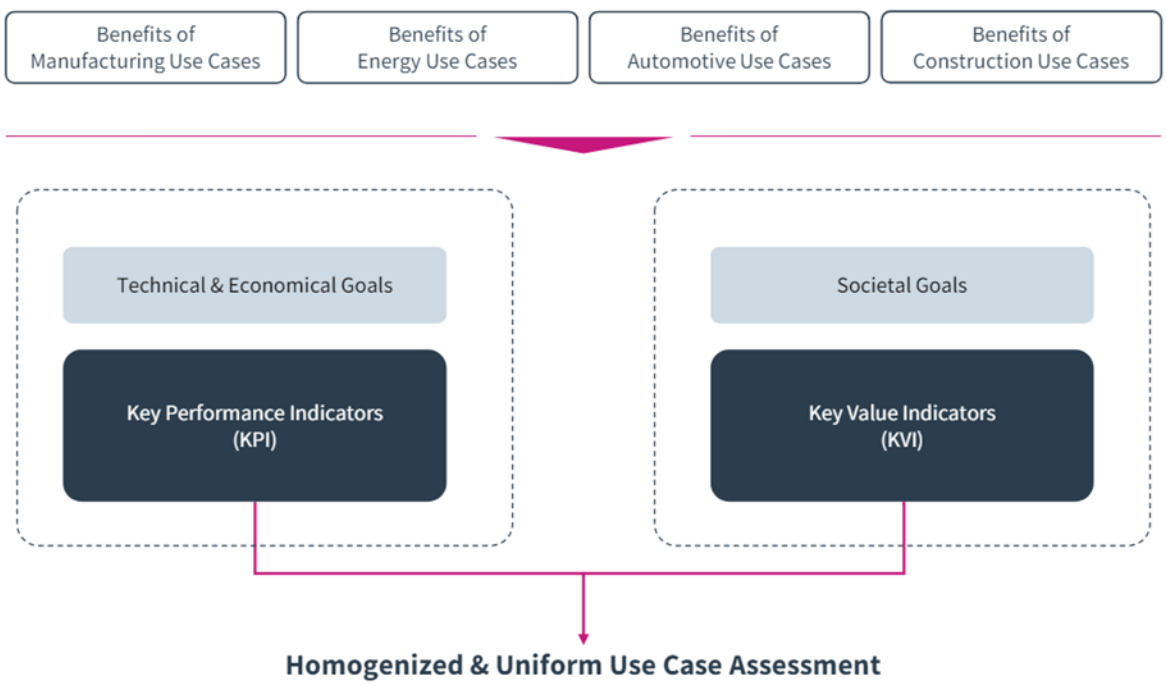

Figure 14: TARGET-X Evaluation Methodologies

TARGET-X will examine further in the course of the project the potential societal goals according to SNS-JU R&I Work Programme 2021 – 2022 as shown in *Table 8*:

Table 8: TARGET-X's potential societal goals for 5G/6G use

TARGET-X's Possible Societal Goals		
Democracy	**Ecosystem**	**Innovation**
Privacy	Sustainability	Safety
Fairness	Business Value	Security
Digital Inclusion	Economic Growth	Regulation
Trust	Open Collaboration	Responsibility
	New Value Chain	Energy Consumption

2.1.4 TRIALS-NET methodology

TRIALS-NET project focuses on the development of the framework that enables the evaluation of use case dynamics for societal and environmental solutions. The concept of KVs will be analyzed across all the use cases in the project for the benefit of not only technological stakeholders but also users in the public, commercial or environmental sectors. The applied procedure which mainly enquires the link between KVs and KPIs, is described below:

Key Value (KV) –Which values are considered important towards societal impact?

Key Value Indicator (KVI) – How can the above Key Values be measured? Can they be measured?

Enablers – Which technological enablers make those values possible?

KPIs – Assign targeted values to measure the technical impact

The framework proposed by TRIALS-NET classifies the values within the following three groups:

- Economical
- Environmental
- Societal

where the defined values may belong to one or more group, depending on the benefit they provide on an economic, environmental or societal scale.

The methodology is illustrated clearly in *Figure 15* according to [4] The procedure starts by defining the KVs that are relevant to the project use cases and assigns a value to them, i.e. the KVIs. Then, the enablers of these KVs are considered as well their technical impact, i.e. the KPIs. For example, in the case where the environmental sustainability is considered as a KV, the corresponding KVI is defined as the CO_2 emissions of the mobile network. The enablers of such KV would aim to a more efficient radio network and the KPI would be measured in bits/Joule.

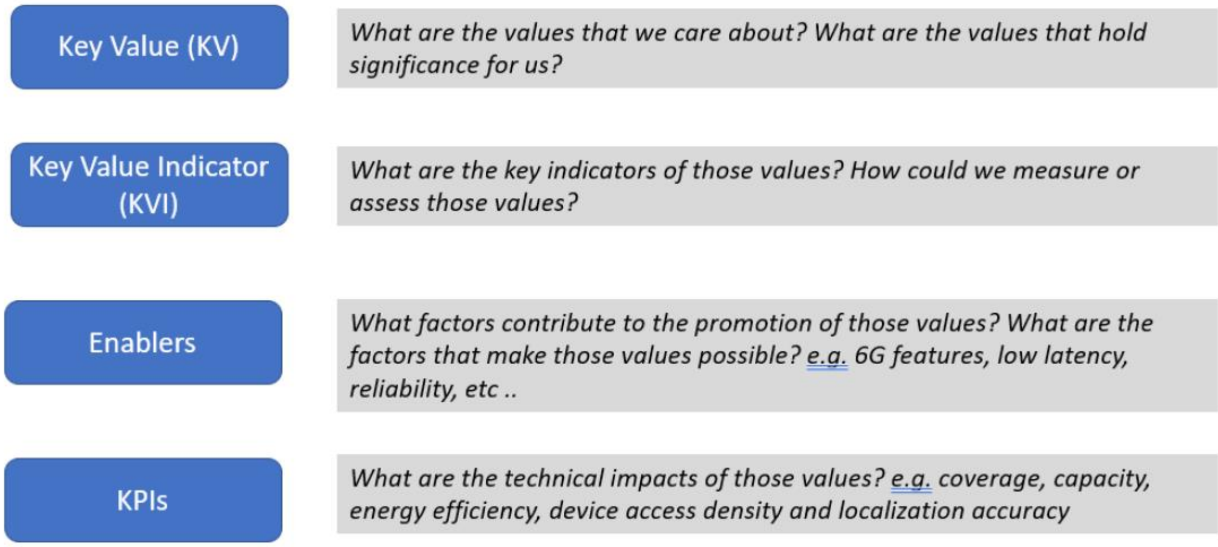

Figure 15: TRIALS-NET Steps and Questions to define KPIs from KVs

2.1.5 CENTRIC Methodology

CENTRIC is a use case agnostic project focusing on technological enablers rather than on specific 6G use cases. Therefore, it is considered difficult to assess the impact of the developed technologies on societal Key Values. CENTRIC's vision strongly emphasizes on the development of technological enablers for a sustainable 6G network [5] . Sustainability is considered to have three dimensions:

- **Environmental Sustainability** - two KVIs are defined in this context; (i) **Energy efficiency improvements,** which refers to the overall energy used to deliver a 6G service to a user and (ii) **Material Efficiency improvements,** defined according to ITU-T L.1023 which proposes a methodology for the quantification of an ICT's circularity potential.

- **Economic Sustainability -** in this context KVIs that are related to CAPEX and OPEX connected to the network deployment and operation are considered.

- **Societal Sustainability –** trustworthiness issues are considered here focusing on: (i) **EMF-aware networks** addressing public concerns about alleged health hazards of exposure to electromagnetic fields and (ii) **user data protection and privacy** addressing public concerns regarding the protection of user data when dealing with AI and ML algorithms.

2.2 Overview of 6G-INTENSE KVIs

2.2.1 Relevance, aim and measurement method

Table 9 provides the relevance of the KVIs defined by the SNS R&I Work Program 2021-2022 for the 6G-INTENSE. These KVIs show how 6G-INTENSE will provide societal impact to vertical sector applications and to European industrial competitiveness. They were formulated through focused group surveys, workshops, webinars, interviews with relevant stakeholders, etc., as they relate to important human and societal values.

Table 9: 6G-INTENSE KVIs

KVI	Relevance
Innovation	
I1: Safety	Safety refers to the ability of a system to avoid harming human life, the environment, or private property due to its unavailability (lack of communication)
I2: Security	It entails the creation of systems that outline who has responsibility for monitoring threats as failure, hacking, and infection
I3: Regulation	Comply with the legal and regulatory framework imposed by the law
I4: Responsibility	Discrete roles/accountability for collaborating partners towards the design, management and use of 6G systems. Additional consideration of how actions may impact the greater society
I5: Energy Efficiency	Reduced energy consumption in the operation of the 6G system end-to-end targeting the long-term challenge of a sustainable and carbon-neutral world by 20230, according to United Nations Sustainable Development Goals (UN SDGs)
Democracy	
D1: Privacy	Appropriate use of the collected end-user data. Updated data protection framework (GDPR) includes more privacy-enhancing measures such as 'the right to be forgotten' and 'the right to access' (personal data concerning them is being processed, where and for what purpose)
D2: Fairness	Ability of the AI/ML algorithms to perform decisions free of discrimination and bias
D3: Digital inclusion	Deploy technologies that serve the historically under-served
D4: Trustworthiness	6G network design should support trustworthiness, collaborative sensing, and distributed learning to enable AI applications
Ecosystem	
E1: Sustainability	Sustainability is the ultimate objective of 6G network design, since 6G should be sustainable from a wider socio-economic and environmental perspective, encompassing not only energy related aspects, but also natural resources consumption, products lifecycles, social sustainability, etc.
E2: Business value	6G systems should demonstrate their commercial benefit for vertical industries and telco operators
E3: Economic growth	Building a competitive and resilient economy, investing in skills, education, and digital transformation
E4: Open collaboration	Use methods based on collaboration and knowledge sharing and interaction according to their capacities

E5: New value chain	The value chain in 6G is expected to increase as a consequence of inclusive (cooperative and interactive) industrialization

Table 10 displays how the two 6G-INTENSE PoC, namely in Distributed Continuum and Metaverse address each KVI. A description of the measurement method for each KVI is provided. The number of crosses '+' next to each KVI indicates the potential of each application in measuring a given KVI:

Table 10: Mapping of 6G-INTENSE KVIs per PoC

KVI	Measurement Method	Frequency	Target Group	Distributed Continuum	Metaverse
Innovation					
I1: Safety	Questionnaire and focused group surveys of stakeholders	Ad-hoc	Stakeholders, Webinar participants		++
I2: Security	Questionnaire and focused group surveys of stakeholders and Nº of incidents	Ad-hoc		+++	
I3: Regulation	OTE and ORO to report on D6.2 – directly engage with policy makers	Ad-hoc	Policy Makers	+++	
I4: Responsibility	RACI charts (identify and interview consortium stakeholders)	Ad-hoc		+	
I5: Energy efficiency	energy consumption per bit >90% (standardized methodologies of ETSI)	Ad-hoc	N/A	+++	+++
Democracy					
D1: Privacy	Nº of privacy issues in the datasets for ML/AI training	Ad-hoc	N/A	+	+++
D2: Fairness	Whitebox testing	Ad-hoc	N/A	+++	
D3: Digital Inclusion	Questionnaires/group surveys (can people with disabilities access network resources?)	Ad-hoc	Disabled people	+++	+++

D4: Trustworthiness	Demonstration of trust through PoCs	Ad-hoc		+	
Ecosystem					
E1: Sustainability	>30% CO2 emissions reductions in 6G systems	Ad-hoc	N/A	+++	
E2: Business value	Arcadia framework – leverage of different levels of expertise	Ad-hoc		+++	
E3: Economic growth	Arcadia framework – leverage of different levels of expertise	Ad-hoc			
E4: Open collaboration	Collaboration with other SNS JU projects	Ad-hoc		+	
E5: New value chain	Raise awareness and engage relevant stakeholders from interested vertical industries	Ad-hoc			

3 Market analysis and business model

3.1 Introduction

The market analysis focuses on the evaluation of the different factors that are relevant for the ICT industries (MNOs, Service Providers, Digital services) in combination with the innovative architectures and paradigms that shape novel business models. The analysis will be later leveraging on specific 6G-INTENSE cases like Native AI, NCF, Management and Orchestration, that will meet the real market needs for future 6G use cases and 6G networks. The sustainable business model is created in a multi-stakeholder and multi-tenant environment, federating the resources pool and opening the door for sustainable business plans. In this phase, the envisioned business model of 6G-INTENSE is separating the service management which is based on a novel implementation of 6G services delivery, from the resources management, which encompasses an innovative DMO and NCF approach as compared to existing approaches.

The Market Analysis and later on, the Business Model for the complex scenario of an Intent-driven Native AI architecture is consolidated around the following key topics:

- Distributed, Intent-driven Management & Orchestration plane (DIMO)
    - DIMO framework that supports multi-tenancy and multi-stakeholder ecosystems
- Service & Resources Ordering, aggregated as SOM and ROM
- Multi-domain orchestration, APIs based configuration
- Dynamic resources and dynamic service management and orchestration, applied to multi-tenant network and compute fabric domains
- Intent based network (IBN), the software-enabled automation process, intelligence applied for Intent driven service fulfillment in autonomous networks
- Benchmarking in relation to the centralized multi-vendor and multi-domain orchestration for dynamic services and resource management

3.1.1 Market Opportunities of DIMO- MANO

As described by different industrial approaches, the actual solution for Management and Orchestration is based on different standards and technical implementations, as in [6] [7] . The market is implementing different M&O models with different flavours with support of ETSI MANO. It should be highlighted that in these scenarios, the automation of the Service Ordering is offered through dynamic actions for Services Creation, Services and Resources orchestration and Service Assurance and Analytics in cross-domain functionality. The industry-relevant markets oversee the Continuous deployment and delivery (CI/CD) of services, automation through design time, run time, deployment and operations. The trends for automated services ordering and orchestration are more oriented to the “Product layer” rather than the “Service Layer”, due to the fact that for the services creation within the multi-domain service layer the end-to-end orchestration and service assurance is implemented through architectural components and software blocks for not only the services design and services ordering, but also through capabilities of multi-service domain orchestration and services inventories applied to single domain layer, that creates limitations for future automated service delivery in multi-domain federated infrastructures. The analysis in the market is extended to the Service Based Architectures and Interfaces through which services can be delivered through orchestration and automation, extension of APIs/CAPIF framework to several TMF APIs for services catalogue management, service ordering, resource allocation, services qualification or services inventory management, topologies changes and notifications. The available markets (TMFs) define also orchestration engines that interacts with the work-flow engines and through the southbound adapters to the network elements (orchestration level flows within the framework SBIs) performs custom actions in the networks.

Essentially, the end-to-end operational framework of orchestration and automation is split in several layers, as follows:

- **Customer Layer**, that is part of the business.
- **Support system**, and it includes the information related to the revenue management, customer management and order management.

- **E2E Layer**, composed by the service operation, service assurance, customer care and security aspects.
- **Network Layer**, the entire network pool of resources, for access domain, transport domain, core domain and cloud domain.

The analysis is extended to the introduction of AI and Autonomous Network (AN) in Telecom domain, where the AN Consumers (B2B, B2C) will efficiently use the available pool of resources within multi-domain networks and infrastructures (as described by TMF [8]), defined as autonomous domains for resources operations. For each of the layers, the approach is to define a domain intelligence for knowledge governance and knowledge optimization within the Intent Management that creates awareness, analysis, decision and execution through the domain control loop management. This foundation applies to the services operation for planning, deployment, maintenance, optimization, and to the business operation to deliver services to the AN consumer.
The analysis identifies new business opportunities for the users, personalized services, automated O&M, real-time experience of operation efficiency and potential business growth through commercialization and production. Under this concept, the closed-loop is extended the business operation (Business Intent), service operations (Service Intent) and resource operations (Resources Intent).
6G-INTENSE identifies the specific requirements for three key pillars, (1) the Service management and orchestration (DMO and t-DMO), (2) Resources management and orchestration, the abstraction of computing and networking (NCF, CEC) and (3) the Native AI toolkit, performance indicators of the underlying LLM models and algorithms (precision, false/positive rate) and requirements related to orchestration, as open source LLM models are analyzed and evaluated in terms of capabilities to support intent-driven automation.
6G-INTENSE proposes DIMO as the future of Management and Orchestration (from industry MANO to DIMO) for the envisioned distributed and heterogeneous 6G infrastructures, with a key component, the NCF abstraction framework, acting as unifying entity of all orchestration domains, by adopting the generative AI techniques. The DIMO and its related management and orchestration components (DMO, tenant, NCF) supports the multi-tenancy and multi-stakeholder ecosystem and it is disaggregating services and resource orchestration through implementation of the DMO. The model proposed expose also unified Intent APIs, supports autonomous self-configuration, self-healing and self-optimization for southbound platforms, through DMO, key innovation:

- separation of the service orchestration from the resource orchestration, NCF that abstracts and unifies the CEC resources as well as allows DMO to select the resources from different resource providers
- multi-tenancy by allowing tenants to run their own management function to handle the service they are deploying
- Intent translation and propagation toward the continuum, from the tenant to the infrastructure

In our concepts, the DMO is the Domain administrative manager; it undertakes the role of the OSS/BSS in the traditional MNOs implementations. It is supported by the NCF which exposes and exploits the computational and networking resources from the resource's pools. The DIMO enables the business cases automated deployment across different autonomous domains that are self-managed, self-optimized and self-healed.

The DIMO is the evolved NFVO into a Domain Management and Orchestration, the new decentralized design supporting the networks and converging on intents supplied to t-DMOs, combined with the NCF. In summary, the DMO is in charge of the network service life-cycle. Tenant DMO (t-DMO) handles the vertical service life-cycle hosting management and orchestration functions. The NCF abstracts the CEC infrastructure resources and enforces the DMO decisions such as deploying network service mesh over a selected set of resource providers, including compute and network resources.

3.2 Market Analysis and Impact

State of the Art and key trends

6G-INTENSE approach is based on the following Key Market Drivers:

- Growing Demand for Rapid and Efficient Processing - Enhanced processing speed is critical in various sectors such as large data centers, telecommunications, gaming, automotive, healthcare, and governmental agencies.
- Surge in Data-Heavy Applications - Industries are experiencing an increase in data-intensive applications, driving the need for more efficient processing solutions.
- Technological Advancements in GPUs and RISC-V Processors - Innovations in graphics processing units (GPUs) and RISC-V processors are crucial for meeting the increasing processing demands.
- Increasing Need for Customizable Solutions - There is a growing need for solutions that can be tailored to specific industry requirements and applications.
- Industrial 5G and Automation - enabling applications such as mobile robots, autonomous logistics, and driverless transport systems within factories.

Native AI

The native AI market, comprising AI tools and platforms embedded within applications or designed to operate across various systems, is witnessing rapid growth due to increasing demand from industries like healthcare, finance, retail, and manufacturing. In 2023, the global AI market was valued at approximately $142.3 billion and is expected to grow at a compound annual growth rate (CAGR) of 37.3% through 2030. This growth is largely driven by the widespread adoption of AI technologies, which help businesses enhance efficiency, reduce costs, and innovate by integrating AI into their core processes.
Several key drivers are fuelling the expansion of the native AI market. Companies are increasingly seeking AI solutions that can be seamlessly integrated into existing workflows to automate tasks and boost efficiency. The rise of edge computing, which allows AI algorithms to run locally on devices like smartphones and IoT devices, is also accelerating this trend by reducing latency, improving performance, and enhancing data security. Furthermore, native AI tools offer more customization and flexibility for specific use cases than generic AI solutions, making them highly valuable for industry-specific applications.
Industry adoption of native AI is broad and diverse. In healthcare, AI is used for applications such as medical imaging analysis, personalized treatments, drug discovery, and virtual health assistants, with the global healthcare AI market expected to reach $107 billion by 2027. Retailers leverage AI for inventory management, personalized marketing, customer service, and demand forecasting, improving real-time customer engagement on e-commerce platforms. In financial services, AI is used for fraud detection, credit scoring, risk management, and chatbots, enabling more seamless integration of these functions within financial systems. Meanwhile, in manufacturing, AI supports predictive maintenance, quality control, supply chain optimization, and robotic automation, allowing for real-time data processing and decision-making on the production floor.
The integration of 6G networks with AI technologies promises significant advancements across multiple sectors, fostering innovation, enhancing efficiency, and driving economic growth. By leveraging the synergies of these two cutting-edge technologies, we are poised to enter a new era of connectivity where the lines between the physical and digital realms are increasingly blurred, offering limitless possibilities. 6G represents a fundamental shift, bringing about groundbreaking capabilities that will transform industries, economies, and societies in profound ways, as demonstrated below:

- *Healthcare*

The fusion of 6G networks and AI is set to revolutionize healthcare delivery. From remote patient monitoring to real-time telemedicine consultations, 6G's ultra-low latency and high reliability will enable critical applications such as remote surgeries performed by AI-guided robotic systems. Additionally, AI-driven predictive analytics will enhance disease detection and treatment outcomes, leading to more personalized and efficient healthcare services [9] [10] .

- *Transportation*

In the transportation sector, 6G networks will drive the widespread adoption of autonomous vehicles and smart transportation systems. AI-powered algorithms will utilize real-time data from vehicle-to-everything (V2X) communication to optimize traffic flow, improve safety, and reduce congestion. Furthermore, the ultra-reliable low-latency communication (URLLC) capabilities of 6G will support split-second decision-making, ensuring the smooth operation of autonomous vehicles even in the most challenging conditions [11] [11] [12] .

- *Manufacturing*

With the advent of Industry 4.0, 6G networks will accelerate the transition to smart factories characterized by interconnected, AI-driven production systems. By utilizing 6G's extensive connectivity and AI's predictive maintenance capabilities, manufacturers can streamline production processes, minimize downtime, and enhance resource efficiency. Collaborative robots equipped with AI algorithms will enable agile and flexible manufacturing workflows, adapting in real-time to changing market demands [13] [13] .

- *Entertainment and Media*

The convergence of 6G networks and AI will transform the entertainment and media landscape, creating immersive experiences and personalized content delivery. From augmented reality (AR) and virtual reality (VR) applications to AI-driven content recommendations, 6G networks will support seamless, high-quality multimedia streaming with minimal latency. AI algorithms will analyze user preferences and behaviour in real-time, providing highly personalized content tailored to individual tastes.

- *Finance and Banking*

In the financial sector, 6G networks will enable the proliferation of AI-driven fintech solutions, transforming payment systems, fraud detection, and risk management. Real-time data analytics powered by AI will allow financial institutions to identify fraudulent transactions with unprecedented accuracy. Simultaneously, 6G's ultra-low latency will ensure near-instantaneous transaction processing, improving the efficiency and security of digital payments [14] [15] .

NCF

The NCF market, valued at approximately $2.3 billion in 2022, is projected to grow to around $5.5 billion by 2027, at a Compound Annual Growth Rate (CAGR) of 18.6%. This robust growth is driven by the increasing demand for high-performance computing (HPC) infrastructure, AI workloads, and enhanced data center efficiency. The expansion of cloud-native applications and multi-cloud environments is also boosting the need for NCF solutions, with the global data center networking market, which includes NCF, anticipated to reach $40.9 billion by 2025. Significant investments in hyperscale data centers by tech giants like Google, Amazon, Microsoft, and Alibaba are further contributing to this trend.

Several key drivers are fuelling the growth of the NCF market. The demand for HPC is rising due to the growth of AI model training and analytics, which require low latency and high-throughput connections between computing resources. The HPC market itself is expected to grow at a CAGR of 7.7% from 2021 to 2028, leading to a corresponding demand for NCF solutions. Additionally, the adoption of edge computing and the Internet of Things (IoT) is accelerating, requiring fabrics capable of efficiently processing and transporting vast amounts of data. The edge computing market, growing at a CAGR of 37.9% and projected to reach $155.9 billion by 2030, is driving the need for NCF to support real-time data processing capabilities.

The monetizable differentiators for each industry player will vary widely. Nonetheless, the NCF will empower CSPs developers, and other participants to introduce new services in diverse contexts, such as the Internet of Senses and connected intelligent machines.

These differentiators can be monetized based on the interplay between harmonized telecom and IT domains, depending on the services the mobile network delivers. Most 6G use cases will generate massive amounts of data, enabling novel insights through intelligent algorithms embedded within the NCF.

The advent of 6G will require CSPs to alter their business strategies, particularly in making services accessible to new customer segments. These services will need to be bundled or aggregated from multiple domains into relevant offerings, ranging from pure connectivity to integrated connectivity and compute, along with other value-added services. These offerings can be provided directly to customers or through ecosystem partners who aggregate services.

The NCF will facilitate new business models by integrating services from various ecosystem actors and offering new technologies for as-a-service models. Automated contract negotiation and fulfilment will support sales, delivery, and charging operations, reducing business friction within different ecosystem constellations. Much of the interaction between players will be conducted through software. Technologies such as distributed ledgers and smart contracts will enable broker-less partnership models among providers.
Application-supporting services will be vital in simplifying application development for providers within the ecosystem. Continued technological advancements and synergies across ecosystems will drive further business model innovation [16] [17] .

3.3 Business model

3.3.1 Value proposition

The project delivers a cutting-edge automation architecture with a Native AI toolkit that facilitates intent declaration, negotiation, and decision automation across autonomous domains, known as Distributed Intent-driven Management and Orchestration (DIMO). Our model, "6G as a Smart Service Execution Platform," aligns with the vision of sustainable infrastructure sharing, reducing space and energy costs, and encouraging collaboration among all members of the value chain under a unified NCF.

6G-INTENSE contributes key technological and scientific innovation as part of the DIMO concept (DMO, NCF, Compute Interconnection (CIC)) to support future multi-stakeholder ecosystems with east/west federation and the potential of internet-scale service instantiation while at the same time ensuring SLA compliance despite the much higher dynamics and resource volatility. Moreover, Native AI is the overarching pillar of the 6G-INTENSE value chain.

3.3.1.1 Business benefits of separation between service and resource management and orchestration

The 6G NCF concept is expected to disrupt the CDN market, which is currently dominated by US-based hyperscalers. The NCF will provide an advantage to Telecom Operators in terms of increased efficiencies through joint optimization and allocation of network and computational resources. It significantly enhances the opportunities for future expansion by abstracting the process of dynamically adding or removing resources (long term such as cloud resources and also volatile such as Deep Edge devices) without requiring detailed bookkeeping, or the implementation of APIs for managing and orchestrating the resources.

Economic Outcome: By expanding the 6G value chain, to include Edge and Deep Edge resource pools, 6G-INTENSE will help the European microelectronics / IoT industry as well as owners of Cloud and Edge infrastructures to become part of the 6G value chain, thus gaining access to new revenue streams.

The significance of 6G-INTENSE contributions primarily via the NCF abstraction framework is to help Cloud and Edge solutions vendors better compete with U.S. cloud providers in the race to shape the future 6G value chain and help grow the Edge Computing market. Moreover, 6G-INTENSE will help European IoT/device value chain to capture part of this revenue as IoT Services, which currently represent only 27% of their market value[7]. As an example, the revenue in the Metaverse market is expected to grow to 120 billion dollars by 2030 in Europe, with a CAGR of 38.45%[8] while the European XR market is expected to grow from 7.59 billion dollars in 2019 to the astonishing 104.3 billion dollars in 2026[9]. These trends clearly illustrate the huge opportunities for the vertical industry and telecom operators. In this context, 6G-INTENSE offers efficient technological enablers that will allow the deployment of extreme 6G use cases in future networks, especially in the edge and far-edge areas, thus improving the services provided to the end-users.

[7] https://www.cbi.eu/market-information/outsourcing-itobpo/industrial-internet-things/market-potential
[8] https://www.statista.com/outlook/amo/metaverse/europe
[9] https://www.researchandmarkets.com/reports/5006475/europe-extended-reality-xr-market-b

3.3.1.2 Business benefits of the native AI toolkit

6G-INTENSE provides for the first time a concrete Native AI framework, contributing to innovative Machine Reasoning approaches for Zero-Touch networks that adopt emerging task decomposition approaches from LLMs.

The ability to optimize network orchestration/management and service delivery is of paramount importance to communications services providers. This is especially the case as 6G networks will add a level of unprecedented complexity due to the heterogeneity of the orchestration domains involved in the 6G service life cycle. Hence, automating the management and orchestration functions using AI/ML approaches is highly needed to overcome the envisioned complexity. In this context, zero-touch management and automated operation is expected to considerably reduce the OPerational Expenditure (OPEX) of network operators and infrastructure managers[10]. Moreover, knowing that many operational activities of existing networks still heavily rely on human interventions (the degree of automation is generally low), increasing the trust in AI/ML using XAI and increasing automation will help reduce the daily operations and maintenance costs. On the other hand, having a unified framework (and one entry point) for tenants to control the life cycle of their service and associated resources, spanning the cloud edge continuum and integrating end-devices (deep edge), will certainly contribute to accelerating 6G services deployment whatever the infrastructure resources used. This is not the case with 5G, which is limited to Cloud/Edge and 5G domains (RAN and CN), where each domain has its orchestration and management system.

Economic Impact:

6G-INTENSE innovations related to OPEX reduction directly increase the competitiveness of infrastructure owners and telecom operators, by:

(a) reducing overprovisioning and energy consumption. This goal will be achieved by a better use of resources and achieving increased resource utilization across the board by more than 20%, and

(b) improving the energy efficiency of training AI models and analytics linked with Zero-Touch by 50%, via Composable AI, and innovative model distillation and quantization approaches.

Operational activities of existing networks still heavily rely on human interventions. For this reason, Zero-touch automation has the potential to continue its expansion, where the market is expected to reach $32.4 billion by 2028, growing at a CAGR of 22.8% during the forecast period of 2021 to 2028.

OPEX reductions also clearly promote the competitiveness of the telecommunications sector which provides high-value jobs and is currently employing more than 1 million people140 in Europe[11].

On the other hand, Native AI technological enablers will allow the deployment of extreme 6G use cases in future networks, via marked improvements in QoS/QoE and SLA breaches decreased by more than 90%, hence breaking the barriers of adoption. Native AI is considered a key capability that can accelerate annual recurring revenue by up to 50%[12].

Societal Impact: OPEX reduction in digital technologies is a key component of increasing EU competitiveness versus U.S. companies and will help the EU bolster its digital sovereignty[13]. Moreover, OPEX reductions promote the competitiveness of the telecommunications sector which provides high-value jobs and has a strategic importance as an enabler for all sectors in society and economy.

3.3.1.3 Business benefits of the DMO

One of the most important 6G-INTENSE innovations is related with the DIMO concept, which was precisely proposed to address the scalability and deployment shortcomings of 5G. The new decentralized DMO design is supporting the “network of networks” vision of federating a huge number of resource pools from third party stakeholders. 6G-INTENSE separates service (or application) orchestration from resource orchestration, hence alleviating one of the key bottlenecks of the 5G OSS,

[10] https://www.ericsson.com/en/blog/2020/2/ai-network-management-energy-costs

[11] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20201215-1

[12] https://www.silverliningsinfo.com/multi-cloud/ai-native-ticket-unicorn-status-cloud-market-says-vc-firm-bessemer

[13] https://ecfr.eu/publication/europe_digital_sovereignty_rulemaker_superpower_age_us_china_rivalry/#introduction-europes-digital-sovereignty

which centralizes slice (resource) management and application (vertical) management. This is especially helpful for indefinitely increasing the coverage area to a huge number of heterogeneous domains which could e.g., span a country, or metropolitan area (or even a single private network). Internet-scale can even be achieved with operator federations, which are facilitated with inter-DMO East/West APIs offered from DMOs, as well as innovative intent negotiation and on-the-fly mapping of service meshes to heterogeneous resource pools.

Economic Impact: The 6G-INTENSE architecture caters to the extreme 6G use cases, securing new revenue streams for the European Vertical industry via new, high-value services. While the public internet is best effort in nature, emerging applications with extreme networking and computational requirements (e.g., extended reality) will become a possibility with the new groundbreaking capabilities offered by 6G-INTENSE in terms of optimized service deployment and orchestration workflows, that can guarantee extreme requirements in terms of resource provisioning from the NCF also extending towards a dependable Deep Edge.

Content consumption and gaming represent the most critical use-cases that drive internet traffic (e.g., Netflix uses up 15% of all Internet downstream traffic worldwide) and have a strong location dependence currently served by CDNs. The SD-WAN component of the NCF has the potential to disrupt the CDN market, allowing telco infrastructures and Deep Edge domains to act themselves as hosting environments for application tasks and (micro-)services, allowing ubiquitous computing and extreme proximity of user-centric processes to end user environments. 6G-INTENSE targets an improvement by a factor of 2 the reliability of SD-WAN, presenting it as a viable alternative for CIC. This has the potential to also benefit telecom operators who could win part of the SD-WAN market, which is projected to reach 13.7 billion by 2026 from USD 3.4 Billion in 2021, at a CAGR of 31.9%[14].

Most importantly, emerging 6G system models with federated infrastructures and the concept of reusability of resource pools contribute to greater levels of sustainability which is one of the UN SDGs. Furthermore, the 6G value chain becomes more open to external players, such as the IoT and device ecosystems and particularly SMEs, which are essential to Europe's competitiveness and prosperity, economic and technological sovereignty, and resilience to external shock. Under this light, 6G-INTENSE is facilitating the future expansion of the 6G value chain within the Edge and IoT domains, helping accelerate the growth of the European Edge Computing Market which for the decade 2020-2030 was forecasted at 26.5%, and helping European IoT/device value chain increase its revenue from IoT Services, which currently represent only 27% of their market value[15].

3.3.2 Value chain components and actors

The envisioned 6G-INTENSE approach involves different stakeholders, these stakeholders interact via different business operations and agreements.

Infrastructure / resource provider

It is the entity that owns 6G resources. It can own one or different types of 6G resources. In 6G-INTENSE, we envision different types of resources:

- Computing: Central cloud, edge cloud, extreme edge, and deep edge with JCAS.
- Networking: Compute Interconnection networks, such as SD-WAN
- Radio: 6G Radio, 5G New Radio, Wifi 6, Satellite.

All the infrastructure providers and resource owners expose their resources through well-defined API using an LMO. To avoid the limitation of NFVO, which statically includes resources, in 6G-INTENSE, the resources are registered dynamically and used by the NCF entity. This way, the resources are exposed and deleted dynamically, supporting the scenario of mobile resources such as drones and cars, which are used as extreme edge nodes. Note that the business interaction between infrastructure providers

[14] https://www.marketsandmarkets.com/Market-Reports/software-defined-wan-market-%2053110642.html?gclid=EAIaIQobChMI5tvjvMu1_gIVDfd3Ch1IIQHMEAAYASAAEgKpgfD_BwE

[15] https://www.cbi.eu/market-information/outsourcing-itobpo/industrial-internet-things/market-potential

and the NCF is Business-to-Business (B2B). The usage of resources can follow the well-known cloud model for pay-as-you-go or long-term business establishment.

NCF

This is one of the critical components of the 6G-INTENSE system as it contributes to the separation of resource and service management, which is one of the key innovations of 6G-INTENSE. The NCF abstracts the 6G resources to the DMO and takes charge of enforcing a 6G service, composed of a set of applications and network functions, on top of the 6G infrastructure. It handles the 6G resources through interaction with resource and infrastructure providers (via LMO). It abstracts the 6G resources to DMO through resource exposure. The NCF can belong to an independent entity from DMO and resource providers. The NCF has a B2B agreement with DMO(s) and resource providers. NCF can serve more than one DMO(s) and register and handle the usage of resources of different infrastructure providers.

DMO

It is the second component of 6G-INTENSE that enables the separation of service and resource management. It is the entity managing the LC of 6G services deployed on the 6G infrastructure. It has the role of translating the vertical requests and needs, via the t-DMO or directly, into a service-level mesh, i.e., a service composed of the vertical applications in addition to Network functions to support the 6G service, such as firewall, security functions, data collector and aggregators, etc. DMO enforces the 6G service-level mesh using the resource exposed by the NCF. The DMO establishes B2B agreements: (i) with different NCFs to use 6G infrastructure, (ii) support different t-DMO(s). While a Business to Consumer (B2C) agreement is established if there is direct interaction with verticals. DMO can belong to an independent stakeholder that represents an administrative domain, like a network operator in 5G.

Tenant-DMO

One of the innovations of 6G-INTENSE is to reduce the complexity of the service management plane by delegating some functions to the vertical service owner. Knowing that many verticals do not know how to manage services, the t-DMO entity has been introduced. In addition, the t-DMO is an entity that sells 6G services to verticals without owning infrastructure or being in charge of enforcing the 6G service on top of the 6G infrastructure as the DMO does. It establishes a B2B agreement with the DMO(s), which allows the DMO to delegate service-level management functions. A t-DMO can be seen as equivalent to the virtual mobile operator actors of 4G and 5G.

Verticals

They are entities that aim to deploy their applications or services as a 6G service on top of the 6G infrastructure. Vertical services or applications aim to use the 6G system capabilities to innovate and improve the final user experience. We can mention autonomous driving, the entertainment industry, smart cities, industry 5.0, etc. In 6G-INTENSE the vertical establishes a business agreement with tenant-DMO or directly with DMO. This type of agreement covers the required Service Level Agreement (SLA), cost, coverage area, etc. The business model between verticals and t-DMO or DMO is in the form of business-to-consumer (B2C).

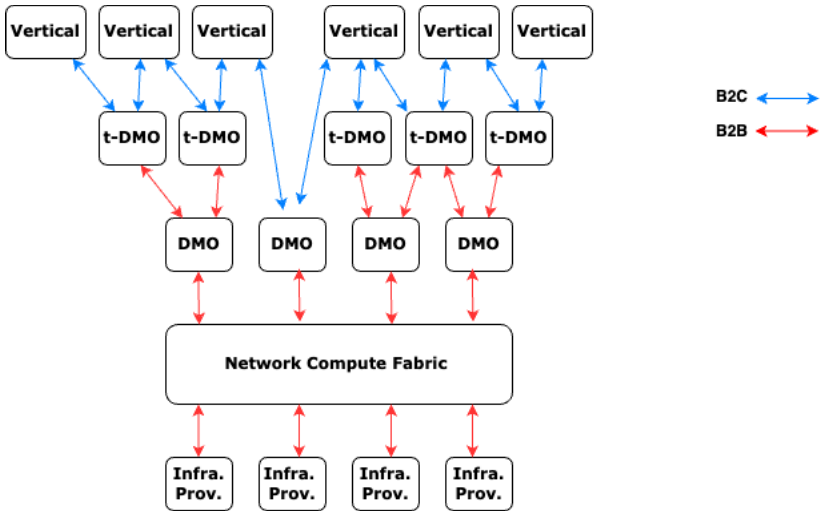

Figure 16: 6G-INTENSE actors' interactions

In *Figure 16*, we illustrate the interaction between different stakeholders, i.e., verticals, t-DMO, DMO, resource providers, as well as NCF. The business, as foreseen by 6G-INTENSE introduces new opportunities to unlock the 6G market by allowing the entrance of new actors, such as t-DMO owners, NCF owners, and DMO owners. In the envisioned business model, a t-DMO and DMO can be one entity or separate entities, while the NCF owner can also own DMO or 6G resources. One of the objectives of 6G-INTENSE is to define well-specified interfaces between the cited entities, guaranteeing interoperability and hence ensuring business agreement establishment for the efficient functioning of the end-to-end system.

Table 11: Benefits of 6G-INTENSE architecture for Actors

Actor	Value Chain component	Value Proposition
MNOs, MVNOs, Private Networks	DMO, NCF	The separation between service and resource management afforded by the DMO and NCF components leads to increased efficiencies; It significantly expands opportunities for future coverage expansion by abstracting the process of dynamically adding or removing resources.
Owners of Cloud, Edge, IoT infrastructures	NCF, Native AI toolkit	Owners of computational resources can seamlessly offer their resources within resource pools, with automated API translations offered by the Native AI toolkit.
Vertical app providers	DMO, Native AI toolkit	The DMO offers automatic service onboarding, instantiation and assurance offered by the Native AI toolkit.
Resource Brokers	DMO	The DMO facilitates new Network Infrastructure as a Service (NIaaS0 business models, where resource brokers expose third party resources to MNOs / MVNOs via a DMO deployment.
Consumers	Native AI	The Native AI toolkit helps ensure SLA compliance despite the much higher dynamics and resource volatility.

3.3.3 Key Resources

- *Technology Infrastructure*

The 6G network infrastructure provides high-speed, low-latency connectivity for seamless operation. This is complemented by the NCF, which integrates network and computational resources to support Distributed Intent-driven Management and Orchestration (DIMO). Additionally, an advanced AI toolkit offers sophisticated AI algorithms and tools designed for intent-driven automation.

- *Human Resources*

Our AI and ML experts develop and maintain the Native AI toolkit, while network engineers ensure robust and reliable 6G network operations. Software developers focus on developing and enhancing the automation platform. Additionally, customer support and success teams provide ongoing support and ensure customer satisfaction.

- *Partnerships*

We rely on collaborations with telecom operators for infrastructure sharing and 6G network deployment, while using cloud service providers to integrate the cloud computing resources. Enterprise solutions providers should ensure seamless integration with ERP, CRM, and other enterprise systems.

- *Intellectual Property*

Obtaining patents and licenses will protect the innovative aspects of DIMO and the AI toolkit, while our proprietary algorithms maintain a competitive edge through unique AI and automation solutions.

- *Financial Resources*

Investments provide funding for research and development as well as scaling operations, while revenue is generated from various streams, such as customization and integration fees, consulting services, revenue sharing from collaborations and partnerships, advanced data analytics and reporting services.

3.3.4 Key Metrics

- *Revenue Metrics*
  - -Monthly Recurring Revenue (MRR): Monthly revenue from services subscription fees.
  - -Annual Recurring Revenue (ARR): Annual revenue from services subscription fees.
  - -Average Revenue Per User (ARPU): Average monthly revenue per customer.
  - -Yearly Revenue Growth Rate: Rate of increase in revenue over a year.
- *Financial Metrics*
  - -Gross Margin: Difference between revenue and cost of solutions, as a percentage of revenue.
  - -Operating Expenses Ratio: Ratio of operating expenses to total revenue.
  - -Net Profit Margin: Percentage of revenue that remains as profit after all expenses.
- *Business Service Level Agreements metrics*
  - *Successful implementation of business-related services: solutions operations efficiency and delivered services related metrics.*
- *Market Penetration Metrics*
  - -Market Share: Percentage of the target market using provided services.
  - -Geographic Reach: Number of regions or countries with active customers.
  - -Industry Penetration: Percentage of target industries using the services.
- *Innovation and Development Metrics*
  - -R&D Spending: Amount spent on research and development.
  - -Solution Development Cycle Time: Time taken to develop and deploy new solutions.
  - -Number of Patents Filed: Number of patents related to 6G and AI technologies.
- *User Engagement Metrics*
  - -Daily Active Users (DAU): Number of unique users interacting with the platform daily.
  - -Monthly Active Users (MAU): Number of unique users interacting with the platform monthly.

3.3.5 Legal and regulatory considerations

Addressing data privacy and security involves ensuring compliance with the General Data Protection Regulation (GDPR) for handling personal data of EU citizens, including data processing, storage, and transfer, as well as adhering to the California Consumer Privacy Act (CCPA) requirements for protecting the privacy of California residents. This also means complying with various international, federal, and state data protection laws that govern the collection, use, and storage of personal data. Telecommunications regulations necessitate obtaining the necessary licenses for using 6G spectrum from relevant regulatory bodies, complying with regulations governing the deployment and maintenance of telecommunications infrastructure, and adhering to net neutrality principles to ensure equal treatment of all data transmitted over the network.

For intellectual property (IP), securing patents for proprietary technology and algorithms used in the DIMO and AI toolkit is essential, along with protecting the brand name and logo through trademarks, and ensuring software and platform content are protected by copyright laws. Employment and labor laws require ensuring employment agreements comply with local labor laws, including non-compete clauses, confidentiality agreements, and intellectual property rights, as well as safeguarding employee data in accordance with relevant privacy laws.

Environmental regulations demand compliance with laws related to energy consumption and electronic waste disposal, and obtaining green certifications for sustainable infrastructure practices, if applicable. Industry-specific regulations include adhering to financial regulations for automated processes in financial transactions, such as those from the SEC, FINRA, and similar regulatory bodies worldwide, complying with HIPAA in the U.S. and similar regulations in other countries for handling patient data in the healthcare sector, and adhering to regulations governing the transport and logistics industry, including customs and import/export controls.

Contract law involves clearly defining Service Level Agreements (SLAs) with customers, outlining the scope of services, performance metrics, and penalties for non-compliance, and ensuring contracts with vendors and partners comply with legal standards and protect the company's interests. Consumer protection laws require adherence to laws preventing deceptive marketing practices, ensuring truthful representation of services, and establishing clear refund and cancellation policies in compliance with them. Finally, compliance and auditing necessitate regular audits and compliance checks to ensure adherence to all relevant laws and regulations and engaging third-party auditors for an unbiased assessment of compliance and security measures.

6G-INTENSE
Business model canvas

Value proposition

- Separation of service (or application) orchestration from resource orchestration
- Native AI toolkit
- NCF abstraction framework/ sustainable infrastructure sharing,
- Multi-stakeholder, decentralized ecosystems based on DIMO concept
- Network-of-networks concepts
- Internet-scale under operator federations

Value chain components

Infrastructure / resource provider
NCF
DMO
Tenant-DMO
Resource brokers
Consumers

Key metrics

- Revenue Metrics
- Financial Metrics
- Operational Efficiency Metrics
- Technology Utilization Metrics
- Market Penetration Metrics
- Innovation and Development Metrics
- User Engagement Metrics

Business actors

- Telecom Operators
- Device Manufacturers
- Software Developers
- Regulatory Bodies
- Infrastructure Providers
- Academic Institutions and Research Organizations

Revenue streams

Expansion of the 6G value chain, to include Edge and Deep Edge resource pools

Greater operational flexibility

Better use of resources→ increase of competitiveness of infrastructure owners and telecom operators

New revenue streams for the European Vertical industry via new, high-value services (e.g., extended reality)→ Enhancement of European strategic autonomy

Key Activities

Identify Innovations: discovery of technological advancements and added-value services (including consultancy and instructional offerings) aimed at the project's target audience.

Analyze the Market: investigation to determine the target demographic for INTENSE-6G, including assessing the competitive environment and spotting emerging trends.

Validate via Demonstrations and Use Cases: the effectiveness of the proposed exploitation strategies will be corroborated through the deployment of use cases and demonstration actions.

Developed Exploitation Models: the project will define and evaluate various avenues for both commercial and non-commercial exploitation.

Craft and Assess Business Models: exploration into the feasibility and sustainability of different business models and alternate approaches for offering the project's solutions and services to its stakeholders.

4 Conclusions

This deliverable focuses on the requirements and PoC scenarios for the 6G-INTENSE project, which aims to innovate by separating service management from resource management. This vision supports new market entrants, such as owners of extreme-edge nodes, and refines PoCs that address technological gaps using 6G technologies. The project explores two PoCs: one on pervasive computing (PoC#1) and the other on the Metaverse (PoC#2). PoC#1 includes experiments on NCF integration and edge intelligence, while PoC#2 involves experiments on user tracking and autonomous management within the Metaverse, leveraging joint communication, sensing, and AI tools.

The deliverable also defines KPIs and KVIs to assess the project's impact on vertical applications and European industrial competitiveness. These indicators are based on prior 5G-PPP ICT-52-2020 project trials, 6G white papers, and consortium expertise. A detailed mapping of KVIs per application is provided, along with a literature review from other projects like HEXA-X, FIDAL, TARGET-X, TRIALS-NET and CENTRIC.

Finally, the deliverable conducts a market analysis to highlight the potential of combining Native AI with 6G networks across sectors. It discusses the benefits of the NCF for Communication Service Providers (CSPs) and introduces a business model for "6G as a Smart Service Execution Platform." The analysis identifies key stakeholders and the advantages 6G-INTENSE offers, thus presenting a comprehensive overview of the project's strategic value proposition and potential market impact.

In summary, the insights and findings outlined in this document offer significant contributions to the ongoing discussions on advanced communication systems, fostering further innovation and progress in the fields of the Metaverse and 6G technology.

5 References

[1] HEXA-X-D1.4 - "Hexa-X architecture for B5G/6G networks – final release"- Available at: https://hexa-x.eu/wp-content/uploads/2023/07/Hexa-X-D1.4-Final.pdf

[2] FIDAL - D2.1 "Requirements, Architecture And Methodologies (Initial Version)"-Available at: https://fidal-he.eu/public-deliverables/d-21-fidal-requirements-architecture-and-methodologies-initial-version

[3] TARGET-X D2.1 "Forward Looking Use Cases, their requirements and KPIs/KVIs" - Available at:https://target-x.eu/wp-content/uploads/2024/02/231231_TARGET-X_D1.1_Forward-looking-use-cases_final-version.pdf

[4] TRIALS-NET – D6.1 " First report on validation and dissemination activities" – Available at: https://zenodo.org/records/10058287

[5] CENTRIC – D5.1 "Early results on KPIs/KVIs, testing methodologies and benchmarking" – Available at: https://zenodo.org/records/10473249

[6] Zero-touch network and Service Management (ZSM); Intent-driven autonomous networks; Generic aspects, ETSI GR ZSM 011 V1.1.1 (2023-02)

[7] Zero-touch network and Service Management (ZSM); Closed-Loop Automation; Part 3: Advanced topics, ETSI GR ZSM 009-3 V1.1.1 (2023-08)

[8] Autonomous Networks Project, https://www.tmforum.org/autonomous-networks-project/

[9] M. D. Howell, G. S. Corrado, K. B. DeSalvo, "Three Epochs of Artificial Intelligence in Health Care," in Journal of the American Medical Association, vol. 331, no. 3, pp.242–244, 2024, doi:10.1001/jama.2023.25057

[10] H. A. Younis, T. A. E. Eisa, M. Nasser, T. M. Sahib, A. A. Noor, O. M. Alyasiri, S. Salisu, I. M. Hayder, H. A. Younis, "A Systematic Review and Meta-Analysis of Artificial Intelligence Tools in Medicine and Healthcare: Applications, Considerations, Limitations, Motivation and Challenges," in Diagnostics, vol. 14, no. 109, 2024, doi: 10.3390/diagnostics14010109

[11] T. Gong, L. Zhu, F. R. Yu, and T. Tang, "Edge Intelligence in Intelligent Transportation Systems: A Survey," in IEEE Transactions on Intelligent Transportation Systems, vol. 24, no. 9, pp. 8919-8944, Sept. 2023, doi: 10.1109/TITS.2023.3275741

[12] J. Perez-Cerrolaza, J. Abella, M. Borg, C. Donzella, J. Cerquides, F. J. Cazorla, C. Englund, M. Tauber, G. Nikolakopoulos, and J. L. Flores, "Artificial Intelligence for Safety-Critical Systems in Industrial and Transportation Domains: A Survey," in ACM Computing Surveys, vol. 56, no. 7, pp. 1-40, 2024, doi: 10.1145/3626314

[13] J. Jenis, J. Ondriga, S. Hrcek, F. Brumercik, M. Cuchor, E. Sadovsky, "Engineering Applications of Artificial Intelligence in Mechanical Design and Optimization," in Machines, vol. 11, no. 577, 2023, doi: 10.3390/machines11060577

[14] N. L. P. Srinadi, D. Hermawan, and A. A. N. A. Jaya, "Advancement of banking and financial services employing artificial intelligence and the internet of things," in Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications, vol .14, no. 1, pp. 106-117, 2023

[15] M. Rahman, T. H. Ming, T. A. Baigh, and M. Sarker, "Adoption of artificial intelligence in banking services: an empirical analysis," in International Journal of Emerging Markets, vol. 18, no. 10, pp. 4270-4300, 2023, doi:10.1108/IJOEM-06-2020-0724

[16] K. David, A. Al-Dulaimi, H. Haas, and R. Q. Hu, "6G Fabric Compiles Microdomains for Sophisticated Service Delivery," in IEEE Vehicular Technology Magazine, vol. 18, no. 1, pp. 16-18, March 2023, doi: 10.1109/MVT.2023.3238481.

[17] D. Vukobratović, N. Bartzoudis, M. Ghassemian, F. Saghezchi, P. Li, et al. "Distributed Sensing, Computing, Communication, and Control Fabric: A Unified Service-Level Architecture for 6G," in arXiv preprint arXiv:2307.10286, 2023

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