D2.1 Requirements and use cases/PoC scenarios definition including preliminary architecture design

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Glossary of terms and abbreviations

Abbreviation / Term	Description
3GPP	3rd Generation Partnership Project
6G	6th Generation
AI	Artificial Intelligence
AIaaS	Artificial Intelligence as a Service
APEC	Accelerated Programmable Edge Computing
API	Application Programming Interface
B2B	Business to Business
BSS	Business Support System
CL	Closed Loop
CLC	Closed Loops Coordination
CPU	Central Processing Unit
DoA	Description of Action
DSP	Digital Service Provider
DT	Digital Twin
eBPF	extended Berkeley Packet Filter
ETSI	European Telecommunication Standards Institute
FPGA	Field-Programmable Gate Array
GA	Grant Agreement
GDPR	General Data Protection Regulation
GSMA	Global System for Mobile communications Association
IaaS	Infrastructure as a Service
IL	Intelligence Layer
IMF	Intent Management Function
IMO	Impact Maximisation Objectives
KPI	Key Performance Indicator
KV	Key Value
KVI	Key Value Indicator
MEC	Multi-access Edge Computing
ML	Machine Learning
MP	Marketplace

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NaaS	Network as a Service
NDT	Network Digital Twin
NFV	Network Function Virtualization
NIaaS	Network Infrastructure as a Service
NIC	Network Interface Card
NPN	Non Public Network
NTN	Non-Terrestrial Network
NoN	Network of Networks
ODA	Open Digital Architecture
PO	Performance Objectives
PoC	Proof-of-Concept
RAN	Radio Access Network
RBAC	Role Based Access Control
REST	REpresentational State Transfer
SBA	Service Based Architecture
SDG	Sustainable Development Goal
SLA	Service Level Agreement
SLO	Service Level Objective
TEF	Trustworthiness Evaluation Framework
TO	Technical Objectives
UC	Use Case
ZSM	Zero-touch network and Service Management

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1 Executive Summary

This deliverable, entitled “Requirements and Use Cases/PoC Scenarios Definition Including Preliminary Architecture Design”, provides the foundational framework for the FLECON-6G project’s development of a flexible, open, and AI-driven 6G connectivity platform. The document addresses the critical need for scalable and modular architectures that integrate both terrestrial and non-terrestrial networks, while embedding trustworthiness, sustainability, and multi-stakeholder collaboration at its core.

The work carried out for this deliverable encompasses several key activities. First, a comprehensive framework for Key Performance Indicators (KPIs) and Key Value Indicators (KVIs) was established, ensuring that both technical performance and societal impact are systematically measured throughout the project. The deliverable also details four representative use cases and proof-of-concept (PoC) scenarios, each carefully selected to validate the feasibility and added value of the proposed solutions in real-world contexts. These scenarios are described in terms of their objectives, technical and operational challenges, requirements, high-level architecture, and associated KPIs, providing a holistic evaluation framework.

A thorough requirements analysis was conducted, involving iterative engagement with stakeholders to elicit, categorize, and refine both functional and non-functional requirements. This process ensures that the FLECON-6G platform is designed to address genuine user needs and operational constraints. Building on these requirements, the deliverable presents a preliminary architectural design for FLECON-6G, outlining the guiding principles, innovative services, and functional components that will underpin the platform’s development.

The main conclusion of this deliverable is that the FLECON-6G architecture is well positioned to address the technical challenges of next-generation connectivity while enabling cross-domain collaboration and delivering measurable societal value. The systematic definition of KPIs and KVIs, combined with a user-driven requirements analysis and a modular architectural approach, provides a robust foundation for subsequent development and validation activities within the project.

The purpose of this deliverable is to serve as a strategic blueprint for the next phases of FLECON-6G. It ensures alignment among consortium partners, supports the validation of innovations through targeted PoCs, and enables the refinement of architectural components for interoperability and scalability. In doing so, it positions FLECON-6G as a cornerstone for Europe’s leadership in sustainable, secure, and intelligent 6G ecosystems.

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2 Introduction

FLECON-6G project, funded under the HORIZON JU SNS programme, is a pioneering initiative dedicated to shaping the next generation of connectivity through the development of a flexible, open, and AI-driven 6G platform. As the digital landscape continues to evolve, the demand for scalable, modular, and trustworthy network architectures has become increasingly urgent. FLECON-6G responds to this challenge by envisioning an "Intelligent 6G Network of Networks," seamlessly integrating terrestrial and non-terrestrial domains and enabling collaborative, multi-stakeholder environments. This vision is underpinned by the convergence of advanced communication technologies, computational resources, and native AI/ML-driven automation, all within a distributed and modular architectural framework.

The transition from 5G to 6G is expected to be transformative, not only in terms of technical capabilities but also in its broader societal, economic, and environmental impact. While 5G introduced cloud-native and edge computing paradigms, 6G aims to embed artificial intelligence as a foundational element, enabling networks to self-optimize, adapt, and deliver unprecedented levels of performance, security, and efficiency. This shift will facilitate the deployment of new services and applications, from immersive reality to autonomous systems, while addressing the growing complexity and diversity of digital ecosystems.

Within this context, the present deliverable serves several critical functions. First, it defines and evaluates Key Performance Indicators (KPIs) and Key Value Indicators (KVIs) tailored to the FLECON-6G vision. KPIs provide measurable criteria for assessing the technical performance of the platform, such as latency, reliability, energy efficiency, and scalability, ensuring that the system meets the stringent requirements of future use cases. KVIs, on the other hand, capture the broader value generated by the project, including societal benefits, environmental sustainability, and alignment with European Union Sustainable Development Goals (SDGs). By establishing a robust framework for both KPIs and KVIs, the deliverable lays the foundation for comprehensive performance and impact assessment throughout the project lifecycle.

Second, the deliverable offers a detailed description of the use cases and proof-of-concept (PoC) scenarios that will serve as practical demonstrations of FLECON-6G's innovations. These scenarios are carefully selected to validate the feasibility, performance, and added value of the proposed solutions in real-world settings, encompassing diverse domains such as immersive reality, autonomous robotics, network digital twins, and public safety services. Each PoC is analysed in terms of its narrative, objectives, technical and operational challenges, requirements, high-level architecture, and associated KPIs, ensuring a holistic and multidimensional evaluation.

Third, the deliverable presents a comprehensive requirements analysis, encompassing both functional and non-functional aspects. This analysis is informed by systematic elicitation processes involving all relevant stakeholders, including all the actors within the project. The requirements are mapped to the project's objectives and use cases, ensuring that the FLECON-6G platform is designed to address real-world needs and constraints.

Finally, the deliverable outlines a preliminary architectural design for FLECON-6G, articulating the guiding principles, innovative services, and functional components that will underpin the platform. This architectural blueprint is intended to support recursive modelling, dynamic composition, and coordinated operation across multi-domain networks, leveraging multi-layer Network Digital Twins (NDTs) and advanced AI algorithms for intent-driven management and orchestration.

2.1 Mapping FLECON-6G Outputs

The following Table 2.1 summarizes the adherence to the FLECON-6G GA deliverable and task requirements, indicating the corresponding chapters and providing a brief justification for each mapping.

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Table 2.1: Adherence to FLECON-6G's GA Deliverable & Tasks Descriptions

FLECON-6G GA Component Title	FLECON-6G GA Component Outline	Respective Document Chapter(s)	Justification
DELIVERABLE			
D2.1 Requirements and use cases/PoC scenarios definition including preliminary architecture design	A detailed analysis of the functional requirements stemming from the use cases/PoC scenarios, and their translation into technical requirements for the preliminary design of the FLECON-6G architecture.	3 (Key Performance Indicators and Key Value Indicators), 4 (Use Cases/PoC Scenarios Definition), 5 (Requirements Analysis), 6 (Preliminary Architecture Design)	This deliverable defines and documents the requirements, use cases, and proof-of-concept (PoC) scenarios for the FLECON-6G project, and provides a preliminary design of the system architecture. It ensures that the proposed 6G architecture is distributed, modular, open, and collaborative, integrating terrestrial and non-terrestrial networks, and embedding trustworthy, native AI-driven automation. The document also details Key Performance Indicators (KPIs) and Key Value Indicators (KVIs), outlines their evaluation methodology, and presents the initial technical framework for validation through targeted experimentation and PoCs
TASKS			
Task 2.1: Requirements' Analysis and Use Cases Refinement	Elicit, analyse, and refine stakeholder requirements; map to use case scenarios.	Section 4 (Use Cases/PoC Scenarios Definition), Section 5 (Requirements Analysis)	Ensures alignment between stakeholder inputs and use case definitions, as mandated by GA. Requirements are systematically categorized into functional/non-functional categories and validated through PoC scenarios.
Subtask 2.1.1: Stakeholder Requirement Elicitation	Conduct workshops/surveys with stakeholders (e.g., operators, vendors, testbed providers) to identify requirements.	Section 5.1 (Requirements Elicitation)	Directly addresses GA's requirement for iterative, user-driven input to ensure use cases reflect real-world needs.
Subtask 2.1.2: Use Case Refinement	Refine use cases based on stakeholder feedback and technical feasibility analysis.	Section 4.1–4.4 (PoC Scenarios)	Validates use case narratives, objectives, and architectures against GA's emphasis on practical validation.

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Task 2.2: KPIs/KVIs Definition, Testing, and Evaluation Methodology	Define KPIs/KVIs, establish testing frameworks, and outline evaluation methodologies.	Section 3 (Key Performance Indicators and Key Value Indicators)	Aligns with GA's mandate to measure technical performance (KPIs) and societal/economic value (KVIs). Testing methodologies ensure PoC validation against benchmarks.
Subtask 2.2.1: KPI/KVI Definition	Define KPIs (e.g., latency, reliability) and KVIs (e.g., sustainability, economic impact).	Section 3.1.1 (KPI Definition), Section 3.2.1 (KVI Definition)	Categorizes indicators per GA's focus on technical excellence and EU SDG alignment.
Subtask 2.2.2: Testing and Evaluation Framework	Develop methodologies for KPI/KVI validation in PoC scenarios.	Section 3.1.3 (KPI Evaluation), Section 3.2.3 (KVI Evaluation)	Ensures GA compliance by linking indicators to measurable outcomes in real-world testing (e.g., testbed infrastructure mapping).
Task 2.3: System Architecture Design and Technical Requirements	Design FLECON-6G's architecture and define technical specifications.	Section 6 (Preliminary Architecture Design)	Delivers GA's core objective of a modular, AI-driven 6G architecture integrating TN/NTN domains and multi-stakeholder collaboration.
Subtask 2.3.1: Architectural Principles	Define principles (e.g., openness, scalability, Zero-Touch automation).	Section 6.1 (Architectural Principles)	Aligns with GA's vision for a "Network of Networks" framework.
Subtask 2.3.2: Technical Requirements Specification	Translate functional requirements into technical specifications (e.g., APIs, protocols).	Section 5.2 (Functional Requirements), Section 5.3 (Non-Functional Requirements)	Ensures GA's technical mandates (e.g., privacy-preserving AI, conflict resolution) are operationalized in the architecture.
Subtask 2.3.3: Functional Architecture Proposal	Propose a preliminary architecture for validation in PoCs.	Section 6.3 (Preliminary Functional Architecture)	Validates GA's requirement for interoperability and dynamic composition across multi-vendor environments.

2.2 Deliverable Overview and Report Structure

This deliverable is structured to present a comprehensive examination of the FLECON-6G project, encompassing the definition and evaluation of Key Performance Indicators (KPIs) and Key Value Indicators (KVIs), an in-depth overview of the identified use case and proof-of-concept (PoC) scenarios, a thorough analysis of system requirements, and a preliminary outline of the architectural design.

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- Executive Summary: Concise summary of the deliverable's key points, findings, and recommendations.
- Introduction: Presents the context, motivation, and objectives of the deliverable, including the mapping of FLECON-6G outputs to project goals.
- Key Performance Indicators and Key Value Indicators: Defines and evaluates the Key Performance Indicators and Key Value Indicators relevant to FLECON-6G.
    - Key Performance Indicators (KPIs): Defines KPIs, details those selected for FLECON-6G, and outlines the evaluation methodology.
    - Key Value Indicators (KVIs): Defines KVIs, presents those identified for FLECON-6G, and describes the evaluation approach.
- Use Cases/Proof of Concept (PoC) Scenarios Definition: Describes the main use cases and PoC scenarios, providing for each: narrative, objectives, challenges, requirements analysis, high-level architecture, relevant KPIs, and testbed infrastructure mapping.
- Requirements Analysis: Details the process of requirements elicitation and presents both the functional and non-functional requirements derived from the use cases and project objectives.
- Preliminary Architecture Design of FLECON-6G: Outlines the architectural principles, describes innovative services and functionalities, and provides a preliminary overview of the functional architecture.
- Conclusions: Summarizes the main findings and outcomes and highlights future directions and next steps for the project.

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3 Key Performance Indicators and Key Value Indicators

Key Performance Indicators (KPIs) and Key Value Indicators (KVIs) play a crucial role in evaluating the effectiveness and success of FLECON-6G's requirements and use cases. These indicators provide measurable criteria to assess both the technical performance and the overall value generated by the proposed solutions.

To ensure a comprehensive evaluation, this chapter defines the specific KPIs and KVIs relevant to FLECON-6G, detailing the methodologies used for their measurement, the benchmarks for validation, and the expected impact on the system's performance. The assessment framework will align with industry standards and best practices, ensuring consistency and reliability in the evaluation process.

By establishing a structured approach to performance and value assessment, this chapter provides the foundation for verifying the feasibility and effectiveness of FLECON-6G's innovations. The defined metrics will not only guide the validation process but also support decision-making for future optimizations and refinements of the system.

3.1 Key Performance Indicators (KPIs)

The aim of this section is to provide a common definition of the KPIs that are used within FLECON-6G's project lifecycle. The goals of such KPIs definition pretend to avoid (i) multiple definitions of the same KPI, (ii) different understanding of a specific KPI, and (iii) different implementations of the same KPI.

During this section, a structured approach will be followed to ensure a clear and standardized understanding of the KPIs relevant to FLECON-6G. First, a general KPI definition framework will be established (Section 3.1.1), outlining the key attributes that each KPI should include, such as metric description, measurement units, evaluation methods, and relevance within the 6G context. Following this, a set of FLECON-6G-specific KPIs will be presented (Section 3.1.2), carefully selected to align with the project's objectives and technological advancements. These KPIs will cover aspects such as network performance, energy efficiency, reliability, and service assurance. Finally, a methodology for KPI evaluation (Section 3.1.3) will be detailed, describing how these indicators will be measured, monitored, and validated throughout the project lifecycle.

3.1.1 KPI Definition

This section outlines the approach used to define and measure KPIs, ensuring alignment with industry standards and project objectives. Each KPI is characterized by a set of attributes that provide a clear framework for measurement, interpretation, and validation.

Table 3.1 presents the key fields used to define KPIs, elaborated for FLECON-6G, detailing their purpose and the criteria for their evaluation. These fields serve as the foundation for assessing the system's efficiency, reliability, and overall impact, enabling data-driven decision-making and continuous optimization.

Table 3.1: KPI definition fields

KPI Field	Description
Category	Classification of the KPI based on its measurement domain (e.g., network performance, service quality, energy efficiency, etc.).
Name	Descriptive name of the KPI that reflects its purpose.
ID	Unique identifier assigned to the KPI within the evaluation system.

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Definition	Detailed explanation of what the KPI measures and its relevance to the evaluation of FLECON-6G.
How	Method or process used to measure the KPI, including tools, metrics, and measurement frequency.
Baseline value (units)	Reference value or current state of the KPI before applying improvements, if exists, expressed in the appropriate units.
Target value (units)	Desired value to be achieved, indicating the expected improvement compared to the baseline.
Standard	Normative framework or specification (e.g., 3GPP, ETSI, IETF) that supports the definition and measurement of the KPI, if applicable.

3.1.2 FLECON-6G's KPIs

This deliverable provides a breakdown of the KPIs defined within the FLECON-6G project. These KPIs are essential metrics for evaluating the technical performance and capabilities of the proposed 6G architecture. Each category of KPIs addresses specific aspects of network performance, with carefully defined metrics that will guide the development and validation of the FLECON-6G system.

Table 3.2 details each KPI category with their corresponding tables, providing insight into how these metrics will be measured and evaluated throughout the project lifecycle. FLECON-6G's general KPIs are included within the Annex I . All the provided KPIs are aligned with the literature [1] [2]

Table 3.2: KPI Categories description

KPI Category	Description
Capacity	It measures the data handling capabilities of the 6G network, including throughput, bandwidth utilization, and connection density. These metrics are critical for evaluating how the network performs under various load conditions and how it meets the increasing demands for high-speed data transfer in next-generation applications.
Latency	It measures the time delay experienced in the 6G network across different planes and service types. Low latency is crucial for real-time applications, mission-critical services, and ensuring seamless user experiences in interactive scenarios.
Packet Loss	It measures the reliability of data transmission in the network. These metrics are crucial for ensuring data integrity, especially in mission-critical applications where information loss can have significant consequences.
Compute	It measures the computational capabilities and efficiency of the network infrastructure. As networks become increasingly software-defined and virtualized, these metrics are essential for ensuring optimal resource utilization and performance.
Security	It measures the network's ability to protect data, detect threats, and ensure privacy. In an increasingly interconnected world, these metrics are fundamental to building trust in the network and ensuring the confidentiality, integrity, and availability of services.

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Service	It measures the overall quality, reliability, and efficiency of the services provided by the network. These metrics focus on the end-user experience and the business aspects of network operation, ensuring that services meet both technical and commercial requirements.

3.1.3 KPI Evaluation

The KPI evaluation process is essential for measuring the effectiveness and success of FLECON-6G's requirements and use cases. This process ensures that each KPI is systematically assessed, providing valuable insights into network performance, service quality, and overall system efficiency. Figure 3.1 showcases the sequential process to be followed during the project lifecycle, tailored for FLECON-6G's KPIs evaluation.

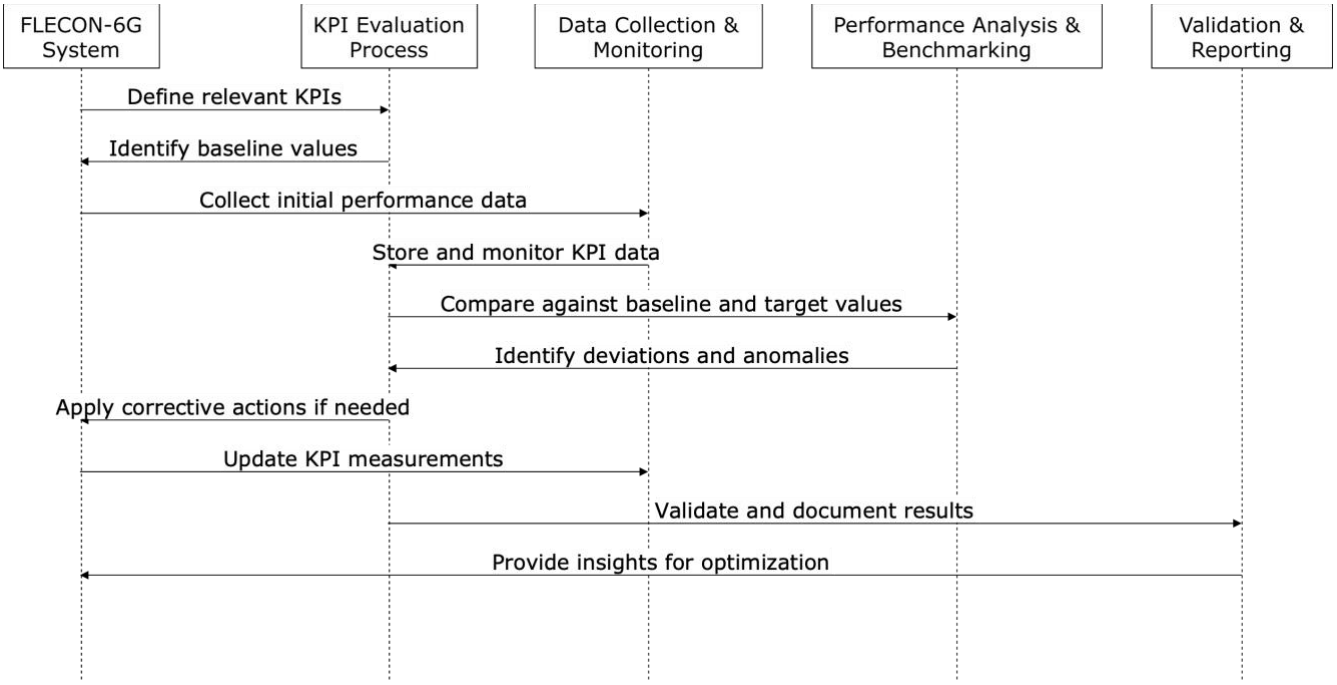

Figure 3.1: KPI Evaluation Process

The evaluation follows a structured approach, consisting of the following key steps:

1. **KPI Identification and Definition** – Selection of relevant KPIs based on project objectives, categorized according to their measurement domain. This phase is covered during the DoA elaboration process as well as outlined through Section 3.1.2.
2. **Baseline Measurement** – Establishing reference values by collecting initial performance data before implementing improvements or optimizations.
3. **Data Collection and Monitoring** – Continuous or periodic measurement of KPIs using appropriate tools, methodologies, and data sources. This step ensures real-time visibility into system performance.
4. **Performance Analysis and Benchmarking** – Comparing measured values against baseline and target values to assess progress and identify deviations. Industry standards (e.g., 3GPP, ETSI, IETF) serve as benchmarks where applicable.
5. **Anomaly Detection and Optimization** – Identifying performance gaps or anomalies and applying corrective actions to optimize system behaviour.
6. **Validation and Reporting** – Final evaluation of KPI outcomes to verify compliance with predefined targets. The results are documented in reports, supporting decision-making for future refinements.

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By following this structured evaluation process, FLECON-6G ensures that KPIs provide meaningful insights, guiding the continuous enhancement of network functionalities and service capabilities.

3.2 Key Value Indicators (KVIs)

Beyond technical performance metrics, it is essential to assess the broader impact and value generated by FLECON-6G. KVIs provide a complementary perspective to KPIs by evaluating how the system contributes to strategic objectives, user experience, business value, and sustainability. This section defines the concept of KVIs, establishes the specific KVIs relevant to FLECON-6G, and outlines the methodology for their evaluation.

3.2.1 KVI Definition

Key Value Indicators (KVIs) are quantifiable measures that estimate the impact of a specific Key Value (KV) within a system. Unlike KPIs, which primarily focus on technical efficiency and system performance, KVIs assess the broader societal, economic, environmental, and user experience benefits of a given technology or service [1] [2]

KVIs aim to measure these benefits in terms of overall "societal/human" value, addressing issues such as democracy (fairness, digital inclusion), responsibility, and energy efficiency. It is a key quality for the KVIs defined for a KV that they should be measurable or estimable in some form. Some KVIs are assuming a deployed network with established use cases, and these can therefore only be measured or estimated later. Other KVIs are based on personal experiences and should be possible to estimate through interviews, questionnaires, trials, or similar. The KVIs assessment could be either subjective (e.g., trials, experiments, measurements), or objective (e.g., questionnaires, interviews, focus groups).

A KVI should be a measurable or estimable quantity that provides insight into the fulfilment of a KV. This measurement can take various forms, such as the number of users benefiting from a service, perceived value realization, or improvements in quality of life. Importantly, a single KV can be evaluated through multiple KVIs, ensuring a holistic and multidimensional assessment.

To ensure reliability, KVIs must be measurable or at least estimable based on available data. However, the timing and method of measurement depend on the nature of the KV:

- Some KVIs require a fully deployed network and established use cases for accurate measurement, meaning they can only be assessed at higher Technology Readiness Levels (TRLs).
- Others can be estimated earlier through interviews, questionnaires, or experimental trials, even before large-scale deployment.
- Certain KVIs rely on expert analysis, which can provide valuable insights even at lower TRLs, influencing early system design.

Given that FLECON-6G's TRLs are expected to reach levels 4-5, both consortium members and external stakeholders will be encouraged to participate in the assessment process. To ensure diverse and representative input, stakeholders will be incentivized (e.g., vouchers, coupons, or other participation rewards) to provide feedback through questionnaires, interviews, focus groups, and surveys. This approach will help evaluate the expected societal impact of FLECON-6G and refine the project's value-driven design.

We provide a brief overview of the related work on KVI definition. According to [3] a list of KVs could include the following: *environmental sustainability, societal sustainability, economical sustainability and innovation, democracy, cultural connection, knowledge, privacy and confidentiality, simplified life, digital inclusion, personal freedom, personal health and protection from harm, and trust*.

Similarly, HEXA-X II [4] addresses sustainability by comprehensively considering *environmental*, *social*, and *economic* factors. These factors extend beyond mere energy efficiency, which is crucial given the anticipated widespread adoption of the 6G ecosystem. The sustainability analysis qualitatively outlines the key values and potential impacts for each use case. These impacts are categorized into *benefits* (sustainability handprints) and *costs* (sustainability footprints).

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FIDAL's proposal for a High-Level Framework for Key Values (KVs) and example indicators are presented in [5] . FIDAL aims to adopt a standardized methodology to identify the parameters that maximize the impact of 5G evolution services on the community. Key Value Indicators (KVIs) complement Key Performance Indicators (KPIs) to balance business and social performance metrics. The main KV clusters identified are: *democracy* (trustworthy, inclusiveness / equal opportunity, fairness, personal freedom, transparency, privacy), *economic* (sustainability, business value, tackling economic inequality), *innovation* (responsibility, open collaboration, flexibility), *environmental* (sustainability, waste management, mitigation strategies, compliance quality standards), *safety and security* (safety, security, data protection), and *societal* (sustainability, healthier community, cultural connection, knowledge, quality of living / wellbeing).

CENTRIC's vision [6] has a strong emphasis on developing technological enablers that contribute to the goal of a sustainable 6G network. Such sustainability can be understood from, mainly, three dimensions: *environmental sustainability* (energy efficiency improvements, material efficiency improvements), *economic sustainability* (CAPEX reductions, OPEX reductions), and *societal sustainability* (EMF-aware networks, user data protection and privacy).

SAFE-6G [7] ensuring the effective measurement and assessment of trust, security, privacy, resilience, and reliability in future 6G networks, identifies the following aspects for KVI analysis: *trust*, *security* / *privacy* / *confidentiality*, *sustainable resource utilization*, *simplified life*, *digital inclusion*, and *societal sustainability*.

3.2.2 FLECON-6G's KVIs

FLECON-6G's KVIs are designed to comprehensively evaluate the societal impact of 6G technologies, focusing on three major driving forces: *Innovation*, *Democracy*, and *Ecosystem*. These forces reflect the different dimensions of value that 6G networks are expected to create. Each KVI within the context of each of the major force represents a measurable factor, enabling the assessment of how 6G technologies contribute to the broader goals of safety, security, regulation, responsibility, energy efficiency, privacy, fairness, inclusion, trust, and sustainability.

In addition, the three major driving forces are related to the European Union Sustainable Development Goals (SDGs) [8] ensuring that the development of 6G networks aligns with key global priorities, such as fostering economic growth, advancing social equity, and promoting environmental sustainability. By aligning with the EU's SDGs, FLECON-6G not only contributes to the technological advancement of 6G but also supports the creation of a more inclusive, sustainable, and resilient digital society, driving innovation while safeguarding essential values that promote well-being and equality across regions. Through these connections, the FLECON-6G framework provides a holistic approach to evaluating the future impact of 6G on both the economy and society at large.

3.2.2.1 Innovation: Accelerating Technological Breakthroughs

This category highlights the technological advancements and how 6G architecture enhances confidence in the safety, security, and efficiency of systems. Key aspects include measuring improvements in energy efficiency, security protocols, and network innovations that positively affect society, such as the integration of AI for optimized performance and learning techniques.

FLECON-6G fosters 6G-native solutions, AI-driven automation, and deterministic networking, contributing to:

- SDG 9 (Industry, Innovation, and Infrastructure): Supporting secure, resilient, and high-performance network architectures that drive industrial digitalization.
- SDG 17 (Partnerships for the Goals): Strengthening cross-sector collaboration, open-source contributions, and partnerships within European R&D ecosystems.

3.2.2.2 Democracy: Ensuring Open, Inclusive, and Transparent Access

The focus here is on ensuring that 6G technologies are developed in a way that aligns with democratic principles such as privacy, fairness, and inclusivity. This includes ensuring compliance with privacy regulations, such as

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GDPR, reducing digital divides, ensuring fairness in AI/ML systems, and building trustworthy systems that promote equal access and participation for all users.

Technological democratization ensures 6G infrastructures and services are accessible, interoperable, and free from proprietary lock-in, aligning with:

- SDG 4 (Quality Education): Providing open access to research, training, and experimental platforms for industry and academia.
- SDG 16 (Peace, Justice, and Strong Institutions): Promoting transparent governance models, policy-driven networking, and decentralized decision-making.

3.2.2.3 Ecosystem: Sustainability and Interoperability

This category assesses the broader socioeconomic and environmental impacts of 6G technologies. It focuses on the sustainability of 6G networks from an environmental, economic, and societal perspective, while also promoting open collaboration and new value chains. The goal is to ensure that 6G technologies not only drive economic growth but also contribute to reducing the carbon footprint, lowering operational costs, and enabling new business opportunities.

The 6G ecosystem must be sustainable, scalable, and interoperable, contributing to:

- SDG 7 (Affordable and Clean Energy): Using AI for energy-efficient network operations.
- SDG 11 (Sustainable Cities and Communities): Enabling intelligent, resilient, and adaptive connectivity.
- SDG 13 (Climate Action): Leveraging carbon-aware networking.

The following figure illustrates the correlation between the three major driving forces of FLECON-6G KVIs and the SDGs.

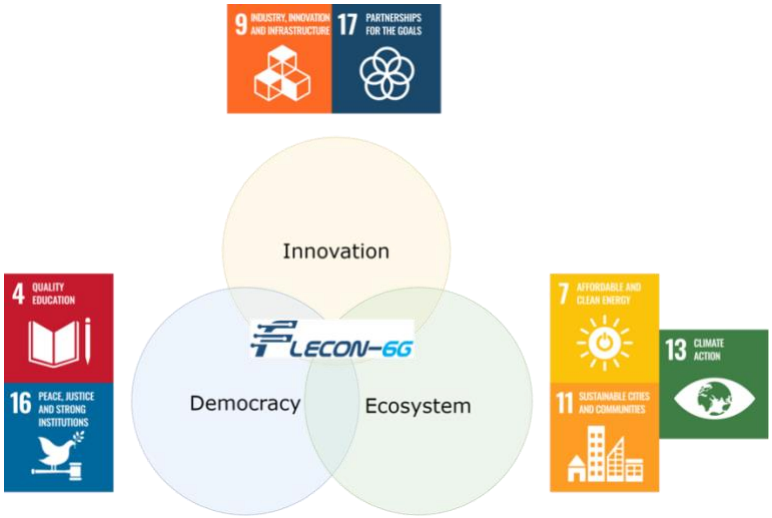

Figure 3.2: FLECON-6G's KVIs three major driving forces

These main forces ensure that FLECON-6G's technology development is closely aligned with societal needs, while also contributing positively to the ecosystem. They foster a democratic, inclusive, and innovative environment, ensuring that 6G technologies serve broader societal goals. A detailed overview of FLECON-6G's KVIs is presented in Table 3.3 extracted from the DoA.

Table 3.3: FLECON 6G's KVIs list

KVI field	Relevance	Aim	How to measure it	Quantitative Evaluation
Innovation				
Safety	The unavailability or degradation of the communication service must not have negative impact on human or the environment.	To explore how 6G architectures improve confidence in technology acceleration with respect to the safety of people and processes.	Through questionnaires and focused group surveys both internally and externally from webinars, workshops, and events. Also, through the PoCs to validate the AIaaS and AI models amongst domains by efficient transfer learning mechanisms performing an optimal synthesis between data-driven and model-based learning techniques.	Achieve >95% optimal synthesis between data- driven and model-based learning techniques.
Security	Protection of data and 6G networks from cybersecurity threats.	To consider security and privacy in the design of 6G systems and prove their robustness against cyber threats.	Identify 6G network vulnerabilities and security concerns through questionnaires and focused group surveys from webinars, workshops, and events. Also, through the security issues log identified in the PoCs.	(i) Address >95% of the security concerns of the focused group through scientific evidence from the PoCs. (ii) 0% threats penetrated in the security issues log of the PoCs.
Regulation	Comply with the regulatory framework imposed by law.	To promote network neutrality in 6G networks regarding access to network resources encouraging the wide adoption of 6G.	OTE, ORO and TID as MNOs are actively involved with policy makers and all levels of licensing bodies and will directly engage with them and constantly monitor and report such aspects in D6.3 and D6.4.	Achieve 100% regulation compliance of AI operations on 6G functionalities.
Responsibility	Linked to accountability and control of 6G networks.	To provide an understanding on the responsible innovation	Through the Plan-Do-Check-Act approach. Use of RACI charts to identify and interview all consortium partners who are Responsible,	100% of technological consortium partners interviewed on responsible innovation.

		approach of FLECON-6G.	Accountable, Consulted and Informed for FLECON-6G technological components.	
Energy Efficiency	Reduced energy consumption in the operation of the 6G network.	To improve the energy efficiency at all architectural levels of the 6G architecture.	Through the PoCs based on the standardised methodologies of ETSI for calculating energy consumption per bit in networks.	Demonstrate overall energy savings >90% relative to existing 5G networks, due to the use of NDTs, and efficient AI models.
Democracy				
Privacy	Appropriate use of end-user data collected and used, aligning with ECįs updated GDPR framework.	To ensure that 6G networks improve the confidence in the protection of the data of individuals and ensure GDPR compliance.	Identify potential privacy issues in the datasets used to train the AI algorithms during the PoCs. Also, carry out a comprehensive risk assessment within the consortium members and externally through focused group surveys.	100% of data anonymised due to privacy preserving techniques
Fairness	Ability of the AI/ML algorithms to perform decisions that are free from discrimination and bias.	To create a next generation 6G networks that results in both high-quality techniques and social justice through de-biasing of metadata and the AI algorithms.	FLECON-6G will design and build data and metadata sets for AI/ML training and fairness optimisation to avoid bias of data as measured through its testing and verification methodology during the PoCs. The methodology will use Whitebox testing that reviews the data used to train the AI/ML models to avoid bias.	100% of AI models performing decisions that are free from discrimination and bias.
Digital Inclusion	Deploy technologies that serve the historically under-served.	To reduce the digital divide between people who have access, and those who do not.	Focused group surveys will be conducted to check whether future 6G services will be more accessible in terms of cost, location types, and accessible for all including persons with disabilities.	Achieve >70% satisfaction level on the inclusiveness in 6G vs existing digital systems

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Trustworthiness	6G networks should support trustworthiness, and distributed learning.	The 6G network is driven by data and intelligence, with new features that allow end-to-end trustworthiness.	FLECON-6G will demonstrate through the PoCs that when AI decisions are made, trust is placed in those decisions.	Reduce SLA violations by at least 90% through trustworthy AI techniques.
Ecosystem				
Sustainability	6G networks should be sustainable from a wider socioeconomic and environmental perspective.	Minimise resource consumption, i.e., the number or transmitted bits in each time interval and the use of basic resources per bit should be minimised.	Sustainability will be measured under 3 angles (stemming from HEXA-X-II), covering societal, economic and environmental aspects.	*Societal* by reducing GHG emissions by >30% in 6G powered sectors of the society. Baseline: a 5G powered service compared to a 6G powered service
				Economical by reducing the OPEX by >20% due to intent-driven resource exposure and auto-negotiation. Baseline: 5G OPEX based on 5G NR SA for network automation and orchestration.
				Environmental by achieving >90% energy savings (see Energy Efficiency KVI above). Baseline: 5G networks.
Business Value	Demonstrate 6G networks benefit and value.	To show that 6G networks provide a real value to MNOs.	Through a dedicated workshop with relevant stakeholders (e.g., MNOs, MVNOs, vendors) using the Arcadia framework that leverages different areas of expertise (technical, economic, strategic, commercial, legal, ethical, and social) to discern routes to market	Corporate investments in 6G networks and applications, empowered by the smart marketplace resulting to increased revenues streams by >30%
Economic Growth	Building a competitive and resilient economy, investing in skills, education, digital transformation.	To boost economic growth though the provision on next generation services that require 6G		

		performance capabilities.	and to capitalise on the investment.	
Open Collaboration	Use methods based on collaboration and knowledge sharing.	To foster open collaboration and knowledge sharing.	Through clustering and joint activities with other ongoing relevant 6G projects in SNS JU, technology clusters, associations, DIH and the 6G-IA, reporting such practices and measuring their level of engagement.	As per D&C KPIs in DoA's sections 2.2.1.1 Dissemination strategy and plan & 2.2.2 Communication strategy and plan.
New Value Chain	New stakeholders or dynamics to enhance existing 5G value chains.	To engage new stakeholders in the 6G value chain.	Through wide dissemination means, workshops, webinars, and clustering activities to raise awareness and engage relevant stakeholders from interested 6G stakeholders.	>500 new stakeholders registered and participate in FLECON-6G webinars, workshops, public events.

3.2.3 KVI Evaluation

The evaluation of KVIs in the FLECON-6G framework is designed to ensure that the technological advancements align with the overarching societal, economic, and environmental goals of the 6G vision. A key aspect of KVI evaluation is to relate these indicators to KPIs, allowing for a measurable and quantifiable assessment of the impact of the technology on the various KVs.

It is a key quality for the KVIs defined for a KV that they should be measurable or estimable in some form. Some KVIs are assuming a deployed network with established use cases, and these can therefore only be measured or estimated later. Other KVIs are based on personal experiences and should be possible to estimate through interviews, questionnaires, trials, or similar. The KVIs assessment could be either subjective (e.g., trials, experiments, measurements), or objective (e.g., questionnaires, interviews, focus groups). Qualitative evaluation includes the methodology for the questionnaires design. Based on the distributed collection, the consolidation and the structuring of the results, we can proceed with the overall societal evaluation. A preliminary framework about Key Values evaluation is presented below.

Table 3.4: KV and KVI Evaluation Framework

KV and KVI Evaluation Framework for UC # / PoC #	
Key Value #	
Definition	Description
Aim	Description
Target Groups	Description

Societal Impact	Description	
Key Value Indicator #		
Type	**Metric**	**Evidence**
Objective	KPI #	Description
Subjective	Survey #	Description

In this framework, we identify and *define* the Key Value for each Use Case and PoC. We investigate the *aim*, the *target groups*, as well as the *societal impact*. As a next step, we focus on the evaluation of specific KVIs. The evaluation process involves the use of a combination of subjective and objective methods, which vary depending on the specific KVI being assessed.

The selected KVs and KVIs, as well as the evaluation metrics will be presented in Deliverable D2.3 Final FLECON-6G Architecture, while the evaluation process will be conducted during the final system validation in PoCs, in WP5.

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4 Use Cases/PoC Scenarios Definition

The PoCs are aiming to showcase FLECON-6G's capabilities to support 6G use cases that are requiring extreme performance characteristics, integrating the architectural elements into a unified system, while validating the key technological innovations and target KPIs.

4.1 PoC #1: Seamless Immersive Reality

4.1.1 Narrative

The Seamless Immersive Reality (SIR) Proof of Concept, developed under the FLECON-6G project, is designed to push the boundaries of next-generation immersive teleconferencing and broadcast applications. It harnesses the potential of 6G networks, AI-driven optimizations, and edge computing to deliver real-time, interactive experiences in both virtual and physical environments.

In response to the increasing demands for immersive content and collaboration tools, the SIR PoC serves as a benchmark for evaluating 6G network efficiency. It demonstrates how future networks can support ultra-high bandwidth, ultra-low latency, and seamless interactions among users distributed across different geographic locations.

The SIR system enables users to interact via stereoscopic avatars, with real-time capture and transmission of gestures and facial expressions using advanced virtual production techniques. Real-time data generation, intelligent optimization, and edge-based processing are key to delivering this low-latency, high-fidelity experience.

Participants use virtual reality (VR) head-mounted displays (HMD) and hand controllers to engage in immersive sessions. Offloading video processing to edge devices allows the VR headsets to operate untethered, improving user freedom and mobility. A stereoscopic camera setup captures the subject in front of a green screen, enabling precise 3D reconstruction.

SIR embodies a convergence of VR, AR, and XR technologies, aiming to support real-time multi-sensory interactions. However, several challenges must be overcome for widespread adoption:

- **Hardware Limitations:** Current mobile devices lack the standalone computing power needed for real-time SIR processing. Progress in mobile hardware has not kept pace with the demands of immersive applications.
- **Bandwidth Constraints:** SIR applications require extremely high wireless transmission capacity. For example, delivering an 8K VR experience requires at least 55 Mbps, while a fully immersive SIR session (e.g., 16 million data points) demands over 1 Gbps. For 16K VR streaming, the requirement may exceed 2 Gbps (assuming a 1:400 compression ratio).
- **Network Load:** These bandwidth demands stress not only the air interface but also the transport network, especially in distributed Metaverse environments where users are connected across various edge sites.

To address these challenges, the SIR PoC:

- Utilizes **edge computing** for computational offloading, enabling lightweight and energy-efficient VR headsets.
- Employs **AI-based optimization** for real-time data compression and transmission.
- Relies on a **high-speed, low latency 6G transport infrastructure**, supporting multi-stakeholder deployments and interconnected edge networks.

All these challenges and details related to this PoC, briefly presented here, will be detailed in the following subsections of this Chapter.

4.1.2 Objectives and Challenges

The Seamless Immersive Reality (SIR) PoC in FLECON-6G aims to validate the feasibility of enabling real-time virtual presence meetings by combining 6G communication technologies, advanced edge computing, and stereoscopic capture techniques. The objectives and challenges are intrinsically connected, as they reflect both the ambitions and constraints of the future networked immersive collaboration systems.

The main objectives of this system are multiple and related to the different aspects the system should comply:

1. Validation of 6G-enabled immersive reality applications
    - Demonstrate the ability of 6G networks to support high-bandwidth, real-time XR experiences.
    - Assess data transmission efficiency and video quality for ultra-high-definition (UHD) XR streaming.
2. Computational Offloading & Edge Optimization
    - Leverage edge computing and deep edge to reduce processing load on user devices.
    - Implement real-time rendering and compression using low latency encoding techniques.
    - Enable standalone and untethered VR headset use by minimizing limitations due to on-premises GPUs and rendering systems.
3. Enhancing Real-Time Telepresence & Virtual Collaboration
    - Creation and transmission of stereoscopic avatars representing participants for immersive virtual meetings.
    - Implement and combine spatial computing and virtual production techniques to merge real and virtual environments.
4. Network Optimization for XR Workloads
    - Validate and test network functions such as slicing and intelligent dynamic traffic routing under multi-user XR environments.
    - Test adaptive bandwidth allocation in multi-user metaverse sessions.
5. Integrated Latency Analysis
    - Evaluate and account for all latency components critical to user experience. This includes not only network latency, but also the video streaming pipeline latencies such as video encoding and decoding latency, rendering latency in VR headsets, capture and buffering latency and camera acquisition latency.

The SIR PoC faces several technical and practical challenges that must be addressed to deliver a truly seamless and immersive experience. The following tables (Table 4.1, Table 4.3, Table 4.4 and Table 4.5) describe the main challenges:

Table 4.1: PoC #1 Computational Constraints Challenges.

Computational Constraints on End-User Devices	
Challenge 1	Current VR headsets and AR glasses lack the processing power for rendering real-time multi-user interactions at maximal resolution. The capture stage will rely on a user equipment (UE) device located at the user's premises, connected to the 6G network via a 5G SA CPE. The capture setup includes a stereoscopic camera pair sampling at 60 frames per second. This stage will generate a stereoscopic video stream at a resolution suitable for subsequent processing stages. To clarify the impact of resolution on system requirements, the corresponding calculations and potential values are reported below:

- 4K Uncompressed Bitrate without alpha channel= Width × Height × Color Depth × FPS × Number of Views = 3840 × 2160 × 24 × 60 × 2 bits per second = 23,86 Gbps
- 4K Uncompressed Bitrate with alpha channel= 3840 × 2160 × 32 × 60 × 2 bits per second = 31,85 Gbps

To enable streaming of the captured content, the system will apply light compression to the video signals to meet radio transmission requirements. Based on the parameters described above, the estimated raw video bitrates are summarized in Table 4.2. Each sub-table presents bitrate values corresponding to different resolutions and color depths, including cases where an alpha channel is embedded.

Table 4.2: Video resolutions and related streaming bitrates vs compression rates.

24-bit Color Depth		
Resolution	**Uncompressed (Gbps)**	**Compressed @1:10 (Mbps)**
720p	2.65	265.4
1080p	5.97	597.2
1440p	10.62	1061.7
4K	23.89	2388.8
8K	95.55	9555.1
16K	382.21	38220.6

32-bit Color Depth		
Resolution	**Uncompressed (Gbps)**	**Compressed @1:10 (Mbps)**
720p	3.54	353.9
1080p	7.96	796.3
1440p	14.16	1415.6
4K	31.85	3185.0
8K	127.4	12740.2
16K	509.61	50960.8

As shown in the tables, even with a 720p resolution stream can saturate the radio link up to 1Gbps. At this stage, it is not possible to define the final streaming resolution, as it directly impacts the subsequent processing steps, particularly in terms of the latency that these steps (capture, streaming, render, etc.) will add to the signal. To ensure smooth and natural communication, the end-to-end delay must remain below approximately 500ms. Therefore, the processing pipeline must be carefully dimensioned to stay within this latency budget while also complying with the 1 Gbps radio transmission target value reported in the GA.

Solution 1	SIR system will offload the UEs and provide data flow that the VR headsets can handle.
Challenge 2	High-power computing (GPU) and high demanding network adapters supplied through laptop connected to headset (standalone XR hardware not sufficient).
Solution 2	SIR system will avoid the employment of users on premises devices to ensure a VR HMD stand-alone experience (WIFI6/7 interfaces directly connected to 6G radio)
Challenge 3	Need for Edge and Core GPUs availability to offload the end User Device and distribute the processing along the transmission path.

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Solution 3	SIR system will offload completely the end users' devices and direct provide the content from the VR optimization service working on the edge.

Table 4.3: PoC #1 Bandwidth and Latency Challenges.

Bandwidth & Latency Bottlenecks	
Challenge 1	Traditional 5G networks struggle with XR's ultra-high data rate demands (>2 Gbps per user).
Solution 1	The SIR system will try to optimize streams through background removal and region-of-interest encoding, significantly reducing data volume while preserving visual fidelity. Real-time customization based on VR headset input ensures only relevant content is transmitted at full quality, keeping bandwidth demands within the 1 Gbps target per user.
Challenge 2	End-to-end latency must stay within to <35 ms for a truly immersive real-time experience.
Solution 2	While network latency in 6G can reach 1 ms, the SIR system is designed to manage total latency holistically. The processing pipeline—including capture, encoding, transmission, decoding, and rendering—is dimensioned to stay below 500 ms, with 100–150 ms typically accounted for video and rendering steps. Edge computing will reduce transport delays and enables faster response loops to maintain real-time interactivity.
Challenge 3	Delays generated by Video encoding and decoding steps.
Solution 3	Encoding and decoding are handled by edge-based GPU-accelerated services using low-latency codecs. By moving these steps off the UE and closer to the rendering point, the system avoids unnecessary hops and reduces cumulative delay, enabling faster decoding at the headset side and maintaining a smooth experience

Table 4.4: PoC #1 Synchronization and Multi-User Challenges.

Synchronization of Multi-User XR Streams	
Challenge 1	Rendering multiple stereoscopic streams across geographically dispersed users is a complex challenge.
Solution 1	The system ensures synchronization by managing each user's video streams through a centralized VR optimization module at the edge.
Challenge 2	Ensuring frame consistency without motion jitter on several streams requires data optimization to ensure a fine experience at user device level.
Solution 2	Each frame is dynamically optimized based on real-time field-of-view input from the headset. This ensures the headset processes only high-priority data at full quality, reducing jitter and resource contention.

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Table 4.5: PoC #1 Scalability and Cost-Efficiency Challenges.

Scalability & Cost-Efficiency of Edge Computing	
Challenge 1	Running real-time rendering and compression at the edge requires cost-effective infrastructure.
Solution 1	The SIR system evaluates a lightweight experimental capture module that streams raw data to edge services, reducing hardware requirements at the user side
Challenge 2	Adaptive workload balancing between cloud, edge, and user devices is essential to avoid bottlenecks.
Solution 2	SIR system will leverage edge services to optimize the content served to the end users' devices, based on the users' real-time preferences (headset orientation and attendees' placement in the VR environment).

4.1.3 Use Case's Requirements Analysis

The PoC1 must meet stringent technical and functional requirements to ensure high-quality immersive experiences. The following subsections will list first the technical requirements at the infrastructure and platform level, and then the functional requirements divided by users and system requirements.

1. **XR Content Rendering & Transmission**
   - Stereoscopic capture of human avatars in real-time.
   - Adaptive 720p-4K (max VR headset supported resolution) video streaming at 60 FPS for natural presence representation.
   - Low latency encoding and adaptive compression for network efficiency.
2. **Network Performance & Connectivity**
   - Minimum data rate per user: 2 Gbps for high-quality XR streaming (1GB for capture & 1GB for stream reception).
   - End-to-end latency: <35 ms to have seamless interactions.
   - Ultra-reliable transport network for synchronization of multi-user interactions.
3. **AI-Driven Optimization & Edge Computing**
4. **User experience quality & System-Platform**
   - Computational offloading at the Edge to minimize headset power consumption (processing).
   - Dynamic network slicing to allocate bandwidth based on user demand.

On the users and system side is worth listing a series of requirements that will ensure the user experience quality and system-platform interactions. The following table showcases the user and system requirements (Table 4.6).

Table 4.6: PoC #1 User and system requirements

ID	**P1-UR01**
Name	Audio communication
Description	Users should be able to generate audio signals (micro) and receive and listen the audios feeds from the others involved users in real time, with excellent quality.

ID	**P1-UR02**
Name	Video communication
Description	Users should be able to generate a video representation of their self and receive and see the video feeds from the others involved users in real time and with excellent quality
ID	**P1-UR03**
NAME	Video and audio quality metrics collection
Description	The modules in charge of generate/receive audio and video streams should be able to generate and collect metrics about the generated/received content.
ID	**P1-UR04**
Name	Virtual environment customization
Description	The users should be able to select a virtual environment to carry out the experience
ID	**P1-UR05**
Name	Alternative video connection
Description	Users should be able to participate to the session with single (standard) video camera
ID	**P1-UR06**
Name	Immersive Stereoscopic Presence
Description	Users must be able to join immersive virtual meetings using lightweight headsets with real-time interaction, supported by stereoscopic avatars representations.
ID	**P1-UR07**
Name	Low-latency interaction
Description	Users expect real-time interaction with minimal lag and seamless motion across distributed locations.
ID	**P1-UR08**
Name	Device energy efficiency
Description	Users want to use lightweight headsets without overheating or excessive battery consumption.
ID	**P1-UR09**

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Name	Network adaptability
Description	Users require the application to be accessible and responsive regardless of network fluctuations or conditions.
ID	**P1-UR10**
Name	Privacy and security
Description	Users require privacy and integrity of the streamed content and safety measures against system penetration
ID	**P1-UR11**
Name	Ecosystem extensibility
Description	Developers need to integrate new processing modules into the system/platform easily.
ID	**P1-UR12**
Name	Zero-touch onboarding
Description	Users should be able to set up and connect to the service quickly, with minimal configuration.
ID	**P1-UR13**
Name	Users/System's session configuration for service request
Description	The system (admin) should be able to communicate the network and service requirements of a new session to the underlying platform before initiation.
ID	**P1-UR14**
Name	SLA negotiation capability
Description	The system should support negotiation, selection and acceptation of proposals based on available options from the platform.
ID	**P1-UR15**
Name	Edge nodes processing offloading
Description	The system should be able to offload specific processing steps to available edge nodes to optimize performance.
ID	**P1-UR16**
Name	System Monitoring

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Description	Service providers should have access to real-time metrics to monitor the application's performance and user experience.

4.1.4 Use Case's High-Level Architecture

The Seamless Immersive Reality (SIR) experience proposed in FLECON-6G enables real-time, multi-user virtual presence meetings through stereoscopic video capture techniques, edge-based processing, and optimized streaming to standalone VR headsets. The architecture is designed to balance ultra-low latency with high-quality rendering, leveraging 6G network capabilities.

The system architecture is composed of several interconnected components (Figure 4.1). Each participating user is involved in two main workflows: the **capture workflow**, which takes place at the user's premises and is responsible for generating the stereoscopic video, and the **incoming workflow**, which involves the VR optimization module at the network edge, responsible for processing the incoming content and preparing it for display on the VR headset. To ensure secure and seamless communication between components, all devices are connected through a Virtual Private Network (VPN). This architecture simplifies routing, preserves privacy, and accommodates the complexities of connecting wireless headsets across different network interfaces.

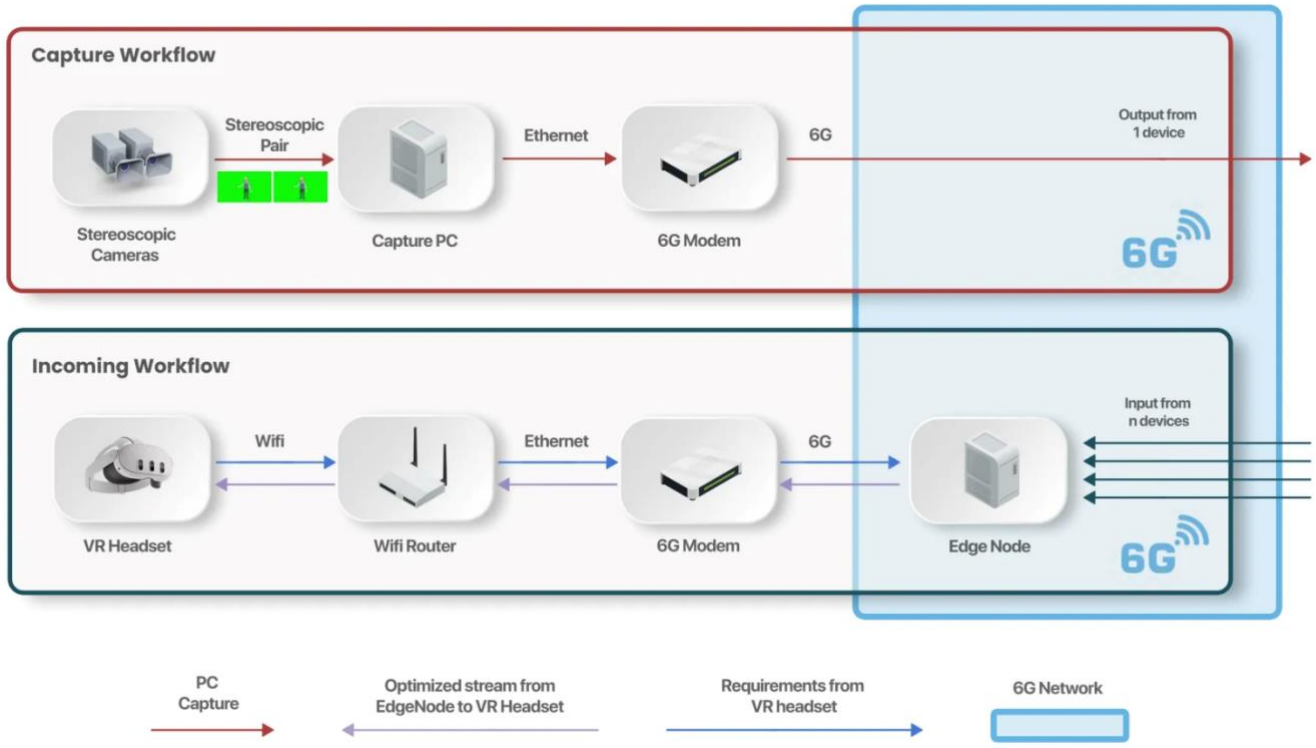

Figure 4.1: PoC #1 Capture and Incoming workflows.

The capture stage will rely on a user equipment (UE) device at the user's premises. This device includes a stereoscopic camera pair operating at 60 frames per second and connected to the 6G network through a 5G SA CPE. This setup allows for capturing a 3D representation of the user, obtaining a stereoscopic stream with a resolution that complies with the further related processing steps. As mentioned in section 4.1.2, the selected resolution is not fixed at this stage, as it depends on the performance of downstream processing modules.

Maintaining an end-to-end latency below 500 ms is essential to ensure a smooth conversational experience, and the total video throughput must remain within the 1 Gbps radio transmission limit.

The captured frames obtained from the camera's signals are preprocessed locally by the **capture PC module** to extract the user's silhouette using segmentation masks. Depending on the capabilities of the streaming protocol employed, these masks are either embedded as alpha channels or used to preprocess and optimize the frame background (flat background color) before sending the stream to the edge.

The processed streams are transmitted over a 5G Standalone (SA) CPE, which connects the user device to the 6G network. For VR headsets, the stream is forwarded via a WiFi 6 or 7 interface, which currently represents the most capable wireless connection available at the device level, supporting up to 960 Mbps.

At the edge, each stream is received by the **Edge Node**, a real-time processing service. This module handles two critical functions. First, it removes unnecessary background elements to reduce the size of each frame, focusing on the user's visual presence. Second, it customizes the video output for each recipient headset. This is done using real-time input from the headset, such as field-of-view information, which helps prioritize bandwidth allocation: users currently in view receive high-quality streams, while those outside the view are transmitted at lower quality. This allows the system to optimize resource usage without compromising the immersive experience. At this point, the content, prepared by the optimization service, is ready to be transmitted and rendered by every VR headset working.

The **rendering engine** on the VR headset receives the customized stream and uses the required included data (user-data channel or stream metadata) to decompose and separate the received frame from the video of each participant and render them separately at the appropriate quality.

This per-user adaptation ensures that rendering stays within the device's limits while maximizing the perception of realism. The stream created for a specific headset will contain, for every frame, the data (user-data channel or stream metadata) required by the headset to decompose the received frame and render separately and with the assigned quality value, the streams coming from the different participants of the session.

Finally, the **VPN** plays a central role by integrating all system elements—capture devices, edge services, and headsets—into a secure and manageable network space. This is particularly important for VR headsets, which often rely on multiple, consecutive network interfaces. The VPN abstracts this complexity and enables consistent, reliable access to services, regardless of the underlying connection path. Figure 4.2 depicts the High-Level Architecture of PoC #1.

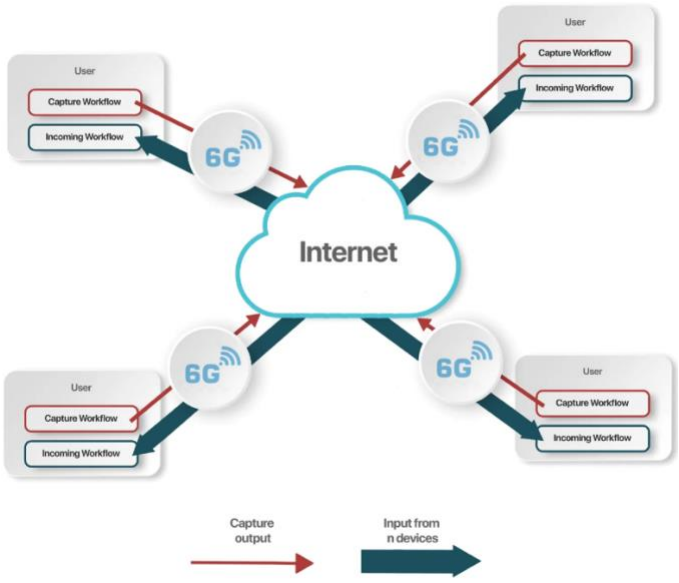

Figure 4.2: PoC #1 High-Level Architecture

This proof of concept (PoC) will consider an SIR session assisted by 4 users and the possibility of emulating the entire group. The actual number of users will depend on the final setup capabilities (infrastructure capacity, UEs, processing modules latencies, etc.). It will also consider the maximum downlink throughput supported by VR headsets (up to 960 Mbps) and the rendering quality achieved for the assistants during the session.

For demonstration and system quality of experience (QoE) assessment purposes, a minimum number of 2 users is proposed to assess the quality of interactions for the virtual conferencing system. Regardless of whether users are real or emulated, a dedicated capture stream will be generated for each participant.

4.1.5 Use Case's KPIs

To assess the functioning of the SIR PoC from several perspectives, two groups of indicators have been identified: network/infrastructure indicators and service/application indicators. The sampling of these indicators will ensure a detailed assessment of the SIR system and understand how it is challenging the computational and network infrastructure. Moreover, the cross analysis of the indicators measured at the application and infrastructure level will provide a clear view about the system components performance as like as how the infrastructure, especially at network level, is processing and carrying the content along its path. The first group of key performance indicators (KPIs), listed below, has been selected from the pool of indicators provided by the project platform/infrastructure. These indicators are described in detail in Annex I at the end of the document. To simplify their identification the "id" is reported.

1. Capacity KPIs

- Experienced Data Rate (ANNEX I id: CAP02): ⍰ 2 Gbps (Baseline: 5G = 100 Mbps–1 Gbps).

2. Latency KPIs

- End-to-End Service Latency (ANNEX I id: LAT03): ≤ 5 ms (Baseline: 5G = 10-30 ms).
- Service setup delay (ANNEX I id: LAT04): ≤ 50 ms (Baseline: 5G = 50 ms).

3. Packet Loss KPIs

- Packet error rate (ANNEX I id: PL01): $< 10^{-7}$ (Baseline: 5G = 10^-5)
- Packet Loss rate (ANNEX I id: PL02): ≤ 0.01% for smooth data transmission.

4. Compute KPIs

- Computational Resource Usage (ANNEX I id: CP01): 70-80% without performance degradation
- Computational Availability (ANNEX I id: CP03): > 99.999% for critical infrastructure
- Resource utilisation (ANNEX I id: CP04): ≥ 80% of XR processing handled at the edge.

The second Group of indicators, collected at the SIR System modules level, will provide meaningful data for the system performance analysis and understand how the network and the underlying computational infrastructure are influencing the system results. As an example, getting data about the processing and emission of the content at the edge level and data about the application (player) at the end user device level can support the assessment of the system and how its functions are influenced by the data transmission step (network/infrastructure). The specific KPIs proposed are focused on the performance of the edge service and of the end user device application performance, as shown in Table 4.7, Table 4.8, Table 4.9, and Table 4.10.

Table 4.7: KPI-POC1-01 Service: Number of incoming streams

KPI Field	Description
Category	Service

Name	Number of incoming streams (connected capture modules)
ID	KPI-POC1-01
Definition	The indicator will provide the number of inputs for the VR optimization module. It corresponds to the number of participants to the session.
How	Service will enumerate the incoming streams.
Baseline value (units)	Minimum number of users 2 (NA)
Target value (units)	Max number of participants is 4 (NA)
Standard	NA

Table 4.8: KPI-POC1-02 Service: Incoming stream bitrate

KPI Field	Description
Category	Service
Name	Incoming stream bitrate
ID	KPI-POC1-02
Definition	Bitrate of an incoming stream.
How	The stream bitrate will be calculated based on the streaming protocol employed and metadata. Alternatively, it could be estimated by the service during the decoding step. Metric: Mbps. Sample Frequency: 1Hz.
Baseline value (units)	Minimum value 200 (Mbps).
Target value (units)	1000 (Mbps)
Standard	NA

Table 4.9: KPI-POC1-03 Service: Output stream bitrate

KPI Field	Description
Category	Service
Name	Output stream bitrate
ID	KPI-POC1-03
Definition	Bitrate of output stream.

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How	The stream bitrate will be calculated based on the streaming protocol employed and metadata. Alternatively, it could be estimated by the service during the encoding step. Metric: Mbps. Sample Frequency: 1Hz.
Baseline value (units)	Minimum value 200 (Mbps).
Target value (units)	960 (Mbps) Max VR headset ingest Capacity
Standard	NA

Table 4.10: KPI-POC1-04 Service: UE Application performance - Incoming stream bitrate

KPI Field	Description
Category	Service
Name	UE Application performance - Incoming stream bitrate
ID	KPI-POC1-04
Definition	Bitrate of incoming stream from VR opt service.
How	The stream bitrate will be calculated based on the streaming protocol employed and metadata. Alternatively, it could be estimated by the service during the decoding step. Metric: Mbps. Sample Frequency: 1Hz.
Baseline value (units)	Minimum value 200 (Mbps).
Target value (units)	960 (Mbps) Max VR headset ingest Capacity
Standard	NA

The KPIs listed are useful indicators that will support the performance assessment of the SIR system while a VR conferencing session is running. The focus of the assessment will be on verifying that the generated and transmitted streams are reaching the respective modules in a reliable way. One of the main issues in video content transmission is the packet loss, especially in the radio transmission step. The loss of packets means the loss of entire frames that can require the resend of packets in case of unreliable communication. The indicators presented will help to verify if the content generated in a module reaches its destination properly. As the number of users connected to the session also influences relevantly the behaviour of the system, the number of users for every session will be key to understanding how the performance variate depending on the system load in terms of users. This means how the number of generated and handled streams is managed to construct a reliable VR conferencing system session, and how the involved data transmission steps through the different systems involved in the infrastructure influence the system performance from different points of view. The main one of course, is ensuring a reliable data transmission with the minimum latency to provide an interactive conferencing system that allow to experience an unprecedented real time metaverse experience.

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4.1.6 Testbed High-Level

Testbed high-level description(picture), technologies in use (RAN, Core, TX, Orchestration, Automation, Edge), Cloud Native, Monitoring, Available APIs, Analytics AI/ML capabilities.

ORO's testbed facility is in Bucharest, with a remote extension to the 5G Lab in Iasi, comprising 5G RAN, Core, Edge Computing, and an advanced SDN Network in the DC, as depicted in Figure 4.3. The two remote facilities are interconnected via a high-speed broadband link (100Gbps) and operate a 5G SA 3GPP Rel.17 features' infrastructure.

The testbed is equipped with cutting-edge 5G-NR, transport network, and 5GC software and hardware solutions, including open-source monitoring tools. The testbed features an advanced programmable network solution built on next-generation Data Centre IPFABRIC and MANO functions. The testbed is offering virtualization support for Cloud Native applications (K8s clusters) and cloud-based applications, and OpenStack clusters are available, offering a broad set of resources and high-speed network (10/25GBps).

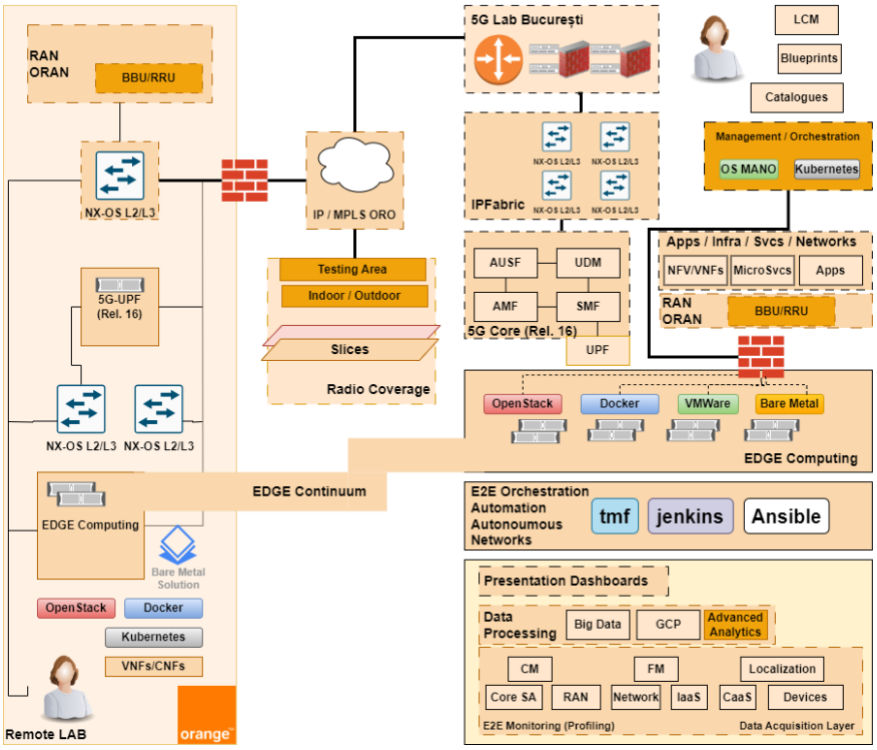

Figure 4.3: PoC #1 ORO Testbed High-level Architecture

The testbeds support dynamic orchestration of the network functions, implementation of dynamic network slicing for end users, and intelligent 5G SA network connections to edge computing nodes. It also features eMBB (1500Mbps/150Mbps DL/UL) and URLLC with one-way latency <3 ms, utilising up to 100MHz of spectrum in the N78 band. To enhance performance, the testbed supports multiple CAs for both DL and UL, including 3GPP carrier aggregation, validated across a range of 5G devices and hardware components, such as Cradlepoint R1900, Siemens MUM856, Quectel RM500Q-GL, Inhand ER805, Nokia FastMile 5G (multi-slice capable). The setup is designed to support high-intensive, capacity-demanding services and use cases across both indoor and outdoor environments. Beyond the testbed network availability and capabilities, including the computing resources and the testbed openness for advanced 6G functional architecture, the testbed is capable of implementing an innovative data collection and monitoring framework, from different sources, regardless of the technology type and aggregating the data into the desired structured, for further analytics actions.

4.2 PoC #2: Machine inspection using autonomous robots and VR

4.2.1 Narrative

With the rapid advancement of industrial automation, machine inspection is increasingly relying on autonomous robots equipped with high-definition cameras and sensors. In this PoC, autonomous robots navigate industrial environments to inspect machinery, capturing real-time video streams that are transmitted to human inspectors for remote analysis.

To this end, we will use two Qualcomm RB5 robots equipped with cameras to capture video for machine inspection. The video stream will be transmitted through the Digital Twin (DT) to a human inspector wearing an Oculus VR headset. The inspector will view both video streams in real-time with high-quality resolution and no degradation.

To implement the ZSM approach, we will develop an AI/ML-based system that collects KPIs from both the RAN and the video client to optimize resource allocation for robots. The AI/ML model will analyse video quality metrics and network performance to detect degradation and adjust RAN resources accordingly.

A closed control loop will be deployed as an rApp on a non-RT RIC, interacting with an xApp on FlexRIC to collect RAN KPIs and enforce resource allocation decisions. The system will also gather video quality KPIs from the Oculus client. Various scenarios, including robot mobility and network congestion, will be tested to validate performance and conflict resolution.

4.2.2 Objectives and Challenges

The objective of this PoC is to showcase the usage of RAN NDT within a ZSM closed-control loop to guarantee constant quality for the video streams collected from the robots that do machine inspections. In this PoC, we will demonstrate FLECON-6G's approach to resolve conflicts in a Native AI - driven closed loop ZSM system to guarantee that robots' video stream is not degraded, even in bad conditions (channel degradation or competition with other flows), by adapting the radio resources allocated to the robots' video stream in real-time.

One of the key issues when deploying critical operations, such as machine inspection is the stability of the quality of the network in treating the video flow transmitted by the robot to the human operator. If the quality degrades, it is very challenging for the human operator to detect anomalies. A high-quality video stream without any degradation in quality is generally needed. However, it is challenging to achieve such an objective, particularly if we consider the wireless channel conditions, which might change drastically due to interference or obstacles or to the parallel traffic in the cell. Therefore, there is a need to a more intelligent approach that should adapt to these conditions by updating radio resources if a video degradation is noticed. Here is where ZSM can be efficient by designing a zero-touch application that relies on AI/ML closed-loop Decision Engines (DEs) to detect and predict video degradation and apply the necessary mitigation actions to correct the issue. However, designing and validating the model and, hence, the application requires data and an environment where to test that the model and solution work as expected before deploying it in production. In this context, FLECON-6G introduces the principle of validating ZSM solutions using NDT. In this PoC, the RAN NDT is also leveraged during runtime, as an arbiter of conflicts among AI-driven DEs.

This PoC will demonstrate the capability of the FLECON-6G RAN NDT to validate ZSM solutions that aims to control the RAN resources. It leverages components from the Intelligence Layer, including the Cognitive Closed Loops Coordination Framework and AI-as-a-Service elements, alongside the Accelerated Programmable Data Plane, where the RAN and Core Network resources will be located.

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4.2.3 Use Case's Requirements Analysis

Table 4.11 showcases the user requirements proposed for PoC #2.

Table 4.11: PoC #2 User requirements

ID	**P2-UR01**
Name	Video stream quality.
Description	The user should be able to see the video stream in real-time and in excellent quality.
ID	**P2-UR02**
Name	RAN NDT management
Description	The rApp should be able to create instances of RAN NDT
ID	**P2-UR03**
NAME	RAN KPI collection
Description	The rApp should be able to collect KPIs from the RAN
ID	**P2-UR04**
Name	Video quality statistics collection
Description	The rApp should be able to collect video quality statistics
ID	**P2-UR05**
Name	Intelligent video stream degradation detection and correction
Description	The rAPP should be able to detect and correct the degradation in the video streams

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4.2.4 Use Case's High-Level Architecture

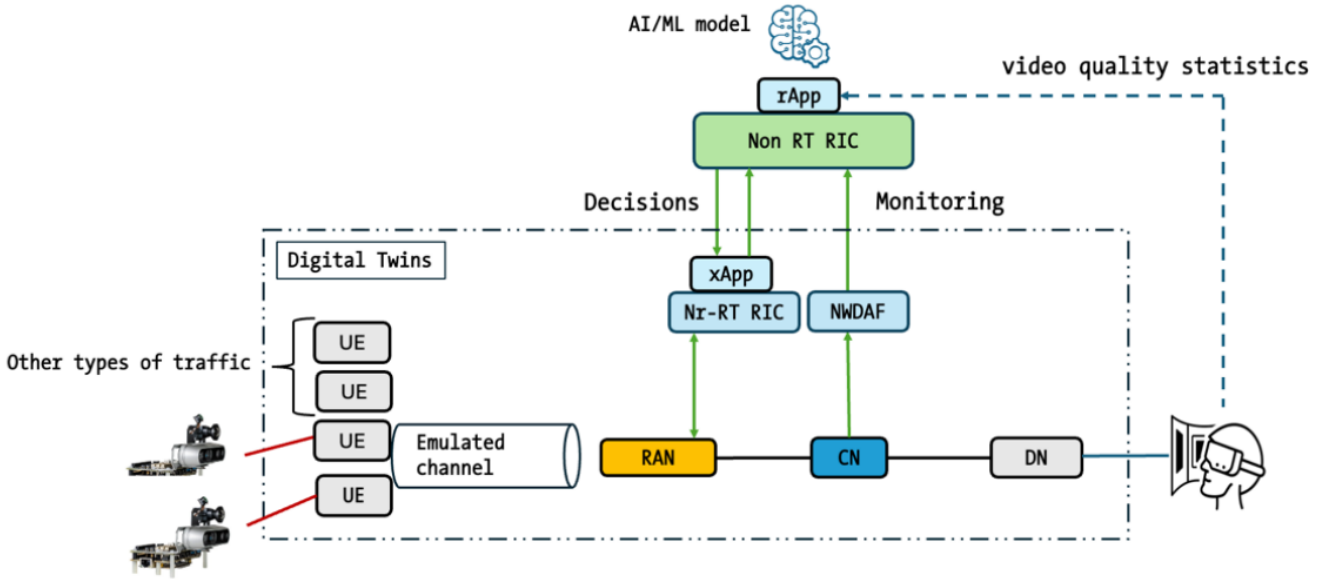

Figure 4.4: PoC #2 High-Level Architecture

PoC #2 High-Level Architecture is depicted in Figure 3.1. This proof-of-concept will use two RB5 robots of Qualcomm, which is a robotics development kit designed specifically for advanced robotics applications. It is built on the Qualcomm QRB5165 System-on-Chip (SoC), which features an octa-core Kryo CPU, Adreno GPU, Hexagon DSP, and the Qualcomm AI Engine. Qualcomm RB5 supports a wide range of sensors commonly used in robotics, including cameras, LiDAR, radar, and inertial measurement units (IMUs). These sensors can be interfaced with the platform to provide input for navigation, object recognition, and environment perception. In this PoC, we will use cameras to capture video simulating a machine inspection. The captured video stream will be streamed through the DT to a Human wearing an Oculus VR. The person should be able to see both streams in real-time and in excellent quality without degradation. To represent the ZSM approach, we will develop AI/ML-based DEs that collect KPIs from the RAN and combine them with video quality statistics obtained from the client (buffer fullness, video freezing, etc.) to decide about the RAN resources (number of pRB) to be allocated to the UEs, which are connected to the robots. The AI/ML model will correlate between the application level KPI (obtained from the video client) and the RAN KPI (channel statistics, PDCP throughput, etc.) to detect degradation of the video streams; in that case, a decision is triggered to the RAN to update the dedicated pRB to the UE connected to the robot.

The closed control loop (achieving ZSM) is enforced as a rApp and deployed on top of a non-RT RIC. The rApp runs the AI/ML application and collects RAN KPI via a xApp deployed on top of FlexRIC (Near-Real Time RIC), which uses the KPM service model to collect RAN KPI and the RC service model to enforce the decisions of the rApp (RB allocation) on the RAN. From the video client (Oculus), the rApp collects service-level KPI describing the quality of the video as perceived by the user. The closed control loop and NDT-assisted conflict resolution will be tested and validated through different scenarios possible with the RAN DT, such as UE (i.e., robots) mobility, channel conditions, and models, as well as parallel traffic by increasing the number of simulated UEs that generate UDP traffic.

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4.2.5 Use Case's KPIs

Deploying the machine inspection using autonomous robots and VR PoC using Flecon-6G framework aims to achieve the following KPIs in terms of network management and orchestration:

- Reduce by half the time to validate a closed control loop ZSM solution with its AI/ML model.
- Early detection & mitigation of at least 20% of indirect conflicts of AI components
- Support at least three different emulation scenarios of the RAN.

In Table 4.12 and Table 4.13 the use case's specific KPIs are shown.

Table 4.12: KPI-POC2-01 Compute: Closed control loop ZSM solution validation time

KPI Field	Description
Category	Compute
Name	Closed control loop ZSM solution validation time
ID	KPI-POC2-01
Definition	Reduce by half the time to validate a closed control loop ZSM solution with its AI/ML model.
How	Using NDT enables rapid validation of closed-loop control solutions before deployment on the actual network.
Baseline value (units)	N/A
Target value (units)	50% of time (%)
Standard	N/A

Table 4.13: KPI-POC2-01 Compute: Early detection and mitigation of indirect AI components conflicts

KPI Field	Description
Category	Compute
Name	Early detection and mitigation of indirect AI components conflicts
ID	KPI-POC2-01
Definition	Early detection & mitigation of at least 20% of indirect conflicts of AI components
How	Leveraging NDT allows for the detection of conflicts within the closed-loop control system.

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Baseline value (units)	N/A
Target value (units)	20% of indirect conflicts mitigated (% conflicts)
Standard	N/A

4.2.6 Testbed High-Level

PoC 2 testbed is hosted at the EURECOM facility (illustrated in Figure 4.5). It 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.

The testbed is accessible through a WebPortal or exposed API. The WebPortal is specifically designed to allow the use-case deployment, while the API can be used by an external component of orchestrator. It permits the deployment of cloud-native applications and services in the forms of Virtual Network Function (VNF) or Container Network Function (CNF).

The NFVO and MEC Orchestrators are homemade software that allows the management of the Lifecycle 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. The 5G NR connectivity is fully supported by OpenAirInterface (OAI) RAN and CN. The RAN supports both FR1 and FR2 deployments.

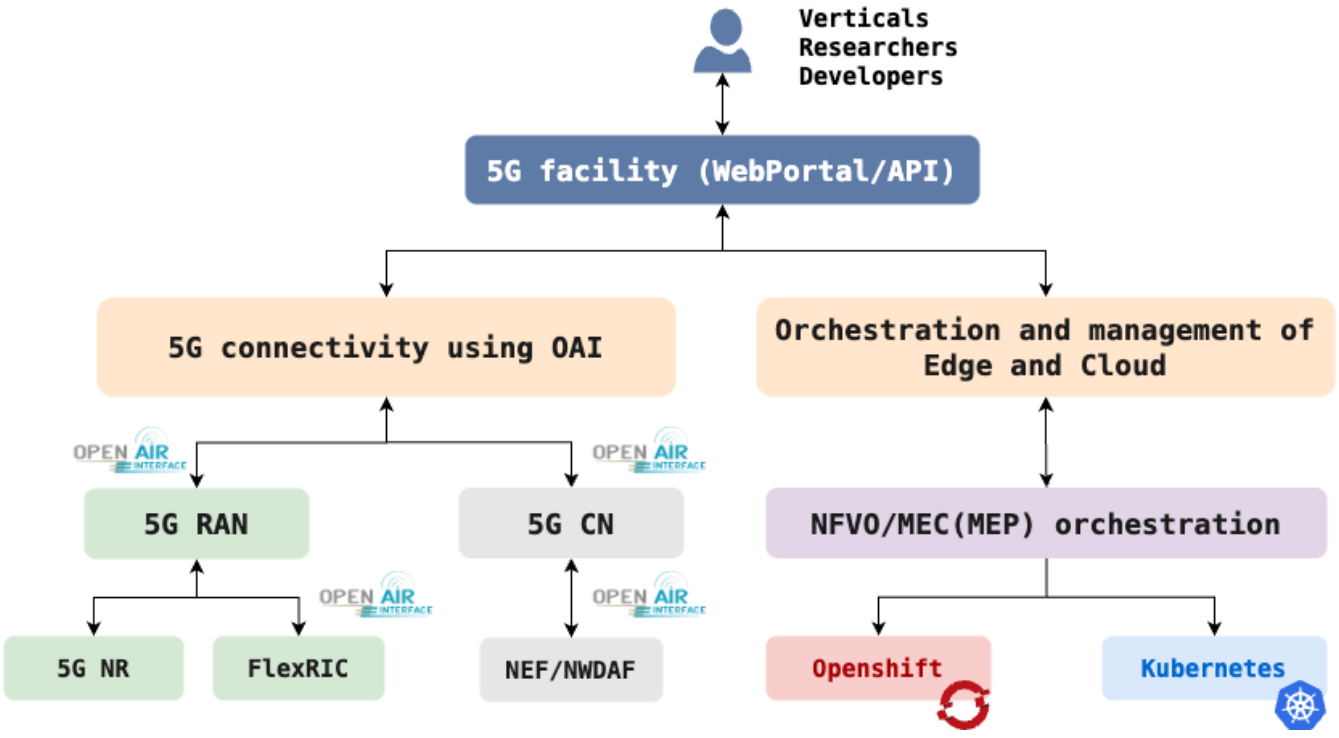

Figure 4.5: PoC #2 EURECOM's Testbed High-level Architecture

4.3 PoC #3: Network Digital Twin with NTN

4.3.1 Narrative

A Digital Twin (DT) is aggregated, generated, and visualised by running dedicated software, including specialised AI/ML algorithms. A DT is neither a pure simulation nor a pure emulation. Instead, it integrates the concepts of simulation and emulation and describes sub-system and system behaviour through models on different abstraction levels. These models can then be connected to real-life running systems. This PoC covers a Network DT (NDT) for 6G network planning, network operation, and industrial process operation. Note that, 6G is considered both an enabler and an application domain for NDTs. Following the concepts of collaborative and programmable multi-domain and multi-layer NDTs, this PoC showcases the creation of sophisticated end-to-end digital twins (E2E DT) for industrial applications, interconnecting the NDT with process component digital twins (PDT), compute system digital twins (CDT), and infrastructure & environment digital twins (IDT). In addition, the E2E DT will also be applied to achieve a ubiquitous network and edge computing by providing seamless access to both TN and NTN (including satellites and/or unmanned aerial vehicles/drones) network systems and services for industrial use cases.

Validating the feasibility and applicability of these E2E DT promises a large set of future business cases. This should happen in a transparent way for the distributed industrial application and finally end user, meeting the requirements (e.g., bit rates, latency) to ensure that industrial needs are covered, with the desired quality of service (QoS).

4.3.2 Objectives and Challenges

This PoC aims at demonstrating the potential of a network digital twin within a mobile communication network, centred around 4 main objectives:

1. **Validate the added benefits of a Network Digital Twin (NDT)**: how an NDT can enhance a process digital twin beyond traditional network planning and provisioning? By leveraging real-time process information, the NDT can optimize network performance dynamically, ensuring efficient resource allocation and improved service quality.
2. **Demonstrate the benefits of clustering Digital Twins in categories**: how to streamline data management, enhance interoperability, and facilitate more effective decision-making processes? By organizing DTs based on their functions and interactions, the NDT can simplify data handling, ensure efficient storage, retrieval, and analysis while reducing redundancy.
3. **Highlight the potential of an integrated NDT, Computing Digital Twin, and Process Digital Twin**: how to explore the synergies created by integrating an NDT with computing and process digital twins? This integrated approach will enable comprehensive monitoring and control, leading to optimized operations, reduced downtime, and increased overall efficiency.
4. **Implement an agnostic network infrastructure**: how to realize an NDT that is agnostic to transport network technology? By combining terrestrial mobile communication with Non-Terrestrial Networks (NTN), this PoC will showcase the seamless integration of NDTs.

These objectives introduce a comprehensive set of challenges that must be addressed to realize the full potential of this PoC. We have identified the following challenges:

1. **Multi-domain NDT**: Different network segments, such as industrial networks, 6G networks, and Non-Terrestrial Networks (NTN), each have their own digital twins that need to be jointly utilized. This requires a set of interfaces and mechanisms to integrate and manage these diverse DTs, ensuring they work together seamlessly to provide a unified and end-to-end view of the network.
2. **Multi-layer NDT**: Beyond just a network digital twin, there is a need for digital twins that encompass the entire process, including applications, infrastructure, and the computing environment. This multi-layer

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approach ensures comprehensive management and optimization across all aspects of the network and its operations.

3. **Dynamic creation of Digital Twins**: Digital twins must be created dynamically using real operational data from systems running industrial processes. This specialization ensures that the DTs are accurate and reflective of the current state of the network, enabling precise monitoring and control.
4. **Network automation strategies assisted by NDTs**: Network automation strategies, supported by NDTs, can proactively address and mitigate underperforming conditions.
5. **Flexible application design**: The NDT must support flexible application design, accommodating multiple communication profiles and topologies across multi-domain and multi-layer components of a distributed, connected computing system. This flexibility is crucial for adapting to varying application requirements and ensuring optimal performance.
6. **Continuously assist automated decisions**: The NDT should continuously support automated decision-making processes, including operations, fault detection, and repair. By providing a joint view from the process, NDTs can enhance the efficiency and effectiveness of these automated decisions, leading to more resilient and reliable network operations.

4.3.3 Use Case's Requirements Analysis

Table 4.14 showcases the user requirements proposed for PoC #3.

Table 4.14: PoC #3 User requirements

ID	**P3-UR01**
Name	Dynamic creation of NDTs
Description	The NDT shall have the ability to dynamically create digital twins using real operational data from networks and/or industrial processes.
ID	**P3-UR02**
Name	Accurate representation
Description	The NDT shall provide an accurate representation of the real-world at each point in time.
ID	**P3-UR03**
Name	Identify and report network behaviour
Description	The NDT shall have the capability to identify specific behaviours in the network (e.g., failures, congestion, and intrusion) and notify it.
ID	**P3-UR04**
Name	Network issue inducement
Description	The NDT shall be capable of injecting a networking issue on its emulation / simulation as well as measure and monitor its impact.

ID	P3-UR05
Name	Estimation of Impact
Description	The NDT shall have the capability to model the future behaviour of the network in order to assess the impact of specific network configurations and policies via simulated / emulated environments.
ID	P3-UR06
Name	Report of Impact
Description	The NDT shall be capable of reporting the status of different network metrics upon the configuration of specific network configurations and policies within the simulated / emulated environments.
ID	P3-UR07
Name	Real-Time Network Optimization
Description	The NDT shall be capable of optimizing network performance dynamically and in real-time either autonomously or following manually configured policies.
ID	P3-UR08
Name	Network automation and assisted decisions
Description	The NDT shall be able to identify anomalies in the network and automate / assist preventive measures.
ID	P3-UR09
Name	Convergence and non-conflicting optimizations
Description	The NDT shall provide stable, non-conflicting optimizations allow for deployed Closed Loops to harmonize as well.
ID	P3-UR10
Name	Integration of Multi-Domain Digital Twins
Description	Each NDT shall support the cross-domain integration of distinct digital twins from various network segments (industrial network, 6G network, NTN network).
ID	P3-UR011
Name	Chained NDTs
Description	The NDT shall allow authorized NDTs to consume information about the capabilities, request network configurations, and retrieve reports of network behaviour.
ID	P3-UR12

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Name	Multi-Layer Digital Management
Description	The NDT shall illustrate distinct logical views, including applications, infrastructure, and computing environments.

4.3.4 Use Case's High-Level Architecture

The high-level overview of the Network Digital Twins use case considers the existence of various real-world networks that might belong to different domains and/or distinct stakeholders. These might include vertical networks (e.g., factory networks), in-device vendor networks (e.g., robotics), computing networks (e.g., Industrial Edge) as well as transport and satellite networks. Thus, each of these real-world networks is represented by its own Network Digital Twin. These digital twins simulate and model the behaviour (both online and offline), performance, and interactions of their respective networks, providing valuable insights and data for optimization and management. The following NDTs have been identified (but not limited to) as being relevant for industrial settings:

1. **Factory Network Digital Twin:** the *Factory NDT* models the network infrastructure within a manufacturing facility. In addition, it includes machine-to-machine communication, data flow between production lines, and integration with third-party systems. This digital twin can support tasks for optimizing production processes, ensuring network reliability, and enhancing overall factory efficiency.
2. **In-Device Network Digital Twin:** the *In-Device NDT* focuses on the internal network within a device. It models the communication pathways, data processing, and interactions between different components within a device. This digital twin can support tasks for optimizing device performance, troubleshooting issues, and enhancing the overall user experience.
3. **Industrial Edge (Network) Digital Twin:** the *Industrial Edge NDT* is designed for industrial environments, where it models the edge computing infrastructure, both in terms of networking and computing aspects. It includes simulations of data processing at the edge, integration with IoT devices, and real-time analytics. This digital twin can support tasks for improving operational efficiency and enabling real-time decision-making on resource allocation.

Additionally, the usage of Transport and Non-Terrestrial Network (NTN) are potential candidate to ensure communication across various locations. Therefore, their counterpart digital twins can provide real-time monitoring, predictive analytics, and optimization capabilities, which are essential for maintaining high performance and operational efficiency of industrial processes.

1. **Transport Network Digital Twin:** the *Transport NDT* represents a virtual model of the transport network infrastructure.
2. **Non-Terrestrial Network Digital Twin:** the *Non-Terrestrial NDT* represents networks that operate beyond the Earth's surface, such as satellite networks and space-based communication systems. It is also capable of modelling satellite trajectories and network connectivity.

By interfacing with one another, these individual digital twins can contribute to a comprehensive End-to-End (E2E) Network Digital Twin, offering a holistic view of the entire network infrastructure (as depicted in Figure 4.6). The aggregation of these views can occur at different stages, allowing for a flexible and scalable approach to network management. For instance, the *Factory Network Digital Twin* might comprise its own NDT but already include information from the *Industrial Edge NDT* and the *In-Device NDT*. This layered integration ensures that each NDT not only provides detailed insights into its specific domain but also contributes to a broader, interconnected network model. Consequently, the E2E Network Digital Twin can further merge with other digital twins, creating an even more comprehensive and unified E2E view of the entire network ecosystem:

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1. **E2E Network Digital Twin:** The End-to-End (E2E) Network Digital Twin provides a comprehensive model of the entire network infrastructure, spanning across different networking domains from the same or distinct stakeholders.

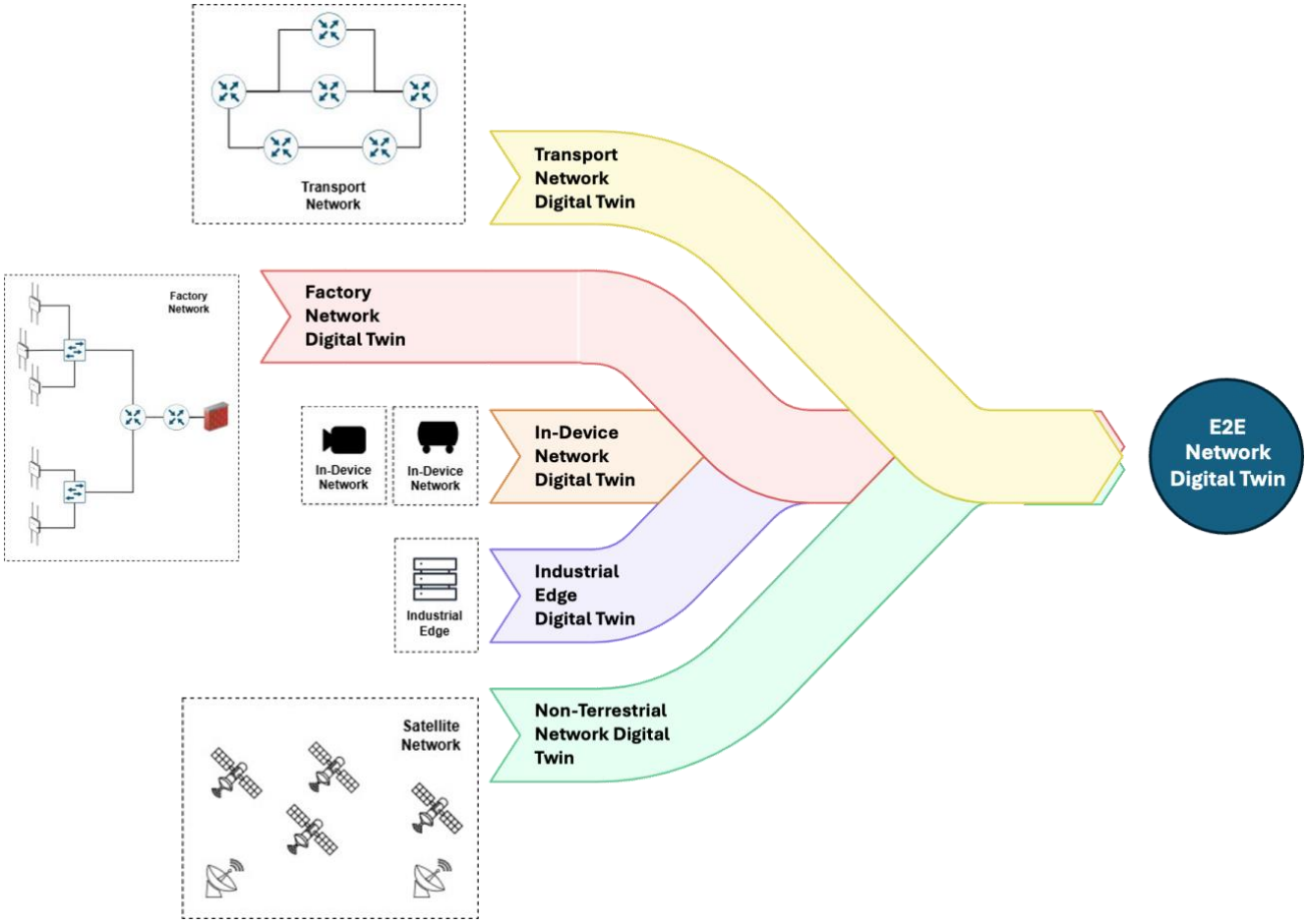

Figure 4.6: PoC #3 Unified E2E Network Digital Twin for five distinct domains

The Network Digital Twins can be viewed from multiple perspectives (as depicted in Figure 4.7), each providing unique insights and functionalities. These views include the Application View, Overlay View, and Infrastructure View, each focusing on different aspects of the network:

1. **Application View:** The Application View focuses on the applications running on the network. It includes components' behaviour / performance, data flow monitoring, and interactions. This view can support software developers and service providers who need to ensure optimal performance for applications running on the network.
2. **Overlay View:** The Overlay View represents the virtual network layers that run on top of the physical network infrastructure, including software-defined networking components (both virtual and physical). This view can enable network operators and cloud service providers on effectively and flexibly managing their overlay networks.
3. **Infrastructure View:** The Infrastructure View focuses on the physical network components, such as routers, switches, and data centers. It includes information about the connectivity, and physical network layout. This view can support infrastructure owners (network and data centers) in managing their physical network assets, ensuring hardware reliability, and optimizing network infrastructure.

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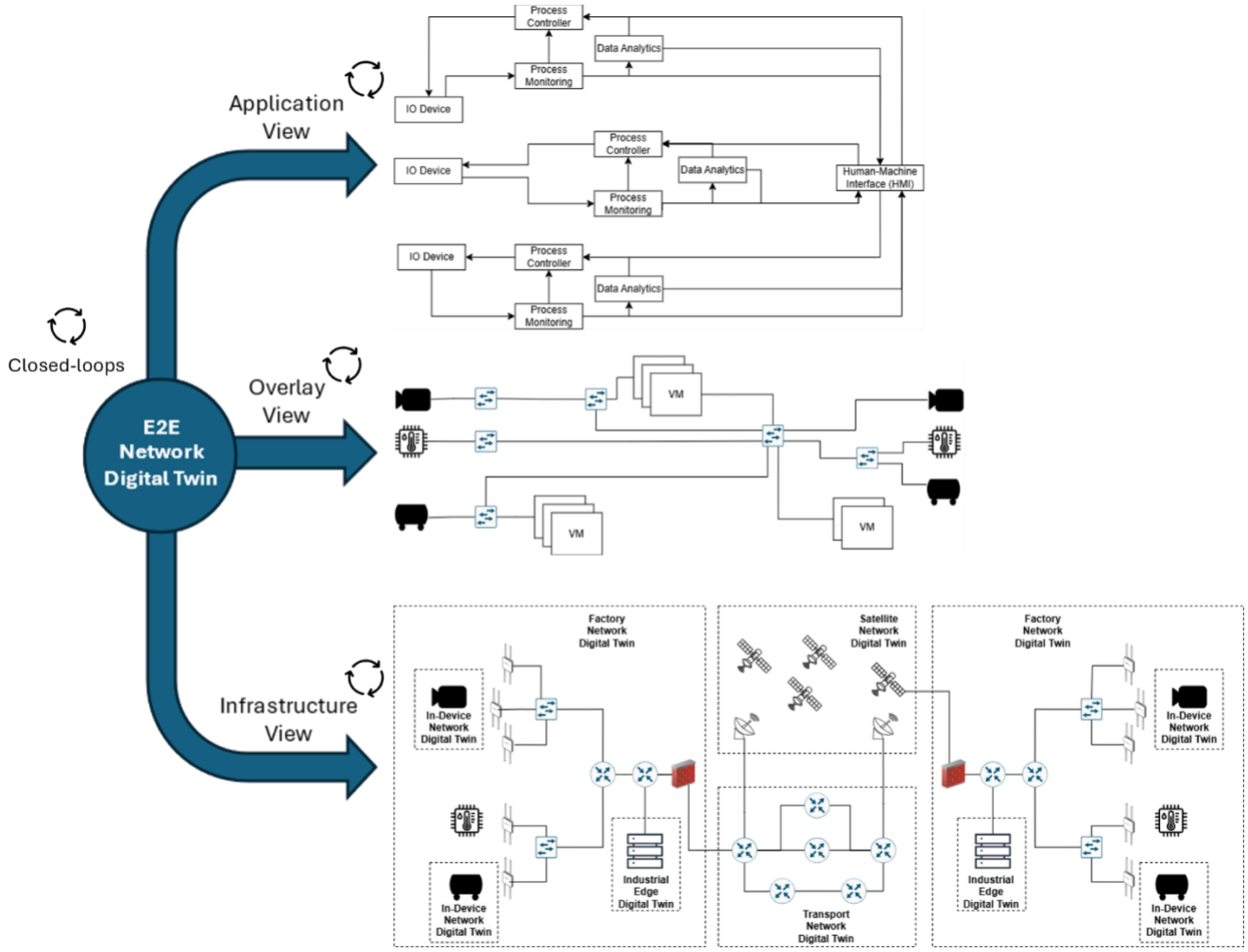

Figure 4.7: PoC #3 Multi-layered View for the Network Digital Twin

Finally, this uses case considers a set of industrial processes that might span multiple network segments, incorporating equipment via a fixed network, a non-public mobile network and Non-Terrestrial Network. Each facet of the process is emulated by the respective FLECON-6G Network Digital Twin, ensuring a comprehensive virtual representation. Industrial processes are engineered to be robust and maintain functionality, even amidst disruptions, and therefore they establish their own private communication and computing infrastructure. The FLECON-6G Network Digital Twin (NDT) framework will allow the validation of distinct configurations and operational scenarios within the E2E-nature of the industrial process.

This use case will be realized, in a reduced scope, as a PoC in WP5, aiming at showing how resources and subsystems from multiple technological (e.g., edge, transport networks, NTN) and administrative domains (e.g., factory networks, transport networks, satellite networks, edge computing provider) can be efficiently chained in E2E services and network topologies. Specialised NDTs will be instantiated and configured on-demand, enabling the creation of an end-to-end multi-layer and multi-domain digital twin covering different technological domains (e.g., industrial network domain, edge computing domain, 6G access/core network domain, satellite network domain as backhaul) and 3 layers (e.g., physical infrastructure, end-to-end network slice including edge computing resources, industrial application service). The PoC will also show how the interactions among different NDTs will allow to elaborate a consistent and fully synchronised representation of the end-to-end system. The composition and network automation logic will be supported through the FLECON-6G Cognitive Closed Loops Coordination Framework, with the assistance of E2E NDTs dynamically provisioned through the FLECON-6G Service & Network Digital Twins as-a-Service Orchestration Framework. Such components will support the

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definition and provisioning of closed loops (operating at the infrastructure, overlay and application level – see Figure 4.7). These are expected to perform e.g. automated re-allocation of edge components, self-recovery of end-to-end network connectivity, and self-optimisation of service components distribution. Their coordination will be handled with the assistance of the NDTs to guarantee the consistency of the overall decisions and avoid the risk of enforcing conflicting actions in different layers or domains. The initial high-level architecture of PoC #3 is depicted in Figure 4.8.

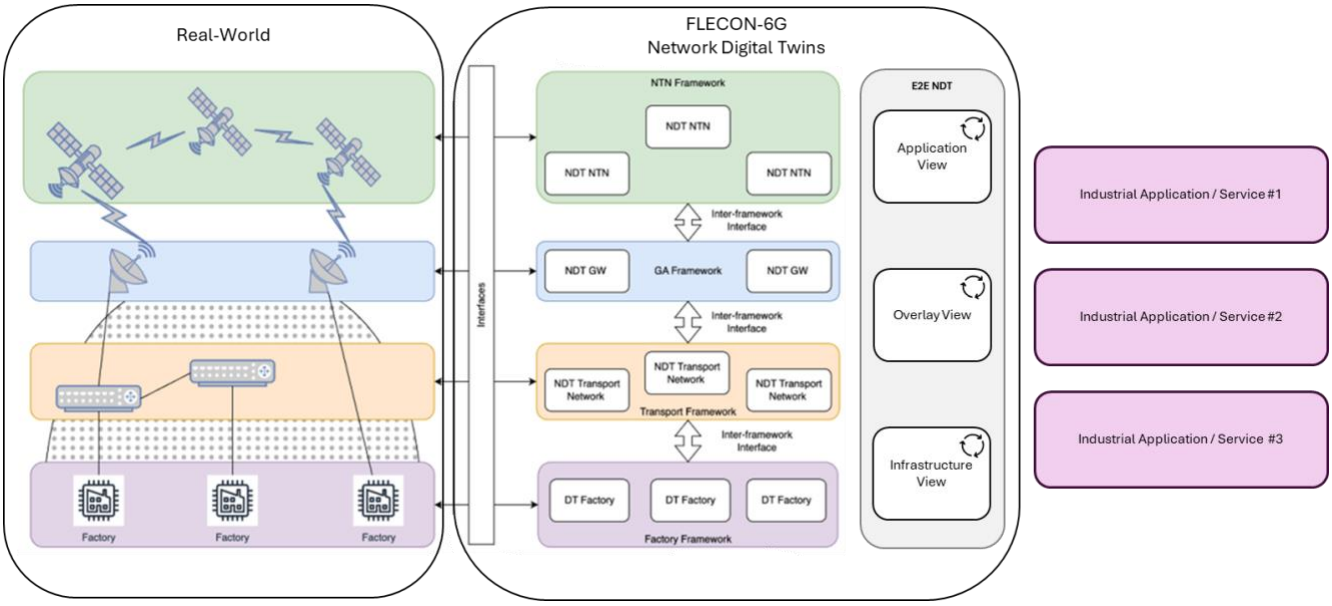

Figure 4.8: PoC #3 High-Level Architecture

4.3.5 Use Case's KPIs

Table 4.15 showcases the KPIs specifically proposed for PoC #3.

Table 4.15: PoC #3 KPIs related with FLECON-6G

KPI	Description
KPI TO 1.3	Enhanced reliability of NTN systems by >50% compared to existing legacy NTN systems, as seen from the end user service perspective by incorporating middleware services on top of the 6G NTN.
KPI TO 4.1	>3 concurrent closed loops coordinated together with the assistance of NDTs.
KPI TO 4.2	Reduce by half the time to validate a closed control loop solution in a real environment.
KPI TO 4.3	Model >3 advanced scenarios per NDT for 6G.
KPI TO 6.1	>5 domains and >3 collaborating stakeholders participating in the collaborative and distributed framework for dynamic composition of 6G NoN, belonging to >2 categories of stakeholders.
KPI TO 6.2	>3 categories of end-to-end services delivered through the composition of ad-hoc topologies of 6G networks of networks.

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KPI TO 6.3	<5 minutes for the time required to compose of a 6G NoN and deliver an end-to-end service across 3 stakeholders, assuming pre-established SLAs.
KPI TO 6.4	<10 minutes for the time required to autonomously re-optimise the composition of 3 concurrent 6G networks of networks across 3 stakeholders, assuming pre-established SLAs.

To assess the functioning of the Network Digital Twin with NTN PoC, two groups of indicators have been identified: system performance and overall multi-domain capabilities. The sampling of these indicators will ensure a detailed assessment of the specific NDTs, as well as inter-NDT integration and operation. These indicators are described in detail in Annex I at the end of the document. The short list of targeted KPIs include (see Table 4.16, Table 4.17, Table 4.18, Table 4.19, Table 4.20, Table 4.21, Table 4.22, and Table 4.23):

1. System performance KPIs

- Enhanced reliability of NTN systems by >50% compared to existing legacy NTN systems, as seen from the end user service perspective by incorporating middleware services on top of the 6G NTN.
- >3 concurrent closed loops coordinated together with the assistance of NDTs
- Reduce by half the time to validate a closed control loop solution in a real environment
- Model >3 advanced scenarios per NDT for 6G

2. Multi-domain KPIs

- >5 domains and >3 collaborating stakeholders participating in the collaborative and distributed framework for dynamic composition of 6G NoN, belonging to >2 categories of stakeholders
- >3 categories of end-to-end services delivered through the composition of ad-hoc topologies of 6G networks of networks
- <5 minutes for the time required to compose of a 6G NoN and deliver an end-to-end service across 3 stakeholders, assuming pre-established SLAs
- <10 minutes for the time required to autonomously re-optimise the composition of 3 concurrent 6G networks of networks across 3 stakeholders, assuming pre-established SLAs

Table 4.16: KPI-POC3-01 Service: System reliability

KPI Field	Description
Category	Service
Name	System reliability
ID	KPI-POC3-01
Definition	Enhanced reliability of NTN systems by >50% compared to existing legacy NTN systems, as seen from the end user service perspective by incorporating middleware services on top of the 6G NTN.
How	System utilizes middleware, adapted to the 6G NTN use case.
Baseline value (units)	To be measured (NA)
Target value (units)	50% reduction

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Standard	NA

Table 4.17: KPI-POC3-02 Service: Closed loop scalability

KPI Field	Description
Category	Service
Name	Closed loop scalability
ID	KPI-POC3-02
Definition	>3 concurrent closed loops coordinated together with the assistance of NDTs.
How	Closed loops will be coordinated with NDTs.
Baseline value (units)	NA
Target value (units)	3 or more closed loops
Standard	NA

Table 4.18: KPI-POC3-03 Service: Closed control loop validation time

KPI Field	Description
Category	Service
Name	Closed control loop validation time
ID	KPI-POC3-03
Definition	Reduce by half the time to validate a closed control loop solution in a real environment
How	Optimized closed loop validation would be developed.
Baseline value (units)	To be measured (NA)
Target value (units)	50% reduction
Standard	NA

Table 4.19: KPI-POC3-05 Capacity: Heterogeneous NDTs

KPI Field	Description

Category	Capacity
Name	Heterogeneous NDTs
ID	KPI-POC3-04
Definition	Model >3 advanced scenarios per NDT for 6G.
How	3 or more scenarios, each per NDT, would be developed to closely collaborate in a unified storyline. North-South APIs for a uniform inter-NDT communication would be utilized.
Baseline value (units)	NA
Target value (units)	3 or more integrated NDTs with specific capabilities
Standard	NA

Table 4.20: KPI-POC3-05 Capacity: Cross-stakeholder NoN composition

KPI Field	Description
Category	Capacity
Name	Cross-stakeholder dynamic NoN composition.
ID	KPI-POC3-05
Definition	>5 domains and >3 collaborating stakeholders participating in the collaborative and distributed framework for dynamic composition of 6G NoN, belonging to >2 categories of stakeholders.
How	Several tailored NDTs would be interconnected, along with NoN orchestration.
Baseline value (units)	To be measured (NA)
Target value (units)	5 or more domains from 3 or more stakeholders of 2 or more value-chain member types
Standard	NA

Table 4.21: KPI-POC3-06 Capacity: End-to-end service integration

KPI Field	Description
Category	Capacity
Name	End-to-end service integration

ID	KPI-POC3-06
Definition	>3 categories of end-to-end services delivered through the composition of ad-hoc topologies of 6G networks of networks.
How	Unified service descriptors would be utilized as long as underlying mechanisms for dynamic service composition
Baseline value (units)	NA
Target value (units)	3 or more end-to-end services of different categories
Standard	NA

Table 4.22: KPI-POC3-07 Service: Service composition time

KPI Field	Description
Category	Capacity
Name	Service composition time
ID	KPI-POC3-07
Definition	<5 minutes for the time required to compose of a 6G NoN and deliver an end-to-end service across 3 stakeholders, assuming pre-established SLAs.
How	Service descriptors parsing and dynamic composition mechanisms would be optimized to enable seamless and immediate service instantiation
Baseline value (units)	NA
Target value (units)	Total time of service composition under 5 minutes
Standard	NA

Table 4.23: KPI-POC3-08 Service: Service optimization time

KPI Field	Description
Category	Service
Name	Service optimization time
ID	KPI-POC3-08

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Definition	<10 minutes for the time required to autonomously re-optimise the composition of 3 concurrent 6G networks of networks across 3 stakeholders, assuming pre-established SLAs.
How	Mechanisms of NoN synchronization would be utilized to ensure system convergence in an optimal timeframe
Baseline value (units)	NA
Target value (units)	Time of system optimization with 3 NoN under 10 minutes
Standard	NA

4.3.6 Testbed High-Level

The PoC will be executed in SIE's NTN Industrial Testbed (illustrated in Figure 4.9) and Industrial Edge-Lab. The former testbed will be used to add NTN capabilities to the use case and emulate global scenarios with mobile infrastructure and application nodes, which form together a highly dynamic connected computing system. The latter testbed will be used to replicate industrial communication networks and infrastructure providing industrial components (e.g., IPCs, industrial network components). Both testbeds will be used to run the use case validation scenarios for the integrated Network Digital Twin, while aiming to provide an environment, where different kinds of industrial applications with their specific requirements, application topologies, and architectures can be analysed, evaluated, and improved in terms of their feasibility and viability.

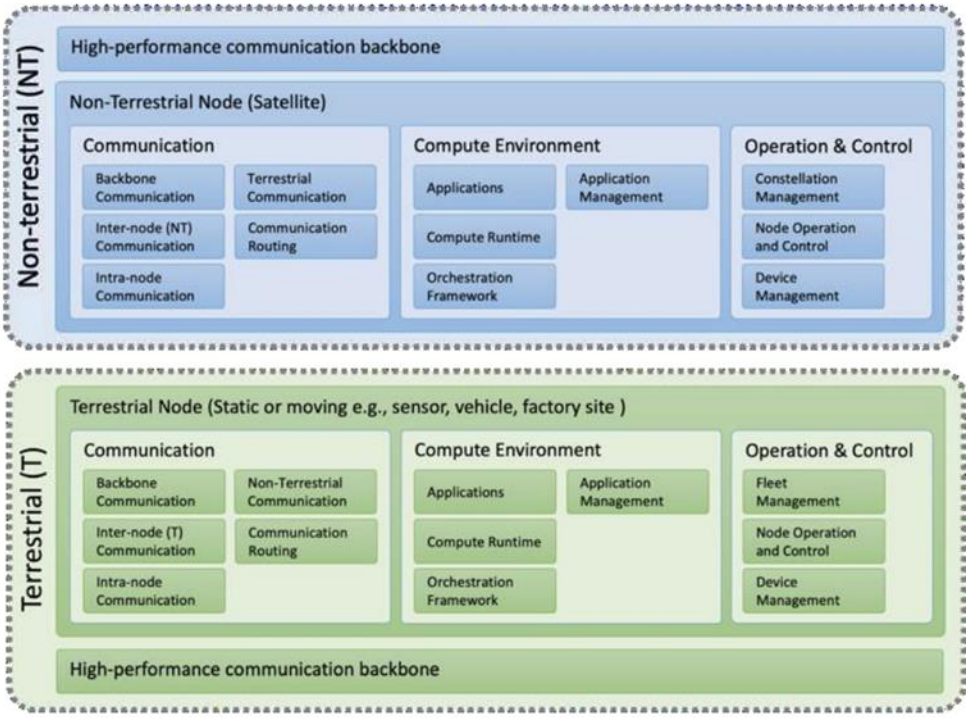

Figure 4.9: PoC #4 SIE Testbed High-level Architecture

4.4 PoC #4: Public Safety Services

4.4.1 Narrative

Public safety communication systems are often challenged by the stringent demands of emergency response scenarios, which require real-time information sharing, reliable connectivity, and robust coordination among first responders. To address these challenges, a Proof of Concept (POC) within the FLECON 6G platform has been developed to significantly enhance situational awareness, response coordination, and decision-making capabilities during emergencies.

The POC involves the deployment of a server component, composed of virtual machines, on the FLECON 6G platform. This server acts as the backbone of the Airbus critical communication solution, providing a secure and reliable infrastructure for mission-critical services. User Equipment (UE) devices, specifically smartphones running the Android operating system, will be utilized by first responders or policemen. These smartphones will have the Airbus secured communication application installed, ensuring that all communications are secure.

The UEs will be connected to the server, enabling seamless and secure communication channels. This setup allows for the simulation of various emergency situations using mission-critical services such as push-to-talk communication. Push-to-talk functionality is particularly valuable in emergency scenarios as it enables instant, clear, and reliable voice communication, like traditional walkie-talkies but with the added benefits of modern technology.

The POC aims to demonstrate the effective use of mission-critical services through the Airbus critical communication solution, which is an end-to-end solution. This means that the entire communication process, from the initial transmission to the final reception, is managed within a secure and optimized framework provided by the FLECON 6G platform.

By leveraging the advanced capabilities of 6G technology, this POC seeks to provide first responders with the tools they need to respond more effectively and efficiently to emergencies, ultimately saving lives and minimizing damage.

4.4.2 Objectives and Challenges

The objective of this PoC is to evaluate the performance of the FLECON-6G platform regarding public safety services. The PoC will showcase how public safety services can be integrated into the platform and validate the suitability for supporting mission critical communications requirements and enhance effectiveness in emergency situations.

Throughout the PoC, emphasis will be placed on evaluating the platform's performance in meeting the stringent requirements of public safety applications, including reliability, latency, security, and coverage. Additionally, the POC aims to showcase the potential of advanced AI-driven capabilities integrated into the platform to enhance, for example, decision-making in emergency scenarios.

The challenges are:

- Integration of critical solution: The PoC will focus on integrating critical communication services with high expectations for reliability, low latency, and robust security. This involves ensuring that the platform can support real-time, high-stakes communications without failure.
- Integration of critical solution: The PoC will focus on integrating critical communication services with high expectations for reliability, low latency, and robust security. This involves ensuring that the platform can support real-time, high-stakes communications without failure.
- Integration of critical solution: The PoC will focus on integrating critical communication services with high expectations for reliability, low latency, and robust security. This involves ensuring that the platform can support real-time, high-stakes communications without failure.

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4.4.3 Use Case's Requirements Analysis

Table 4.24 showcases the user requirements proposed for PoC #4.

Table 4.24: User requirements for PoC #4

ID	**P4-UR01**
Name	Voice communication
Description	The user should be able to speak with another user
ID	**P4-UR02**
Name	Reliability
Description	The user should be able to use the application at anytime
ID	**P4-UR03**
Name	Video stream
Description	The user should have a good quality stream
ID	**P4-UR04**
Name	Latency
Description	The latency should be reduced <300 ms
ID	**P4-UR05**
Name	Throughput
Description	The data throughput must be high >50 Mbps

4.4.4 Use Case's High-Level Architecture

The system is composed of a central server and a diverse range of User Equipment (UE) devices, all interconnected to form a robust communication network. The entire solution is virtualized and deployed on a scalable platform, with a clear separation between backend and frontend components to ensure efficient management and operation (illustrated in Figure 4.10).

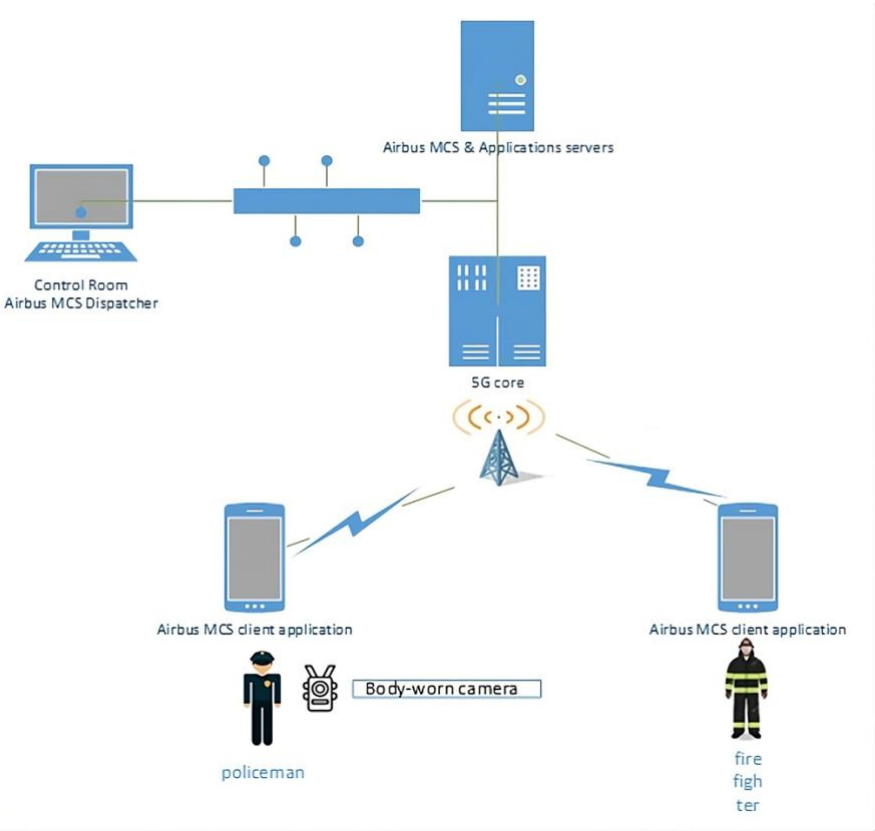

Figure 4.10: PoC #4 High-Level Architecture

The MCX solution is built upon a virtualized architecture, with both backend and frontend components hosted on virtual machines. The backend serves as the administrative hub, responsible for managing groups, user authorizations, and system configurations. It ensures that only authorized users can access specific groups and services, maintaining the security and integrity of the communication platform. The backend also monitors the system's performance and health, providing administrators with real-time insights and alerts.

The frontend, on the other hand, focuses on operations management. It offers a user-friendly interface for administrators and operators to monitor the real-time status of MCX services, configure service parameters, and troubleshoot any issues that may arise. The frontend and backend components work in tandem to deliver a seamless and efficient user experience.

The MCX communication platform is designed to support a wide range of services tailored to mission-critical operations. It provides high-quality, low-latency voice communication with push-to-talk functionality, enabling users to quickly and efficiently exchange information. Instant messaging is also supported, allowing users to send secure, real-time text messages to individuals or groups.

For enhanced situational awareness, the platform offers high-definition video calling and streaming capabilities. This enables users to share live video feeds, collaborate on tasks, and make informed decisions based on visual information. Additionally, the platform includes location services, which provide real-time tracking and location-based services to improve coordination and response times.

The Android-based MCX application is designed to be deployed on a variety of UE devices, catering to different use cases and environments. Smartphones serve as the primary communication devices for human users, providing them with a familiar and intuitive interface to access MCX services.

The MCX PoC is seamlessly integrated with the FLECON-6G architecture, leveraging its advanced features and capabilities to deliver enhanced mission-critical communications. This integration enables improved network

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performance and reliability, supporting a wide range of UE devices and use cases. The FLECON-6G architecture also provides the scalability and flexibility needed to accommodate future growth and expansion, ensuring that the MCX solution can adapt to evolving requirements and technologies.

4.4.5 Use Case's KPIs

The following tables (Table 4.25, Table 4.26, Table 4.27, Table 4.28, and Table 4.29) showcase the KPIs established for PoC #4.

Table 4.25: KPI-POC4-01 Latency: System Performance

KPI Field	Description
Category	Latency
Name	System Performance
ID	KPI-POC4-01
Definition	Ensure short latency as required for critical communication
How	Measuring mouth to ear latency.
Baseline value (units)	<20 ms
Target value (units)	<20 ms
Standard	NA

Table 4.26: KPI-POC4-02 Service: Throughput – Downlink

KPI Field	Description
Category	Service
Name	Throughput - Downlink
ID	KPI-POC4-02
Definition	Ensure a high throughput as required for critical communication
How	Measuring the speed of the network using end-to-end MCXDATA exchanges
Baseline value (units)	< 100 mbps
Target value (units)	> 100 mbps
Standard	NA

Table 4.27: KPI-POC4-03 Service: Throughput – Uplink

KPI Field	Description
Category	Service
Name	Throughput - uplink
ID	KPI-POC4-03

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Definition	Ensure a high throughput as required for critical communication
How	Measuring the speed of the network using end-to-end MCXDATA exchanges
Baseline value (units)	< 100 mbps
Target value (units)	> 100 mbps
Standard	NA

Table 4.28: KPI-POC4-04 Service: System Hallucinations

KPI Field	Description
Category	Service
Name	System hallucinations
ID	KPI-POC4-04
Definition	Reduce Hallucination Evaluation Index for telco LLMs by > 15%
How	System utilizes new framework for analysis.
Baseline value (units)	To be measured (NA)
Target value (units)	15% reduction
Standard	NA

Table 4.29: KPI-POC4-05 Service: System Reliability

KPI Field	Description
Category	Service
Name	System reliability
ID	KPI-POC4-05
Definition	Reduce SLA violations by at least 50% via Trustworthy AI techniques
How	System utilizes new framework for analysis.
Baseline value (units)	To be measured (NA)
Target value (units)	50% reduction
Standard	NA

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4.4.6 Testbed High-Level

The PoC will be executed in ISI/ATH beyond 5G testbed. The ISI/ATH 5G testbed facility, located at the ISI premises in Greece, implements a full stack 5G system, as illustrated in Figure 4.11, 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 MEC nodes and ETSI OSM based is Orchestration components. It currently being upgraded with O-RAN compliance while zero touch management, MANO and dynamic slice reconfiguration enablers are developed.

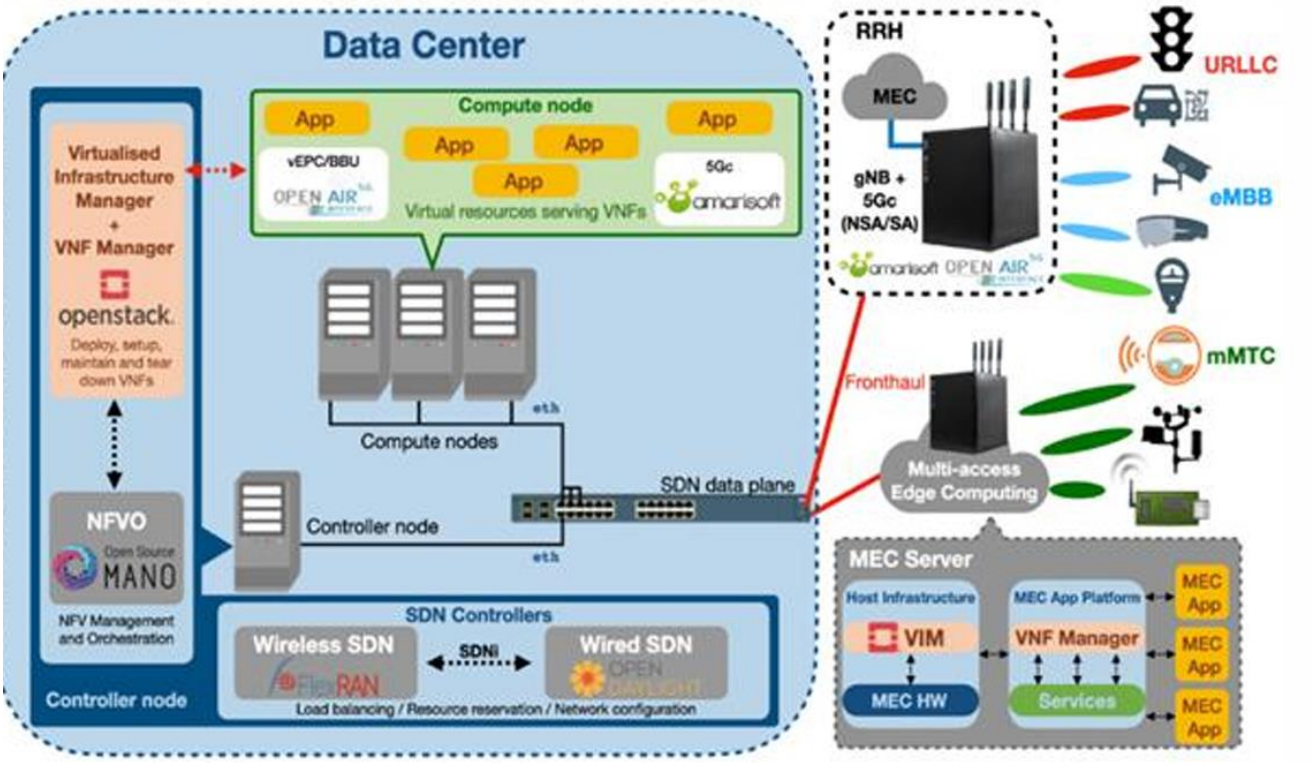

Figure 4.11: PoC #4 ISI/ATH Testbed High-level Architecture

5 Requirements Analysis

5.1 Requirements Elicitation

In FLECON-6G, technical requirements are collected starting from the analysis of the use cases and their specific UC-driven requirements, as defined in the previous section, and combining them with the technical objectives, high-level architectural principles, and innovations proposed for the overall FLECON-6G system. The requirements have been defined at the global system level and, where possible, already classified based on their impact on the main architectural blocks of the FLECON-6G system. This preliminary classification will facilitate the design of the system components, their interactions, and interfaces.

The definition of the technical requirements follows a common template, described in the following, which has been designed to drive their subsequent processing across the different phases of the project. In detail, the requirements will be used as input for the design of the various cycles of the architecture and the definition of the implementation plan in WP3 and WP4, considering the requirements priority. Moreover, they will feed the PoC-driven experimentation and verification phase in WP5, considering the originating PoC and the fit criterion. This will allow to obtain a final table at the end of the project with the details of the technical requirements matched by the architecture and by the implemented system, with references to their validation. Finally, it should be noted that the requirements collection is a continuous activity: feedback from architecture design and implementation, as well as from the interactions with the external ecosystem, will be continuously processed to update and enrich the requirements list where needed.

The template for the collection of the requirements is the following:

- **Requirement ID:** Unique identifier of the technical requirement across the whole project. It is structured as: TR-<X>-<Y>-<Z>, where
  - X: {“GEN_”<CAT>, “UC_”<UC-ID>}, identifying the origin of the technical requirement, where “GEN_”<CAT> is used for requirements mainly related to the technical objectives/innovations of the project (transversal to use cases), while “UC_”<UC-ID> is used for requirements directly associated to a particular UC. For <CAT> values, see next element.
  - Y: {“F”, “NF”}, identifying if the requirement is functional or non-functional.
  - Z: progressive integer
- **Category:** identifies the related architecture layer or macro-block, as follows:
  - FLECON-6G system as a whole (SYS)
  - Marketplace (MP)
  - NoN-Framework (NoN)
  - Intelligence Layer (IL)
  - Network Digital Twin Framework (NDT)
  - Cognitive Close Loop Coordination Framework (CLC)
  - AI-as-a-Service Framework (AI)
  - Data Plane (APEC)
- **Description:** describes the requirement in technical terms, explaining what the system should do (functional) or how the system should behave (non-functional) – with reference to KPIs if needed.
- **Priority:**
  - High (H): mandatory, e.g., because mentioned in the proposal, technical enabler for a given UC, or strategic in terms of innovations, standard compliance, or business exploitation;
  - Medium (M): nice to have, e.g., for the implementation or demonstration of a given UC;
  - Low (L): optional.
- **Linked PoC:** where applicable, the UC, the technical requirement is originating from, and the PoC where it will be validated.
- **Type:** functional (F) or non-functional (NF).

- **Rationale:** describe why the requirement is needed, e.g., linked to project technical objectives or innovations, or UC narrative, challenges, or requirements.
- **Fit criterion:** indicates how the requirement matching can be assessed in the final architecture, e.g., through measurement, presence or design of a component, interface or sequence diagram, etc.
- **Impact on FLECON-6G Architecture:** preliminary high-level analysis of how the requirement could be matched in the architecture.

The requirements are detailed in the subsequent sections, being organized as follows:

- Functional Requirements
  - System Requirements in Table 5.1.
  - Marketplace Requirements in Table 5.2.
  - Network of Networks Framework Requirements in Table 5.3.
  - Intelligence Layer Requirements in Table 5.4.
  - Network Digital Twin Framework Requirements in Table 5.5.
  - Cognitive Closed Loop Coordination Requirements in Table 5.6.
  - AI-as-a-Service Framework Requirements in Table 5.7.
  - Data Plane Requirements in Table 5.8.
- Non-Functional Requirements
  - System Non-Functional Requirements in Table 5.9.
  - Marketplace Non-Functional Requirements Table 5.10.
  - Network of Networks Framework Non-Functional Requirements in Table 5.11.
  - Network Digital Twin Framework Non-Functional Requirements in Table 5.12.

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5.2 Functional Requirements

5.2.1 System Requirements

Table 5.1: FLECON-6G System requirements

Req. ID	Category	Description	Priority	Linked PoC	Type	Rationale	Fit Criterion	Impact on FLECON-6G Architecture
TR-GEN_SYS-F-01	SYS	The architecture must provide appropriate information models to support unified representation, configuration and monitoring of different digital object, such as resources, systems and services	High	--	F	Ensures unified monitoring and joint operation of resources, subnetworks, subsystems, and services, to achieve extensive interoperability among different technological and administrative domains in the composition of 6G Networks of Networks (link to TO6).	Verified through discovery, accessibility and interoperability tests	Establishes accessibility and interoperability of heterogeneous components to support unified monitoring and joint operations.

5.2.2 FLECON-6G Marketplace Requirements

Table 5.2: FLECON-6G Marketplace requirements

FLECON-6G project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grand Agreement No 101192462

Req. ID	Category	Description	Priority	Linked PoC	Type	Rationale	Fit Criterion	Impact on FLECON-6G Architecture
TR-GEN_MP-F-01	MP	Self-service partner portal to register and verify organisations, manage users/roles, and onboard/offboard offers and resources into the marketplace across domains.	High	PoC1	F	Enables Partners to sign-up and manage their account and lifecycle as stakeholders in the marketplace, facilitating dynamic resource composition across multiple domains and stakeholders.	Collaborating stakeholders from different categories, are onboarded and participate in the smart marketplace offerings.	The Marketplace solution provides means for diverse stakeholders (dataset providers, ML algorithm developers, network operators, service providers, AI functions/tools providers, infrastructure providers) to onboard their offering and resources into the marketplace.
TR-GEN_MP-F-02	MP	Agreement management features should provide means for charging and usage management, multi-party charging across partner services part of the same intent.	Low	--	F	Agreements are created and maintained for each stakeholder and their provided resources, as part of the multi partner management operating with SLAs and billed based on usage features.	Agreements are operated in patterns and templates that contain offerings based on resources provided, usage and charging features and guaranteed SLAs.	Provides agreement templates and lifecycle operation in accordance to offerings, services, resources, SLAs defined and usage and charging methods.

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TR-GEN_MP-F-03	MP	The marketplace will act as a federation zero-touch partnering broker that makes available Computational Infrastructure Resources, Network Resources, AI Models, and Digital Network Twins.	High	PoC1	F	The smart marketplace provides intent driven negotiation capabilities by using brokers in the negotiating process with multiple partners that provide similar offerings of resources for a given intent.	Network and Resource providers are able to upload their resource pools and related offerings in the smart marketplace portal, and their resources are integrated in the portal catalogue.	Enables multi-stakeholder resource management and brokerage for negotiation and intent-driven consensus.
TR-GEN_MP-F-04	MP	The services are made available towards customers, through the portal, offering features from offer management, selling and orchestration through intent management, and assurance functions.	Medium	PoC1	F	Resource pools that partners onboard in the smart marketplace should be synchronized with the marketplace catalogue to facilitate intent negotiation during offer, then service intent fulfilment in the NoN and resource build and activation.	End to end offer-service-resource fulfilment is achieved through intent based management fulfilment and assurance functions.	Infrastructure sharing among MNOs is implemented with the use of intent management at business layer (Marketplace) and service layer (NoN). Federation Brokers facilitate sharing of Computational Infrastructure Resources (IaaS), Network Resources (NaaS / NIaaS), AI Models (AIaaS paradigm) and Digital Network Twins (DTaaS).

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TR-GEN_MP-F-05	MP	The Smart Marketplace should provide features for tenants to sign-up, manage their account, see their usage reports, billing statements, manage their active intents, report problems or visualize intent and service monitoring.	High	PoC1	F	Digital Service Consumers should be able to negotiate new intents, or manage their active intents, monitor their lifecycle, check billing and usage statements.	The Marketplace ensures intent lifecycle management, intent negotiation, and business operations in an autonomous intent-based network.	The marketplace portal provides intent API that support lifecycle management of active intents, new intent submission, and assurance and SLA monitoring features.
TR-GEN_MP-F-06	MP	Settlement and reconciliation features such as invoice reconciliation based on the contract data, imported partner's usage and comparison.	Low	--	F	Automating settlement and reconciliation by comparing contract terms with partner usage ensures accurate billing and minimizes discrepancies.	The solution must accurately reconcile invoices against contract data and imported partner usage records.	Implements data integration for ingesting partner usage, data processing for comparison and reconciliation logic, and a secure, auditable data store for contracts, usage, and reconciliation records.
TR-GEN_MP-F-07	MP	Marketplace Catalog Management should provide features to manage available offerings made available to intents, based on available partner offerings (IaaS, Naas, AIaaS, DTaaS).	High	PoC1	F	Centralized management of marketplace offerings, aligned with partner capabilities and intent-driven needs, streamlines discovery and consumption of	The system must allow for the creation, categorization of available IaaS, NaaS, AIaaS, and DTaaS offerings based on partner availability and features to check	Flexible catalog data model that represents diverse service and resource types and their attributes encapsulated as offerings in the marketplace, search and filtering

						diverse services, aligned in the catalogues of the NoN layer and marketplace layer.	feasibility in context of business intents.	functionalities driven by intents, and a mechanism to dynamically ingest and update partner offering information.
TR-GEN_MP-F-08	MP	Services are requested by tenants in the form of Intents – e.g. AI models, Edge nodes, Slice SLA, etc. using capabilities to test intent feasibility, best performing intent or most efficient intent, depending on trade off of accuracy or cost.	High	PoC1	F	Abstracting services and resources as Intents allows tenants to focus on desired outcomes rather than underlying infrastructure details, enabling intelligent selection of negotiated, optimal configurations.	The system must allow tenants to define their needs as Intents (e.g., specifying AI model type, edge node requirements, slice SLA), and provide capabilities to evaluate intent feasibility and rank options based on performance or cost trade-offs, using brokers and federated consensus during service bid step.	Intent management layer is able to parse and interpret tenant requests, a service discovery mechanism can identify suitable resources, and a decision engine capable of evaluating feasibility and optimizing service selection based on defined criteria (accuracy, cost).
TR-GEN_MP-F-09	MP	Marketplace specific knowledge based should be used for intent translation, closed loops instantiation used for decomposition and specification of service intents	High	PoC1	F	Leveraging marketplace-specific knowledge for intent translation and closed-loop instantiation ensures accurate decomposition and specification	The system must utilize a dedicated knowledge base containing marketplace-specific information to translate high-level service intents into service intents consumable by the	This requires a specialized marketplace knowledge base, an intent translation engine that can access and utilize this knowledge, and a closed-loop control system

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		towards the NoN layer.				of service intents tailored to the platform's unique offerings and underlying network capabilities.	NoN layer, employing closed-loop and NDT mechanisms to ensure valid instantiation and guaranteed SLA during lifecycle management.	capable of orchestrating the decomposition and instantiation of intents based on the translated service intents in the NoN layer.
TR-GEN_MP-F-10	MP	Intents submission feature by tenants with the constraints, objectives and SLA requirements, should be managed in a negotiation process, for decentralized consensus convergence (e.g., via dynamic game theory).	High	PoC1	F	Managing intent submissions through a negotiation process (e.g., driven by dynamic game theory) enables decentralized consensus on resource allocation and service provisioning while respecting tenant constraints, cost, and SLA requirements.	The system must provide a mechanism for tenants to submit intents with constraints, objectives, cost and SLA requirements, (e.g., implementing a dynamic game theory-based negotiation process) to achieve decentralized consensus on resource allocation and service provisioning among relevant stakeholders.	Intent-driven decentralized consensus convergence is obtained for business intents negotiated with service intents in the NoN layer, using a negotiation engine capable of implementing dynamic game theory algorithms, a mechanism for representing and exchanging intent information and constraints, and a distributed consensus mechanism to finalize agreements on resource allocation and service parameters.

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TR-GEN_MP-F-11	MP	Continuous (re-) negotiation should be implemented as triggered by the NoN Framework, operating in a composition of autonomous domains with federation by the use of intent API.	High	PoC1	F	Implementing continuous (re-) negotiation, triggered by the NoN Framework across federated autonomous domains via intent APIs, ensures ongoing optimization and adaptation of service configurations to dynamic network conditions and evolving tenant needs	The system must enable the NoN Framework to initiate renegotiation processes based on its operational status managed by the CL Governance framework and the NDTs, across a composition of autonomous domains, utilizing intent APIs for communication and coordination to dynamically adjust service parameters.	Based on NDTs outputs derived from changing network conditions, and governed by the CL Framework, the NoN Framework triggers renegotiations, using intent APIs for cross-domain communication and negotiation, operating across autonomous domains to adjust service configurations. Intent lifecycle is constantly updated within its objectives, or when conflicts cannot be solved, intent is potentially required to be updated.
TR-GEN_MP-F-12	MP	The marketplace should use an inventory of intents, where their lifecycle is managed and internal conflict is handled, managing the offerings and services capacity and feasibility	High	--	F	Maintaining a managed inventory of intents, with lifecycle management and conflict resolution, synchronized with the NoN	The marketplace must maintain a central inventory of active intents, track their lifecycle, and synchronize offering and service capacity and feasibility data with	A persistent intent repository with lifecycle management capabilities is implemented with CL Governance framework working closely with active

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		in synchronization with the NoN Framework, keeping intent feasibility and lifecycle updates accurate.				Framework's capacity and feasibility, ensures accurate and up-to-date information on available offerings and service potential within the marketplace.	the NoN Framework to ensure the accuracy of intent feasibility and lifecycle updates.	NDTs for conflict resolution, and integration between the marketplace inventory and the NoN Framework regarding resource availability and service feasibility.
TR-GEN_MP-F-13		The marketplace should interface with NoN Framework in a bi-directional setup: NoN Exposure Layer will be called by the Marketplace at intent submission for the build phase, and NoN Framework will notify and update the Martketplace for (re-)negotiation of resources and usage.	High	--	F	A bi-directional interface between the marketplace and the NoN Framework ensures seamless intent submission for service deployment and continuous feedback on resource status, enabling proactive renegotiation and accurate marketplace representation of service availability.	The marketplace must implement a mechanism to invoke the NoN Exposure Layer API upon tenant intent submission to initiate the service build phase, and the NoN Framework must be capable of sending notifications and updates to the marketplace regarding resource status and triggers for (re-)negotiation.	APIs implementation for communication between the marketplace and the NoN Exposure Layer (for intent submission), and a notification reporting system within the NoN Framework to push updates to the marketplace, ensuring both systems can interact in real-time for service lifecycle management.
TR-GEN_MP-F-15		Partner Portal Problem Management APIs should be used with Partners ecosystems for	Low	--	F	Exposing Problem Management APIs to partner ecosystems enables efficient	The marketplace must provide standardized Problem Management APIs	This necessitates the development and exposure of well-defined Problem

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		partner ticket problem reporting that provide insight on affected services and resolution time.				and transparent reporting of issues affecting services, providing valuable insight into impact and resolution timelines.	that allow partners to report service-related issues, including details about affected services, and receive updates on the problem status and estimated resolution time.	Management APIs, integration with internal ticketing and incident management systems, and mechanisms to securely share relevant problem details and status updates with authorized partners.

5.2.3 FLECON-6G Network of Networks Framework Requirements

Table 5.3: FLECON-6G NoN Framework requirements

Req. ID	Category	Description	Priority	Linked PoC	Type	Rationale	Fit Criterion	Impact on FLECON-6G Architecture
TR-GEN_NoN-F-01	NoN	The NoN framework shall support the management of service intents requested from the Marketplace.	High	--	F	Support of service intent management in multi-stakeholder scenarios (link to TO3 and TO6)	Presence of an Intent Management Function operating at the service layer, interfacing with the components responsible of multi-domain service and resource composition,	NoN Framework offering a northbound intent-based management interface. NoN Framework with functional components for Service Intent Management, including mechanisms for intent translation and lifecycle management.

							provisioning and assurance. Presence of an intent-based API.	
TR-GEN_NoN-F-02	NoN	The NoN framework shall enable mechanisms to provide onboarding and dynamic management mechanisms for heterogeneous resource domains.	High	PoC3	F	Support for abstract modelling, control and exposure of multi-technology resources, needed to enable their recursive composition and delivery in E2E services (link to TO6).	Functional testing of resource and service on-boarding procedures within a domain, for different types of technologies.	Definition of management interfaces and workflows for resource domain onboarding and advertising. Definition of functional components for catalogue and exposure management.
TR-GEN_NoN-F-03	NoN	The NoN framework shall support dynamic composition and orchestration of heterogeneous services and resources from multiple administrative domains, composing elements from stakeholders not directly participating in the marketplace, but with pre-established peer-	High	PoC3	F	Enables the seamless and recursive service and resource composition, allocation and provisioning in multi-stakeholder scenarios (link to TO6).	Functional testing of end-to-end service composition, delivery and runtime management. Measurement of service composition efficiency comparing single vs. multi-stakeholder scenarios.	Definition of interfaces for resource querying, publishing and discovery. Definition of information models for resource abstraction including computing, multi-technology networks and services, Digital Twins and AI models. Definition of functional components for service and resource composition, as well as

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		to-peer relationships.						E2E lifecycle management.
TR-GEN_NoN-F-04	NoN	The NoN framework shall enable publishing and discovery of services and resources available in the local catalogue towards cooperating stakeholders, including synchronization and support of configurable policies for confidentiality and abstraction of exposed information.	High	PoC3	F	Enables service and operational level collaboration among stakeholders with peer-to-peer agreements (link to TO6).	Functional testing of resource and service exposure among federated domains, including mechanisms for synchronization and policy-based regulation of abstraction and visibility level.	Definition of federation APIs and inter-domain service and resource advertising workflows. Definition of functional components for federation and inter-domain abstract exposure. Definition of mechanisms for resource and service catalogues synchronization across the NoN framework.
TR-GEN_NoN-F-05	NoN	The NoN framework shall enable publishing and discovery of feasible service intents from services/resources in the local catalogue into the Smart Marketplace, including synchronization.	High	--	F	Enables the participation of stakeholders in the marketplace (link to TO3)	Presence of abstraction and exposure components to advertise service intents into the Marketplace. Availability of API for service intent advertisement.	Definition of service intents advertising workflows, including synchronization between NoN framework and Marketplace.

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TR-GEN_NoN-F-06	NoN	The NoN framework must provide the Marketplace with a unified and abstracted view of service intents which can be composed via services and multi-technology resources obtained by other domains from stakeholders with peer-to-peer agreements.	Medium	--	F	Enables the participation of stakeholders in the marketplace (link to TO3) with the possibility to collaboratively combine and compose services and resources from federated domains (link to TO6)	Capability to abstract and expose service intents combining services/resources from different federated stakeholders into the Marketplace.	Definition of functional components to coordinate composition and abstraction mechanisms for publishing of service intents.
TR-GEN_NoN-F-07	NoN	The NoN framework shall provide mechanisms for advertising service and resource monitoring capabilities and expose the related monitoring data.	High	PoC3	F	Support distributed monitoring among different domains, as enabler for service and network automation and baseline functionality to feed closed loops and NDTs logic (link to TO6 and TO4).	Functional testing of monitoring capabilities. Successful integration of monitoring capabilities in closed loops and NDTs.	Definition of federation and northbound APIs for exposure of monitoring data, linked to different elements (intents, services or resources). Definition of intra- and inter-domain monitoring and telemetry components.
TR-GEN_NoN-F-08	NoN	The NoN framework shall interact with the Intelligence layer for the provisioning	High	PoC3	F	Enables support for network automation and continuous service assurance through programmable and	Availability of operational workflows and interfaces between NoN	Definition of interfaces for querying, deployment and configuration of closed loops and groups of

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		and configuration of end-to-end and per-domain closed-loops. This should include mechanisms for delegation and escalation of orchestration and assurance logic to the CLs.				customizable control loops for service and resource control and optimization (link to TO6).	framework and cognitive closed loop coordination framework at the intelligence layer. Successful integration between NoN and Cognitive CL Coordination frameworks.	closed loops to be coordinated together. Definition of workflows enabling the NoN framework to request provisioning and activation of CLs, including mechanisms for notifications of CL failures and escalation.
TR-GEN_NoN-F-09	NoN	The NoN framework shall implement runtime optimization mechanisms leveraging CLs for the continuous optimization based on the service and resource constraints and dynamicity.	High	PoC3	F	Support of self-optimization mechanisms, including mechanisms for conflict detection, mitigation and/or resolution at runtime for intent and service assurance.	Successful demonstration of autonomous re-optimization actions involving multiple layers and/or domains, with autonomous resolution of conflicting CLs.	Definition of multi-layer and multi-domain CLs for self-optimization at resource, network, service, intent level. Definition of mechanisms for coordination of multi-layer and multi-domain CLs, including mechanisms for conflict detection, mitigation and/or resolution, and interfaces for notifications of CL failures and escalation.
TR-GEN_NoN-F-10	NoN	The NoN framework shall be able to interact with FLECON-6G APEC using a	High	--	F	Enable the provisioning of services and applications on top of the	Successful testing of operations and monitoring on APEC infrastructure	Establishment of APEC services and operations.

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		unified and programmable interface.				APEC resources (Link to TO5).	from the NoN framework.	Definition of information models, drivers and south-bound APIs to interact with APEC.
TR-UC_03-F-01	NoN	The NoN framework shall support at least the following types of technological domains: edge and cloud computing domains, NPN domain, MNO domain, NTN domain, industrial IoT domain. Such domains shall be administered by at least 3 different stakeholders.	High	PoC3	F	Support of the scenario defined for PoC3, with related technologies.	Successful experimental validation and demo of PoC3.	Definition of information models, drivers and south-bound APIs to interact with the required technology domains.

5.2.4 FLECON-6G Intelligence Layer Requirements

Table 5.4: FLECON-6G Intelligence Layer requirements

Req. ID	Category	Description	Priority	Linked PoC	Type	Rationale	Fit Criterion	Impact on FLECON-6G Architecture
TR-GEN_IL-F-01	IL	The IL must support intent interpretation from natural language into a	High	All PoCs	F	Enables tenants to express service requests using NL and interpret them	The IL should demonstrate successful translation of NL into a structured format	Enhances the ability of the system to translate user intents into machine-readable

		structured intent format				for downstream orchestration.	(e.g., TMF intent format).	actions, enabling seamless orchestration.
TR-GEN_IL-F-02	IL	The IL must provide Autonomous Domains (ADs) with Native integration of AI/ML algorithms, intent ingestion and propagation	High	All PoCs	F	Supports decentralized intelligence and intent processing across networked domains.	Each AD should exhibit AI/ML integration for intent ingestion and propagation during live demonstrations.	Improves distributed intelligence across domains, supporting autonomous operation and localized decision-making.
TR-GEN_IL-F-03	IL	Each IL AD must be able to decompose structured intent into sub-intents that can be handled by task-specific control loops	High	All PoCs	F	Facilitates detailed orchestration and multi-level policy enforcement.	Sub-intents should be visibly decomposed and handled by distinct control loops within test scenarios.	Facilitates fine-grained orchestration and coordination by enabling decomposition of intents into executable sub-components.
TR-GEN_IL-F-04	IL	The IL adopts AI models that can generalize in different scenarios and multi-stakeholder infrastructures.	High	All PoCs	F	Ensures portability and adaptability of IL decisions across domains.	AI models in the IL should generalize across distinct domains with minimal retraining.	Improves cross-domain applicability of AI-driven decisions, ensuring flexibility and reusability of intelligence functions.
TR-GEN_IL-F-05	IL	The IL adopts Trustworthy AI models offering uncertainty	High	All PoCs	F	Critical for mission assurance, minimizing errors	The IL should produce AI decisions accompanied by confidence scores	Strengthens the reliability and transparency of decisions made by

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		quantification and explainability.				and establishing trust.	and post-hoc explanations.	AI models, boosting trust.
TR-GEN_IL-F-06	IL	The IL offers intent conflict detection and resolution capabilities	High	All PoCs	F	Prevents service outages and conflict between overlapping intents.	Conflicts among overlapping intents should be detected and resolved automatically in stress-testing simulations.	Enhances operational resilience by proactively identifying and resolving conflicting service intents in real-time.
TR-GEN_IL-F-07	IL	The IL ADs support Knowledge representation, and Reasoning, and agentic AI techniques for task planning and workflow orchestration.	High	All PoCs	F	Improves autonomous decision-making and dynamic service composition.	The IL should show evidence of agent-based planning and knowledge-driven workflow execution in orchestrated services.	Improves the orchestration process with knowledge-driven reasoning and planning, to enable smarter automation and workflow execution.
TR-GEN_IL-F-08	IL	The IL must support machine-readable and actionable structured intents	Medium	All PoCs	F	The intent must adhere to a clear and unambiguous syntax that can be easily parsed and understood by the system components.	Standardized communication formats (e.g., JSON, YAML, or XML). Well-defined schema definition. Modularity, Adaptability and support for versioning	Crucial for effective automation, policy enforcement, and network behaviour management.

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TR-GEN_IL-F-09	IL	The IL must create structured definitions of trustworthy dimensions that will be used for individual service evaluation.	High TO2	All PoCs	F	IL must define trustworthy dimensions for AI services, including reliability, security, privacy, integrity, transparency, accountability, fairness, explainability, their sub-dimensions and metrics for their evaluation	Well-defined structured evaluation indicators for evaluation of trustworthy dimensions	Ensure trustworthiness and SLA compliance.
TR-GEN_IL-F-10	IL	The IL must create a trustworthy evaluation framework for evaluating the trustworthiness of collaborating services.	High TO2	All PoCs	F	IL must define a structured framework for trustworthy evaluations of AI services, assigning appropriate context-aware weights in their dimensions and producing a trustworthy index for sets of services.	Well-defined evaluation framework for fusion of trustworthy evaluations and generation of trustworthy indexes	Ensure trustworthiness and SLA compliance.
TR-GEN_IL-F-11	IL/SYS	The IL must define XAI requirements for AI services.	Medium	All PoCs	F	IL must define an XAI requirements policy for AI services to support by-design/default explainability and interpretation, especially for	Policy for well-defined XAI requirements	Compliance with European Union's AI Act, Alignment with NIST, ISO/IEC 23894:2023 (Guidance on Risk Management for AI)

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						complex AI models.		

5.2.5 FLECON-6G Network Digital Twin Framework Requirements

Table 5.5: FLECON-6G Network Digital Twin Framework requirements

Req. ID	Category	Description	Priority	Linked PoC	Type	Rationale	Fit Criterion	Impact on FLECON-6G Architecture
TR-GEN_NDT-F-01	NDT	The NDT Framework shall provide the mechanisms to support real-time inter-layer communication between lower-layer NDTs (e.g., 6G RAN, Optical Transport, NTN) and upper-layer NDTs (e.g., Slice and Service Level).	High	PoC3	F	Ensures hierarchical modelling and synchronization between lower-layer and upper-layer NDTs for optimization.	Verified real-time data exchange between layers under operational scenarios.	Facilitates accurate, multi-layer visibility and cross-domain optimization of 6G services.
TR-GEN_NDT-F-02	NDT	The NDT Framework shall provide the interfaces to allow for feedback to/from NDTs across different domains such as NTN, RAN, and transport networks.	High	PoC3	F	Ensures seamless communication and coordination across different network domains.	Verified bidirectional feedback mechanisms between NDTs in NTN, RAN, and transport networks under operational scenarios.	Facilitates the coordination between different domains and improves the accuracy of the E2E NDT.

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TR-GEN_NDT-F-03	NDT	The NDT framework shall expose its own capabilities as well as those from the available NDTs, and visibility/accessibility constraints, and NDT chaining dependencies (e.g., computing/RAN, RAN/computation).	Medium	PoC3	F	Enables dynamic discovery, orchestration, and integration of NDT components across domains, while respecting access policies and dependency chains.	Verified exposure of NDT capabilities and constraints via available interfaces, and validated chaining logic under operational scenarios.	Supports modular, composable NDT architecture with policy-aware chaining and service composition, enhancing flexibility and automation in 6G network management.
TR-GEN_NDT-F-04	NDT	The NDT Framework shall allow authorized NDTs to consume information about the capabilities, request network configurations, and retrieve reports of network behaviour.	Low	PoC3	F	Allows authorized entities to access and utilize network data effectively.	The NDT should enable authorized access to network capabilities, configurations, and reports.	Improves collaboration and information sharing among network stakeholders.
TR-GEN_NDT-F-05	NDT	The NDT Framework shall have the ability to dynamically create E2E digital twins by chaining individual NDTs which in turn use real operational data from industrial and networking processes.	High	PoC3	F	Ensures real-time representation and analysis of industrial processes.	The NDT must integrate seamlessly with data sources to create digital twins dynamically.	Enhances real-time monitoring and decision-making capabilities.

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TR-GEN_NDT-F-06	NDT	The NDT Framework must enable provisioning and lifecycle management of NDT instances across all layers (lower, upper, and slice/service).	High	PoC3	F	Supports the creation, monitoring, and management of hierarchical digital twins for comprehensive modelling.	Verified through provisioning tests and lifecycle monitoring of NDTs.	Establishes real-time lifecycle control for NDT instances to support 6G services.
TR-GEN_NDT-F-07	NDT	The NDT shall illustrate distinct logical views, including applications/services, slicing, infrastructure, and computing environments.	Low	PoC3	F	Provides clear visualization of different network aspects for better understanding.	The NDT must illustrate logical views of applications, infrastructure, and computing environments.	Enhances network transparency and aids in strategic planning.
TR-GEN_NDT-F-08	NDT	The NDT should have a capability to report the visualization-related information about its underlying network, including network topology and network traffic.	Low	---	F	Offers detailed insights into network topology and traffic patterns.	The NDT should report visualization-related information about network topology and traffic.	Improves network analysis and helps in identifying optimization opportunities.
TR-GEN_NDT-F-09	NDT	The NDT Framework shall have the capability to identify specific behaviours in the E2E network (e.g., failures, congestion, and intrusion), and	Medium	PoC3	F	Enables proactive management of network issues such as failures, congestion, and intrusions.	The NDT must detect and alert relevant stakeholders about specific network behaviours.	Facilitates timely interventions and enhances network reliability and security.

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		provide corresponding interfaces for their notification.						
TR-GEN_NDT-F-10	NDT	The NDT Framework shall be capable of injecting a networking issue on the E2E NDT as well as measure and monitor its impact.	Medium	---	F	Ensuring the NDT can inject and monitor networking issues allows for comprehensive testing and validation of network resilience and performance under various conditions.	The NDT must accurately simulate network disruptions and provide detailed metrics on their impact, ensuring reliable and repeatable testing scenarios.	Enables proactive identification and mitigation of potential network vulnerabilities.
TR-GEN_NDT-F-11	NDT	The NDT Framework shall have the capability to model the future behaviour of the E2E network in order to assess the impact of specific network configurations and policies.	Low	----	F	Assesses the impact of network configurations and policies before implementation.	The NDT should simulate future scenarios based on current data and configurations.	Supports strategic planning and optimization of network resources.
TR-GEN_NDT-F-12	NDT	The NDT Framework shall be capable of reporting the status of different metrics within the E2E network, over standard APIs, upon the configuration of specific network	Medium	PoC3	F	Provides insights into the performance and health of the network under different configurations.	The NDT must generate detailed reports on network metrics in simulated environments.	Enhances visibility into network performance and aids in fine-tuning configurations.

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		configurations and policies.						
TR-GEN_NDT-F-13	NDT	The NDT Framework shall expose the interfaces (both to external and internal components) for monitoring and verification capabilities to ensure the optimal functioning of the network.	High	PoC3	F	Maintains network integrity and performance through continuous assessment, monitoring, and validation of network operations.	Verified real-time monitoring and verification via the E2E NDT, including performance metrics, and automated compliance checks.	Enhances operational resilience and reliability, enabling proactive maintenance, rapid troubleshooting, and informed network optimization strategies.
TR-GEN_NDT-F-14	NDT	The NDT Framework must interact with the Cognitive Closed Loop Coordination Framework to process runtime configuration commands for NDTs.	High	PoC3	F	Ensures the framework can support closed-loop decision-making with dynamic updates to digital twins.	Validated runtime command delivery and application in simulated closed-loop scenarios.	Enables dynamic response and adaptation to changing network conditions.

5.2.6 FLECON-6G Cognitive Close Loop Coordination Framework Requirements

Table 5.6: FLECON-6G Cognitive Close Loop Coordination Framework requirements

Req. ID	Category	Description	Priority	Linked PoC	Type	Rationale	Fit Criterion	Impact on FLECON-6G Architecture
TR-GEN_CLC-F-01	CLC	The CLC Framework must retrieve real-time monitoring data from the NDT	High	PoC3	F	Provides accurate, up-to-date network and service data for intelligent decision-	Validated monitoring data	Enables iterative evaluation of automation

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		Framework via the Northbound API to evaluate configuration commands and their effects.				making and optimization.	retrieval in closed-loop workflows.	strategies for better decision-making.
TR-GEN_CLC-F-02	CLC	The CLC framework must send runtime configuration commands to the NDT Framework to update network settings dynamically.	High	PoC2, PoC3	F	Supports proactive and dynamic network management to adapt to real-time conditions.	Validated command delivery, execution, and feedback in simulation tests.	Implements real-time network optimization and closed-loop automation processes.
TR-GEN_CLC-F-03	CLC	The CLC Framework must be able to manage specialized loops, e.g. in automation of services, slices, network of networks, resources, to implement the logic to coordinate their decisions and actions, possibly in different time scales.	High	PoC2, PoC3	F	Supports coordination of specialized loops across services and resources, while it enables intelligent automation and consistent decision-making in complex network environments.	Orchestration of multiple specialized loops in different layers, service and resource.	Implements closed loops management and metrics retrieval requested for decision-making within the loops which target services and comprising.
TR-GEN_CLC-F-04	CLC	The CLC framework must interact with AIaaS framework for retrieving any LLM, RL, MR algorithm in	High	PoC2	F	Integrating with the AIaaS framework allows the CLC to access advanced AI algorithms for	AI models services retrieval from the AIaaS framework and use of their outputs in the	Facilitates accurate decision prediction for AI tasks within the closed loops.

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		order to generate predictions and outputs which help in decision phase of control loop.				autonomous decisions in the control loop.	Decision phase of the closed loops.	
TR-GEN_CLC-F-05	CLC	The CLC framework must use operations such as updating, inserting, retrieving policies and QoS settings configurations from Knowledge Base framework on specific API format. This action is triggered based on monitoring data and from intent reports.	High	PoC2	F	Dynamic interaction with the Knowledge Base enables the CLC to adapt policies and QoS configurations as a response to real-time monitoring, ensuring responsive and intent-driven network behaviour.	API-based requests to update, insert, and retrieve policies and QoS settings based on monitoring data or intent reports.	Enables feedback retrieval and updates performed by closed loops for policies update, based real-time monitored metrics from networks.
TR-GEN_CLC-F-06	CLC	The CLC framework must allow CLs operations - create, update, retrieve. Operations should be used by Intent Handlers and NDTs within their corresponding Closed Loops in build and monitor phases.	High	PoC2, PoC3	F	Supporting lifecycle operations (create, update, retrieve) for Closed Loops allowing interaction with other components, ensures responsive and intent-aligned automation during the build and monitoring phases.	Exposed interfaces for create, update, retrieve for CL governance.	API-based communication is implemented between CLC Framework and other components such as Intent Handler, NDT Framework, AIaaS Framework.

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5.2.7 FLECON-6G AI-as-a-Service Framework Requirements

Table 5.7: FLECON-6G AI-as-a-Service Framework requirements

Req. ID	Category	Description	Priority	Linked PoC	Type	Rationale	Fit Criterion	Impact on FLECON-6G Architecture
TR-GEN_AI-F-01	AI	The AIaaS Framework must train and deploy AI models for predictive resource management using real-time data, which can be collected directly from monitor processes or via the NDT Framework.	High	PoC2	F	Supports predictive analytics for proactive optimization of resources and services.	Verified prediction accuracy against test scenarios.	Enhances the efficiency and adaptability of automated resource allocation strategies.
TR-GEN_AI-F-02	AI	The AIaaS Framework must test the AI models against real-time maintained datasets from the corresponding layer Knowledge Base (e.g. business, service, resource).	High	PoC2	F	To ensure AI models deliver accurate, context-aware insights, they must be continuously validated against up-to-date, real-world data from each relevant knowledge layer.	AIaaS must perform AI model validation/testing based on automated retrieve and use real-time data from Knowledge Base layers (business, service, resource) and logging each test iteration of the model.	Provides up to date AI models which can ensure zero touch network operations without human interaction.
TR-GEN_AI-F-03	AI	The AIaaS Framework must store and	Medium	PoC2	F	Provide consistency between AI outputs and the underlying	The system must synchronize configurations with	Facilitates optimal search and use of service and

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		constantly update service and resource configurations and specifications with Knowledge Base and provide hierarchical support within the Knowledge Base.				infrastructure, while hierarchical support (e.g., via graph-based modelling or GNNs) enables scalable and structured knowledge representation.	the Knowledge Base and represent them in a hierarchical structure accessible via API.	resource specifications and configurations, that are coherent and consistent.
TR-GEN_AI-F-04	AI	The AIaaS Framework must provide support for Federated Learning to allow other agents to train the AI models on the framework's resources.	High	PoC2	F	Federated Learning enables distributed model training across multiple agents without centralizing data, leveraging data privacy while utilizing the framework's computing resources.	The system must allow external agents to initiate training tasks using Federated Learning preventing sharing information between agents.	Facilitates resource sharing among agents from different NoNs.
TR-GEN_AI-F-05	AI	The AIaaS Framework must integrate with Knowledge Base from Marketplace Portal component to store and update datasets, configurations, policies and service-	High	PoC2	F	Integration with the Marketplace Portal's Knowledge Base centralizes consistent management of datasets, configurations, policies, and service-resource relationships, enabling interoperability	The system must connect to the Marketplace Portal Knowledge Base and support read/write operations for datasets, configurations, policies, and service-resource mappings, with logging.	Facilitates integration and data synchronization with Marketplace Knowledge Base.

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		resource relationships.				across the AIaaS ecosystem.		
TR-GEN_AI-F-06	AI	The AIaaS Framework must be able to execute MLOps pipelines necessary for ML model deployments, training and testing processes.	High	PoC2	F	Enables automation and standardization in AI/ML model's lifecycle: training, testing, deployment stages.	Supports execution of MLOps pipelines with logs or dashboard displaying successful pipeline runs and status per model. Can be integrated with CI/CD for version control.	Facilitates automatic processes for ML algorithm lifecycle stages: training, testing and deployment on updated network data.
TR-GEN_AI-F-07	AI	The AIaaS Framework must store the ML features in a service catalog format, published and kept in synchronization with the Marketplace Catalog.	High	PoC2	F	Store ML features in a service catalog ensures discoverability and reusability across the components, e.g. in the business intent, from the Marketplace Catalog.	Synchronization of AI services on catalog driven approach with Marketplace Catalog helps compliant intent creation with AIaaS services, when requested in the business intent.	Facilitates intent creation with supported services on a specific catalog format which support intent syntax validation.
TR-GEN_AI-F-08	AI	The AIaaS Framework must leverage trustworthiness for delivering Foundation Models to the stakeholders by avoiding conflicts of interests, data leaks between the stakeholders, security policies,	High	PoC2	F	Ensuring trustworthiness in Foundation Models protects stakeholders privacy, while promoting transparency through explainability (XAI).	Enforces security policies, data leakage prevention, and explainability features integrations for root causes discoverability containing logs for all Foundation Model deliveries.	Facilitates delivery of reliable prediction, optimization, and decision automation services aligned with privacy and SLA requirements.

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		and explainability (EXplainableAI).						
TR-GEN_AI-F-09	AI	The AIaaS Framework must integrate generalizability which targets seamless deployment and usage by different stakeholders independently of their use cases, using corresponding foundation models (as template models).	High	PoC2	F	Easily deployed and used by various stakeholders across different use cases, fosters broad applicability and flexibility.	Ensures deployment and usage by multiple stakeholders.	Flexible integration of multiple, simultaneous stakeholders use cases when incorporating AI/ML models.

5.2.8 FLECON-6G Data Plane Requirements

Table 5.8: FLECON-6G Data Plane requirements

Req. ID	Category	Description	Priority	Linked PoC	Type	Rationale	Fit Criterion	Impact on FLECON-6G Architecture
TR-GEN_APEC-F-01	APEC	The APEC layer should expose API towards the application layer	High	PoC1	F	Provide a programming abstraction for applications to describe the desired processing of the data plane	Functional assessment of the programming interface	Enables simplified access to data plane acceleration of network processing

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TR-GEN_APEC-F-02	APEC	Fine-grained network telemetry framework	Medium	PoC1	F	Provide a dashboard for real-time monitoring of QoS/QoE network metrics	Validated through the design and presence of the monitoring system	Allows the visualization of the data plane performance status and immediate evaluation of KPI
TR-GEN_APEC-F-03	APEC	The APEC layer should optimize task scheduling dynamically to balance performance and energy efficiency	Medium	PoC1	F	Efficiently manage computation distribution between devices at the edge	Functional assessment based on task distribution policies and resulting energy savings	Introduces adaptive edge computing policies, critical for sustainable and scalable services
TR-UC_01-F-01	APEC	Low-latency audio and stereoscopic video acceleration at the network edge	High	PoC1	F	Ensure seamless real-time communication for XR by minimizing processing overhead	Assessment through end-to-end latency measurements and successful synchronisation of streams during XR sessions	Enhances the edge processing capabilities crucial for time-sensitive media applications and user synchronization
TR-UC_01-F-02	APEC	The APEC platform shall prioritize offloading for video rendering, encoding and user synchronization tasks	Medium	PoC1	F	Offload heavy AI-bases workloads from XR devices to edge nodes	Validation through profiling of XR devices resource usage	Optimizes device energy consumption and ensures performance across heterogeneous devices

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5.3 Non-Functional Requirements

5.3.1 System Non-Functional Requirements

Table 5.9: FLECON-6G System requirements

Req. ID	Category	Description	Priority	Linked PoC	Type	Rationale	Fit Criterion	Impact on FLECON-6G Architecture
TR-GEN_SYS-NF-01	SYS	The system must provide accessibility of objects in accordance to Open Science and FAIR principles	High Link to proposal section 1.2.9	All PoCs	NF	The system must support findability, accessibility, interoperability and reusability of all created/utilized digital objects (datasets, AI algorithms, services, tools, etc.).	Verified through discovery, accessibility and interoperability tests.	Establishes adherence to Open Science and FAIR principles, promoting reusability, reproducibility and replication of scientific results.

5.3.2 FLECON-6G Marketplace Non-Functional Requirements

Table 5.10: FLECON-6G Marketplace requirements

Req. ID	Category	Description	Priority	Linked PoC	Type	Rationale	Fit Criterion	Impact on FLECON-6G Architecture
TR-GEN_MP-NF-01		The marketplace must support authentication and authorization processes for partners - resource providers and eligible verticals	Medium	PoC1	Non-Functional	Robust authentication and authorization mechanisms are essential to securely manage access for partners providing resources	The marketplace must implement secure authentication processes to verify the identities of partner resource	This requires the integration of a secure identity management system capable of handling partner and tenant credentials, and the implementation of an

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		tenants which request NoN intent-driven deployment.				and eligible tenants requesting intent-driven deployments within the marketplace.	providers and eligible vertical tenants, and enforce granular authorization controls to ensure they can only access permitted resources and functionalities related to their roles.	authorization framework (e.g., RBAC, ABAC) to control access to marketplace resources and APIs based on user roles and permissions.

5.3.3 FLECON-6G Network of Networks Framework Non-Functional Requirements

Table 5.11: FLECON-6G NoN Framework requirements

Req. ID	Category	Description	Priority	Linked PoC	Type	Rationale	Fit Criterion	Impact on FLECON-6G Architecture
TR-GEN_NoN-NF-01	NoN	The NoN must use a distributed deployment across multiple domains, without any management plane hierarchy	High	--	NF	Enables the fully distributed view of the 6G NoN framework.	Presence of federation logical component to interact with peer resource and service domains. Availability of East-West APIs for advertisement, provisioning, monitoring and management.	Definition of fully distributed deployment models and scenarios. Definition of per domain minimal framework, services and interfaces, which can be easily replicated in different domains.

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TR-GEN_NoN-NF-02	NoN	The NoN framework shall implement authorization and authentication mechanisms.	High	--	NF	Compliance with security requirements and support of multi-tenancy.	Availability of mechanisms for Role-Based Access Control (RBAC).	Definition of roles and support of authN/authZ and RBAC mechanisms at North-bound and East-west APIs.
TR-GEN_NoN-NF-03	NoN	The NoN framework shall implement mechanisms to guarantee security and privacy	Low	--	NF	Compliance with security and privacy requirements generic for the entire FLECON-6G system.	Availability of suitable interactions with the trustworthiness evaluation framework offered by the IL	Adoption of security-by-design best practices in definition of NoN framework architecture and interfaces. Definition of interfaces towards the trustworthiness evaluation framework.

5.3.4 FLECON-6G Network Digital Twin Framework Non-Functional Requirements

Table 5.12: FLECON-6G Network Digital Twin Framework requirements

Req. ID	Category	Description	Priority	Linked PoC/UC Reqs.	Type	Rationale	Fit Criterion	Impact on FLECON-6G Architecture
TR-GEN_NDT-NF-01	NDT	The NDT Framework shall provide an accurate representation of the E2E	High	PoC3	NF	Provides a reliable and precise simulation of the network's current state.	The NDT should consistently update its model to reflect real-world changes accurately.	Improves the accuracy of network assessments and operational decisions.

		network at each point in time.						
TR-GEN_NDT-NF-02	NDT	The NDT Framework shall assist the CLC into providing stable, non-conflicting optimizations.	High	PoC3	NF	Ensures harmonized operations within deployed Closed Loops.	The NDT should provide optimizations that do not conflict with existing network policies.	Maintains operational consistency and prevents policy conflicts.

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6 Preliminary Architecture Design of FLECON-6G

The design of the FLECON-6G architecture follows an iterative methodology with three planned releases:

- Release 1 (R1), at M8, reported in this D2.1
- Release 2 (R2), at M14, to be reported in D2.2
- Release 3 (R3), at M22, to be reported in D2.3

The **first release R1**, targeted in this deliverable, starts from the definition of the use cases and the analysis of the technical requirements reported in the previous sections to identify the main layers of the architecture, their scope and functionalities, as well as the high-level procedures and functional components. In this direction, the analysis of each technical requirement has identified a preliminary impact on the FLECON-6G architecture, in terms of components, functionalities, procedures, and interfaces. This first release also identifies general principles and common design patterns to provide transversal guidelines for the internal design of the FLECON-6G components and innovations in WP3 and WP4. Moreover, through a State of the Art survey performed in these initial months of the project, the applicable standards and innovative aspects have been refined from the initial proposal. The analysis of standards evolution will continue during the entire project in order to guarantee the alignment and compatibility of the proposed solution with other systems and environments, while feeding the 6G standardization process with the main results of FLECON-6G architectural work.

The **second release R2** will enrich the first release by defining the workflows for FLECON-6G procedures and the specification of the high-level interfaces, protocols, and information models, including FLECON-6G proposals for extensions to standard interfaces. Moreover, exploiting the tight collaboration with WP3 and WP4, an internal insight into the functional components of FLECON-6G architecture layers will be provided.

The **third release R3** will provide refinements to the global architecture, considering the feedback from WP3 and WP4 implementation activities, and will identify deployment models and customization options for relevant target scenarios and stakeholders, in collaboration with WP5. Moreover, a roadmap for FLECON-6G features adoption and integration will provide concrete guidelines to progressively introduce FLECON-6G concepts into operational deployments and commercial products. The third release will also assess the matching of the technical requirements with a matrix to evaluate the level of requirements' support at the design and implementation level.

This section describes the first release of FLECON-6G architecture, presenting its architectural principles (section 6.1) and a review of the FLECON-6G innovative service and functionalities presented at the proposal stage (section 6.2). The functional architecture with the different layers is presented in section 6.3, also discussing the applicability of the relevant standards.

6.1 FLECON-6G Architectural Principles

The design of the FLECON-6G architecture is based on the following architectural design principles:

- **Distributed and federated architecture, with autonomous and interoperable domains.** This principle will allow the cooperation of different providers, where each of them can operate heterogeneous technologies and offer specialized types of services (e.g., infrastructure resources, mobile network connectivity, satellite network connectivity, edge/cloud computing, AI/ML capabilities, etc.). These providers will build dynamic and modular federations to cooperate for the joint delivery of end-to-end services. The distributed nature of the architecture will allow each provider to customize, adapt, and deploy a relevant subset of FLECON-6G components in their own environments over distributed infrastructures in the continuum. Each provider will deploy one or more autonomous instances of the FLECON-6G system components (e.g., for different technological domains), providing and consuming services from other domains through unified and open interfaces that guarantee the required level of interoperability. Federation of management systems across various operators, providers, verticals, and

other stakeholders will make use of standard interfaces and apply trust models for cross-domain interactions, including SLA exchange, negotiation, enforcement, and monitoring. While maintaining the autonomous operation within the boundaries of each administrative domain, service composition and assurance at the Network of Networks framework will follow shared inter-domain protocols to be standardized.

- **Trustworthiness and native AI integration.** The architecture will adopt AI/ML techniques pervasively in its different layers: smart marketplace, Network of Network framework at its management and control functionalities, and Intelligent Layer relying on ML models as basis for multi-layer Digital Twins and Closed Loops' internal logic. As consequence, the architecture will offer services for native support for AI/ML pipelines and AI/ML models lifecycle management (e.g., covering data ingestion, training, publishing and discovery of ML models, deployment of models or inference functions, continuous models' validation, drift detection and re-training), supporting different techniques (Reinforcement Learning, Federated Learning, etc.). These services will be used by the internal elements of the FLECON-6G system, e.g., for service and network orchestration, composition and automation in the NoN framework, as well as for service offerings selection and composition in the Smart Marketplace. Moreover, they will be offered and exposed to customers and third parties in service bundles. Due to the multi-stakeholder and collaborative characteristics of the FLECON-6G system, particular attention will be paid to aspects related to explainability and auditability, as well as security and confidentiality. Explainable AI outputs will facilitate trust among different stakeholders and compliance with AI and data-related regulations, as well as troubleshooting in case of issues with multi-domain decisions and operations. Auditability will allow to keep a trace of the AI decisions provenance and related data lineage, from origin to transfer, transformation, storage, and final consumption.
- **Support for network automation based on closed loops.** FLECON-6G architecture will support mechanisms for increasing levels of network automation through a closed loop (CL) based framework. This will imply several elements. First, a pervasive monitoring system should guarantee deep observability by collecting data from multiple sources using programmable monitoring jobs. The monitoring data should include infrastructure, network, and service KPIs, as well as traces and events. This will feed both AI techniques at the different stages (training, validation, inference, monitoring, re-training) and CL processes. Second, the framework should support unified modelling and open interfaces to design, define, and manage CLs in a modular and composable manner, with loosely coupled CL functions, possibly provided by different vendors. CLs should operate with different scopes (e.g., per domain at device, RAN, core, edge, or cross-domain, or per layer at infrastructure, virtual resources, network subnets or slices, services). Moreover, CLs should be programmable in order to decouple policy definition from CLs implementation, enabling dynamic automation policies without requiring a re-design of the CL. Third, the system should enable multi-CL coordination and collaboration via different interaction patterns, hierarchical, nested, or peer-to-peer, even across federated domains, either mediated through a CL coordination framework or with direct inter-CL communications. Fourth, the execution of CL-driven automation actions should be deterministic and verifiable, to monitor the validity and the impact of such actions and avoid potential instability or cascading failure effects, especially when applied to federated scenarios. Finally, CLs should adopt a cognitive approach applying AI/ML techniques at their different stages (potentially in all CL functions, including monitoring and execution). Optionally, the use of CLs based on agentic AI may be explored, investigating the challenges of how the active and autonomous nature of AI agents could align with the requirements of determinism, predictability, verifiability, and security of mobile networks.
- **Adoption of intent-based management patterns.** FLECON-6G architecture should adopt intents as a pillar of the entire system, enabling simplified definition of high-level goals at different layers (business, service, and resource) and supporting per-domain and cross-domain translations into specific low-level decisions and technical actions. Intents will be used at north-bound interfaces and, where applicable, east-west interfaces in support of federation. Moreover, advanced mechanisms for intent management

should be investigated, in support of bi-directional collaboration models between intent owners and handlers.

- **Openness and programmability.** The architecture will be based on open interfaces, making use of well-established models, languages, and standards for their specification and documentation (e.g., OpenAPI, YANG, TOSCA, etc.). Moreover, they will use a combination of communication patterns, e.g., based on REST API or asynchronous APIs and publish/subscribe models for event-driven or long-running processes. Service-based architecture (SBA) principles will be applied for exposing and consuming functions, services, and capabilities within and among domains, in full compliance with 3GPP principles. Modular and dynamic adapters and pluggable components will be adopted to facilitate the integration with multi-vendor technologies. Programmability and monitoring will be applied to multi-tenant and federation scenarios, guaranteeing access control among different domains and stakeholders, e.g., in terms of visibility, disclosure, isolation, arbitration for service or resource contention, and secure coexistence of conflicting services.
- **Compliance with standards and interoperability.** The architecture will adopt the latest standards from 3GPP, ETSI ZSM, NFV, MEC, TM Forum Open Digital Architecture, and GSMA Operator Platform, to ensure interoperability. Extensions to existing standards will be designed following the relevant guidelines and promoted in the target standardization bodies to achieve consensus. Moreover, the architecture will comply with relevant security frameworks (e.g., from 3GPP SA3 and ETSI NFV SEC), as well as privacy, cybersecurity, and AI regulations (GDPR, NIS2 Directive, Cyber Resilience Act, AI Act).
- **Resiliency and security.** FLECON-6G will adopt the principles of a zero-trust architecture, particularly crucial for interfaces and functions in multi-stakeholder environments. Internally in each autonomous domain, it will assume the adoption of mechanisms for security monitoring with anomaly detection capabilities and automated processes for incident response.
- **Sustainability and efficiency.** Sustainability will be enabled through specialized closed loops for optimization of energy consumption. Moreover, the smart marketplace and the Network of Networks frameworks will enable deeper levels of collaboration among stakeholders, optimizing resource utilization and service composition, thus contributing to economic sustainability aspects.

6.2 FLECON-6G Innovative Services and Functionalities

This section describes the main innovative services and functionalities offered by the FLECON-6G architecture.

Intent Management with an agentic Intent Management Function. FLECON-6G adopts intent management across different architectural layers. The architecture introduces Intent Management Functions, optionally based on agentic AI, for interpretation, management, fulfilment, and assurance of intents at the business, service, and resource level, across federated domains. Business intents are handled at the Smart Marketplace, while Service and Resource Intents are managed at the Network or Networks framework. Declarative intents are used to describe high-level goals and expected operational outcomes at the different layers, without specifying how the given expectations should be achieved. Internally, intents are continuously validated, and reconciliation processes are handled through the closed loops. Intents' descriptions are based on semantic models, leveraging TMF921 standard [10] , with a scope that is extended beyond network, computing, and infrastructure, to cover AI models, functions, and services.

***-as-a-Service Marketplace.** FLECON-6G Smart Marketplace enables the collaboration of different types of stakeholders (infrastructure owners, mobile and satellite network operators, digital service providers, AI solution providers, verticals, …) implementing mechanisms for intent-based service discovery, automated negotiation, conflict detection, and consensus convergence. The marketplace operates at the BSS level and handles business intents, translating business-level objectives and constraints to identify and select the most convenient bundle of services from the offers of all the 6G stakeholders participating in the marketplace. The marketplace is designed as a framework of intent-driven federation brokers, offering a single, unified and multi-service intent API towards the customers. Beyond the traditional infrastructure and network services (IaaS, NaaS and NIaaS),

FLECON-6G marketplace extends the offer to AIaaS, providing AI/ML models as well as AI platforms and capabilities to execute custom training, deploy models, run inference tasks, etc.

Network of Networks composition, management and exposure. FLECON-6G architecture introduces a fully distributed Network of Networks (NoN) Collaborative Framework at the OSS level. This framework enables different stakeholders to collaborate in a federated manner for the design, composition, and delivery of new networks and services, including AI/ML models and services. Externally, towards the Marketplace, the NoN framework exposes interfaces to request service intents, with constraints elaborated by the Marketplace itself, e.g., on coverage areas or target providers. Internally, it implements the end-to-end orchestration and runtime operation of ad-hoc service and network topologies spanning over multiple technological and administrative domains. Each domain may offer mobile terrestrial or satellite network resources, edge or cloud infrastructure resources, as well as other devices, security service functions, data storage capabilities, AI/ML model training, trained models, etc., which can be combined.

Distributed network intelligence. The intelligence and the logic of FLECON-6G are distributed among the various elements of the architecture and specialized for its domains and technologies. The Intelligence Layer offers AI/ML, closed loops, and (Network) Digital Twin services, provisioned and configured on demand, which can be consumed by the other layers of the architecture (i.e., marketplace and NoN framework) for assistance in making decisions and executing procedures and workflows. The scope of the network intelligence services can vary from single technological or administrative domains, up to multi-domain. In this case, suitable interfaces and federation mechanisms must be designed on the east-west boundaries to establish secure and scalable collaborations among the network intelligence systems of different stakeholders.

Multi-layer Digital Twins. FLECON-6G introduces a framework for the modelling and management of Digital Twins specialized for different types of domains and for their compositing, modelling interdependencies, and inter-domain constraints. FLECON-6G addresses digital twins for RAN, packet transport networks, Non-Terrestrial-Networks, and computing resources. (Network) Digital Twins are handled in the context of the distributed network intelligence services and they provide support to other services, e.g., planning and selection at the marketplace (for business intents) and NoN framework (for service intents), validation of CL decisions and CL coordination, conflict detection, etc.

Cognitive Closed Loops for network automation and optimization. FLECON-6G integrates a framework for governance and coordination of cognitive closed loops, which can be specialized for automation tasks and decisions at different layers, domains and scopes. FLECON-6G CL can cooperate for inter-domain and inter-layer automation, with mechanisms for conflict detection, mitigation and resolution of concurrent and contrasting CLs. The interfacing with the AIaaS system allows building and dynamically updating cognitive CLs, making use of AI/ML models, which can be handled through MLOps procedures. The cooperation with the NDT framework allows for assisting CL coordination with preliminary validation of CLs combined impact in programmable sandboxes based on NDTs.

6.3 FLECON-6G Preliminary Functional Architecture

The preliminary functional architecture of the FLECON-6G system is aligned with the architecture defined during the proposal phase, and it is reported in the following. Only minor adjustments and clarifications have been introduced in this first release, to highlight the role of the architecture components with regard to intent management and the collaboration workflow between the marketplace and NoN framework for the decomposition and fulfilment of business-level intents through multiple service intents. The internal details of the architectural blocks will be specified in release 2 (D2.2).

FLECON-6G architecture is based on three main pillars: (i) multi-layer intent management, from business down to service and resource intents, and (ii) flexible, intelligent, and fully distributed collaborative frameworks for service operations, (iii) both supported by pervasive network intelligence.

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The collaborative frameworks are organised in individual networks (e.g., RAN, satellite network, transport network, etc.), subsystems (e.g., edge platforms, NPNs), and/or technological domains. Each stand-alone element integrates its own infrastructure and resources with a full stack of control, management, orchestration, and security functions. These frameworks run over physical infrastructures that may span from devices and extreme edge up to edge and cloud resources, integrating a combination of terrestrial and non-terrestrial networks. Each framework embeds its internal logic, but it may also rely on the services of the FLECON-6G Intelligence Layer, offering Native AI, cognitive closed loops, and NDTs services. Moreover, the frameworks can be administered by various stakeholders collaborating. Different collaboration models are supported, either through the marketplace, acting as an aggregator, or via direct peer-to-peer federations between pairs of stakeholders.

The physical infrastructure adopts the technological pillars of virtualisation and network programmability to enable fine-grained control of the resources. The disaggregated and software-defined RAN/core elements follow the cloud-native approach. The split in modular micro-functions enables a flexible tuning of their composition, which can be tailored to specialized intents and service requirements. Finally, the adoption of open service-based architectures simplifies federation and collaboration among actors operating in different sectors, e.g., mobile and satellite network operators, digital service providers, etc. All these technological components constitute the baseline to compose together cloud-native network and application functions, following a multi-tenant approach. The integrated orchestration of access, core, and transport network, together with vertical applications, is optimised for the FLECON-6G multi-technology and multi-domain infrastructure continuum. FLECON-6G functional architecture is represented in Figure 6.1, with main building blocks described Table 6.1.

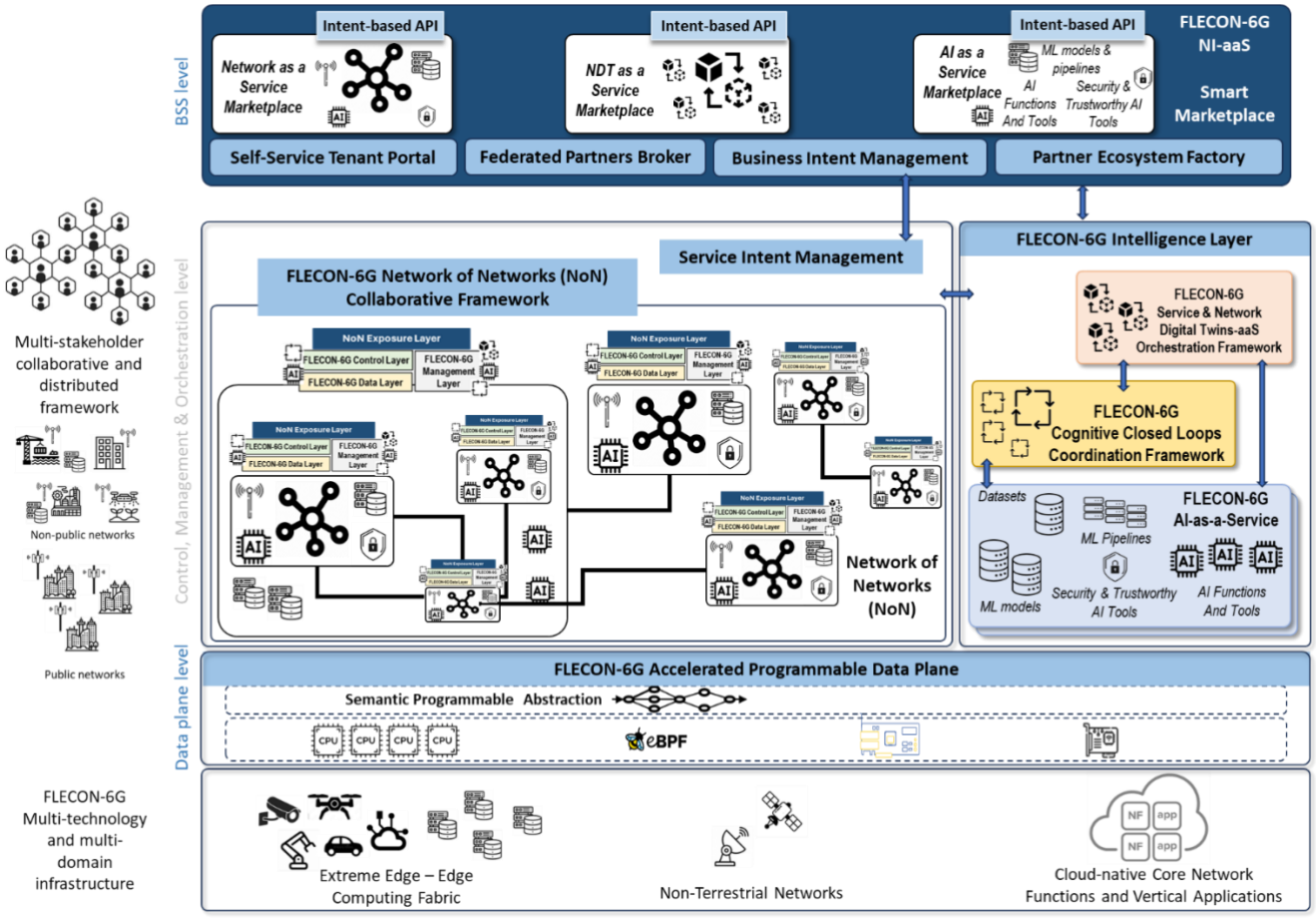

Figure 6.1: FLECON-6G functional architecture

Table 6.1: Functional architecture components

FLECON-6G component	Description
Smart Marketplace	The Smart Marketplace operates at the BSS level, to offer Network Infrastructure as a Service (NIaaS) to verticals and application developers, extended with NDTs, trustworthy AI and security tools and services, which can be discovered and consumed on-demand by vertical applications and upper layers through a North-bound, intent-based interface. Intent-driven federation, auto-negotiation and consensus convergence strategies and business implications will be considered for the various cooperation models, considering security, trustworthiness aspects and a variety of accounting and pricing processes to automate business collaborations and monetisation of added-value network services. Trustworthiness will be assessed by the Trustworthiness Evaluation Framework (TEF), which will continuously monitor and fuse trustworthy factors (e.g., privacy alignment, robustness, performance, interpretability, explainability) of network elements and services and correlate with historical trends and patterns to provide a holistic evaluation and plan contingencies. The marketplace will handle business intents, delegating Service Intent Management to the underlying NoN framework. The open interface between the two components will enable dynamic, interoperable and secure publishing, discovery, query and composition of tools, virtual functions, services and capabilities. End-to-end service design, provisioning, and delivery can involve a combination of services and resources from public and non-public networks. Internally in the marketplace, a Self-service Tenant Portal allows users with multiple roles to access their accounts and use features according to their role: partners can onboard their offerings and check settlement invoices, B2B clients can check active intents or browse the catalog, or submit new intents, developers can provide code bits (as partners) or use AIaaS from the catalog of the portal (as clients), data providers can upload data sets and check settlement (as partners). The Partner Ecosystem Factory provides features for partners' management (partner onboarding, product catalogue, contract management, SLA management). The marketplace implements federated catalog management functions needed to expose the final product offering to the end users. Business intent interpretation and ontology will be mapped to the product offering made available, based on available product (from partners). Further capacity and feasibility of each service for the selected product is managed by catalogue constraints and translated from service intent through intent management methods and dedicated knowledge base and algorithms. The GSMA Open Gateway Initiative proposes a unified API framework across operators for exposing network capabilities, laying the foundation for marketplace aggregation via northbound interfaces to developers and enterprises[11] . The TMForum has advanced the Marketplace Aggregator Model[30] in collaboration with GSMA, defining how partner capabilities can be federated and exposed through a central broker platform, with support for dynamic catalog exposure, contract management and monetization. Meanwhile, ETSI ZSM defines foundational principles for cross-domain closed loop automation and intent-based service delivery[31] , advocating for service management architectures that support dynamic federation and operation. The proposed smart marketplace advances this field by

	integrating business intents in natural language, federated catalogue exposure, partner ecosystem automation, within a unified, intent-native business orchestration fabric.
Network of Network (NoN) Collaborative framework	The FLECON-6G Network of Networks (NoN) Collaborative Framework works at the OSS level, with control, management and orchestration mechanisms a flexible, scalable, dynamic and efficient composition of 6G Networks of Networks and their improved automation, optimised and sustainable operation. In general, a 6G NoN comprises multiple capabilities, well beyond mobile connectivity. In FLECON-6G the focus is on computing in the continuum, multi-technology connectivity (including satellite), and AI/ML capabilities. In the following, a provider offering one or more of these services will be referred to as a Digital Service Provider (DSP), to highlight the heterogeneous nature of the provided services. The NoN composition, management and orchestration logic is implemented through the FLECON-6G Intelligence Layer, with intelligence services that can be embedded in each NoN framework instance or consumed from external stakeholders. The NoN framework uses Intelligence Layer services in an on-demand manner, driving the provisioning and configuration of AI/ML models or inference functions, CL and NDT instances according to the managed elements to be controlled and their sub-components, e.g., a NoN, a slice, a communication service enriched with edge computing and AI capabilities, etc. The NoN collaborative framework follows a fully distributed model, without centralized aggregation points. Each DSP participating in the federation to provide one or more types of resources and/or services deploys its own NoN framework covering its administrative domain. Each deployment includes the subset of NoN system components required to manage resources or services among the internal «technical» domains of the given DSP. Moreover, a technical domain may be handled through a specialized NoN framework instance, interacting with other instances from the same DSP through hierarchical or peer-to-peer interactions. Each DSP offers end-to-end service intents available from resources in its own administrative domain or composing services offered by federated DSPs with direct cooperations (i.e., not mediated through the aggregator at the marketplace level). The decisions about how to decompose service intents among services or resources available in its own technical domains or federated administrative domains are taken entirely at the NoN framework level, according to the boundaries and constraints set by the marketplace in the intent request. Moreover, the fulfilment and the continuous assurance of the service intent in DSP domains is entirely delegated from the marketplace to the related NoN frameworks. If a DSP domain cannot guarantee the intent fulfilment, in a temporary or permanent manner, this should be notified to the marketplace for further actions. Internally, the NoN collaborative framework implements functions for service intent management, NoN exposure (to handle direct federations with other DSPs and expose offerings and capabilities towards the marketplace), as well as NoN management and control for intra- and inter-domain services. In practice, this will imply functions for network infrastructure programmability and real-time monitoring, continuum orchestration and dynamic security services, cooperating with an integrated approach and communicating each other through a fully distributed integration fabric. On one hand, these control and management functions are applied with a deeper level of specialisation and customisation in each technical domain, e.g., to match technological constraints or optimisation criteria of the various deployments. On the other hand, they feature

	increasing levels of abstraction in the recursive composition of wider NoNs, especially when combining elements from different DSPs. The NoN Collaborative framework adopt the GSMA Operator Platform [11] as reference standard for the interaction among different DSPs with direct federation and the composition of resources from underlying technical domains in the DSP administrative domain. Inter-DSP interactions are modelled through enhanced east-west interfaces [12]], while southbound interfaces [13] [14] with suitable translation and integration functions are considered to interact with heterogeneous technical domains. In both cases, extensions beyond the current support of network and computing services will be proposed, for the horizontal federation and vertical integration of additional services, like security, data, AI, NDTs, etc.
Intelligence layer	The FLECON-6G Intelligence Layer comprises the following: • pervasive and trustworthy AI/ML driven Intent Management Functions (IMF), implementing AI algorithms for intent translation, resource allocation and function placement, end-to-end composition and predictions for proactive network and service automation; • a multitude of specialised cognitive closed loops working in concurrent mode to drive automation actions in various domains or for different objectives. For example, closed loops can be specialized for SLA or intent assurance, optimisation of energy consumption, migration of service components across edge nodes to guarantee end-to-end low latency, etc. • multi-layer Digital Twins (DTs) deployed and configured dynamically to mirror the ad-hoc service and network topologies. DTs can be used to assist in intents feasibility checks, to preliminary validate decisions of one or more closed loops, or to detect and resolve conflicts from data-driven decisions and configurations. They provide a configurable sandbox to test reconfiguration actions before their enforcement.
Accelerated Programmable Data Plane	The FLECON-6G Accelerated Programmable Data Plane operates at the data plane level, by providing a unified programmable interface to applications and services, while implementing lower-level accelerated techniques for improved traffic and service performance offloading, e.g., for ultra-low latency data processing and safety-critical virtual and augmented reality applications. The Accelerated Programmable Edge Computing (APEC) framework exposes innovative semantic programming abstractions based on application-specific processing primitives that can be executed directly in the fast data path of the network. The APEC model combines the power of CPU cores with the offloading capabilities of programmable NICs by internally implementing appropriate communication mechanisms to handle processing cooperation between host and hardware processors. The key enablers of the FLECON-6G approach are the full integration of smart network devices (SmartNICs, FPGA-based NICs) in the processing path and the use of new high-level programming models (e.g. data stream processing) together with domain-specific languages (e.g. eBPF) and specialised compilers for specific hardware. APEC represents an evolution of the In-Network Computing (INC) paradigm, targeting unprecedented packet processing speeds and latency reductions. INC marks a significant architectural shift, relocating computation from terminal hosts to the network core and thereby challenging the long-held end-to-end principle.

	The growing adoption of INC is supported by research demonstrating its advantages in performance and resource efficiency across use cases such as distributed caching [15] , RPC acceleration [16] , congestion control [17] , security [18] , gateway design [19] , network monitoring [20] , machine learning [21] , and load balancing [22] . Other research works focus on making INC easier to program. They tackle this by making it work across different hardware types [23] , by making the code more modular [24] , by distributing resources [25] , and by creating better programming abstractions [26] . Finally, a separate group focuses on the hardware side, building new systems [27] , creating new hardware features [28] , and adding new capabilities through APIs [29] .

7 Conclusions

This deliverable has provided the foundational groundwork for the development of the FLECON-6G platform, delivering key results that advance the project's strategic objectives. It consolidates a structured and traceable set of functional and non-functional requirements, defines a comprehensive framework for Key Performance Indicators (KPIs) and Key Value Indicators (KVIs), and presents an initial definition of use cases and Proof-of-Concept (PoC) scenarios, along with a preliminary architecture design. These outputs collectively contribute to shaping a flexible, open, and AI-native 6G platform designed for distributed, multi-stakeholder, and multi-domain operation.

Beyond technical detailing, this deliverable brings forward a design approach that is value-driven and impact-aware from the outset. The definition of KPIs and KVIs enables early alignment between technical features and societal or economic relevance—linking FLECON-6G's architectural pillars (e.g., AI-native orchestration, Network Digital Twins, and a modular Network of Networks framework) to business and sustainability metrics such as energy efficiency, automation, service availability, fairness, and trust. The four PoC scenarios, representing diverse vertical needs, provide the contextual grounding to ensure architectural applicability and to drive requirement validation with user-centred evidence.

Importantly, this deliverable marks a starting point in an iterative technical and architectural process. Its outputs will be further detailed and validated in the upcoming deliverables—D2.2 Initial FLECON-6G Architecture, D3.1 Frameworks for Collaborative and Distributed 6G Network of Networks, and D4.1 NDT Architecture Prototyping—which will refine and expand the functional architecture, define cross-domain orchestration workflows, and integrate zero-touch and AI-native automation mechanisms. These steps will be underpinned by progressive PoC implementation and system-level testing.

As the project moves forward, future work will focus on iterative requirement validation, deepening of the architectural design, and evaluation of both performance and value in real-world testbeds. The progressive operationalisation of core FLECON-6G concepts—trustworthy AI, sustainable multi-domain orchestration, and federated intelligence—will underpin the platform's contribution to Europe's strategic leadership in 6G and digital sovereignty.

Finally, it must be noted that several components and their interdependencies remain under active design and exploration. Their complete definition and validation will be addressed in the next iterations of WP2, as well as through the development activities of WP3 and WP4. These deliverables will collectively provide a cohesive and technically validated architecture, paving the way for large-scale, standards-aligned experimentation and evaluation in WP5.

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8 References

[1] M. Dieudonne, H. Wang, I. Mesogiti, and E. Kosmatos, “Beyond 5G/6G KPI Measurements,” 2023, doi: 10.5281/ZENODO.7963247.

[2] L. Nielsen et al., “Beyond 5G/6G KPIs and Target Values,” Jun. 2022, doi: 10.5281/ZENODO.6577506.

[3] G. Wikström et al., “What societal values will 6G address?,” May 2022, doi: 10.5281/ZENODO.6557534.

[4] HEXA-X II, “Deliverable 1.3: Environmental and social view on 6G,” Smart Networks and Services Joint Undertaking. [Online]. Available: https://hexa-x-ii.eu/wp-content/uploads/2024/03/Hexa-X-II_D1.3_v1.00_GA_approved.pdf

[5] FIDAL, “Deliverable 2.1: Requirements, Architecture And Methodologies (Initial Version),” Smart Networks and Services Joint Undertaking. [Online]. Available: https://fidal-he.eu/public-deliverables/d-21-fidal-requirements-architecture-and-methodologies-initial-version

[6] CENTRIC, “Deliverable 5.1: Early results on KPIs/KVIs, testing methodologies and benchmarking,” Smart Networks and Services Joint Undertaking. [Online]. Available: https://zenodo.org/records/10473249

[7] SAFE-6G, “Deliverable 2.4: 6G Trustworthiness KPI & KVI definition and validation methodology,” Smart Networks and Services Joint Undertaking. [Online]. Available: https://zenodo.org/records/14943206

[8] “THE 17 GOALS | Sustainable Development.” Accessed: Jan. 30, 2025. [Online]. Available: https://sdgs.un.org/goals

[9] ITU-R, ITU-R M.2410-0 (11/2017) - Minimum requirements related to technical performance for IMT-2020 radio interface(s), Geneva., 2017. [Online]. Available: https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2410-2017-PDF-E.pdf

[10] TM Forum, TMF921, Intent Management API User Guide v5.0.0, April 2024. [Online]. Available: https://www.tmforum.org/resources/specifications/tmf921-intent-management-api-user-guide-v5-0-0/

[11] GSMA, OPG.02, Operator Platform: Requirements and Architecture, v8.0, February 2025

[12] GSMA, OPG.04, East-Westbound Interface APIs, v6.0, February 2025

[13] GSMA, OPG.03, Southbound Interface Network Resources APIs, v4.0, February 2024

[14] GSMA, OPG.08, Southbound Interface for Operation, Administration and Maintenance APIs, v1.0, February 2024

[15] X. Jin et al., "NetCache: Balancing Key-Value Stores with Fast In-Network Caching," in Proc. 26th ACM Symp. Oper. Syst. Princ. (SOSP), 2017.

[16] B. Zhao, W. Wu, and W. Xu, "NetRPC: Enabling In-Network Computation in Remote Procedure Calls," in Proc. 20th USENIX Symp. Netw. Syst. Des. Implement. (NSDI), 2023.

[17] Y. Li et al., "HPCC: High Precision Congestion Control," in Proc. ACM SIGCOMM, 2019.

[18] J. Xing, W. Wu, and A. Chen, "Ripple: A Programmable, Decentralized Link-Flooding Defense Against Adaptive Adversaries," in Proc. USENIX Secur. Symp., 2021.

[19] T. Pan et al., "Sailfish: Accelerating Cloud-Scale Multi-Tenant Multi-Service Gateways with Programmable Switches," in Proc. ACM SIGCOMM, 2021.

[20] Z. Liu et al., "One Sketch to Rule Them All: Rethinking Network Flow Monitoring with UnivMon," in Proc. ACM SIGCOMM, 2016.

[21] A. Sapio et al., "Scaling Distributed Machine Learning with In-Network Aggregation," in Proc. 18th USENIX Symp. Netw. Syst. Des. Implement. (NSDI), 2021.

[22] R. Miao et al., "SilkRoad: Making Stateful Layer-4 Load Balancing Fast and Cheap Using Switching ASICs," in Proc. ACM SIGCOMM, 2017.

[23] J. Gao et al., "Lyra: A Cross-Platform Language and Compiler for Data Plane Programming on Heterogeneous ASICs," in Proc. ACM SIGCOMM, 2020.

[24] H. Soni et al., "Composing Dataplane Programs with µP4," in Proc. ACM SIGCOMM, 2020.

[25] N. Sultana et al., "Flightplan: Dataplane Disaggregation and Placement for P4 Programs," in Proc. 18th USENIX Symp. Netw. Syst. Des. Implement. (NSDI), 2021.

© FLECON-6G, 2025

[26] W. Xu et al., "ClickINC: In-network Computing as a Service in Heterogeneous Programmable Data-center Networks," in Proc. ACM SIGCOMM, 2023.
[27] M. Yang et al., "Using Trio: Juniper Networks' Programmable Chipset for Emerging In-Network Applications," in Proc. ACM SIGCOMM, 2022.
[28] V. Shrivastav, "Stateful Multi-Pipelined Programmable Switches," in Proc. ACM SIGCOMM, 2022.
[29] D. Kim et al., "TEA: Enabling State-Intensive Network Functions on Programmable Switches," in Proc. ACM SIGCOMM, 2020.
[30] TMForum, IG1396 Zero Touch Partnering for Open Gateway, v3.0.0, https://www.tmforum.org/resources/technical-specification/ig1396-zero-touch-partnering-for-open-gateway-v3-0-0/
[31] ETSI GS ZSM 016 v.1.1.1, Zero touch Network and Service Management, Intent-driven closed loops, https://www.etsi.org/deliver/etsi_gs/ZSM/001_099/016/01.01.01_60/gs_ZSM016v010101p.pdf

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Annex I FLECON-6G's Key Performance Indicators

Table 8.1: KPI-CAP-01 Capacity: Peak Data Rate

KPI Field	Description
Category	Capacity
Name	Peak Data Rate
ID	KPI-CAP-01
Definition	Maximum achievable data rate under ideal conditions per user/device. The received data bits assuming error-free conditions assignable to a single mobile station, when all assignable radio resources are utilized.
How	Measurement in controlled environment with optimal signal conditions using signal generators and network analysers.
Baseline value (units)	20 Gbps (Downlink), 10 Gbps (Uplink)
Target value (units)	1000 Gbps (Downlink), 500 Gbps (Uplink)
Standard	ITU-R M.2410-0 [9] 3GPP TS 38.306

Table 8.2: KPI-CAP-02 Capacity: User Experienced Data Rate

KPI Field	Description
Category	Capacity
Name	Experienced Data Rate
ID	KPI-CAP-02
Definition	Data rate that is achievable for users in real-world environments. Defined as the 5% point of the cumulative distribution function (CDF) of the user throughput.
How	Statistical measurement in various environments and under different network loads. Field measurements using drive tests and crowd-sourced data collection.
Baseline value (units)	5G: 0.1 Gbps (Downlink), 0.05 Gbps (Uplink)
Target value (units)	1 Gbps (Downlink), 0.5 Gbps (Uplink)
Standard	ITU-R M.2410-0, 3GPP TR 38.913

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Table 8.3: KPI-CAP-03 Capacity: Service Bandwidth

KPI Field	Description
Category	Capacity
Name	Service Bandwidth
ID	KPI-CAP-03
Definition	Amount of spectrum dedicated to a specific service or application.
How	Spectrum analyser measurements and service quality monitoring.
Baseline value (units)	5G FR1: up to 100 MHz, FR2: up to 400 MHz
Target value (units)	Dynamic allocation based on service needs with guaranteed minimum bandwidth
Standard	3GPP specifications

Table 8.4: KPI-CAP-04 Capacity: Area Traffic Capacity

KPI Field	Description
Category	Capacity
Name	Area Traffic Capacity
ID	KPI-CAP-04
Definition	Total traffic throughput served per geographic area.
How	Aggregated measurements across multiple base stations in defined area.
Baseline value (units)	5G: 10 Mbps/m²
Target value (units)	1 Gbps/km²
Standard	ITU-R M.2410-0, Beyond 5G/6G KPIs whitepaper

Table 8.5: KPI-CAP-05 Capacity: Connection Density

KPI Field	Description
Category	Capacity
Name	Connection Density

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ID	KPI-CAP-05
Definition	Number of connected devices per unit area that can be supported under specified QoS.
How	Statistical count of active connections in test environments. System-level simulation following M.2412 methodology.
Baseline value (units)	5G: 1 million devices/km²
Target value (units)	10 million devices/km²
Standard	ITU-R M.2410-0, 3GPP TS 22.261

Table 8.6: KPI-LAT-01 Latency: User Plane Latency

KPI Field	Description
Category	Latency
Name	User Plane Latency
ID	KPI-LAT-01
Definition	Time taken to deliver a packet from source to destination through the user plane.
How	End-to-end packet transmission time measurement with precision timestamping at endpoints.
Baseline value (units)	5G URLLC: 1 ms
Target value (units)	< 100 µs
Standard	3GPP TS 38.913, ITU-R M.2410-0

Table 8.7: KPI-LAT-02 Latency: Control Plane Latency

KPI Field	Description
Category	Latency
Name	Control Plane Latency
ID	KPI-LAT-02
Definition	Time required for a device to transition from idle to active state.

How	Measurement of state transition time in test environments.
Baseline value (units)	5G: 20 ms (10 ms encouraged)
Target value (units)	< 10 ms
Standard	3GPP TS 38.913

Table 8.8: KPI-LAT-03 Latency: E2E Service Latency

KPI Field	Description
Category	Latency
Name	End-to-End Service Latency
ID	KPI-LAT-03
Definition	Total time from user request to service response including all network and processing delays.
How	Complete service request-response cycle measurement in test environments.
Baseline value (units)	5G: 10 ms (eMBB)
Target value (units)	< 1 ms for ultra-reliable services
Standard	Beyond 5G/6G KPIs whitepaper

Table 8.9: KPI-LAT-04 Latency: Service Setup Delay

KPI Field	Description
Category	Latency
Name	Service Setup Delay
ID	KPI-LAT-04
Definition	Time needed to establish a service after the initial request.
How	Measurement from service request to first usable data.
Baseline value (units)	5G: 50 ms
Target value (units)	< 10 ms
Standard	5G-PPP phase III projects

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Table 8.10: KPI-LAT-05 Latency: Slice Setup Delay

KPI Field	Description
Category	Latency
Name	Slice Setup Delay
ID	KPI-LAT-05
Definition	Time required to establish a new network slice.
How	Measurement from slice request to operational status.
Baseline value (units)	5G: 10-30 s
Target value (units)	< 1 s
Standard	3GPP specifications

Table 8.11: KPI-LAT-06 Latency: Runtime Delay

KPI Field	Description
Category	Latency
Name	Runtime Delay
ID	KPI-LAT-06
Definition	Processing time for computational tasks in the network.
How	Measurement of computational processing time in edge and cloud infrastructure.
Baseline value (units)	5G: 20-50 ms
Target value (units)	Dependent on application type, generally < 5 ms
Standard	N/A

Table 8.12: KPI-PL-01 Packet Loss: Packet Error Rate

KPI Field	Description
Category	Packet Loss
Name	Packet Error Rate

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ID	KPI-PL-01
Definition	Percentage of packets containing errors in transmission. Critical for URLLC applications.
How	Statistical error detection in test traffic using error-detection protocols (e.g., CRC).
Baseline value (units)	5G URLLC: 10^-5
Target value (units)	< 10^-9 for URLLC
Standard	3GPP TS 38.913, ITU-T G.7710

Table 8.13: KPI-PL-02 Packet Loss: Packet Loss Rate

KPI Field	Description
Category	Packet Loss
Name	Packet Loss Rate
ID	KPI-PL-02
Definition	Percentage of packets that fail to reach their destination.
How	Statistical analysis of sent vs. received packets.
Baseline value (units)	5G: 10^-5
Target value (units)	< 10^-7
Standard	Beyond 5G/6G KPIs whitepaper

Table 8.14: KPI-COM-01 Compute: Computational Resource Usage

KPI Field	Description
Category	Compute
Name	Computational Resource Usage
ID	KPI-COM-01
Definition	Utilization level of computing resources in the network.
How	Resource monitoring in network nodes and edge computing facilities via telemetry APIs.

Baseline value (units)	5G: 40-50% utilization
Target value (units)	Optimal utilization of 70-80% without performance degradation
Standard	ETSI NFV-MAN 001

Table 8.15: KPI-COM-02 Compute: Operation Expenditure

KPI Field	Description
Category	Compute
Name	Operation Expenditure
ID	KPI-COM-02
Definition	Cost associated with running computational resources in the network.
How	Financial analysis of operational costs.
Baseline value (units)	5G OPEX baseline
Target value (units)	50% reduction compared to traditional non-optimized deployments
Standard	N/A

Table 8.16: KPI-COM-03 Compute: Availability

KPI Field	Description
Category	Compute
Name	Computational Availability
ID	KPI-COM-03
Definition	Percentage of time computational resources are available and operational.
How	Uptime monitoring and service availability tracking.
Baseline value (units)	5G: 99.99%
Target value (units)	> 99.999% for critical infrastructure
Standard	N/A

Table 8.17: KPI-COM-04 Compute: Resource Utilisation

KPI Field	Description
Category	Compute
Name	Resource Utilisation
ID	KPI-COM-04
Definition	Efficiency of computational resource usage across the network.
How	System-wide monitoring of compute resource allocation vs. utilization.
Baseline value (units)	5G: 0.6 (60% efficiency)
Target value (units)	> 0.85 (85% efficiency)
Standard	N/A

Table 8.18: KPI-COM-05 Compute: Scale-out latency

KPI Field	Description
Category	Compute
Name	Scale-out Latency
ID	KPI-COM-05
Definition	Time required to provision additional computational resources in response to demand.
How	Measurement of time from scale-out trigger to resource availability.
Baseline value (units)	5G: 30 s
Target value (units)	< 5 s for most services, < 1 s for critical services
Standard	N/A

Table 8.19: KPI-SEC-01 Security: Anomaly Detection Precision

KPI Field	Description
Category	Security
Name	Anomaly Detection Precision

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ID	KPI-SEC-01
Definition	Accuracy of identifying security threats and network anomalies.
How	Testing with labeled attack datasets in controlled environments.
Baseline value (units)	95% true positive rate
Target value (units)	> 99.9% true positive rate with < 0.1% false positive rate
Standard	NIST SP 800-53, ISO/IEC 27001

Table 8.20: KPI-SEC-02 Security: Security Conformance

KPI Field	Description
Category	Security
Name	Security Conformance
ID	KPI-SEC-02
Definition	Compliance with security standards and protocols.
How	Security audits and compliance assessments.
Baseline value (units)	5G: 95% compliance with relevant security standards
Target value (units)	100% compliance with relevant security standards
Standard	

Table 8.21: KPI-SEC-03 Security: Tenant Data Privacy

KPI Field	Description
Category	Security
Name	Tenant Data Privacy
ID	KPI-SEC-03
Definition	Level of isolation and protection for multi-tenant data.
How	Penetration testing and privacy impact assessments.
Baseline value (units)	5G: GDPR compliance with limited cross-tenant protection

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Target value (units)	Complete data isolation between tenants with zero cross-tenant data exposure
Standard	GDPR

Table 8.22: KPI-SVC-01 Service: Availability

KPI Field	Description
Category	Service
Name	Availability
ID	KPI-SVC-01
Definition	Percentage of time services are available to users.
How	Uptime monitoring via SLA tracking tools.
Baseline value (units)	5G: 99.9% ("three nines")
Target value (units)	99.9999% ("six nines")
Standard	ITU-T Y.1541, 3GPP TS 28.552

Table 8.23: KPI-SVC-02 Service: Reliability

KPI Field	Description
Category	Service
Name	Reliability
ID	KPI-SVC-02
Definition	Consistency of service performance over time.
How	Statistical analysis of service failures over time.
Baseline value (units)	5G: Mean Time Between Failures (MTBF) of 3 months
Target value (units)	MTBF > 1 year for network services
Standard	N/A

Table 8.24: KPI-SVC-03 Service: Service safety, integrity, maintainability

KPI Field	Description
Category	Service
Name	Service Safety, Integrity, Maintainability
ID	KPI-SVC-03
Definition	Composite measure of service robustness, data integrity, and ease of maintenance.
How	Combined assessment of safety incidents, integrity violations, and maintenance metrics.
Baseline value (units)	5G: Manual intervention required for most maintenance tasks
Target value (units)	High level of safety with minimal manual intervention required
Standard	N/A

Table 8.25: KPI-SVC-04 Service: CAPEX & OPEX Reduction

KPI Field	Description
Category	Service
Name	CAPEX & OPEX Reduction
ID	KPI-SVC-04
Definition	Reduction in capital and operational expenditures compared to previous generation networks.
How	Financial analysis of deployment and operational costs.
Baseline value (units)	5G deployment and operational costs
Target value (units)	30% CAPEX reduction, 50% OPEX reduction compared to 5G
Standard	N/A

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