



LEARNING-DRIVEN AND
EVOLVED RADIO FOR 6G
COMMUNICATION SYSTEMS

D7.1 – Prototype Plan and Evaluation Methodology

31/08/2025



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Abstract	D7.1 defines the evaluation methodology and integration planning for the five Proof-of-Concepts. It outlines KPI-driven monitoring, validation, and demonstration processes aligned with the project's innovation pillars. D7.1 also details the test environments, roles, schedules, and risk mitigation strategies. This framework supports the execution of PoCs and sets the basis for future deliverables D7.2 and D7.3.
Keywords	PoC planning, Evaluation methodology, KPI validation, Monitoring framework, Demonstrator integration, Testbed deployment, Phase-based execution, TRL, Risk mitigation, Performance assessment, Innovation pillars, 6G architecture.



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ABBREVIATIONS AND ACRONYMS

3GPP	Third Generation Partnership Project
5G	Fifth Generation
5QI	5G QoS Identifier
6G	Sixth Generation
ADC	Analog to Digital Converter
AI	Artificial Intelligence
AirComp	Air Computation
AoI	Age of Information
AR	Augmented Reality
ARM	Advanced RISC Machine
ARNO	Advanced Research on NetWorking
ASCII	American Standard Code for Information Interchange
B5G	Beyond 5G
CA	Consortium Agreement
CM	Conflict Manager
CN	Core Network
CPU	Central Processor Unit
CU	Central Unit
dApp	Distributed Application
DL	Down Link
DPU	Data Processing Unit
DU	Distributed Unit
E2E	End to End
EE	Energy Efficiency
EM	Energy Management
eMBB	Enhanced Mobile Broadband
EMF	Electromagnetic Field
EMS	Energy Manager Saving
ER	Expected Result
ES	RAN defined Energy Saving
EuCNC	European Conference on Networks and Communications
FA	Fluid Antenna
FDD	Full Duplexing Division
FLOPS	Floating Point Operations Per Second
FR	Frequency Range
GA	General Agreement
gNB	next-generation Node B
GNSS	Global Navigation Satellite System

GPS	Global Position System
GPU	Graphic Processor Unit
HD	Hard Disk
HW	Hardware
IA	Innovation Action
ID	Identification
IMU	Inertial Measurement Unit
INT	In-Band Telemetry
IoT	Internet of Things
IP	Internet Protocol
IPR	Intellectual Property Rights
JSON	JavaScript Object Notation
KER	Key Exploitable Result
khW	kilowatt-hours
KPI	Key Parameter Indicator
KPM	Key Parameter Measurement
KVI	Key Value Indicator
LoRa	Long Range
LTE	Long Term Evolution
MIG	Multi-Instance GPU
MIMO	Multiple Input Multiple Output
ML	Machine Learning
MNO	Mobile Network Operator
MS	Milestone
MSE	Mean Squared Error
MWC	Mobile World Congress
NB-IoT	Narrow Band IoT
NIC	Network Interface Card
NOMA	Non-Orthogonal Multiple Access
NR	New Radio
O-CU	Open Central Unit
O-DU	Open Distributed Unit
OFDM	Orthogonal Frequency Division Multiplexing
OFH	Open Front Haul
ORAN	Open RAN
O-RU	Open Radio Unit
OTA	Over The Air
PC	Project Coordinator
PHY	Physical (layer)
POC	Proof-of-Concepts
PPDR	Public Protection and Disaster Relief
PRB	Physical Resource Block

QCI	QoS Class Identifier
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
rApp	RAN Application
RF	Radio Frequency
RIC	RAN Intelligent Controller
RIS	Reconfigurable Intelligent Surface
RRU	Remote Radio Unit
RT	Real Time
SDN	Software-Defined Networking
SHO	Smart Handover
SNR	Signal to Noise Ratio
SNS JU	Smart Networks and Services Joint Undertaking
SOTA	State of the Art
SSB	Synchronization Signal Block
SW	Software
TCP	Transmission Control Protocol
TDD	Time Division Duplexing

TDP	Thermal Design Power
TGW	Telemetry Gateway
TM	Technical Manager
TRL	Technology Readiness Level
TS	Traffic Steering
UAV	Unmanned Aerial Vehicles
UDP	User Datagram Protocol
UE	User Equipment
UL	Up Link
UMi	Urban Micro
URLLC	Ultra-Reliable Low-Latency Communication
USB	Universal Serial Bus
USRP	Universal Software Radio Peripheral
VR	Virtual Reality
WiFi	Wireless Fidelity
WP	Working Package
xApp	Extensible Application
XR	eXtended Reality

EXECUTIVE SUMMARY

This Deliverable, **D7.1: PROTOTYPE PLAN AND EVALUATION METHODOLOGY** defines the evaluation methodology and planning framework for the five Proof-of-Concepts (PoCs) that will be developed within the **6G-LEADER** project. Its main objective is to establish a common, structured approach to assess and demonstrate the technological innovations across the project's strategic focus areas. The methodology outlined here ensures that the evaluation and validation activities are coherent, consistent, and aligned with the broader goals of **6G-LEADER** specifically, the advancement of AI/ML-driven radio access, semantic communications, novel antenna designs, and energy-efficient multi-access techniques. The final goal is to deliver measurable outcomes that support the project's technical conclusions and feed into future deployments and standardisation efforts.

The five PoCs are designed to reflect and validate the seven core innovation pillars of **6G-LEADER** described in detail in chapter 2. They serve as practical implementations that align each PoC with the project's strategic objectives. Each PoC targets specific pillars, ensuring that key advancements—such as AI/ML integration, semantic communications, and novel RF components—are demonstrated and evaluated in realistic settings. A consistent mapping has been established between the project's reference architecture, each PoC implementation, and the corresponding KPIs, ensuring that every technical component is evaluated within a coherent and goal-driven framework.

The planning of the PoCs is organised into two major phases. Phase A will focus on the integration of components, alignment with the test environments, and early validation of system readiness. Phase B will consolidate the implementation, including full-scale testing and live demonstrations. Each PoC will follow a tailored development plan that includes defined responsibilities, intermediate milestones, and contingency strategies. The planning also includes provisions for risk monitoring and stakeholder coordination to ensure timely delivery and quality outcomes.

The PoCs will be deployed across four dedicated testbeds contributed by consortium partners, each supporting different innovation pillars of **6G-LEADER**. The CNIT ARNO testbed will enable semantic communication experiments and AI-driven edge computing; DICAT's SONIC Labs will support O-RAN-based RIC development and conflict management; MB's setup will be tailored for RIS-based FR3 beamforming; UC3M's testbed will focus on fluid antennas and reconfigurable RF hardware; and SRS's RAN platform will enable integration of novel PHY techniques. Together, these environments will provide the technical foundation for testing, validating, and demonstrating the full spectrum of innovations across the project.

The evaluation methodology is structured into three sequential stages: data and metrics collection, validation, and demonstration. First, KPIs and metrics relevant to each PoC will be defined, and corresponding data collection frameworks will be put in place to support consistent tracking. Next, the validation phase will verify whether each PoC performs as intended, confirming that the observed behaviour matches expected outcomes under various scenarios. Finally, the

demonstration phase will showcase the PoC capabilities in realistic environments, aiming to present the practical relevance of the developed solutions to internal and external stakeholders. Each stage is designed to support decision-making and technical learning across the project.

The key output of this document is a comprehensive execution and validation plan for all the PoCs. This plan provides a unified approach to assess progress, identify risks, and demonstrate the technical readiness of each solution. Through this plan, the project guarantees that its innovations are tested in a consistent and transparent manner, supporting the credibility of the findings and maximising their relevance for the future of 6G networks.

1 Introduction

Deliverable D7.1 of the **6G-LEADER** project covers the execution of three main works regarding the prototype descriptions and their architecture definitions; the development plans, and finally, the evaluation and validation methodologies for the five Proof-of-Concepts (PoCs) to demonstrate the project's key innovations. These PoCs are designed to bring together the technical work from earlier stages of the project and test it in real-world or close-to-real-world environments. This deliverable is the first step toward validating the practical applicability of the theoretical developments across Working Packages (WP) 3-6.

The **6G-LEADER** project focuses on several new technologies that shape the future of 6G networks, these include Artificial Intelligence (AI) for smarter network decisions, new types of antennas like Fluid Antennas (FA) and Reconfigurable Intelligent Surfaces (RIS), more efficient ways of spectrum sharing, and the use of semantic information to reduce unnecessary data transmission. D7.1 describes how the consortium plans to test these ideas, what is expected to measure, and how the results will be evaluated to meet the project's goals.

To do this, a clear and common methodology is needed so that all PoCs are evaluated in the same way. This includes not only defining what is being tested (like latency, energy use, or data rates) but also how and where the tests will happen, what equipment will be used, and how the results will be collected and analysed. This ensures that the evaluations are fair, meaningful, and useful for guiding the remainder of the project.

This document also helps PoC leaders to keep the project on track. It sets the stage for how the PoCs will be monitored, how progress will be checked, and how any issues will be managed. It connects the technical work done in WPs 3 to 6 with the practical demonstrations that happen in WP7, making sure everything is aligned and working toward the same goals.

The following sections describe the main scope and objectives of the deliverable, and how it is linked to other parts of the **6G-LEADER** project, while the last section describes in detail the document structure.

1.1 Scope and objectives of D7.1

The primary objective of Deliverable D7.1 is to define a detailed and coherent prototype development and evaluation plan for the five selected PoCs envisioned within the **6G-LEADER** project. This document sets the basis for an aligned approach, ensuring demonstrators reflect the partners' interests and project innovation pillars.

Specifically, D7.1 aims to:

- Provide a structured plan for the preparation, set-up, integration, and evaluation of demonstrators.
- Define common evaluation methods and criteria that will be applied across all five PoCs, ensuring consistency and comparability.
- Outline a clear roadmap for monitoring progress and ensuring the timely execution of tasks related to the demonstrators and PoCs.
- Assess and document the Technology Readiness Levels (TRLs) of individual **6G-LEADER** components, validating their readiness for integration into each PoC.
- Develop a general specification framework encompassing testing and piloting activities, focused on demonstrating and validating the core **6G-LEADER** innovations.

The document provides the necessary framework to identify critical challenges within each PoC scenario, describe how these challenges are addressed by specific functionalities and services of the **6G-LEADER** ecosystem, and establish methodologies for measuring expected outcomes against the project's targeted KPIs.

1.2 Relationship to Task 7.1 and to WP3–6 developments

The deliverable D7.1 presents the results and plans derived from Task 7.1, which plays a crucial role in connecting technological developments across Work Packages 3 through 6 to practical demonstrations and validations. Task 7.1 essentially forms the bridge that translates the project's research innovations into concrete PoCs, ensuring they are realistically tested, integrated, and evaluated.

WP3 primarily focuses on developing advanced physical layer techniques using Machine Learning (ML), predictive algorithms, and semantics-driven communication. These innovations include predictive channel estimation, improved beam management, and Over-the-Air Computation (AirComp) techniques, aiming for greater spectral efficiency and reduced communication overhead. The role of Task 7.1 is to define clear methodologies and test scenarios where these new PHY technologies can be practically evaluated, validating their effectiveness against established Key Performance Indicators (KPI)s in real-world scenarios. These WP3 innovations will be demonstrated in multiple PoCs: predictive channel estimation and AI/ML-enhanced PHY techniques will be validated in PoC#1 and PoC#5, while AirComp methods and associated PHY-layer improvements will be tested in PoC#4.

WP4 introduces novel antenna concepts and efficient multiple-access schemes, including FAs and RISs, aiming for enhanced energy and spectral efficiency. Task 7.1 closely interacts with WP4, specifying scenarios and tests that demonstrate the real-world feasibility and advantages of these antenna technologies. By preparing PoC scenarios that clearly incorporate these antenna innovations, Task 7.1 ensures that practical evaluations will accurately reflect the

benefits claimed by WP4 developments. Specifically, the RIS-related designs will be validated in PoC#2, while Fluid Antenna (FA) technologies and multiple access techniques will be demonstrated in PoC#5.

WP5 develops semantics-empowered networking solutions, focusing on significantly reducing data transmission by removing redundant or unnecessary information. This approach aims to boost efficiency and sustainability in network operation. Within Task 7.1, clear test specifications and evaluation methods are defined to measure and demonstrate the real-world impact of semantics-based communication solutions, ensuring the PoCs authentically validate these innovations under realistic operational conditions. These solutions will be demonstrated in PoC#1, PoC#3, and PoC#4, where semantic filtering, control-plane optimisation, and goal-oriented data processing are key components of the system evaluation.

WP6 enhances Open RAN (O-RAN) functionalities through intelligent, AI-driven semantic modules and advanced conflict management techniques. These components support smarter and more efficient network management through semantic awareness and sophisticated decision-making loops. Task 7.1 ensures these enhancements are effectively tested within the PoCs by setting detailed integration plans and performance evaluation methodologies. This will provide robust validation of the semantic-driven O-RAN enhancements, demonstrating their operational readiness and practical effectiveness. These innovations will be showcased in PoC#3 and PoC#4, where semantic-based RAN control and conflict mitigation mechanisms are evaluated under diverse network scenarios.

Overall, Task 7.1 directly defines how the technological innovations identified from WP3 through WP6, can be specified in the PoCs and how these can be evaluated under an identified demonstration methodology. By systematically planning, defining clear evaluation methods, and preparing detailed PoC scenarios, Task 7.1 provides a practical pathway for validating each WP's innovations. This structured, collaborative approach ensures that project outcomes are effectively demonstrated, realistically tested, and closely aligned with both stakeholder expectations and project KPIs.

1.3 Link to project KPIs

The **6G-LEADER** project is strategically designed around clearly defined objectives, testbeds, and expected outcomes to ensure a structured and measurable path toward validating its key innovations. At its core, the project aims to develop AI/ML-driven, semantics-empowered wireless communication solutions, novel antenna technologies such as fluid antennas and reconfigurable intelligent surfaces, and efficient multiple-access schemes to boost spectral efficiency. These goals translate into concrete and quantifiable KPIs—such as up to 50% improvement in spectral efficiency, up to 30% reduction in energy consumption, and up to 50% reduction in latency—depending on the specific technology or use case evaluated.

A detailed KPI analysis in D2.1 [1] establishes how these technological developments are linked to the project's expected impacts. It highlights the anticipated outcomes, including machine learning-enhanced physical layer solutions, sustainable and reconfigurable RF components, and innovative RAN architectures. These innovations are expected to deliver improved spectrum utilisation, lower energy use, and more efficient and scalable wireless systems.

To demonstrate and validate these goals, the project leverages five PoC scenarios specifically shaped to showcase these technical advancements. Each PoC is developed using a robust plan detailed in the following sections of this document, explicitly designed to align with technical development in earlier WPs. The five PoCs are as follows:

- PoC#1: XR and UAV seamless real-time interaction
- PoC#2: Enhanced Mobile Broadband Experience
- PoC#3: AI/ML Trainable 6G RIC Conflict Manager
- PoC#4: Wireless for AI based on AirComp
- PoC#5: AI/ML-aided enhanced multiple access

The PoCs utilize fourth major testbeds, as described in Section 3.4, located at DICAT (SONIC Labs in the UK), CNIT (S2N and ARNO testbeds in Italy), Massive Beams in Berlin Germany, and UC3M in Madrid, Spain; providing extensive infrastructure and computational resources necessary for sophisticated AI/ML applications and radio network tests. For instance, the SONIC Labs at DICAT provide robust GPU capabilities and comprehensive test and measurement facilities, enabling realistic testing scenarios and precise validation of KPIs under near-operational conditions.

These PoCs have clearly defined KPIs directly tied to the objectives of the project as described in Table 1.1 . For instance, PoC#1 aims to reduce the volume of communicated data up to 60%, increase Unmanned Aerial Vehicle (UAV) battery lifetime up to 30% (excluding flight power), achieve up to 30% reduction in effective information rate without degrading perceived quality, and deliver more than a 30% sum-rate improvement through ML-based Non-Orthogonal Multiple Access (NOMA) strategies. Next, PoC#2 focuses on achieving up to 30% increase in energy efficiency, a 50% improvement in spectral efficiency, and up to 30% reduction in hardware cost by using near-field RIS-based beamforming.

Moreover, PoC#3 targets to achieve up to 15% energy savings while maintaining Quality of Experience (QoE) and aims to reduce network control conflicts by 50% through AI-driven policy mitigation. Also, PoC#4 seeks to reach over 95% real-time inference accuracy, up to 30% improvement in spectral efficiency, up to 30% reduction in energy consumption, and about 40% decrease in control-plane overhead by embedding semantic intelligence into AI-native wireless architectures. Finally, PoC#5 specifically targets measurable outcomes such as over 25% reduction in Electromagnetic Field (EMF) exposure, a 30% reduction in energy consumption, and up to 40% increase in overall data sum-rate improvement compared to current multiple access solutions.

Table 1.1. KPI for each PoC.

KPI id	KPI	Description
POC1.KPI1	Volume of communicated information.	Target: 60% reduction. Justification: Performance will be improved, over current approaches that neglect the semantics of information.
POC1.KPI2	Lifetime of the UAV. battery for the operation of the UAV.	Target 30% increase. Justification: HiFi cameras will be activated only at a fraction of time, thus, we will further decrease the interruption times. These gains come from the fact that we transmit and process less information and at the same the camera energy consumption is less, leaving more
POC1.KPI3	Effective rate.	Target 30% reduction with the same QoE at the user, with and without the neuromorphic setup. Justification: AI/ML-driven optimisation and semantics will lead to intelligent resource allocation.
POC1.KPI4	Sum-rate increase.	Target >30% improvement over cases with orthogonal multiple access. Justification: The use of ML-aided channel prediction and PHY parameter optimisation will facilitate non-orthogonal multiple access schemes, grouping together
POC2.KPI1	Beamforming Energy Efficiency Increase.	Target: >30% increase when compared to traditional beamformers. Justification: Over-the-Air combining of signals is more efficient in comparison to using discrete combiner/splitter structures.
POC2.KPI2	Data rate increase.	Target: >50% increase. Justification: Due to much larger beamforming gain / antenna aperture size increase Signal-to-Noise Ratio increases.
POC2.KPI3	Cost reduction of radio hardware.	Target: >30% decrease. Justification: Leveraging simple RIS hardware technology instead of discrete beamformer technology.
POC3.KP1	Energy Efficiency.	For this PoC, the aim is to yield 10-15% energy saving
POC3.KP2	Number of direct conflicts.	Reduction by 50%.
POC4.KPI1	Real-time Inference Accuracy.	Target: >95% accuracy. Justification: Leveraging semantically-aware dApps/xApps will result in improved real-time inference accuracy by optimising task allocation and resource utilisation.
POC4.KPI2	Spectral Efficiency Increase.	Target: >30% increase. Justification: Integration of AirComp and semantically-aware dApps/xApps will optimise resource allocation and reduce control plane overheads.
POC4.KPI3	Energy Consumption Reduction.	Target: >30% energy consumption reduction. Justification: Intelligent power control & task allocation optimisation by semantically-aware dApps/xApps.
POC4.KPI4	Control Plane Overheads Reduction.	Target: >40% reduction in control plane overheads. Justification: By leveraging semantic information, minimised control plane overheads will be achieved.
POC5.KPI1	EMF-exposure reduction.	Target: >25% reduction. Justification: Exploiting AI/ML algorithms and high FA reconfigurability will ensure reduced transmit power levels compared to current FPA systems.
POC5.KPI2	Energy consumption reduction.	Target: >30% increase. Justification: The use of extensive datasets from measurements to evaluate AI/ML algorithms optimising FA operation and power allocation for NOMA will ensure reduced energy consumption over non-AI/ML-aided systems with FPAs.
POC5.KPI3	Sum-rate improvement.	Target: >40% increase. Justification: AI/ML-aided multiple access schemes, integrating FAs' increased degrees of freedom will outperform current multiple access solutions.

Each PoC aligns with distinct project objectives, interconnected KPIs and expected outcomes, facilitating systematic evaluation through the defined methodologies. The detailed evaluation methodology described in this deliverable, integrates these KPIs into a coherent evaluation framework, ensuring consistent validation across the PoCs as shown in Table 1.2. This task explicitly aims to provide a unified framework that clearly maps the technological advancements developed in other WPs to measurable criteria and outcomes. It defines evaluation tests, integration strategies, and monitoring approaches to ensure timely execution and precise measurement of outcomes against targeted KPIs.

Table 1.2. Project objective and KPI coverage.

KPI	Covered by PoCs
Communication overhead	Yes
Latency	No
Spectral Efficiency	Yes
Energy and Power Consumption	Yes
EMF power	Yes
Age on Information	No
Packet transmission	Yes
CPU and Memory utilization	No
AI/ML Accuracy	Yes
Cost - no measurement tool	Yes
Lifetime - no measurement tool	Yes
Number of conflicts - no measurement tool	Yes

Thus, the project's evaluation methodology serves as the cornerstone for validating the PoCs and their associated technologies. By explicitly linking project objectives, KPIs, PoCs, and testbed capabilities, the evaluation strategy ensures rigorous, replicable, and meaningful validation outcomes. The methodology's emphasis on technology readiness assessment further ensures that all components introduced into the PoCs meet required maturity levels, facilitating integration into realistic scenarios and paving the way for future adoption.

Through these structured development plans and comprehensive evaluation methodologies, the project is focused on delivering impactful results directly aligned with the defined KPIs. The expected impacts are not merely theoretical but are demonstrated practically through well-defined PoCs that validate each technological advancement in realistic settings, ultimately contributing significantly to the European leadership in next generation 6G systems.

1.4 Document structure

This deliverable is structured to provide a comprehensive guide through the development, evaluation, and validation of the PoC scenarios. Following the introductory section, [Chapter 2: Overview of the PoC Scenarios](#) provides an extensive overview of the five PoC scenarios and describes their prototypes. This includes presenting a high-level reference architecture, defining the main functional blocks and interfaces, and offering detailed descriptions for each PoC. The detailed description of each PoC covers key technical aspects, interfaces, and their integration within the preliminary **6G-LEADER** architecture, that is being investigated in WP2.

[Chapter 3. PoC Development Plan](#), outlines the PoC development plan, including defined phases, milestones, roles, and responsibilities of the project partners. It provides a structured breakdown of tasks and activities specific to each PoC, facilitating effective project management. Furthermore, this section addresses resource allocation and risk management, identifying potential challenges and mitigation strategies to ensure timely and successful project execution.

In Chapter 4, *Evaluation & Demonstration Methodology*, the deliverable presents a detailed evaluation, validation, and demonstration methodology, starting with the general methodology and process steps including preparation, setup, integration, and execution. It highlights the test environments and infrastructure available and test beds. Chapter 4 also specifies the metrics, KPIs, and assessment criteria to be used for validating the demonstrators, as well as defining the data collection, analysis, and reporting processes. Additionally, it describes a monitoring framework for each PoC, validation steps and checkpoints, and evaluates the readiness of sub-components. This section concludes by emphasizing stakeholder alignment and feedback loops, as well as considerations for scalability, security, and manageability.

Finally, [Chapter 5, Conclusions and Future Work](#), summarizes the outputs presented in D7.1, defining the next steps towards subsequent deliverables D7.2–D7.5. It also provides insights into long-term perspectives, highlighting future demonstration opportunities within WP7, thereby setting a clear and actionable roadmap for future activities.

2 Overview of the PoC Scenarios

Five PoCs have been planned to be realised during the **6G-LEADER** project's lifetime, covering the different RAN elements of 6G communication networks, that will be evolved during the project following the innovation pillars.

The PoCs are designed to validate the **6G-LEADER** innovative system architecture concept and showcase how different system components can be integrated and work together (see Section 2.1), in such a way to cover the **6G-LEADER** Innovation Pillars described in Table 2.1, and their mapping with the project PoCs.

Table 2.1. Involvement of PoCs and Innovation pillars

Innovation Pillar	Involved PoCs
<i>Innovation Pillar 1)</i> Enabling an AI/ML-driven physical layer with high predictive capabilities and resource efficiency.	1, 2, 3, 4 & 5
<i>Innovation Pillar 2)</i> Integrating of AI/ML to accommodate multiple access solutions, in the form of random and non-orthogonal multiple access and multiple access for in-radio network AI.	1, 4 & 5
<i>Innovation Pillar 3)</i> Developing highly reconfigurable RF components, focusing on tuneable FAs and RISs.	2 & 5
<i>Innovation Pillar 4)</i> Optimizing spectrum usage, exploding of the FR3 band and coexistence with the FR1 band.	2 & 5
<i>Innovation Pillar 5)</i> Injecting goal-oriented semantics- empowered communication principles at both the control and user planes.	1 & 4
<i>Innovation Pillar 6)</i> Adding a real-time RAN control loop by embedding RAN intelligence between Open-Central/ Distributed Units (O-CUs/O-DUs) and Open-Radio Units (O-RUs) for real-time applications.	2, 3 & 4
<i>Innovation Pillar 7)</i> Incorporating a Conflict Manager tasked with efficiently managing semantically enhanced xApps across control and optimisation loops.	3

The Table 2.2 provides a summary of the planned PoCs' main focuses, leaders, available testbeds, and development platforms, along with a brief description of each PoC. In Section 2.2 a more detailed description of the PoCs is given.

Table 2.2. PoC partners, testbeds and tools.

PoC#	Title	Partners Involved	Available Testbeds	Available tools and platforms
PoC#1	XR and UAV seamless real-time interaction	CNIT, LIU, AALTO, UGR, UCY, ACC, NOKIA, TEF	Federated CNIT testbed (ARNO Testbed in Pisa and S2N testbed in Genoa)	ACC dRAX Platform, XR, UAVs, Edge Nodes (ORIN, Bluefield), SRS DU Platform
PoC#2	Enhanced Mobile Broadband Experience	DICAT, MB, SRS, NOKIA	DICAT, MB and SRS O-RAN Testbeds	MB RU Platform and SRS DU Platform
PoC#3	AI/ML Trainable 6G RIC Conflict Manager	DICAT, ACC, SRS, SRUK, ATOS, FDI	DICAT, ACC	DICAT, ACC dRAX (RIC) Platform, SRS DU Platform
PoC#4	Wireless for AI based on AirComp	FDI, ICCS, ATOS, UPC, TEF, ACC	Federated CNIT testbed (ARNO testbed in Pisa and S2N testbed in Genoa)	Development of dApps, semantic communications, AirComp novel algorithms, over ACC dRAX and SRS DU Platforms
PoC#5	AI/ML-aided enhanced multiple access	UC3M, AALTO, UCY	Local testbed in UC3M including FA prototype and measurement equipment	Spectrum analysers, network analysers, signal generators, computational cluster, fluidic gear

Table 2.3 presents the initial list of expected technical input from the other technical WPs. All five PoCs will require input from WP2 (e.g., for requirement mapping, definition of use cases, etc.), and the related output for evaluation, validation, and demonstrations will be part of WP7.

Table 2.3. Technical WPs and expected input for each PoC

PoC#	WP#	Expected input
PoC#1	WP3	AI/ML-based channel estimation and link prediction
	WP4	Application of NOMA techniques
	WP5	The design and implementation of semantic-based enablers
	WP6	O-RAN architectural extensions and semantic integration approaches
PoC#2	WP4	RIS designs and FR1/FR3 coexistence analysis results from WP4
	WP6	Extension of the OFH interface, DU support of the near-field RIS beamformer O-RU
PoC#3	WP5	The design and implementation of semantic-based enablers
	WP6	Initial, intermediate, and final results of AI/ML-driven and semantically enhanced RAN control and conflict management to be integrated, evaluated, validated, and demonstrated within O-RAN architecture
PoC#4	WP3	Advanced AI/ML algorithms and AirComp methods
	WP5	The design and implementation of semantic-based enablers
	WP6	O-RAN architectural extensions and semantic integration approaches
	WP7	Validation framework and reporting procedures for comprehensive evaluation
PoC#5	WP3	AI/ML-based channel estimation and reconfiguration techniques
	WP4	Multiple access techniques for FA

2.1 High-level reference architecture

The preliminary **6G-LEADER** architecture follows the modular design principles defined by the O-RAN framework, which separates base station functions into distinct units and allows for the effective integration of the technological innovations of the project (see Figure 2.1). At the time of writing, this architecture is being actively defined and evaluated as part of the ongoing work in Task 2.4. Its main component, the next-generation node B (gNB) comprises three parts: the O-CU, the O-DU and the O-RU. The project **6G-LEADER** focuses on enhancing the radio access aspect of the network using AI/ML and semantic-based communication techniques together with advanced antenna technologies, namely, fluid antennas and reconfigurable intelligent surfaces.

An integral part of the architecture is its use of closed-loop control through RAN Intelligent Controllers (RICs). **6G-LEADER** builds upon the two control loops already present in O-RAN, that is, the non-real-time (RT) (rApp-based) RIC and near-RT RIC (xApp-based). Both are enhanced with AI/ML-based prediction and decision-making, as well as with semantic-empowered schemes to understand the meaning of the exchanged information. This approach helps towards more efficient utilization of the antenna elements as well as better allocation of the available radio and computing resources, which in turn reduce energy consumption, lower EMF exposure, and improve spectrum efficiency. Moreover, **6G-LEADER** introduces real-time RAN control by deploying distributed applications (dApps) close to the O-CU and O-DU. These applications enable a third control loop between the O-DU and O-RU that operates with response time under 10 milliseconds. This loop is designed to manage time-critical RAN functions, applying the project's research outputs with respect to channel prediction, beam management and signal processing.

The architecture, investigated in WP2 and described in detail in D2.1 [1], will also extend existing O-RAN interfaces to support direct communication between O-DUs to facilitate distributed or federated learning, thus improving their ability to make AI/ML-based decisions. Such communication allows the **6G-LEADER** system to detect and address potential conflicts between different dApps that may have overlapped or competing goals. To manage these interactions and prevent performance issues, the architecture includes a conflict manager within the near-RT RIC. This component facilitates information exchange between near-RT RICs through the non-RT RIC, enabling conflict mitigation procedures for shared control targets. This conflict resolution ensures that the network operates smoothly with minimal RAN performance degradation.

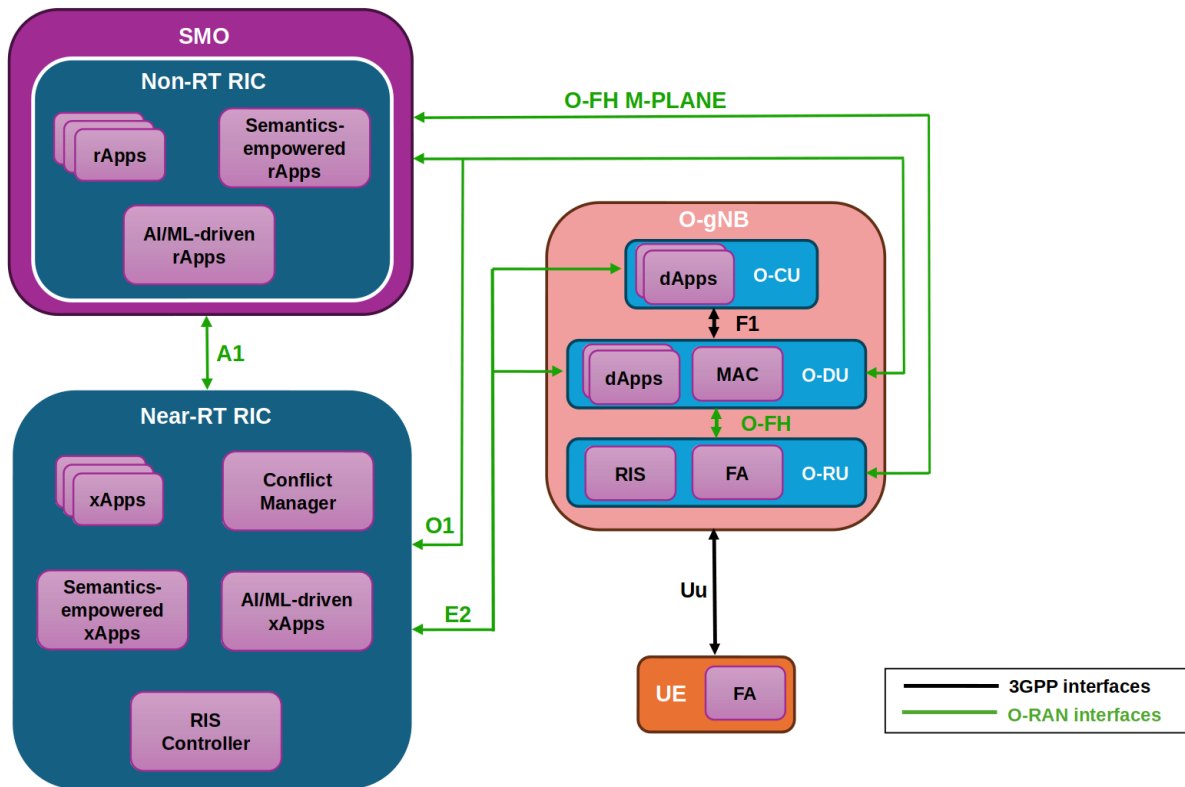


Figure 2.1. 6G-LEADER's O-RAN Architectural framework.

2.2 PoC Descriptions

Section 2.2 provides a detailed description of each of the five PoCs being developed within the **6G-LEADER** project. For each PoC, the section outlines the key technical components, the target use cases, and how the proposed innovations—such as AI/ML techniques, novel antenna systems, or semantic communications—are integrated and tested. The descriptions include the functional architecture of each PoC, relevant interfaces, and how these components align with the overall system architecture. This section helps clarify the role and scope of each PoC and sets the foundation for their implementation and evaluation in later stages of the project.

2.2.1 PoC#1: XR and UAV seamless real-time interaction

PoC #1 is hosted at CNIT Lab in Pisa, Italy (see testbed description in Subsection 3.4.3). It will validate the **6G-LEADER** solution for seamless real-time interaction between XR headsets and UAVs. They can be equipped with cutting-edge sensors and cameras that provide XR headsets with virtual component information acquired from different and complementary perspectives. The

validation scenario involves an XR headset and two UAVs (see Figure 2.2). A neuromorphic camera, offering low energy consumption, is adopted for scene understanding at the cost of reduced resolution. UAVs, employing high-fidelity cameras, are then used to obtain greater transmission quality. However, their camera consumes more power. To optimize energy efficiency, the high-fidelity camera is activated only when the neuromorphic camera detects a relevant event. Depending on the application requirements, the video streams can either be switched by replacing the low-resolution, low-power stream with the high-resolution, higher-power one, or merged by layering high-fidelity content over the neuromorphic stream to enhance detail during critical events.

Semantics-aware, real-time video transmission is performed on the XR headset. Semantic segmentation is applied to isolate and process only critical visual information, thereby minimizing the volume of data that needs to be transmitted.

Furthermore, a split inference strategy is employed, wherein part of the processing is performed onboard the UAV, and the remainder is offloaded to an edge node via compressed feature vectors. This approach supports responsive and energy-efficient reconstruction of the surrounding environment, ensuring a high QoE for the end user. Given the UAVs' mobility and the potential for ultra-low-latency requirements, the **6G-LEADER** framework is applied to enhance the communication link using advanced AI/ML-driven physical-layer radio technologies. This enables high-throughput, bi-directional data exchange, even under peak traffic conditions.

Accurate localization is also critical in this setup. In addition to video streams, the UAV's position must be transmitted to align spatial content with the user's visual perspective in the XR headset. Therefore, precise and timely localization is essential to reduce transmission overhead. By leveraging preloaded environmental data and static maps stored on the user's device, redundant data transmissions are avoided, enabling smooth and immersive real-time interaction without overloading the network.

This PoC is well suited for use cases and applications such as remote inspection, search and rescue, and environmental monitoring, where continuous low-power operation is essential but occasional high-detail views are needed. It can also be beneficial in defence and surveillance scenarios, enabling intelligent resource management without compromising situational awareness.

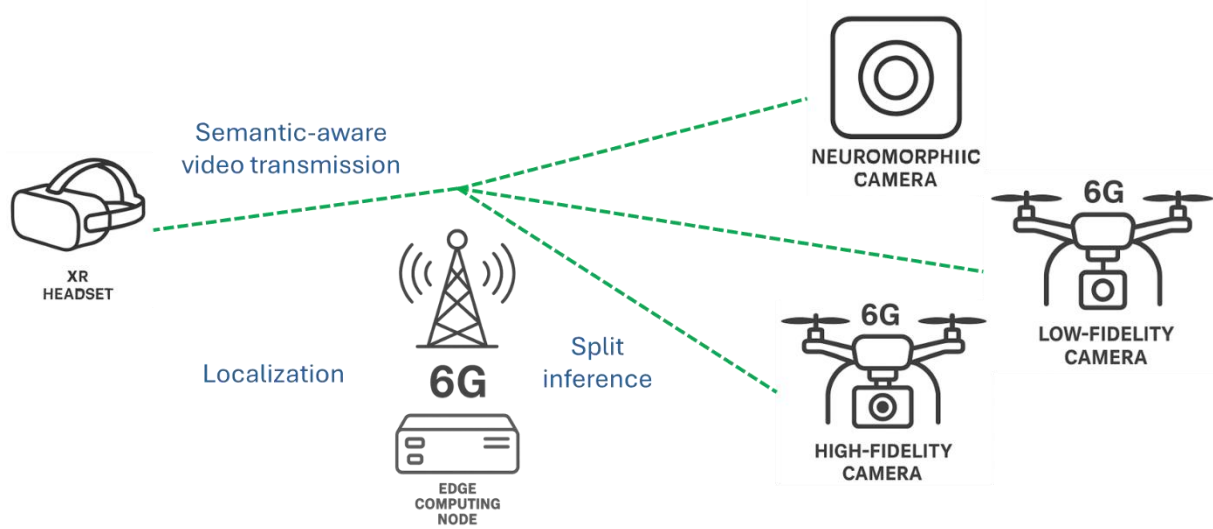


Figure 2.2. PoC#1 on XR and UAV seamless real-time interaction.

In POC#1, the aim is to significantly reduce the volume of communicated information by 60%, leveraging semantic-aware data processing. This involves transmitting only contextually relevant information, as opposed to traditional approaches that send all raw data. Implementation requires integrating semantic filtering mechanisms into the communication pipeline, and validation will involve measuring the volume of transmitted data before and after the semantic layer is applied.

To improve UAV operational endurance, we target a 30% increase in battery lifetime (focusing on processing and transmission, i.e., not considering the power consumption used for flying the drone). This will be achieved by limiting the activation of high-fidelity cameras to critical moments, thus reducing their energy usage. By minimizing unnecessary data collection and transmission, the UAV's energy consumption will decrease. Validation entails comparing battery discharge profiles and operational durations in scenarios with and without selective camera activation.

The effective rate of information transmission is expected to decrease by 30% without affecting the perceived QoE for end users. This reduction will result from intelligent, AI/ML-driven resource allocation that transmits only the most valuable data. Implementation includes deploying neuromorphic setups and ML-based traffic shaping, with validation focusing on user-level QoE assessments and effective throughput measurements under both conventional and optimised conditions.

Lastly, a sum-rate improvement of over 30% is targeted compared to traditional orthogonal multiple access schemes. This will be achieved through ML-based channel prediction and physical layer parameter tuning, enabling more efficient NOMA strategies. Implementation involves integrating predictive models into the communication protocol stack, and performance will be validated by comparing the aggregate data rate achieved with and without NOMA under identical network loads.

2.2.2 PoC#2: Enhanced mobile broadband experience

PoC#2 will incorporate the results of Task 4.2 (Energy & cost-efficient FR3 beamformer design based on near-field RIS technology), where hardware, firmware and software for a RIS-aided radio is developed for the lower FR3 band. The RIS is deployed in the near-field of the active base station antenna to enable cost-effective and energy-efficient analog FR3 beamforming. The antenna configuration is incorporated into an O-RAN compliant RU that can leverage hybrid digital-analog beamforming and MIMO technologies within the FR3 frequency band. Corresponding algorithms are developed for the RU and DU to optimize the performance of the proposed set up.

PoC#2 will be hosted at MB's premises. The testbed consists of an SRS O-DU, a MB FR3 O-RU and a Rohde & Schwarz FR3 measurement grade equipment serving as user equipment, as illustrated in Figure 2.3.

The following hardware and software elements are developed for and used in PoC#2:

- SRS O-DU with hybrid beamforming capability, driven through a near-RT RAN control-loop (xApp/dApp).
- O-RAN compliant fronthaul between O-DU and O-RU to send, among others, the beamforming information from the O-DU to the O-RU.
- MB O-RU connected to a RIS in the near-field, which is expected to have 64 dual-polarized antennas.
- Rohde & Schwarz FR3 measurement grade equipment.

The aim of the considered RIS-based antenna architecture and FR3 beamforming is to increase the energy and spectral efficiency while minimising the cost of the hardware. In particular, the PoC aims to increase the energy efficiency by 30% and the spectral efficiency by 50%, compared to traditional beamformers obtained by Over-the-Air combining of signals and a larger antenna aperture size and beamforming gain. By leveraging simple RIS hardware technology instead of digital beamformer technology, the aim is to decrease the cost by 30%.

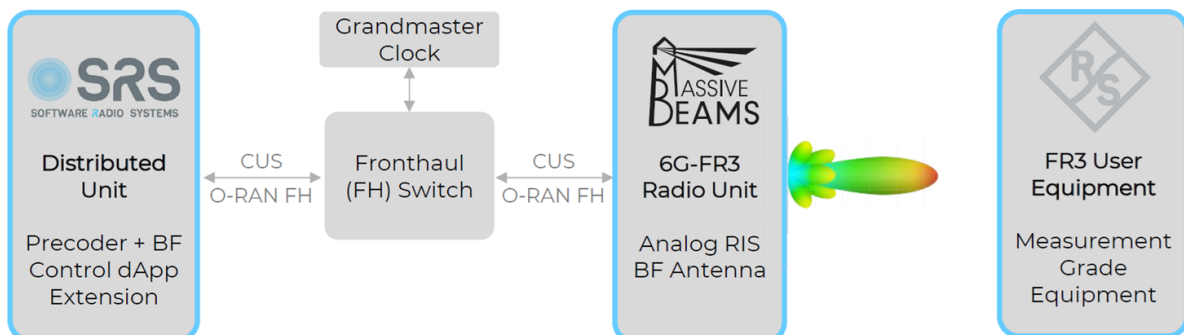


Figure 2.3. PoC#2 demonstrator for RIS-based hybrid beamforming.

2.2.3 PoC#3: AI/ML trainable 6G RIC conflict manager

6G networks will have continuous monitoring and optimisation of network Energy Efficiency (EE) and will require advanced Traffic Steering (TS) capabilities, e.g., to improve the user experience for mission-critical and prioritised services while minimising the overall energy consumption. These two network optimization techniques, EE and TS, will potentially generate conflicts in the 6G Open RAN where xApp(s)/rApp(s) dedicated to these optimizations will impose different and possible conflicting demands on optimisation priorities and control actions of the network. The optimal mitigation of these conflicts in varying and diverse mobility and network coverage scenarios is complex and beyond current direct cooperative 5G mitigation capabilities. For **6G-LEADER**, this PoC will demonstrate an AI/ML-driven Conflict Manager to determine mitigation policies that can quantifiably demonstrate optimal 6G RIC operation in those optimization cases.

Among available xApps, this PoC will utilise Energy Manager Saving (EMS) and Smart Handover (SHO) xApps in the **6G-LEADER** Open RAN demonstrator at DICAT SONIC Labs (Figure 3.6). The dRAX near-RT RIC function will be extended with an AI/ML trainable Conflict Manager, researched and developed as part of the **6G-LEADER** WP5 and WP6 and integrated in WP7 into the PoC infrastructure. The EMS/SHO xApps are going to be deployed in SONIC Labs testbed, and after training the ML-driven near-RT RIC Conflict Manager models based on data sets provided by SONIC Labs RAN Emulation platform, the functionality and gains will be assessed based on different configuration of cells, users, and propagation environments that can be emulated by the RAN Emulation platform. In a second phase, this emulated platform will be replaced by a real RAN network. This O-RAN stack will be created by integrating the O-CU solution from ACC and the O-DU solution from SRS into the testbed.

The aim of the Conflict Manager is to ensure that the optimisation objectives for individual network policies will be met, by guiding the way how xApps act, while also minimising the discrepancy between action commands as a result of conflict mitigation. For this PoC, the aim is to yield 10-15% energy saving with negligible impact on users QoE and reducing the number of direct conflicts by 50%. Various use cases can exploit the Conflict Manager solutions developed in this PoC. For instance, for Public Protection and Disaster Relief (PPDR) first responders and public safety use cases that require TS capabilities for prioritising services, while optimising EE within the network.

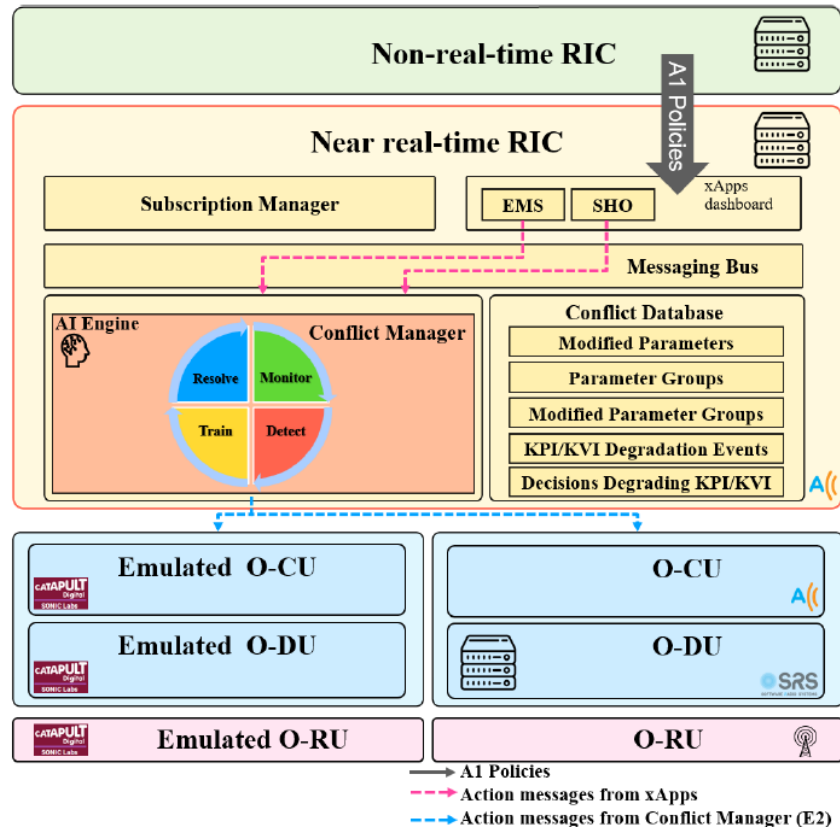


Figure 2.4. PoC#3 AI/ML Trainable 6G RIC Conflict Manager

2.2.4 PoC#4: Wireless for AI based on AirComp

The increasing integration of AI within digital ecosystems has led to a surge in intelligent services, placing extraordinary demands on network connectivity, real-time responsiveness, and large-scale data processing. Although 5G networks have achieved significant improvements in throughput and latency, they often fall short under standard deployment scenarios, particularly in meeting the stringent real-time requirements of AI-enabled functionalities. Challenges such as limited spectrum availability, centralized processing inefficiencies, and the complexity of managing heterogeneous, latency-critical data streams continue to hinder performance. Innovative solutions like AirComp introduce a transformative approach by merging communication and computation processes. However, their practical deployment remains constrained by technical and operational challenges. Additionally, current edge AI infrastructures lack the necessary flexibility and scalability to effectively distribute computational workloads across diverse endpoints, thereby limiting the efficiency of on-device training and inference. These constraints highlight the pressing need for advanced wireless architectures that are inherently intelligent and adaptive, capable of supporting AI-native applications at scale.

PoC#4 seeks to demonstrate the feasibility and advantages of delivering Wireless for AI services as depicted in Figure 2.5 through the deployment of semantically aware dApps and xApps. These

intelligent agents exploit semantic understanding to enhance task distribution, improve resource efficiency, and reduce control plane overhead, key challenges in enabling AI workloads at the network edge. This PoC explores how semantic enrichment can boost near real-time decision-making and model aggregation by dynamically aligning computational tasks with device capabilities and application-level quality constraints. A central objective is to identify the optimal number of participating devices required to satisfy predefined MSE thresholds while minimizing both energy consumption and on-device latency.

The approach comprises three main stages: initially, edge-collected data is enriched with semantic context using ontologies or knowledge graphs. Subsequently, computation tasks are intelligently partitioned and offloaded, with dApps and xApps orchestrating context-aware and energy-efficient execution. Finally, results are aggregated, either locally or centrally, in accordance with the performance and latency requirements of diverse AI-driven applications.

This PoC illustrates how embedding semantic intelligence within the network fabric can enable more efficient, scalable, and adaptive wireless infrastructures tailored to the demands of AI-native services.

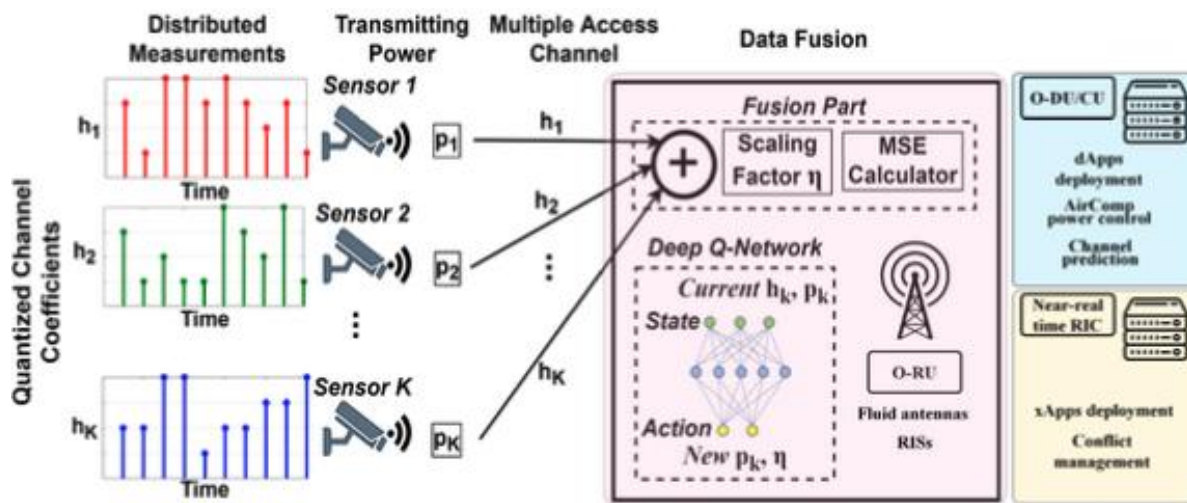


Figure 2.5. PoC#4 Wireless for AI

More specifically, This PoC will demonstrate an O-RAN-based Wireless for AI architecture that combines AirComp-based in-network model aggregation with AI/ML-aided PHY algorithms to support efficient, low-latency intelligence at the wireless edge. The proposed approach focuses on enhancing AirComp through energy-aware resource allocation and adaptive weighting strategies, allowing devices to adjust their participation and transmission power based on energy and computing constraints, and channel conditions.

In terms of task orchestration, depending on service time criticality, xApps or dApps will take care of resource allocation, model updates coordination and inference workloads. Then, the developed xApps/dApps will incorporate lightweight semantic metadata, such as task relevance or node status to guide context-aware task prioritisation and improve signalling efficiency. The PoC will

be validated across diverse topologies with varying number of edge nodes and service requirements. Performance evaluation will be assessed against various 6G KPIs, including inference accuracy, spectral efficiency, energy consumption, and control-plane overheads. Additionally, 6G KQIs, such as service adaptability, system scalability, and AI-native responsiveness will be monitored to ensure alignment with broader 6G and O-RAN goals.

This PoC will be hosted on CNIT's ARNO testbed in Pisa. This testbed offers a comprehensive end-to-end infrastructure that spans 5G, optical transport, edge and cloud computing, as well as domain-specific vertical systems as shown in Figure 2.6 and further detailed in Subsection 3.4.3. The testbed integrates both commercial and open-source 5G technologies, including O-RAN (srsRAN, developed by SRS), alongside high-performance computing nodes equipped with GPUs, smart NICs, and programmable network fabrics. It also features advanced edge micro-data center prototypes optimized for energy-efficient execution of AI workloads. With extended support for applications involving robotics, UAVs, and high-resolution sensing, the ARNO testbed provides a flexible and realistic environment for validating AI-powered wireless services across a broad range of operational scenarios.

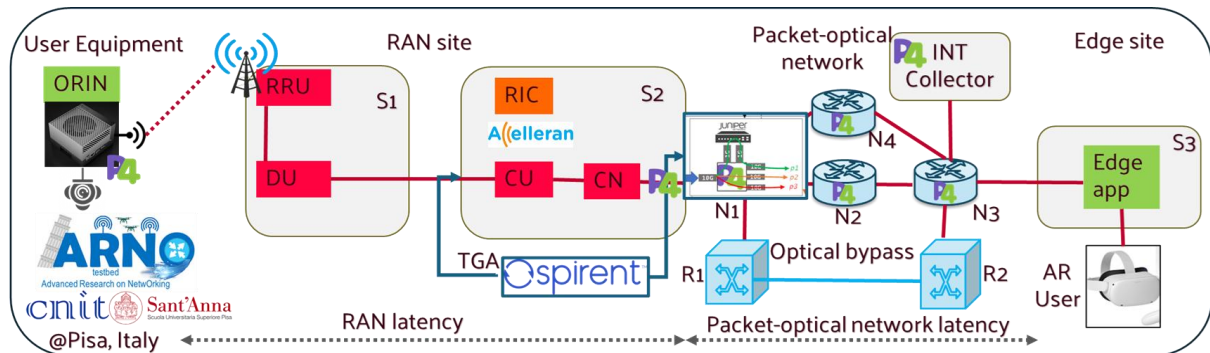


Figure 2.6. PoC#4 CINIT ARNO Testbed in Pisa, Italy.

This PoC implementation explores the application of AirComp in distributed sensing and control scenarios, particularly within the domains of environmental monitoring, smart cities, and autonomous systems. The objective is to demonstrate how AirComp can support the efficient computation of global functions, such as averages or maxima, directly from sensor transmissions, thereby significantly reducing communication overhead and latency.

Various use cases can exploit the AirComp solutions developed in this PoC. For instance, in environmental monitoring or smart city contexts, a distributed network of sensors measuring variables like temperature and humidity could benefit from AirComp-enabled aggregation. Instead of individually transmitting all sensor readings to a central node, AirComp allows simultaneous transmissions from all sensors, leveraging the wireless channel to directly compute desired functions, such as the average or maximum reading. This reduces communication burden and enables near real-time insight generation.

Another illustrative use case involves wireless control systems for autonomous agents, such as vehicles or robots, where periodic state synchronization is essential. Here, AirComp techniques

could support the real-time computation of consensus functions, such as the average state across agents, which is crucial for coordinated behaviours in applications like vehicular platooning. In such scenarios, synchronized control of speed, acceleration, and trajectory is necessary to ensure safety and efficiency.

In summary, PoC#4 targets achieving over 95% real-time inference accuracy while ensuring AI-driven decisions remain timely and reliable. Additionally, this PoC aims to deliver up to 30% increase in spectral efficiency through enhanced resource allocation and AirComp-enabled in-network aggregation, alongside a 30% reduction in energy consumption by intelligently managing power and task distribution across edge devices. Finally, by leveraging semantic information to streamline signalling, the PoC seeks to achieve up to 40% reduction in control plane overhead, validating the practical benefits of this architecture for real-time AI-driven applications in 6G networks.

2.2.5 PoC#5: AI/ML-aided enhanced multiple access

PoC#5 consists of a reconfigurable FA aimed to reduce EMF exposure and energy consumption, used in FR1, FR3 frequency bands. Figure 2.7. sketches the architecture of the PoC. Generally, a FA accounts for two different branches, the moving parts of the antenna (MA), used to reconfigure the antenna in accordance to the channel status and CSI, which stands for the second part. The addition of AI/ML techniques will improve reconfiguration capabilities and modelling techniques for FA. Not only is FA implementation considered but also particular channel estimation/modelling technologies for FAs are going to be tested in this context. As a result, an improvement in sum-rate and/or achievable rate is expected for multiple access schemes.

Hosted in UC3M (Madrid, Spain), PoC#5 is meant to demonstrate the capabilities of FA to become a relevant prototype in the field. It features a liquid (at room temperature) metal called eGaln, that can be placed in different positions, acting as an antenna. By iteratively exploring different manufacturing techniques, a PoC of a reconfigurable antenna based on electrowetting will be developed. Specifically, the reconfiguration will be achieved using solely electric impulses. Different use cases will be supported and tested by the same device, implementing linear and circular FA topologies. Nonetheless, a particular focus will be put on mitigating severe blockage events that otherwise would limit the communication capabilities of the device. The implementation focuses on addressing the following KPIs.

- **EMF-exposure (-25%):** Since reconfigurability in FA is directly related to using the spatial dimension, the system position may be altered to both benefit from different communication circumstances and lower the RF exposure of a person close to the device. Furthermore, the anticipated rise in achievable rate will increase efficiency by requiring less power to transmit the same information, decreasing EMF exposure.
- **Energy Consumption (-30%):** The use of a single reconfigurable RF-chain for reception will save energy consumption when compared to other structures which require the use of a dedicated RF-chain per antenna element.

- **Sum-rate improvement (40%):** The use of novel algorithmic solutions implemented in FA devices will increase the efficiency drastically in tested use cases such as multiple users or blockage mitigation.

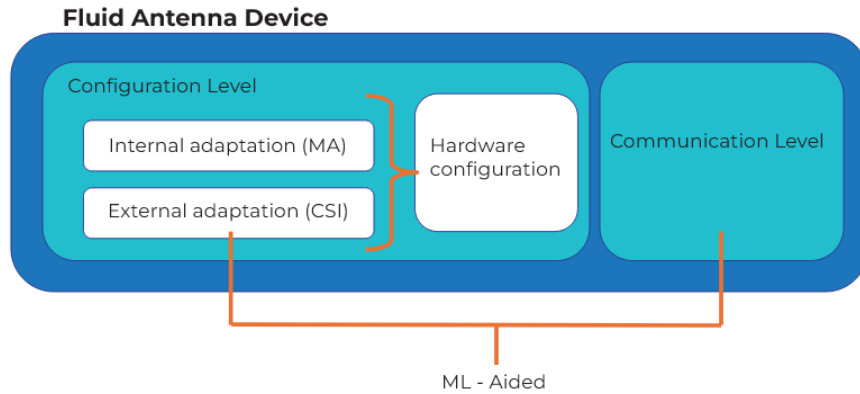


Figure 2.7. PoC#5 General Architecture.

To successfully address all these KPIs, the current limits of the state-of-the-art methods need to be advanced. In particular, the movement of the liquid metals, the distribution of the ports, their RF connections or the radiation pattern are examples of current limitations that are going to be evaluated within the context of this PoC.

2.3 Mapping PoC prototypes onto the 6G-LEADER architecture

To align the architecture detailed in the D2.1, Section 3 [1], with the PoCs outlined in this deliverable (Section 2.2), an analysis of the key components, requirements, and implementation strategies proposed by **6G-LEADER**, is started, as illustrated in the high-level architecture in Figure 2.8. The subsequent step involves mapping each PoC architecture, described in Subsection 2.2.1 to Subsection 2.2.5, to the high-level architecture and creating the mapping Table 2.4.

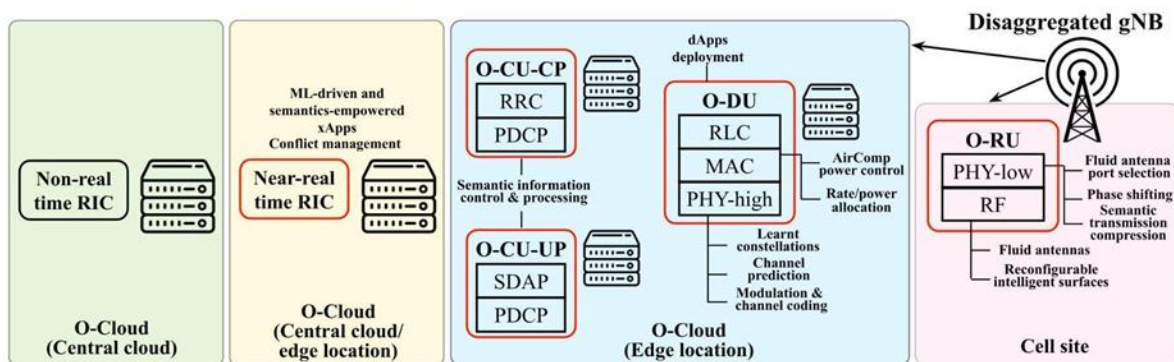


Figure 2.8. 6G-LEADER preliminary High-Level Architecture.



Figure 2.9 offers a clear and concise visualization that illustrates how each individual PoC architecture integrates with the overarching architecture of **6G-LEADER**

D7.1 Prototype plan and evaluation methodology.

Table 2.4. Architectural components mapped into 6G-LEADER PoCs.

ARCHITECTURE COMPONENTS				PoC#1: XR and UAV seamless real-time interaction	PoC#2: Enhanced Mobile Broadband Experience	PoC#3: AI/ML Trainable 6G RIC Conflict Manager	PoC#4: Wireless for AI based on AirComp	PoC#5: AI/ML-aided enhanced multiple access
Cell Site	O-RU	RF	FA					Reconfigurable FA for FR1& FR3 bands.
			RIS		RIS-aided radio for FR3 band			
		PHY Low	FA port selection					Reconfigurable FA for FR1& FR3 bands.
			Phase Shifting		RIS-aided radio for FR3 band			
			Semantic transmission compression	AI/ML-driven physical-layer radio technologies, ML-based channel prediction and physical layer parameter tuning, for NOMA strategies				
O-Cloud (Edge Location)	O-DU	PHY-High	Learned Constellation					
			Channel Prediction					
			Modulation & Channel Coding					
		MAC	AirComp Power control	Semantics-aware, real-time video transmission, Semantic		Integrating the O-CU solution from ACC and the O-	Combines AirComp-based in-network model aggregation with	

D7.1 Prototype plan and evaluation methodology.

				segmentation and Neuromorphic for Low energy consumption		DU solution from SRS	AI/ML-aided PHY algorithms to support efficient, low-latency intelligence at the wireless edge	
			Rate/Power allocation					
		RLC						
		dApps deployment			Hybrid beamforming capability using xApp/dApp.		Semantically aware dApps and xApps	AI/ML techniques would improve reconfiguration capabilities and modelling techniques for FA
	O-CU	O-CU-CP	RRC					
			PDCP			Integrating the O-CU solution from ACC and the O-DU solution from SRS		
		Semantic information control & processing		Semantic-aware data processing			Edge-collected data is enriched with semantic context using ontologies or knowledge graphs	
		O-CU-UP	SDAP					
			PDCP			Integrating the O-CU solution from ACC and the O-DU solution from SRS		
O-Cloud (Central cloud/	Near-RT RIC	ML-driven & Semantic empowered xApp		AI/ML-driven resource allocation, Split	Hybrid beamforming	Energy Manager Saving (EMS) and	Semantically aware dApps and xApps, and	AI/ML techniques for reconfiguration capabilities and

D7.1 Prototype plan and evaluation methodology.

Edge location)				inference and Accurate localization	capability using xApp/dApp.	Smart Handover (SHO) xApps	Combining AirComp-based in-network model aggregation with AI/ML-aided PHY algorithms	modelling techniques for FA
		Conflict management				AI/ML trainable Conflict Manager		
O-Cloud (Central cloud)	Non-RT RIC							



3 PoC Development Plan

In this chapter, the development phases and milestones of PoC activities, along with the work breakdown for conducting evaluation, validation, and demonstration of each one of the PoCs is presented. Also, the role and responsibilities of partners within all PoCs are identified and presented.

3.1 Development phases and milestones

The development of the five PoCs is divided into two phases, each with an 18-month duration.

Phase A will focus on integrating **6G-LEADER**'s technological innovations and adapting the PoCs to the deployment, integration, and evaluation infrastructures. Detailed requirements for each PoC will be gathered, and activities will follow the specific schedules outlined later in this deliverable. Deployment and integration will take place within the relevant testbeds, with a contingency plan in place to manage potential issues. Any problems across network elements will be tracked in coordination with the relevant partners. Continuous verification of all components will ensure proper functionality and performance before releasing the end-to-end (E2E) integrated solution. Validation results will be fed back to WP2–WP6 to support further refinement of the innovations, tools, and KPIs/KVIs.

In summary, Phase A will include the following activities,

- Deploy the network components and solutions and integrate the systems E2E.
- Examine the tools, innovation pillars, and KPIs/KVIs, benchmark the test results against reference values.
- Demonstrate the initial results of the PoCs and use cases.

This will enable the consortium to successfully achieve the **6G-LEADER** Milestone MS 10 “*Intermediary Release of the PoCs*” by M18, and the related results will be reported in Deliverable D7.2.

Phase B will follow the completion of Phase A, where the final version of PoCs will be developed and entails the following activities.

- Enhance the testing setup, KPIs/KVIs, scope of innovation pillars and use cases according to the observations and learnings from the evaluations and validations of Phase A.
- Evaluate, validate, and demonstrate the effectiveness and efficiency of the innovation pillars developed within WP2-6 through the PoCs.
- Conduct performance evaluations, validations, and demonstrations of PoCs for different scenarios and conditions and for the selected KPIs/KVIs.

- Report the outcomes to WP8 to drive the exploitation plan's definition.

This will enable the consortium to successfully achieve the **6G-LEADER** Milestones MS 13 “PoCs 1-5 demonstration videos ready” by M26, and MS15 “Second demo workshop organised” by M34. Also, the related results and recommendations will be reported in Deliverable D7.3 which is the final deliverable on reporting PoC evaluations.

3.2 Roles and responsibilities

This section outlines the specific roles and responsibilities of each partner involved in the five PoCs of **6G-LEADER**. Each PoC is coordinated by a leading organisation and supported by a consortium of partners contributing with testbeds, hardware components, software modules, algorithmic development, and integration efforts. The assignments reflect each partner's expertise and contributions across technical work packages, ensuring that the design, deployment, validation, and demonstration phases are effectively executed. For each PoC, the timeline of responsibilities is presented along with the corresponding network component providers, giving a complete view of the collaborative implementation and integration strategy.

3.2.1 Roles for PoC#1

PoC#1 is led by CNIT, which is responsible for the design and validation of semantic communication solutions. CNIT also hosts the testbed environment and supports the integration testing and validation of end-to-end scenarios stemming from Task 5.2. ACC contributes to the PoC by supporting the design and development of real-time RIC components, including related xApps and dApps. SRS provides the DU, incorporating enhancements developed during the project. LIU is involved in the design of semantics-aware algorithms that enable context-aware data processing. Telefónica, in its role as a mobile network operator, supports the PoC by translating service-level requirements into network-level requirements, defining the use case, and contributing to KPI identification and evaluation analysis. Although not contributing technical implementations, Telefónica monitors and supports the entire PoC process from definition to evaluation, aligned with Tasks T2.1, T2.2, and T2.4. NOKIA contributes to the design of semantics-aware algorithms based on split inference models, distributed between the UAV and the edge node. UGR is involved in the design of goal-oriented semantics-aware algorithms and models. Table 3.1 presents the roles per schedule for this PoC, while Table 3.2 discussed the network providers.

Table 3.1. Roles per schedule for PoC#1

Activities	Partners involved
Phase A	
Integration of AI/ML algorithms (T3.1), AirComp + T3.3	FDI, UCY, ICCS, AALTO
Development of initial xApp	FDI, ACC.
Functional Validation	All Partners
Wireless for AI initial prototype evaluation	All Partners
Phase B	
Semantic annotation in xApp	LIU, ACC
Deployment in CNIT testbed	CNIT, SRS, ACC, FDI
Full scale validation	All Partners
Providing results to WP8	All Partners

Table 3.2. Network component providers for PoC#1.

Component	Details	Component provider	Phase A	Phase B
UEs	N.3 5G Quectel RM500Q-GL; N.2 5G Quectel RM500Q-GL Evaluation board; N.1 G Quectel RG501Q – embedded within Teltonika RUTX50 Industrial-grade router	CNIT	x	x
DUs	SRS DU	SRS	x	x
Sensors	Camera	CNIT	x	x
dRAX	Accelleran	ACC	x	x
RU	Ettus USRP N310 B210, X310	CNIT	x	x
CU	Accelleran's CU	ACC	x	x

3.2.2 Roles for PoC#2

For PoC #2, Table 3.3 presents the specific role of each partner for the tasks. MB is the lead for this PoC, and will prepare the RU to extract beam IDs at RUs (pcaps with beam IDs), enable a near-field RIS-aided beamformer for the FR3 band, and will integrate this into an O-RU. MB will also provide the testbed for the beam scheduling evaluation. SRS will develop a beam ID scheduling scheme for the O-DU on the C-Plane, and will integrate the near-field O-RU RIS-aided beamformer into the O-DU. For this PoC, NOKIA and DICAT will join the PoC activities for evaluation, validation, and demonstration. The network components provided by each partner (e.g. hardware and test equipment) are shown in Table 3.4.

Table 3.3. Roles per schedule for PoC#2.

Activities	Partners involved
Phase A	
SRS DU in FDD mode with MB RU connected to test all RU functions	MB, SRS
RU fronthaul only loopback test with cable connections, no RF	All partners

Deliverable D7.2	All partners
Phase B	
Phase B.1: RU with RF functions in FR1	
DL in test mode with RF signal analyzer (fully loaded 100 MHz DL signal)	MB, SRS
UL in test mode with DL/UL RF loopback	MB, SRS
End-to-end system in test mode in FR1	All partners
Phase B.2: FR3 beam sweep showcase	
Transmission of beam IDs from DU to RU in the C-plane	MB, SRS
Beam sweep at RU (SSB signals)	MB, SRS
Full-scale evaluation of the proposed solution	All partners
Deliverable D7.3 (final report for all phases of this PoC)	All partners

Table 3.4. Network component providers for PoC#2.

Component	Details	Component provider	Phase A	Phase B
RF signal analyser	R&S	MB	N/A	x
RU	N/A	MB	x	x
RIS	N/A	MB	N/A	x
DU	N/A	SRS	x	x

3.2.3 Roles for PoC#3

For PoC #3, the specific role of each partner for the tasks as defined within the PoC's schedule is presented in Table 3.5. DICAT is the lead for this PoC, and will host the PoC activities for evaluation, validation, and demonstration, and will provide the RIC Tester for RAN scenario generation. ACC will provide the dRAX (RIC-CU-DU), plus the Telemetry Gateway to interconnect with the VIAVI RIC Emulator. Also, ACC will provide the ML hook to connect AI/ML models to the xApps, and will also provide an xApp framework useful for the Conflict manager. For this PoC, SRS will provide srsRAN (DU) and support its integration to the other O-RAN components (i.e., ACC RIC-CU and O-RU) and xApps comprising the demonstration core (e.g. enhance current srsRAN E2 interface) in Phase B. SRS will also provide an O-RU and help with integrating it to its DU to be used during Phase B. SRUK will provide energy efficiency xApp, retrain the AI model for the PoC network scenario and deploy in PoC. SRUK will also support the development of AI-enabled Conflict Manager. ATOS will integrate its MLOps platform to train ML models to be embedded in the future set of 3 xApps to create conflicts in the RAN elements in order to validate the Conflict Manager development. For this PoC, FDI will deliver two xApps; the first aims to maximise downlink cell throughput. It dynamically allocates PRBs in near real-time, taking into consideration the channel quality indicators and the user traffic demands, so that spectral resources are assigned to users and links with the greatest potential data rates. The second xApp focuses on energy efficiency. It identifies the minimum number of PRBs required to meet each user's demand and allocates only those blocks, which reduces overall resource usage and lowers power consumption on unused subcarriers while still satisfying demand.

The network components provided by each partner within this PoC (e.g. test equipment, RAN components, etc.) are summarised in Table 3.6.

Table 3.5. Roles per schedule for PoC#3.

Activities	Partners involved
Phase A	
Deploy RIC platforms on the servers	ACC, DICAT
Integrate RIC platforms with RAN Emulator	ACC, DICAT
Integrate xApp(s)/rApp(s) within RIC	ACC, SRUK
Assess the gains that individual applications can offer	ACC, SRUK
Demonstrate the gains for a number of RAN scenarios	ACC, SRUK
Develop early version of Conflict Manager application	ACC
Deliverable D7.2	All partners
Phase B	
Phase B.1: Using RAN Emulator	
Deploy and integrate early version of Conflict Manager into the PoC	ACC, DICAT
Assess the impact of conflicting objectives	ACC, SRUK
Fine tune the design of xApp(s)/rApp(s), Conflict Manager, and enhanced version of conditions for RAN scenarios	ACC, SRUK
Integrate a new set of xApp(s)/rApp(s) (from Task 6.2) within the PoC	ACC, SRUK, ATOS, FDI
Assess the gains of xApp(s)/rApp(s) individually and together with Conflict Manager	ACC, SRUK, ATOS, FDI
Demonstrate the gains of xApp(s)/rApp(s) for a number of RAN scenarios	ACC, SRUK, ATOS, FDI
Integrate the new Conflict Manager solution developed within Task 6.3	ACC, SRUK, ATOS, FDI
Evaluate the gains/discrepancies based on the new Conflict Manager for selected xApp(s)/rApp(s) and RAN scenarios	ACC, SRUK, ATOS, FDI
Demonstrate the gains of selected xApp(s)/rApp(s) for Conflict Manager for a number of RAN scenarios	ACC, SRUK, ATOS, FDI
Phase B.2: Using real RAN Stack	
Deploy and integrate real RAN stack and O-RU, and integrate that within the PoC	ACC, SRS, DICAT
Evaluate the gains/discrepancies based on the new Conflict Manager for selected xApp(s)/rApp(s) within real RAN system	ACC, SRUK, ATOS, FDI
Demonstrate the gains of selected xApp(s)/rApp(s) for Conflict Manager within real RAN system	ACC, SRUK, ATOS, FDI
Deliverable D7.3 (final report for all phases of this PoC)	All partners

Table 3.6. Network component providers for PoC#3.

Component	Details	Component provider	Phase A	Phase B
UE	Commercial UE	DICAT	x	x
RU	N/A	SRS	N/A	x
DU	N/A	SRS	N/A	x
CU	N/A	ACC	N/A	x
RIC	dRAX provides both Non-RT RIC and Near-RT RIC functionalities	ACC	x	x
Emulated RAN	VIAVI AI-RSG Version 2.4	DICAT	x	x
COTS/compute/storage servers	For deploying DU, CU, RIC (and applications)	DICAT	x	x

xApp (SW)	N/A	ACC, SRUK, ATOS, FDI	x	x
Conflict manager (SW)	N/A	ACC	x	x
MLOps platform	Support the end-to-end lifecycle management of AI models (e.g., xApps). ATOS can provide access to MLOps resources to PoC#3 partners. Details can be given.	ATOS	x	x

3.2.4 Roles for PoC#4

For PoC #4, Table 3.7 shows the specific role of each partner for the tasks. FDI is the leader for this PoC, and will conduct the overall coordination, integration of AI/ML models, and semantics-aware orchestration, and development of xApps/dApps. ICCS and UCY are responsible for development of advanced AI-driven algorithms for channel prediction and AirComp aggregation, and ATOS and UPC are responsible for implementation of ML-driven algorithms for optimal resource allocation and scheduling. ACC will conduct the development of related xApps/dApps, and design and development of real-time RIC components and related xApps/dApps. SRS will be responsible for design and development of related DUs, LIU will be designing the semantics-aware algorithms to enable context-aware data processing, TEF will be responsible for provisioning the requirements, operational use cases, and evaluation criteria. UGR is involved in rendering the AI-driven algorithms for semantics-aware processing trustworthy. For this PoC, CNIT will host a testbed environment, support integration testing, and validation of end-to-end scenarios.

The network components provided by each partner (e.g. sensors, RAN components, etc.) for this PoC are summarised in

Table 3.8.

Table 3.7. Roles per schedule for PoC#4.

Activities	Partners involved
Phase A	
Integration of AI/ML algorithms (T3.1), AirComp + T3.3	FDI, UCY, ICCS
Development of initial xApp	FDI, ACC, ATOS
Functional Validation	All Partners
Wireless for AI initial prototype evaluation	All Partners
Phase B	
Semantic annotation in xApp	LIU, ACC
Deployment in CNIT testbed	CNIT, SRS, ACC, ATOS, FDI
Full scale validation	All Partners
Providing results to WP8	All Partners

Table 3.8. Network component providers for PoC#4

Component	Details	Component provider	Phase A	Phase B
UEs	N.3 5G Quectel RM500Q-GL; N.2 5G Quectel RM500Q-GL Evaluation board; N.1 G Quectel RG501Q – embedded within Teltonika RUTX50 Industrial-grade router	CNIT	x	x
UEs	AmariUE	FDI	x	x
UEs	srsUE	SRS	x	x
DUs	srsDU	SRS	x	x
Sensors	Multimodal dry container, Drone sensors, Posture sensors	CNIT	x	x
Near-RT RIC	dRAX	ACC	x	x
RU	Ettus USRP N310 B210, X310	CNIT	x	x
CU	Accelleran's DU	ACC	x	x

3.2.5 Roles for PoC#5

For PoC #5, the specific role of each partner for the tasks as defined within the PoC's schedule is shown in Table 3.9. UC3M is the lead and host for this PoC, and will prepare the testbed and perform the measurement campaign, and will lead the manufacturing process. AALTO will contribute to the channel estimation and resource allocation techniques in this PoC, and UCY will contribute to the deployment and validation efforts.

The test equipment provided by each partner within this PoC are summarised in Table 3.10.

Table 3.9. Roles per schedule for PoC#5.

Activities	Partners involved
Phase A	
Review of SoA	All partners
Architecture definition	UC3M, UCY
First hardware implementations and testing	UC3M
Evaluation of solutions	All partners
Deliverable D7.2	All partners
Phase B	
Fine re-evaluation of variables and KPIs	All Partners
Prototype Manufacturing	UC3M
Iterative evaluation of solutions	UC3M, AALTO, UCY
Measurement Campaign	UC3M
Final Architecture Evaluation	All Partners
Deliverable D7.3 (final report for all phases of this PoC)	All partners

Table 3.10. Network component providers for PoC#5.

Component	Details	Component provider	Phase A	Phase B
RU - Network Analyzer	Test the FA and its future incorporation to a network (Keysight)	UC3M	x	x
RU - Spectrum Analyzer	Characterize the response of FA to improve its design (Keysight)	UC3M	x	x
RU - Signal Generator	Transmit a testing signal using the FA (Keysight)	UC3M	x	x

3.3 Work breakdown structure per PoC

The work breakdown for deployment, integration, and conducting evaluations, validations, and demonstrations of each of the five PoCs are presented in this section.

3.3.1 PoC#1 schedule and deliverables

PoC#1 will follow the two-phase approach of **6G-LEADER** described in detail in Figure 3.1.

Phase A (M9–M18): This phase focuses on the initial integration of **6G-LEADER** technologies and their adaptation to the UAV/XR interaction scenario.

- **M9–M12:** Initial development will involve configuring the neuromorphic camera, the UAV platforms with high-fidelity cameras as well as enabling event-driven activation logic for energy-aware video capture.
- **M13–M15:** AI/ML-based channel estimation and link prediction from T3.1 will be adapted to UAV mobility profiles to improve link robustness. Furthermore, split inference mechanisms will be implemented, with the onboard processing and edge offloading pipeline established using compressed feature vectors. Semantic segmentation models from WP5 will be preliminary integrated targeting real-time performance on the XR headset.
- **M16–M18:** The first prototype will be validated in terms of real-time responsiveness, energy efficiency, and video quality metrics. Emphasis will be placed on functional testing, ensuring the seamless operation of neuromorphic event detection, selective camera activation, and semantic data handling.

Phase B (M19–M36): This phase will focus on the refinement of the PoC and the integration of semantic-awareness and localization capabilities for immersive XR experiences.

- **M19–M24:** Lightweight semantic annotations will be integrated into the video processing pipeline and UAV-to-XR communication. Edge computing functions will be aligned with XR QoE demands, and positioning data will be incorporated to enable spatial content alignment.
- **M25–M30:** The full semantics-aware split inference and localization system will be deployed and validated using the CNIT testbed. AI/ML-enhanced physical layer

mechanisms will be stress-tested under variable throughput and latency conditions to ensure bi-directional responsiveness.

- **M31–M36:** Full-scale evaluation will be conducted, covering system scalability, network load resilience, energy efficiency, and end-to-end latency. The final PoC will be assessed against 6G KPIs and KVs, with a specific focus on user QoE in XR environments under mobile UAV scenarios.

PoC#1 will receive inputs from WP5 deliverables (D5.1, D5.2, and D5.3) covering semantic communications. It will also exploit O-RAN advancements (D6.1, D6.2, and D6.3), particularly in relation to real-time control and semantic data exchange. In addition, WP3 contributes with AI/ML-based channel estimation and link prediction techniques, which will be integrated to optimise the physical layer and enhance the responsiveness and efficiency of XR-UAV interactions. WP2 supports PoC#1 by providing use case specifications, system requirements, and architecture guidelines essential for scenario definition and alignment with project-wide objectives. The validation process will follow the methodology defined in D7.1 and feed into D7.2 and D7.3, which report on testing results for Phases A and B, respectively.

D7.1 Prototype plan and evaluation methodology.

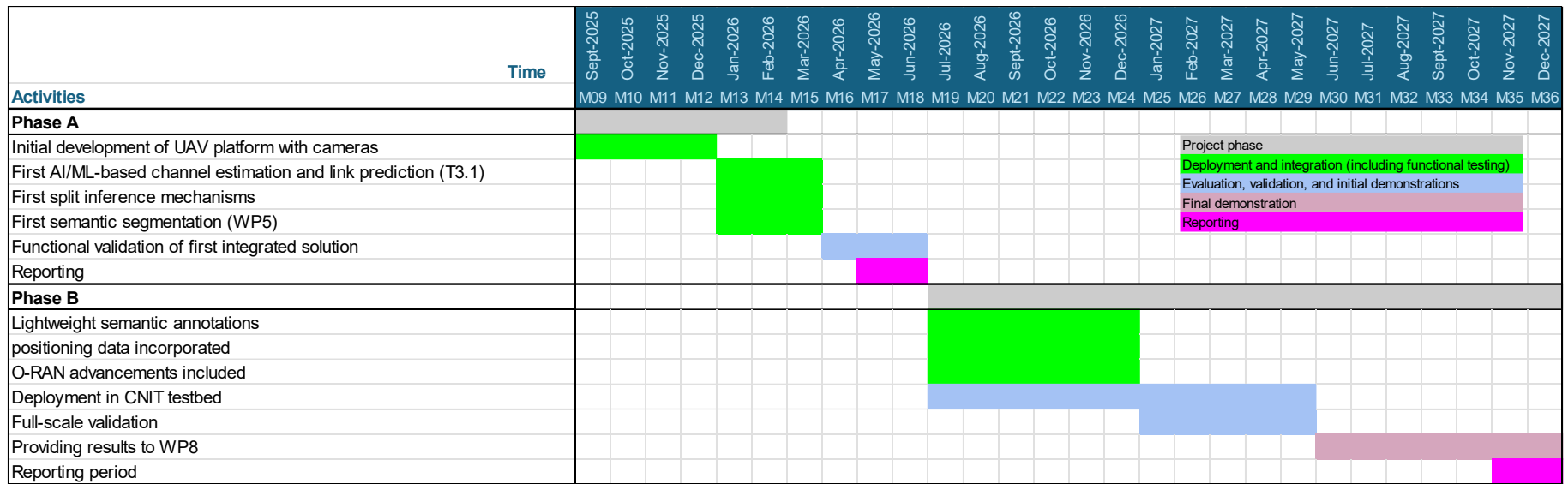


Figure 3.1. Time plan for PoC#1

3.3.2 PoC#2 schedule and deliverables

The development and testing schedule of PoC#2 is defined based on the following phases:

Phase A (M9–M18):

- Integrate the SRS DU, in full duplex “FDD” mode, with MB’s RU. Validate the integrated system and test all RU functions.
- Develop and validate the “beamforming” DU-RU fronthaul, starting with a simplified loopback setup. In this initial testing, no RF will be utilized (between UL and DL), and the DL signal will be looped-back (transmitted) in the UL port at the same time (providing a fully-loaded UL and DL test).
- The first milestone of PoC#2 is expected in M18, with the initial integration of the SRS DU and the MB RU, capable of running a non-RF real-time full-stack configuration using the DU test-mode (i.e., exchange of front-haul traffic without RF, exercising the complete stack). This milestone will be included in the D7.2.

Phase B (M19–M36):

Phase B.1 [M16-M21]:

- Extend the implementation resulting from the first milestone by deploying an end-to-end system in test mode in FR1, fully using the RF chains of the RU.
- As a first step, a limited DL-only configuration will be utilized, still employing the DU test-mode, while interfacing the RF ports of the RU with the R&S signal analyzer as UE. This test will target a fully-loaded 100 MHz DL signal use-case.
- As a second step, the UL will be incorporated. While the DU test-mode will be kept, the setup will implement a DL/UL RF-loopback.
- The 2nd milestone of PoC#2 is expected in M21, with an intermediate integration of the SRS DU and the MB RU, capable of running a real-time full-stack configuration using the RF functions and the SRS DU test- mode (i.e., RF UL/DL loopback).

Phase B.2 [M22-M36]:

- SRS will extend the front-haul functionalities in their DU to enable the transmission of beam IDs to the RU in the C-plane messages. The beam IDs will enable the RU to implement a beam sweep (e.g., starting with SSB signals). As a first step, the beam IDs will be assigned on a frame basis (i.e., one frame, one beam ID), to subsequently move to a subframe basis. A second step will enable the beam IDs to be assigned on a slot basis. The final goal is to enable the assignation of beam IDs on an OFDM symbols basis.
- MB will work to complete its analog RIS beamformer (with an antenna feeder) at 7.1 GHz. As a first step, near field measurements between the feeder and the RIS beamformer will be performed. Finally, far field measurements from the RIS beamformer to the RF signal analyser will be conducted to validate the complete RF functionalities.
- MB will prepare the RU to extract the beam IDs (e.g., extract the beam IDs from PCAPs capturing the front-haul traffic between the DU and the RU), and SRS will prepare its DU

to allow scheduler control of the new antenna architecture by sending the required beam IDs.

- The 3rd milestone of PoC#2 is expected in M30, with a complete integration of the SRS DU and the MB RU, showcasing a beam-sweep configuration in FR3. Finally, in M36 the PoC will contribute to D7.3 by including comprehensive evaluation results resulting from the full-scale evaluation of the proposed solution (to be conducted between M31 and M36).

PoC#2 will receive inputs from WP4 deliverables (D4.1, D4.2, and D4.3) covering the RIS designs and FR1/FR3 coexistence analysis results. It will also exploit the O-RAN enhancements produced in WP6 (D6.1, D6.2, and D6.3), particularly relating to the extension of the OFH interface and the enhanced DU to support the near-field RIS beamformer O-RU. WP2 contributes to PoC#2 by defining the use case requirements, expected impact areas, and integration conditions with the overall system architecture. The validation process will be dictated by the methodology defined in D7.1, and provide its results in D7.2 and D7.3. the detailed time plan is presented in Figure 3.2.

D7.1 Prototype plan and evaluation methodology.

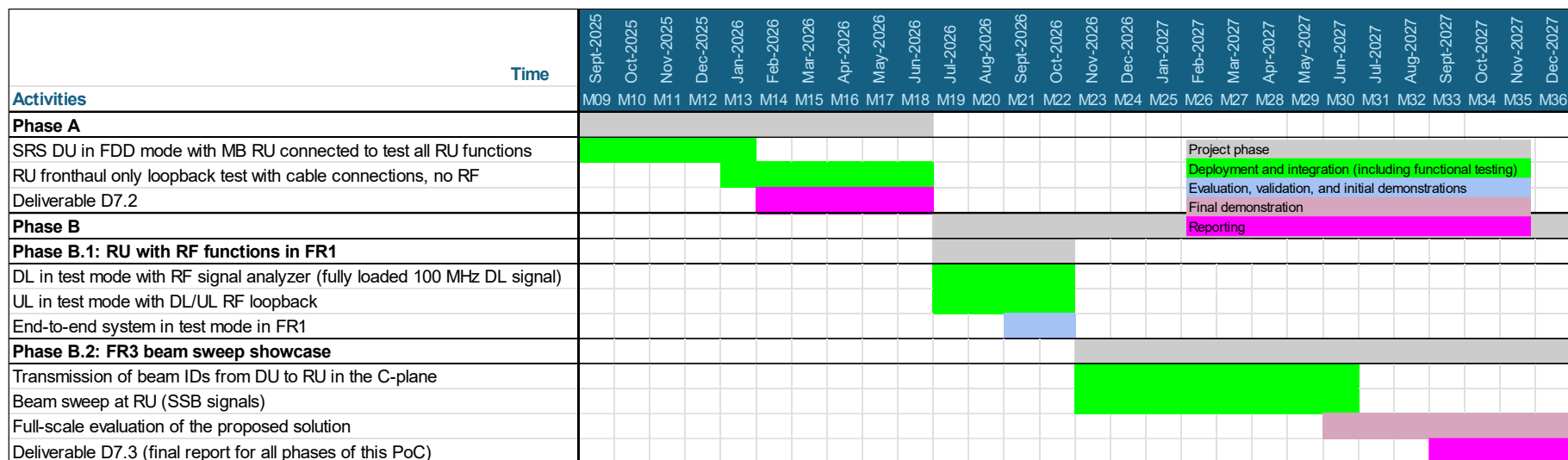


Figure 3.2. Time plan for PoC#2

3.3.3 PoC#3 schedule and deliverables

For the PoC#3, the schedule follows the two-phase approach of **6G-LEADER**, and includes the following activities:

Phase A (M9–M18): will focus on deploying near-RT and non-RT RIC units and integrating them with RAN Emulator, deploying and integrating traffic steering and energy efficiency xApp(s)/rApp(s) within the RIC platforms, and conducting evaluation, validation, and demonstration of the gains that the applications can offer to the network when they are running individually.

Phase B (M19–M36): Here, the refined and enhanced final version of the PoC from Phase A will be developed.

- **M19-M26:** The early version of the Conflict Manager solution will be deployed to assess the impact of conflicting objectives for the traffic steering and energy efficiency xApp(s)/rApp(s) that are running together. This will follow by fine tuning the design of xApp(s)/rApp(s) and Conflict Manager and conducting assessment of the two use cases based on enhanced RAN configurations to better reflect the dynamics of real wireless network scenarios.
- **M26-M32:** The designed AI-driven and semantically-enhanced applications (developed as part of Task 6.2) will be integrated into this PoC#3, and the related gains will be assessed and demonstrated.
- **M31-M36:** The real RAN stack will be deployed and integrated in DICAT SONIC Labs testbed to conduct the assessment and demonstration of the gains that can be offered from the latest versions of the developed **6G-LEADER** xApp(s)/rApp(s) and Conflict Manager in real network
- **M32-M36:** The developed Conflict Manager framework that will be trained with realistic data sets (within Task 6.3) will be integrated within PoC#3, and based on the chosen sets of xApp(s)/rApp(s), the resultant gains and discrepancies will be optimised and demonstrated.

Regarding the relation of PoC#3 with the other WPs and deliverables, it receives input from WP2 tasks and deliverables for requirements and architectural design, and also WP6 activities (mainly Tasks 6.2 and 6.3) and related deliverables (D6.2 and D6.3) that cover the intermediate and final results of the studies for AI/ML-driven and semantically-enhanced O-RAN applications. The contribution for the design and implementation of semantic-based enablers from WP5 will be applied through WP6 tasks.

The evaluation, validation, and demonstration of PoC#3 will follow the methodology as described in Section 4.1, and the related testing and validation reports will be presented as part of deliverables D7.2 (for Phase A) and D7.3 (for Phase B). A time plan and activities for PoC#3 are presented in Figure 3.3.

D7.1 Prototype plan and evaluation methodology.

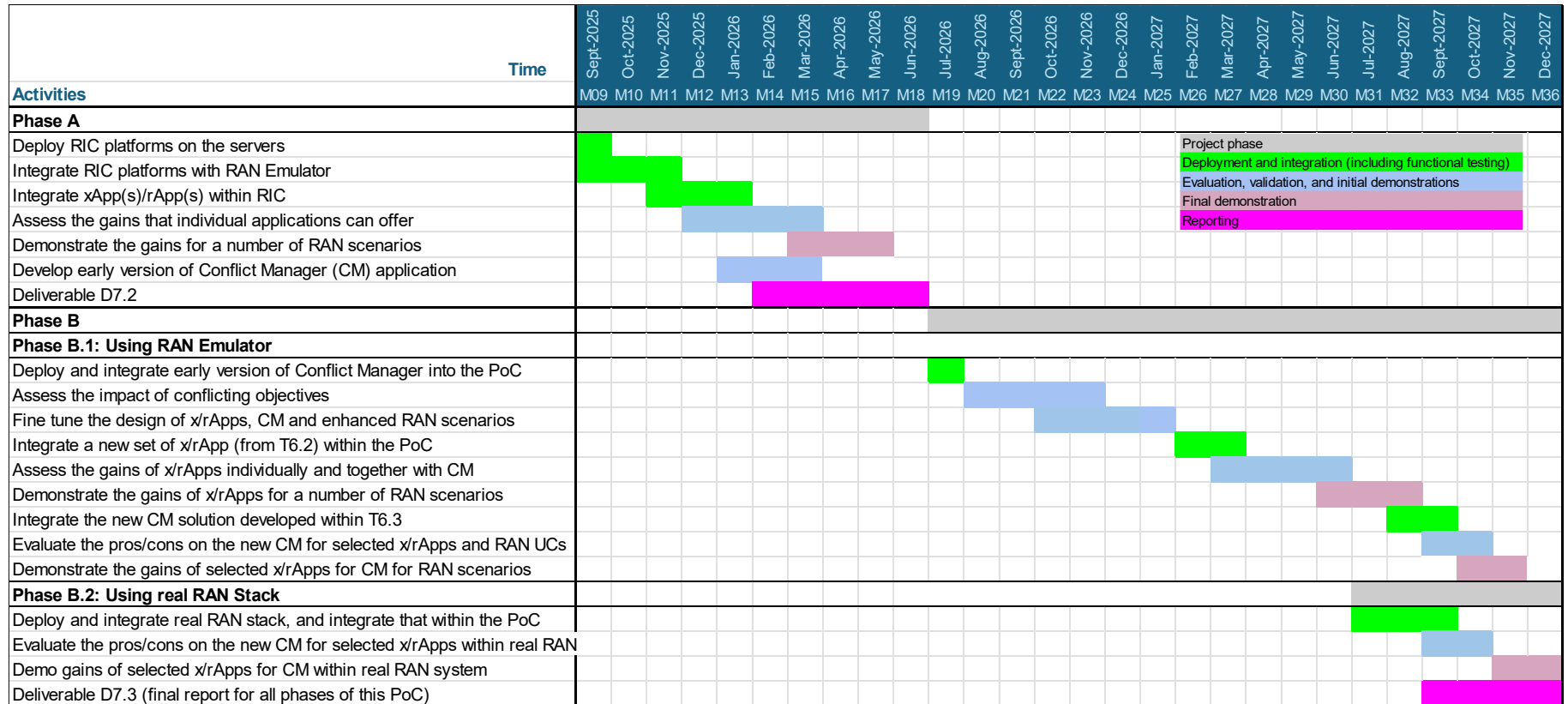


Figure 3.3. Time plan for PoC#3

3.3.4 PoC#4 schedule and deliverables

The schedule of PoC#4 shown in Figure 3.4, follows the two-phase approach of **6G-LEADER** and includes the following activities:

Phase A (M9–M18): This phase will focus on integrating the **6G-LEADER** technological innovations and adapting the PoC to the deployment infrastructure.

- **M9-M12:** Combination of the AI/ML-aided channel estimation/prediction algorithms from T3.1 with AirComp scheduling, weighting and aggregation mechanisms from T3.3, enabling efficient resource allocation for edge devices.
- **M13–M15:** Initial xApps will be developed for task orchestration, based on predefined network requirements and testbed configurations. Validation during this phase will focus on functional testing, ensuring interoperability across the testbed.
- **M16–M18:** Initial prototype of the Wireless for AI PoC will be released for performance evaluation, in terms of mean squared error (MSE) of inference tasks, energy consumption, and spectral efficiency. The outcomes of these tests will drive the refinements of the PoC in the next phase.

Phase B (M19–M36): The refined and final version of the PoC will be developed, leveraging semantics-awareness for improved resource efficiency.

- **M19-M24:** Lightweight semantic annotations into xApps, aiming to improve resource optimisation and task allocation, will be integrated.
- **M25–M30:** Semantics-aware orchestration will be deployed and validated in the CNIT testbed. Final evaluation will focus on the efficiency of the semantic enhancements, validating performance against 6G-related KPIs and KVIs.
- **M31–M36:** Full-scale validation will be conducted, including assessment of system scalability, energy efficiency, and MSE level for varying number of edge nodes and different inference tasks. The final PoC results will be delivered to WP8 for exploitation planning and sustainability assessment.

Regarding PoC#4's relation with deliverables, it will exploit WP2 outputs on architectural design (D2.2 and D2.3), which are essential for deploying the PoC within an O-RAN-compliant environment. This PoC also receives input from WP3 deliverables (D3.1, D3.2, and D3.3), which provide initial, intermediate, and final results on AI/ML-aided PHY algorithms and AirComp optimisation mechanisms. Moreover, PoC#4 incorporates contributions from WP5 (D5.1, D5.2, and D5.3), where semantics-based schemes are developed to reduce control-plane overhead and improve the performance of over-the-air computation. Additionally, the PoC will build on WP6 results (D6.1, D6.2, and D6.3) related to architectural extensions enabling real-time control (via dApps) and semantic integration. PoC#4 will follow the evaluation and validation methodology outlined in this deliverable and contribute its results to D7.2 and D7.3, which report on the outcomes of Phases A and B, respectively.

D7.1 Prototype plan and evaluation methodology.

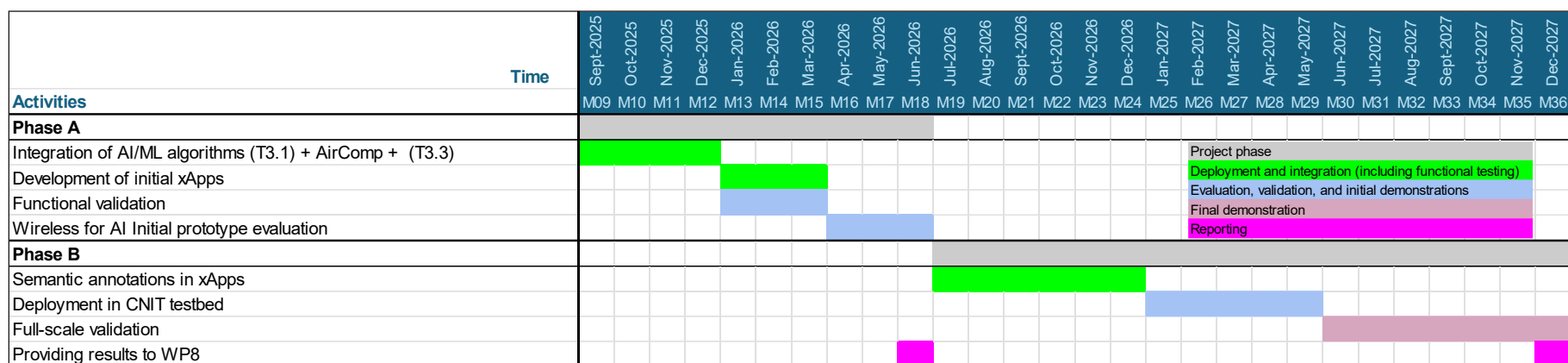


Figure 3.4. Time plan for PoC#4

3.3.5 PoC#5 schedule and deliverables

PoC#5 will receive inputs from deliverables of WP2, WP3, and WP4 as they address different architectures and evaluation of solutions taken for FA technologies. Deliverables associated with WP7 will directly state the development of PoC#5 and will naturally reflect the evolution of this PoC, as well as the results obtained and their discussion. The schedule for PoC#5 follows the structure of **6G-LEADER** hence it is divided in two main phases:

Phase A (M1-M18): Using inputs from other WPs and SOTA, the main goal during this period is to define a suitable design for this PoC. Its architecture strongly depends on the solutions that are to be agreed by the different partners. During this period, the manufacturing of the first hardware designs will start, giving additional inputs to the partners to iteratively upgrade initial ideas. This process will conclude with deliverable D7.2, in which a final architecture will be presented for this PoC. Preliminary tests are planned to evaluate the designs with hardware.

- **M9–M11:** Initial antenna design iterations and simulations begin, exploring electrowetting and reconfigurable RF-chain options. Test scenarios and PoC requirements are finalised.
- **M12–M14:** Early integration of AI/ML algorithms for channel estimation and reconfiguration. Laboratory-based testing of single-device FA prototypes.
- **M15–M18:** Evaluation of EMF exposure reduction and energy savings begins. Metrics such as power consumption and sum-rate are measured, and the first internal release of the PoC prototype is validated in the UC3M testbed.

Phase B (M18-M36): Once the final architecture is decided, the manufacturing process can start, making sure that the outcome addresses the different KPIs presented in **6G-LEADER**. A thorough measuring and testing campaign will be conducted in parallel therefore design can be upgraded in accordance with our expectations. This campaign must ensure that the reconfiguration process occurs thoroughly, addressing reconfiguration speed, accuracy and repeatability. Furthermore, the communication link has to be evaluated as well, measuring reflected power, radiation pattern, energy consumption, which would be necessary to successfully assess the performance of the PoC.

- **M19–M24:** System-level tests are executed under varying user densities and RF conditions to validate multiple access enhancements. Integration with PoC5 monitoring and control components is completed.
- **M25–M30:** Full interoperability with the rest of the O-RAN testbed is established. Targeted validations are conducted on KPIs such as energy consumption (-30%), EMF exposure (-25%), and sum-rate improvement (+40%).
- **M31–M36:** Final demonstration activities are conducted, supported by a refined version of the prototype. The PoC outputs are reported to WP8 for exploitation and long-term sustainability planning.

The evaluation of the final PoC and its reporting stage will end with deliverable D7.3. The time plan of this PoC is shown in Figure 3.5.

D7.1 Prototype plan and evaluation methodology.

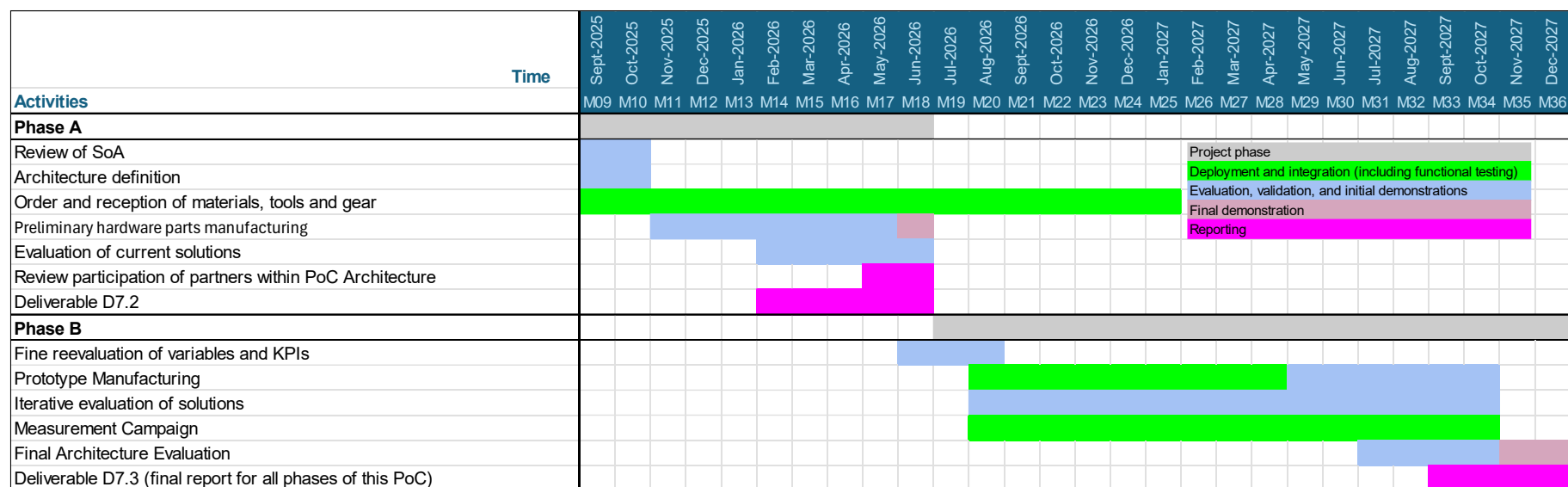


Figure 3.5. Time plan for PoC#5

3.4 Test environments and infrastructure

For the PoC developments and experimental evaluations, four testbeds will be used that are located at DICAT premises (SONIC Labs in the UK), MB testbed (Berlin, Germany), CNIT (S2N in Genoa and Arno in Pisa, Italy), and UC3M (Madrid, Spain).

3.4.1 DICAT SONIC Labs

DICAT SONIC Labs is a distributed network, seamlessly connecting four strategic sites that provide commercially-neutral, multi-tenancy open network testbeds, and provides infrastructure (computing, networking and storage) for deploying the network solutions. As shown in Figure 3.6, it provides real-world indoor and outdoor scale environments, including test and measurement capabilities. The testbed spans across four strategic sites, namely Site 1 at DICAT Euston Road Floor 9 (Lab), Site 2 at Ofcom Riverside House, Site 3 at DICAT Euston Road Floor 8 & 9, and Site 4 (Outdoor) at Fulham/Parsons Green.

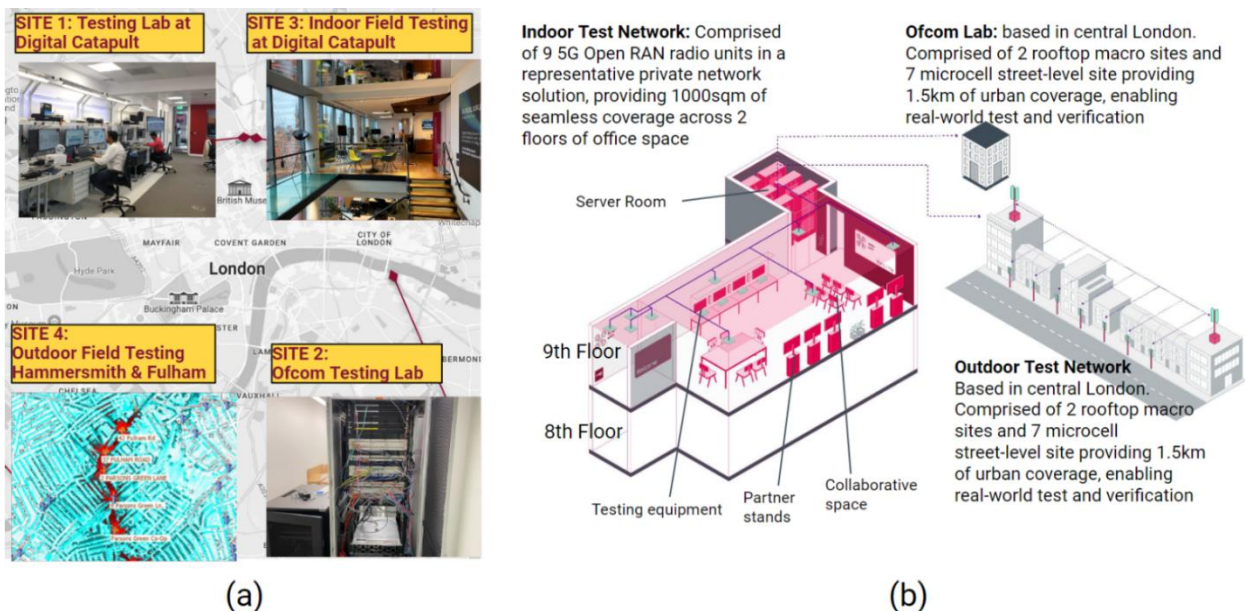


Figure 3.6. DICAT SONIC Labs a) four strategic sites. b) High level description.

Here, Site 1 at DICAT Euston Road (Figure 3.7) acts as the primary infrastructure site supporting the other three sites through common infrastructure.

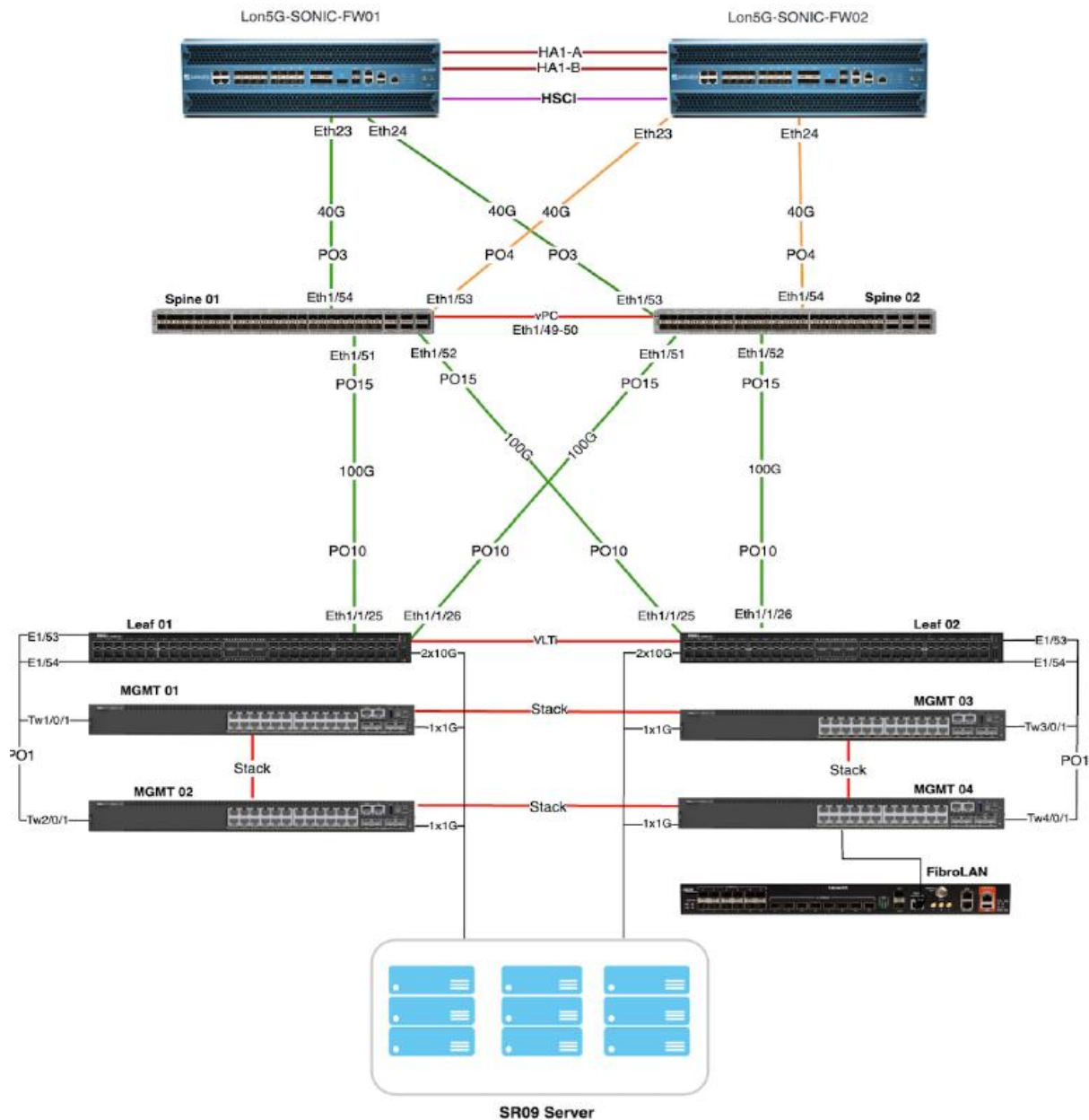


Figure 3.7. DICAT Site-1 Infrastructure Diagram: High available and fail safe.

DICAT infrastructure is equipped with a sheer amount of computing, networking, and storage capabilities, comprising:

- Over 1440 CPU Cores.
- 32 x Dell PowerEdge R750.
- 3 x Dell PowerEdge R740.
- 2 x ARM Servers.
- 7 x SuperMicro IoT SuperServer SYS-110P-FRN2T.

To support the AI/MLOps in **6G-LEADER** that entail computationally intensive calculations, GPUs are typically more preferred options than CPUs. The GPU processing capabilities at DICAT are not limited to the SONIC Labs testbed, and DICAT provides more capacity and diversity for GPU-based processing, i.e. DICAT provides 39 GPUs (A2, A40, and A100 NVIDIA GPUs, deployed on the servers across different sites) and examples of product specifications for these GPUs are provided in Table 3.11.

Table 3.11. Specifications of A40 and A100 GPUs

Specification	GPU A40	GPU A100
GPU Architecture	NVIDIA Ampere	NVIDIA Ampere
Compute Cores	10,752 CUDA Cores 336 Tensor Cores 84 RT Cores	6912 CUDA Cores 432 Tensor Cores
Double-Precision Performance	FP64: 0.585 TFLOPS (584.6 GFLOPS)	FP64: 9.7 TFLOPS; FP64 Tensor Core: 19.5 TFLOPS
Single-Precision Performance	FP32: 37.4 TFLOPS; TF32: 74.8 149.6* TFLOPS	FP32: 19.5 TFLOPS; Tensor Float 32 (TF32): 156 TFLOPS 312 TFLOPS*
Half-Precision Performance	INT8: 299.3 TOPS 598.6 TOPS*; INT4: 598.7 TOPS 1197.4 TOPS*	INT8: 624 TOPS 1,248 TOPS*; INT4: 1,248 TOPS 2,496 TOPS*
Integer Performance	73.1 TFLOPS	312 TFLOPS 624 TFLOPS*
GPU Memory	48 GB GDDR6 with ECC	40GB HBM2
GPU Memory BW	696 GB/s	1,555 GB/s
Max Thermal Design Power (TDP)	300W	250W
Multi-Instance GPU	Not Supported	Up to 7 MIGs @ 5GB
NVLink Interconnect	112.5 GB/s	600 GB/s

Also, RAN emulation is provided by the RIC tester platform. For RAN emulation, a scenario can be created close to the real-life network, by setting the desired configurations for the cells (such as TDD/FDD, frame format), users (mobility model, slice type), and propagation environment (channel model and geo information), and expose different KPMs/KPIs, e.g., to form data sets required for training ML-driven methods for near-RT RIC xApps.

To train new AI/ML-driven algorithms for xApp/rApp products, developers require (ideally) operational live data, which is very challenging to be provided in practice as such real-life network data sets cannot be fine-tuned according to the specific design requirements and also, they are typically classified as commercially sensitive information to be provided by Mobile Network Operators (MNOs). Hence, RANs can be emulated based on the targeted scenarios, and the required parameters for training purposes can be exposed in the form of data sets of different types.

For example, the aim of the O-RAN defined Energy Saving (ES) use case [2] is to leverage AI/ML-driven methods (on non-RT and near-RT RIC) and open interfaces to enable energy-efficient solutions that are designed around switching the operating modes of RAN components at different times, e.g., based on traffic-load on cells. In this case, to train the new AI/ML-assisted algorithms, the given scenario for the network (e.g., number and location of cells and their configurations, user types and their mobility models, etc.) can be emulated, and the exposed measurement parameters can be used for xApp/rApp training.

For the RAN emulation, using SONIC Labs facilities, the scenario can be created close to the real-life network (e.g., as depicted in Figure 3.8), by setting the desired configurations for the cells, users, and propagation environment, and then providing the data sets (e.g., as CSV files) of KPIs/KPMs for developers to train their AI/ML data-driven methods. Table 3.12, Table 3.13 and Table 3.14 provide a summary of some of the key parameters that can be configured for cells, users, and propagation environment to emulate the desired RAN scenario, respectively. For the KPI/KPM data sets, several parameters can be reported, namely, at

- **UE-level:** Such as UE's throughput request for UL/DL, average UL/DL Physical Resource Blocks (PRBs) used for data traffic, 5G QoS Identifier, etc.
- **Cell-level:** Not limited to performance parameters (such as for both UL and DL, the mean PRBs used for data traffic, maximum number of PRBs available, total usage in percentage of PRBs), but also providing energy consumption measurements at cells in terms of standardised KPIs [3] (e.g., average power consumed over the measurement period in watts, and energy consumed in kilowatt-hours, kWh) and non-standard KPIs (e.g., energy efficiency in bits per joule).

In summary, providing RAN emulation data sets that reflect the characteristics that are close to real-life network data is one of the key requirements for xApp/rApp developers to train their AI/ML-driven models. This can be provided based on highly-configurable models available at SONIC Labs.

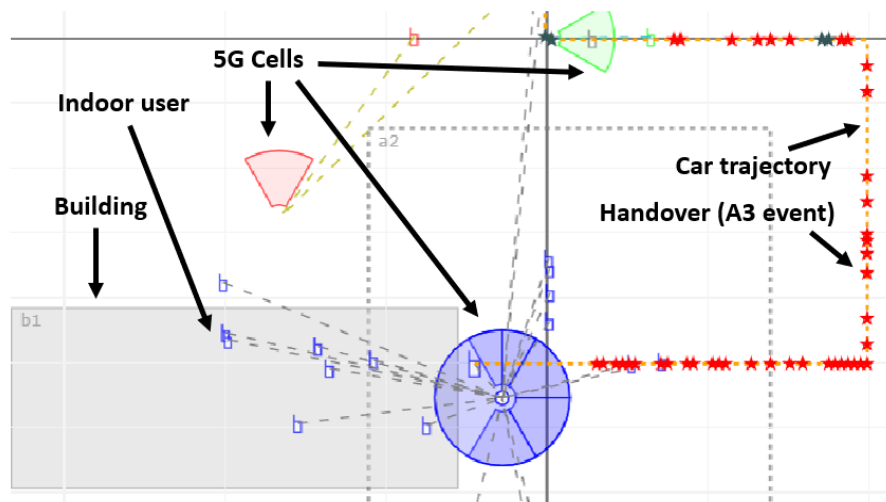


Figure 3.8. Example of a scenario for RAN emulation including indoor and mobile users.

Table 3.12. Cell Configurable key parameters for RAN emulation

Cell Parameters		Remark
Mobile cellular technology	LTE/NR	
Transmitter/site parameters	Power, azimuth, tilt	
Configurations for transmission	TDD/FDD, frame structure, bandwidth, 5G numerology	

Table 3.13. Users Configurable key parameters for RAN emulation

User Parameters	Remark
UE type	Indoor and outdoor (pedestrian, car)
Service type	Main parameters such as slice type (e.g., eMBB, URLLC), QoS Identifier (5QI/QCI), and more detailed parameters such as targeted service throughput, average call duration, etc.
Mobility models	e.g., Manhattan/Berlin (and specify speed)

Table 3.14. Radio Propagation Configurable key parameters for RAN emulation

RF Parameters & Propagation Environment	Remark
Map	Can be different types. Based on ASCII diagram, several parameters are available to be adjusted, e.g., street width, details of buildings (location/height)
Geo information	Location/height for UE(s) and cell(s)
Propagation scenario	e.g., Umi [4]
Antenna models	e.g., isotropic or other models from a vendor
Inter-cell interference	Can be considered complying O-RAN TIFG E2E Test specs

3.4.2 MB Testbed

PoC#2 will be evaluated at MB in Berlin. The testbed is under preparation/construction and will consist of an SRS O-DU, a MB FR3 O-RU and a Rohde & Schwarz FR3 measurement grade equipment serving as User Equipment (UE).

In particular, the Massive Beams testbed features an 8×8 dual-polarized FR3 NFED-RIS prototype with integrated 2-bit switched delay lines. The prototype is illuminated by a 2×2 feed array within a configurable near-field Over-the-Air (OTA) setup. The alignment and distance between the RIS and feed are precisely optimized to maximize coupled S-parameters. The RIS can be controlled via configuration updates over a digital interface, enabling analog beamforming experiments. This configuration allows for a detailed analysis of near-field illumination patterns, mutual coupling, and polarization behaviour (see in Figure 3.9). The system will be deployed in a large anechoic chamber with increased transmitter-receiver separation to study far-field beam patterns and polarization-multiplexed transmission. The anechoic chamber for far-field measurements is currently being prepared and will be ready for use starting in M10.

The Massive Beams RU SDR platform, "MODRAD", will be used as an open RAN-compliant radio unit to generate downlink and uplink signals and control the beamforming weights of the NFED-RIS beamformer. The beamforming weights are transmitted to the RU by the SRS open RAN-compliant DU. A Rohde & Schwarz RF signal analyzer acts as the UE.

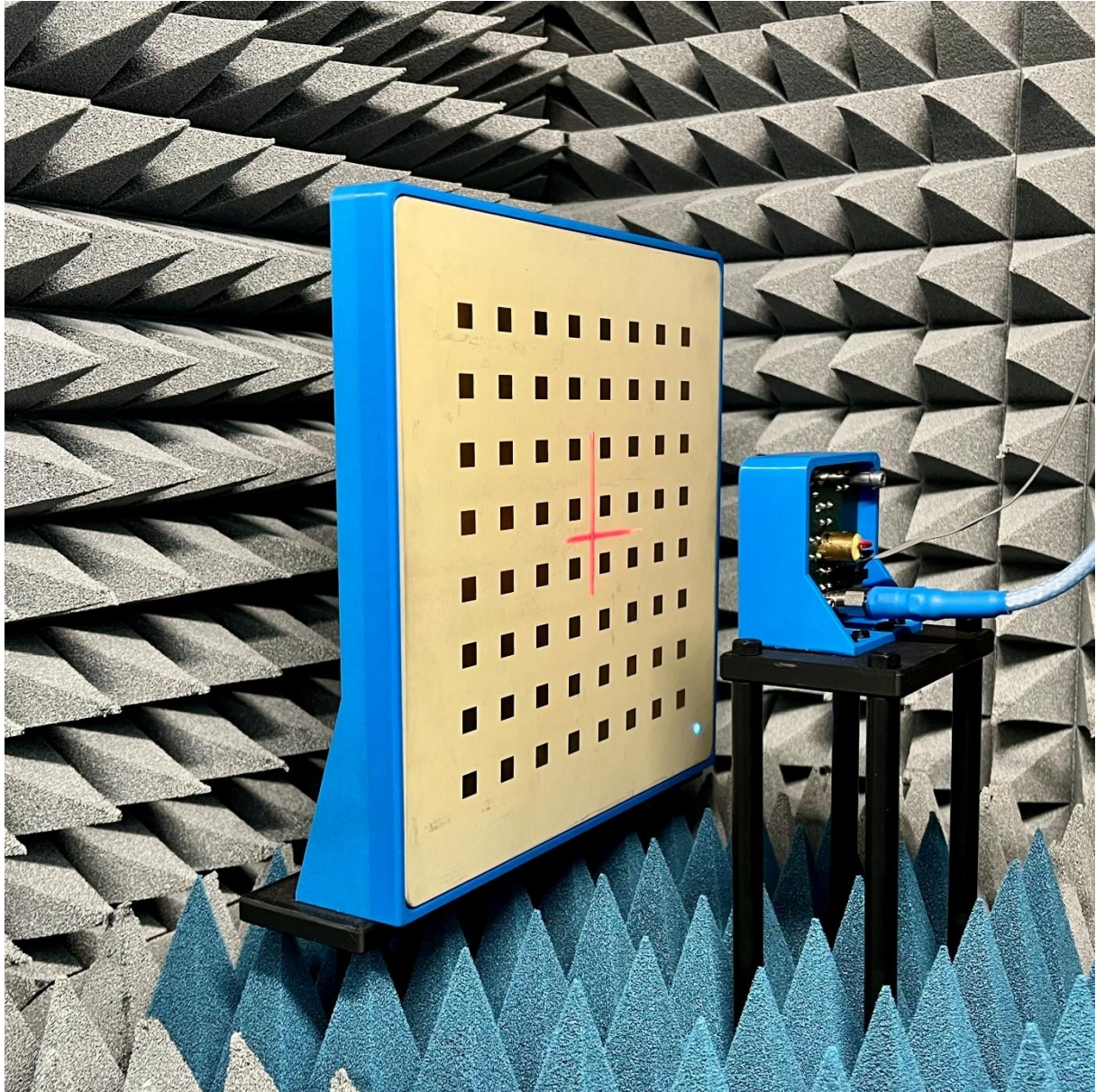


Figure 3.9. Massive Beams Near-field measurement setup

3.4.3 CNIT ARNO Testbed

The experimental assessment of PoC#1 and PoC#4 will be performed in the CNIT Advanced Research on NetWorking (ARNO) testbed located in Pisa (Italy), federated with the CNIT testbed in Genova (Italy). The testbed includes heterogeneous computing and networking resources, from 5G solutions to optical transport and access networks as well as edge and cloud computing infrastructures, as illustrated in the Figure 3.10.

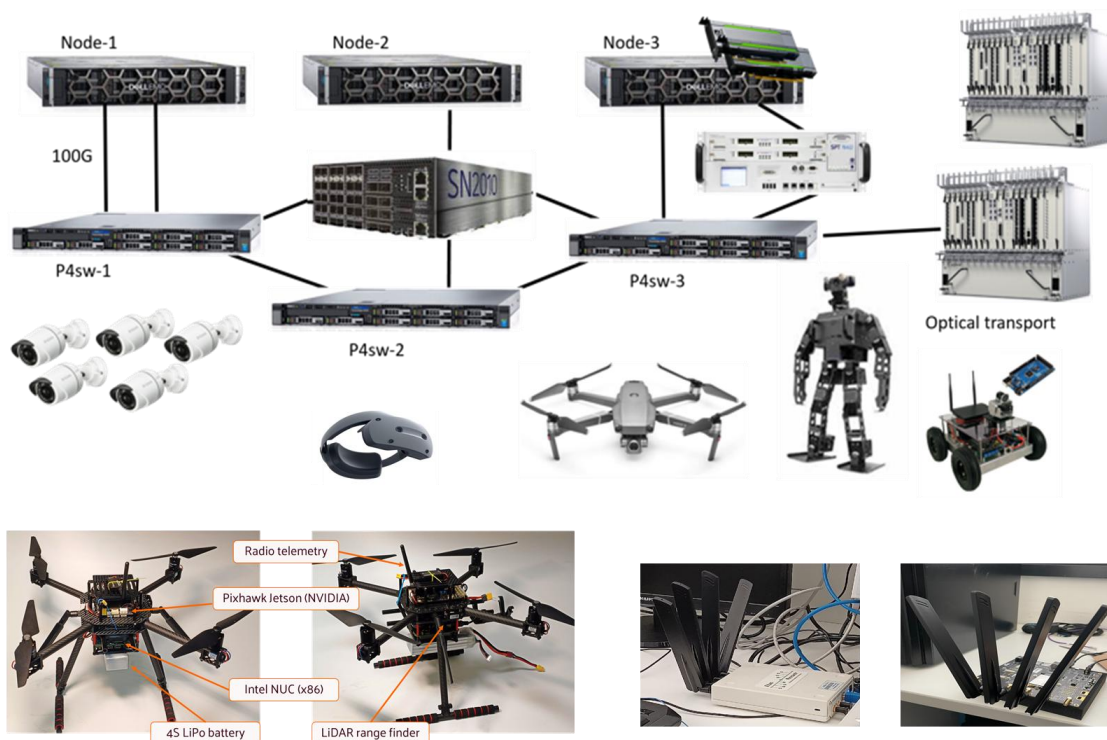
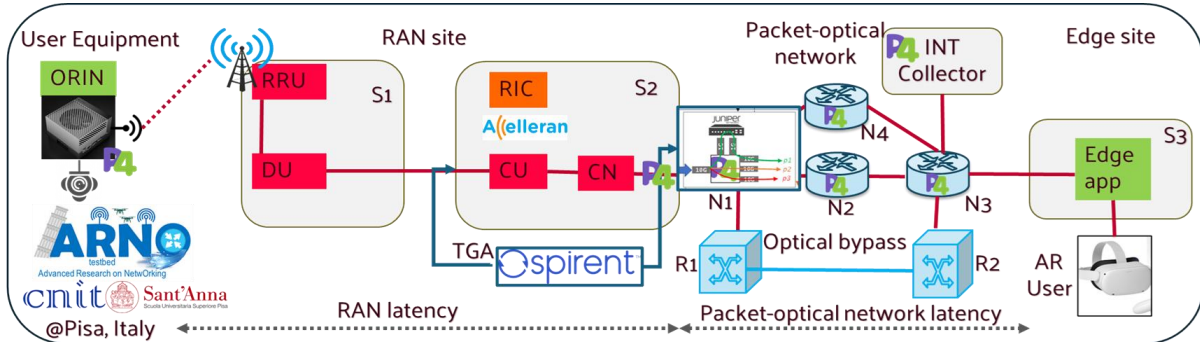


Figure 3.10. PoC#1 and PoC#4 Site infrastructure.

The following Hardware and Software systems are made available during the project lifetime:

- **5G technologies:** Commercial 5G solution by BubbleRan, 5G O-RAN prototype solution developed by Accelleran and SRS, mobile network software (OAI5G, srsRAN) with Ettus B210, X310, N310, and Quectel 5G.
- **Computing resources:** n.10 DELL PowerEdge with NVIDIA Tesla GPU and/or 100G/200G smart NICs (NVIDIA Bluefield 2 and 3) and a prototype of a power-efficient Edge Micro Data Center, named BRAINE, encompassing CPU, GPU, innovative liquid cooling system, advanced monitoring solution for energy efficient control of workload execution.
- **Wired network infrastructure:** P4 Programmable 100G switches (n.3 Mellanox, n.1 APS Intel Tofino1), n.8 Cisco and Juniper routers, metro optical transport technologies including 400Gb/s IPOWDM switch, n..4 ROADMs, n.2 coherent 600G transponders;

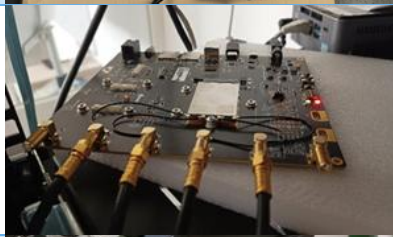
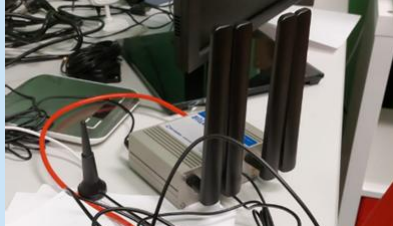
teraFlow SDN Controller; traffic generator and analysers (Spirent N2X at 1-10Gb/s, VIAVI at 10-100-400Gb/s).

- **Infrastructures for verticals:** n.2 drones with payload NVIDIA ORIN and cameras, n.3 SuperDroid 4WD rovers, n.6 HD cameras, VR/AR Headset, Humanoid robot Robotis OP3.



Figure 3.11. PoC#1 and PoC#4 Laboratories.

Table 3.15. CNIT Lab available UEs

Description	Quantity	Type	Image
5G Quectel RM500Q-GL	3	Quectel	
5G Quectel RM500Q-GL Evaluation board	2	Quectel	
5G Quectel RG501Q – embedded within Teltonika RUTX50 Industrial-grade router	1	Quectel	

These UEs are typically connected via USB 3.0 to a gateway device (e.g., an x86-based NUC), which can also collect sensor data from additional connectivity systems, such as LoRa/LoRaWan, NB-IoT, wi.fi, Bluetooth, or USB (see Figure 3.12).



Figure 3.12. Setup for sensor connectivity.

The IoT sensors currently available at CNIT lab are:

- **Multimodal dry container:** Prototypes of racking and monitoring systems for ISO 668 dry containers are available at CNIT lab. Each prototype includes [5]:
 - **Tracking & Motion Sensing:** (1) GNSS receiver for precise container location and movement tracking, (2) accelerometer to measure mechanical shocks, vibration, and motion events during transport.
 - **Environmental Monitoring:** (1) Temperature sensor (ambient) to monitor container internal/external temperature thresholds; (2) humidity sensor inside the container; (3) Pressure sensor (barometric), potentially used to detect door opening or environmental changes.
 - **Other Status Sensors:** Tamper sensors / door open-close switches, used to detect unauthorized access or theft attempts.
- **Drone sensors.** Each UAV is equipped with:
 - Inertial sensors (accelerometers, gyroscopes).
 - Positioning (GPS, altimeter).
 - Imaging (cameras).
 - Environmental (temperature, humidity).
 - Motor and battery monitoring sensors.
 - **Posture sensors:** IMU (Inertial Measurement Unit) each equipped with accelerometers, gyroscopes, and magnetometers.

In addition to the already available IoT sensors, others could be considered and purchased, for example to demonstrate smart manufacturing (pressure, flow, current, vibration, temperature, humidity), natural disaster detection (seismic sensors, accelerometers, geophones, high-precision GPS, barometric pressure, tiltmeters, inclinometers, sound or vibration).

3.4.4 UC3M Testbed

The Laboratory of the Group of Communications at UC3M in Madrid, Spain, is a facility designed for the characterization of the physical layer in diverse communication systems. Particularly, for addressing PoC#5, it offers an array of instrumentation, including:

- Network analysers
- Programmable waveform generators
- Oscilloscopes
- Spectrum analysers
- USRPs
- Computational Cluster for demanding operations (+100 CPUs)

This venue empowers both students and researchers to analyse critical parameters for communications in general as shown in Figure 3.13.



Figure 3.13. General view of testbed for PoC#5.

There is also space to address the fluidic demands of the prototype basically consisting of:

- Syringe pumps
- Optical tables
- Signal Generators
- ADC, Acquisition Board
- Microfluidic gear (tubes, joints...)

Furthermore, the university offers additional space to accommodate specialized tests, such as extensive channel measurements, in which the characterization of the environment is addressed. In addition, external facilities at campus provide other general services such as 3D printing.

4 Evaluation & Demonstration Methodology

This chapter introduces the general methodology developed for the evaluation and demonstration of the **6G-LEADER** PoCs, structured in defined phases to support alignment with project goals. The evaluation methodology is divided into three main components: monitoring, validation, and demonstration. Monitoring and validation form the core of the evaluation process and will be discussed in detail in the following sections. In particular, validation is directly linked to the phased implementation of each PoC, described in Section 3.1, ensuring that evaluation activities are integrated into the overall development lifecycle. This phased approach allows for continuous assessment and correction, supporting a more agile and reliable innovation process. The demonstration phase provides a practical view of each PoC's capabilities and impact. Through real-world testing and live sessions, **6G-LEADER** will showcase how each solution operates under realistic conditions, providing clear evidence of its relevance and value.

This structure not only supports technical assessment but also ensures that the evaluation outcomes are aligned with the interests and expectations of the project's stakeholders. By focusing on traceable KPIs and clear validation procedures, the methodology builds trust in the results and strengthens the connection between technical work and stakeholder needs.

Moreover, the chapter addresses the risks associated with PoC implementation and evaluation. The methodology includes mechanisms to monitor these risks and implement mitigation strategies where needed, ensuring the robustness of the process. Finally, a dedicated section explores key considerations around scalability and security. These aspects are critical for assessing the long-term applicability of the proposed solutions and ensuring that the innovations developed in **6G-LEADER** can be extended and adopted in broader, real-world deployments.

4.1 General evaluation methodology

The PoC development and validation activities within WP7 of the **6G-LEADER** project follow a structured and systematic methodology designed to ensure the coherent demonstration of the key innovations and alignment with the overall technical objectives. The methodology is composed of four fundamental phases: Preparation, Setup, Integration, and Execution, each encompassing specific processes to ensure technological readiness, interoperability, and rigorous evaluation.

- **Preparation Phase:** During the preparation stage, detailed technical specifications are consolidated for each PoC based on the functional requirements derived from the **6G-LEADER** innovation pillars. This includes identifying the targeted use cases, defining the relevant scenarios, and determining the experimental conditions. Partners responsible for the

PoC coordinate to align development timelines and resource availability. Furthermore, test environments and measurement tools required for each PoC are validated for compliance with project objectives. This phase also included the definition of the monitoring framework (detailed in the following subsection) where the metrics, KPIs, and data collection procedures are defined.

- **Setup Phase:** The setup phase involves the deployment of the necessary components in the different testbeds, including DICAT SONIC Labs, TBD, CNIT ARNO, MB and UC3M facilities. During this phase, the necessary system components and technological building blocks are deployed and configured to enable the creation and validation of the PoCs. These may include hardware, software, and network elements provided by different partners, which are prepared to ensure their correct operation within the defined test environments. Particular attention is given to the interoperability of all components, ensuring compatibility across interfaces and facilitating seamless integration during subsequent phases.
- **Integration Phase:** Once individual subsystems are operational, the integration phase focuses on establishing seamless interoperability between all modules, ensuring E2E functionality of each PoC. This includes the consolidation of control and user planes, real-time data exchange, semantic information flows, and orchestration mechanisms via AI/ML-powered applications. Interfaces, such as those specified by O-RAN standards, are rigorously validated. Additionally, component monitoring and logging mechanisms are embedded to facilitate comprehensive performance tracking during experimental execution.
- **Execution Phase:** The final phase entails the systematic execution of experiments across the designated PoCs under controlled and real-world conditions. Each PoC undergoes iterative testing campaigns to assess functionality, stability, and performance against defined KPIs. Experiments are conducted under diverse scenarios, including varying traffic loads, mobility patterns, interference profiles, and hardware configurations. The execution process ensures that each PoC demonstrates its technological contributions in alignment with **6G-LEADER** objectives, enabling the collection of reliable datasets and empirical evidence to support subsequent validation, analysis, and dissemination activities. The Execution phase can be detailed in the following phases.
 - **Data & Metrics Collection:** This phase ensures that each PoC is equipped with the necessary mechanisms to gather accurate and relevant data for evaluation and validation. It begins with the definition of KPIs and supporting metrics tailored to each PoC's objectives. Based on this, a data collection framework is implemented to capture performance indicators consistently across test environments. This step is essential to enable meaningful analysis, ensure traceability, and support evidence-based assessment in later phases.
 - **Validation Phase:** The validation phase aims to confirm that each PoC performs as intended and delivers results that are consistent, repeatable, and aligned with its original design goals. This involves verifying the stability of the system over time, benchmarking results against reference values, repeating experiments to ensure consistency, and analysing different aspects such as implementation, assumptions, and test setups. Validation ensures that the outputs are technically sound and mature enough to support further development or integration.

- **Demonstration Phase:** The demonstration phase focuses on showcasing the practical value of each PoC in a real or emulated environment. This includes executing live tests or presentations that highlight how the solution behaves under realistic conditions, providing clear evidence of its capabilities and benefits. The goal is to communicate results effectively to stakeholders, validate integration across system components, and gather final feedback that can inform future improvements or deployments.

It is important to mention that the general evaluation phases are parallel to the development plan described in section 3.1. Phases A and B are derived from the timing on the project and the milestones associated, while the evaluation phases are defined to support the validation methodology in the project.

4.2 Monitoring, validation & component readiness

The evaluation and validation process begins with the definition of metrics and KPIs for each PoC. These indicators are derived from the specific objectives and expected outcomes of the PoCs and are aligned with the broader goals of the **6G-LEADER** project. This step ensures that performance, efficiency, scalability, and other relevant aspects can be measured in a meaningful and consistent way across all PoCs.

Once the KPIs and metrics are defined, a dedicated data collection framework is established for each PoC. This framework specifies what data needs to be gathered, how it will be captured, and at which points during the PoC execution. It ensures consistency across different test environments and provides a foundation for reliable performance evaluation and comparison.

Building on the data collection setup, a monitoring and validation framework is implemented for each PoC. This framework is fit to the nature of the PoC and the specific KPI groups it addresses. It allows real-time or post-processing analysis, to track the demonstrators' progress towards the objectives, and supports validation by confirming that each PoC performs as intended.

Finally, it describes the methodologies used to evaluate the readiness of the technical results, focusing on their maturity and ensuring alignment with the project's overall goals.

4.2.1 Metrics and KPIs

The performance evaluation and validation of the **6G-LEADER** PoCs are grounded in a robust framework of metrics, KPIs, and assessment criteria designed to quantify the impact of the project's technological innovations. These elements ensure objective measurement of functional, operational, and qualitative improvements achieved through AI/ML-driven enhancements, semantic communication principles, reconfigurable radio components, and advanced ORAN architectures.

Evaluation metrics are defined in alignment with the **6G-LEADER** innovation pillars and cover a wide range of technical domains. The following are a preliminary list of KPIs identified for the project, while a formal description will be presented as a result of WP2.

- Physical layer and RAN Performance:
 - Spectral efficiency improvements (>50% target for selected PoCs).
 - Enhanced sum-rate capabilities in multiple access schemes (target >40%).
 - AI/ML-driven channel prediction accuracy and robustness.
 - Reduction of EMF exposure (target 30% reduction).
 - Optimization of energy consumption in radio subsystems.
- Communication Efficiency and Semantics Integration:
 - Reduction in non-essential packet transmissions (target 60% reduction).
 - Communication overhead minimization via semantic data processing (target reduction of up to 90%).
 - Improved effective data rates with maintained QoE (target 30% reduction in transmission rate with same QoE).
- O-RAN and Control Loop Enhancements:
 - Deployment of AI/ML-empowered xApps and dApps for near real-time control.
 - Conflict Manager efficiency, aiming for up to 15% energy savings with minimal QoE impact and a 50% reduction in conflicting control actions.
 - Bounded control loop latencies (<10 ms target for real-time responsiveness).
- AI-Native and Wireless for AI Capabilities:
 - Latency reductions for AI model aggregation and inference tasks.
 - Adaptive orchestration of AI workloads with energy-efficient resource allocation.
 - Scalability metrics assessing system performance under increasing node densities.

Assessment criteria of the PoCs is based on rigorous comparison against:

- Baseline performance of existing 5G systems.
- Theoretical benchmarks derived from simulation models and standard references (e.g., 3GPP specifications).
- Targeted improvements as defined in the project KPIs.
- Repeatability and consistency across multiple experimental evaluations
- System resilience under realistic deployment conditions, including hardware variability, environmental factors, and user mobility.
- Contribution to achieving the overarching goals of the project by enhancing performance, efficiency, sustainability, and adaptability of future 6G networks.

Throughout the evaluation process, results are validated through systematic testing, data collection, and statistical analysis to ensure reliability and credibility. Where deviations from expected outcomes occur, iterative refinements to system configurations, algorithms, or hardware components are applied, following the continuous improvement approach embedded in the **6G-LEADER** methodology.

4.2.2 Data collection, analysis and reporting definition

The workflow for data collection and analysis for the PoCs is shown in Figure 4.1.

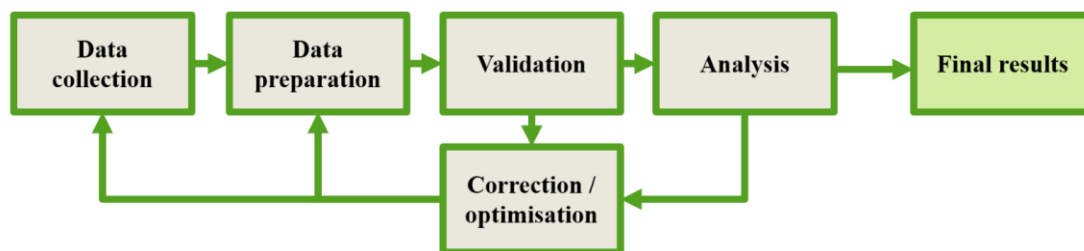


Figure 4.1. Workflow for data collection and analysis.

As a first step, it starts by collecting the data from experimental evaluations, which is primarily log files from test and measurement equipment and/or network nodes. At this stage, the required KPI to capture the related data types and sources, and also the mechanism for data acquisition and storage are already defined.

Then, the second step is the data preparation phase in which the desirable information is extracted from the raw data. At this stage, the data is prepared for processing at the subsequent stage. The preparation of the data may include data deletion and cleaning by removing the outliers and non-applicable values, identifying missed or corrupted information, applying normalisations on the data sets, and conducting overall quality audits to ensure the data sets are accurate and reliable.

Subsequently, the extracted information is validated to ensure the collected data sets meet the expected level of consistency and accuracy, and are trustworthy when benchmarked against existing data sets. This can be achieved by benchmarking against the results of secondary research, using tools available in standard specifications to theoretically calculate KPIs for a given set of parameters, etc. At this stage, if the observations were far from expected results, further iterations for the experimental evaluations will be conducted to re-run the experiments based on new setup, configuration parameters, or design. Once the results are validated, further analysis will be conducted that requires reflection, insight, and foresight. Once this stage is completed, the readiness of results will be confirmed for reporting.

4.2.3 KPI framework for the PoC

The KPI frameworks play a critical role in the **6G-LEADER** project by systematically collecting, analysing, and visualizing key performance data across the various PoCs. Their primary objective is to enable accurate and consistent measurement of progress, ensuring that each PoC delivers a level of outcomes aligned with the project's plan. The following subsections define each specific KPI and objectives, detailing the expected toolset that will be used for its evaluation.

4.2.3.1 Packet transmission

This KPI measures the number of data packets successfully delivered by means of the **6G-LEADER** architecture within a specific time frame. It reflects the efficiency and stability of the communication channel. By targeting semantic-empowered 6G communications, the project's focus is on goal-oriented semantic data networking to maximize the use of network resources. The project specifically targets a substantial reduction in non-effective packet transmissions. In this context, the KPIs addressed in the project related to packet transmission are presented in Table 4.1. These indicators aim to quantify improvements in communication efficiency, data handling, and network performance driven by semantic-aware and AI/ML-enabled technologies.

Table 4.1. Packet transmission PoC KPIs

POC	KPI	Target	Description
PoC#1	Volume of communicated information	60% reduction	Performance will be improved over current approaches neglecting the semantics of information.
PoC#1	Effective rate	30% reduction with the same QoE at the user, with and without the neuromorphic setup.	AI/ML-driven optimization and semantics will lead to intelligent resource allocation.
PoC#1	Sum-rate increase	30% improvement over cases with orthogonal multiple access.	ML-aided channel prediction and PHY parameter optimization will facilitate NOMA schemes, grouping together users with high channel asymmetries and optimized power allocation.
PoC#2	Data rate increase	50% increase.	Due to much larger beamforming gain / antenna aperture size increase, SNR increases.
PoC#5	Sum-rate improvement.	40% increase.	AI/ML-aided multiple access schemes, integrating FAs' increased degrees of freedom will outperform current multiple access solutions.

The Table 4.2 provides a concise overview of packet transmission measurement tools, highlighting both hardware and software solutions. It includes proprietary tools such as network device-based flow statistics for detailed traffic monitoring, high-speed traffic generators like VIAVI for precise latency evaluation, and MATLAB's Communications Toolbox for validating communication protocol designs. These tools collectively support comprehensive performance assessment across different layers and use cases in network systems.

Table 4.2. Packet transmission measurement tools.

Name	Type	Ownership	Description
Packet flow statistics provided by network devices	HW	Proprietary	Packet flow statistics (meters and counters at the flow level, considering IP addresses, TCP/UDP ports, errors, etc) provided by network devices, such as programmable switches (Intel Tofino) and smartNICs (NVIDIA Bluefield DPU)
VIAVI Traffic generator [6].	HW	Proprietary	Traffic analyzer/generator (VIAVI and Spirent[7]) operating at rates up to 400Gb/s. Provides

			accurate latency performance of the system under test by comparing timestamps of generated and received packets
MATLAB: Communications Toolbox [8]	SW	Proprietary	Design validation for multiple access techniques

4.2.3.2 Communication overhead

Another **6G-LEADER** objective is to significantly reduce communication overhead by leveraging advanced information compression techniques and enhancing transmission robustness under challenging wireless conditions. This includes considering channel noise and network dynamics during source coding, as well as enabling reliable information recovery in scenarios where partial data loss occurs – such as in the presence of hardware impairments. The description of the communication overhead reduction KPI follows in the Table 4.3. This KPI aims at quantifying the reduction in the control plane overhead in 6G networks.

Table 4.3. Communication overhead PoC KPIs

POC	KPI	Target	Description
PoC#4	Control Plane Overheads Reduction	40% reduction in control plan overhead.	By leveraging semantic information, minimized control plane overheads will be achieved.

The Table 4.4 provides a concise overview of a hardware-based, proprietary tool for measuring communication overhead. It highlights packet flow statistics collected through meters and counters embedded in network devices like programmable switches (e.g., Intel Tofino) and smartNICs (e.g., NVIDIA BlueField DPU), capturing flow-level data such as IP addresses, ports, and errors to support detailed traffic analysis.

Table 4.4. Communication overhead measurement tools.

Name	Type	Ownership	Description
Packet flow statistics (meters and counters) provided by network devices	HW	Proprietary	Packet flow statistics (meters and counters at the flow level, considering IP addresses, TCP/UDP ports, errors, etc) provided by network devices, such as programmable switches (Intel Tofino) and smartNICs (NVIDIA Bluefield DPU)

4.2.3.3 Latency

The Latency KPI measures the time from the moment a packet is sent until it is received by the destination reflecting the response time of the network. The project aims to significantly reduce E2E network latency by incorporating advanced AI/ML-driven methodologies. This includes the evolution of a predictive and resource-efficient 6G PHY and the integration of intelligent multiple

access strategies within in-radio network AI frameworks. In this case, since latency is a transversal issue of all the different PoCs in **6G-LEADER** project and a key issue to mitigate in 6G networks, it has not been assigned a specific target. However, the **6G-LEADER** project expects to achieve E2E latency reduction in 6G communications.

The Table 4.5 provides a concise overview of latency measurement tools, highlighting both hardware-based and software-based solutions. Proprietary hardware tools like VIAVI/Spirent and Keysight offer high-precision, high-speed performance analysis, ideal for lab environments. In contrast, open-source software tools such as srsRAN E2 and Python Time offer accessible, flexible latency insights within RAN and application-level environments, respectively. This combination supports diverse use cases from real-time testing to research and development.

Table 4.5. Latency measurement tools

Name	Type	Ownership	Description
VIAVI [6] / Spirent [7] traffic generator	HW	Proprietary	Traffic analyzer/generator (VIAVI and Spirent) operating at rates up to 400Gb/s. They provide latency performance of the system under test by packets timestamp comparison.
srsRAN E2 latency measurements [9]	SW	Open-source	RAN metrics provided through the CU/DU E2 interface (C++ implementation). E2SM_KPM: all Report Service Styles (1 - 5) are supported, monitoring period limited to 1s
Python Time [10]	SW	Open-source	Python library to measure code execution e.g., xApp execution time, conflict resolution/detection time, etc.
Keysight S5040A Open RAN Studio Player [11]	HW	Laboratory Equipment	Exposes uplink latency measurements

4.2.3.4 Spectral efficiency

The spectral efficiency metric measures how efficiently the available bandwidth is used to transmit data. Higher spectral efficiency means more data can be sent over the same frequency range, improving network capacity and performance. The **6G-LEADER** project aims to significantly enhance spectral efficiency in 6G networks by introducing AI/ML-driven random and non-orthogonal multiple access techniques, RF reconfigurable capabilities, and O-RAN applications for intelligent control. The target KPIs related to spectral efficiency considered in this project are presented in Table 4.6. These indicators aim to quantify improvements in energy efficiency and resource allocation.

Table 4.6. Spectral Efficiency PoC KPIs.

POC	KPI	Target	Description
PoC#2	Beamforming Energy Efficiency Increase	30% increase when compared to SoTA beamformers	Over-the-air combined signals are more efficient compared to discrete combiner/splitter structures.

PoC#4	Spectral Efficiency Increase	30% increase	Integration of AirComp and semantically-aware dApps/xApps will optimize resource allocation and reduce control plane overheads.
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The Table 4.7 provides a concise overview of spectral efficiency measurement tools, highlighting both proprietary and laboratory-grade hardware solutions. It includes advanced platforms like the MB MODRAD Open RAN O-RU SDR, which leverages enhanced beamforming to boost SNR, and standard lab instruments such as the R&S FSW26/FieldFox analyzers and the SMW200A vector signal generator, which are essential for accurate signal and spectrum analysis.

Table 4.7. Spectral efficiency measurement tools.

Name	Type	Ownership	Short Description
MB MODRAD Open RAN O-RU SDR Platform + MB FR3 RIS [12]	HW	Proprietary	SDR platform with RIS support for FR3, enabling higher SNR through increased beamforming gain and aperture size for spectral efficiency testing.
R&S FSW26 [13] or Keysight FieldFox signal and spectrum analyzer [14] .	HW	Laboratory Equipment	High-performance instruments used to measure signal strength, spectrum characteristics, and noise levels across various frequencies.
R&S SMW200A vector signal generator [15]	HW	Laboratory Equipment	Precision generator used to create complex, modulated RF signals for testing and validating wireless communication system performance.
Amari UE [16] / SRS RAN DU metrics [17].	SW	Proprietary	Derive channel BW from parameters (e-g. MIMO) and measure throughput

4.2.3.5 Energy and power consumption

Energy and power consumption are assessed using dedicated measurement tools that quantify usage during both data transmission and processing. These tools provide insights into system efficiency and support the evaluation of energy-related KPIs. The project investigates the trade-off between performance and energy/resource usage by employing resource-efficient techniques. It aims to lower energy consumption by leveraging AI/ML-based approaches for multiple access and reconfigurable radio transmission, as well as semantics-driven xApps to enable a more sustainable RAN. The following KPI is addressed within the project (Table 4.8):

Table 4.8. Energy and Power Consumption PoC KPIs

POC	KPI	Target	Description
PoC#3	Energy Efficiency	10% energy saving	AI/ML-driven techniques can directly reduce the energy consumption in 6G networks
PoC#4	Energy Consumption Reduction	30% energy consumption reduction	Intelligent power control & task allocation optimization by semantically-aware dApps/xApps.

The Table 4.9 provides an overview of various energy and power consumption measurement tools, spanning both HW and software SW solutions. Proprietary hardware tools like the KinetiQ

PPA2510 and Keysight instruments offer precise physical measurements, while platforms such as MODRAD enable detailed internal component analysis. On the software side, open-source solutions like srsRAN and Viavi RIC tester focus on RAN energy metrics and KPI-based evaluations. Proprietary software like Matlab and the dRAX Energy System xApp support simulation, validation, and telemetry-based power analysis across network components.

Table 4.9. Energy and Power consumption measurement tools.

Name	Type	Ownership	Short Description
Power meter KinetiQ PPA2510 [18] and software tools for measuring battery status	HW	Proprietary	Measures the power consumption and the lifetime of UAV
MB MODRAD [12] Open RAN O-RU SDR Platform + MB FR3 RIS	HW	Proprietary	Increased energy efficiency when compared to traditional beamformers. Over-the-Air combining of signals is more efficient in comparison to using discrete combiner/splitter structures. Internal power management from MODRAD provides detailed information on the power consumption of the individual components (baseband unit, rf transceiver, amplifiers, etc.)
srsRAN JSON metrics [19]	SW	Open source	RAN energy consumption measurement (consumed by the CU/DU implementation) through run-time metric console reporting via JSON
Viavi RIC tester capabilities [20]	SW	Open source	energy consumption measurements at cells in terms of standardised and non-standard KPIs
MATLAB	SW	Proprietary	Simulation and validation via PoC to minimize power consumption by reducing RF chains. Simulations (MATLAB) used as thresholds for energy consumption during reconfiguration and RF transmission. Energy measurements validated with oscilloscope (reconfiguration) and network analyzer (RF transmission).
Keysight Oscilloscope [21]	HW	Proprietary	
Keysight network analyzer [22]	HW	Proprietary	
dRAX Energy System xApp [23]	SW	Proprietary	An xApp integrated with the Telemetry Gateway (TGW) to collect information from RU and Servers and measure/calculate the power consumption of each equipment. Information collected via Influx DB and Kalfa.

4.2.3.6 EMF power

Another important aspect concerns the level of EMF power emitted by communication equipment. Reducing potential EMF exposure while maintaining adequate network performance is essential for ensuring user safety. The project aims to support low-EMF communications by prioritizing operation within the lower ranges of the FR3 frequency bands. This will be accomplished through advanced reconfigurability techniques, the development of targeted power control applications,

and the use of AI/ML-driven algorithms to minimize EMF emissions. Within **6G-LEADER**, the KPI shown in Table 4.10 are referring EMF power reduction.

Table 4.10. EMF Power PoC KPIs

POC	KPI	Target	Description
PoC#5	EMF-exposure reduction	25% reduction	Exploiting AI/ML algorithms and high FA reconfigurability will ensure reduced transmit power levels compared to current FPA systems.

Table 4.11 provides a concise overview of key EMF power measurement tools, including both software and hardware-based solutions. It highlights tools for direct exposure assessment (e.g., power density and electric field strength), simulation and optimization (e.g., CST for EM validation and beamforming tuning), and hardware-based radio pattern analysis, though the latter lacks further detail and would benefit from additional clarification.

Table 4.11. EMF measurement tools.

Name	Type	Ownership	Short Description
Power density/Electric Field strength	SW	Proprietary	Measures the EMF exposure of the users in the network (DL & UL)
CST EM Simulation [24]	SW	Other	Simulation and validation of proposed design through SW and HW means. Reduce EMFP by optimisation of beamforming
Radio Pattern	SW	Other	

4.2.3.7 AI/ML accuracy

It is crucial to assess how AI/ML model performs when carrying out classification, prediction, or decision-making tasks. Higher accuracy is essential for ensuring that AI/ML-enabled network functions operate effectively and contribute to overall system performance. **6G-LEADER** aims to integrate AI/ML techniques across various parts of the network to enable intelligent, data-driven decision-making in areas such as channel prediction, physical-layer radio optimization, and resource allocation, among others. The Table 4.12 shows the considered metrics, which are related to AI/ML accuracy

Table 4.12. AI/ML Accuracy PoC KPIs.

POC	KPI	Target	Description
PoC#4	Real-time Inference Accuracy.	95% accuracy	Leveraging semantically-aware dApps/xApps will result in improved real-time inference accuracy by optimizing task allocation and resource utilization.

The Table 4.13 provides a brief overview of AI/ML accuracy measurement tools, highlighting open-source software solutions such as Python libraries like scikit-learn and HuggingFace's

evaluate. These tools are widely adopted in the machine learning community for their ease of use, transparency, and robust set of evaluation metrics.

Table 4.13. AI/ML Accuracy measurement tools.

Name	Type	Ownership	Description
Open source libraries and python scripts	SW	Open-source	open source libraries (e.g., scikit learn [25], evaluate Hugging Face platform[26])

4.2.3.8 Others monitoring elements

6G-LEADER project also targets several additional areas. These areas include, among others, operational cost, UAV lifetime, and conflict reduction. The KPIs associated with these focus areas for the different PoCs are presented in Table 4.14.

Table 4.14. Other PoCs KPIs

POC	KPI	Target	Description
PoC#1	Lifetime of the UAV, and UAV battery duration.	30% increase	By transmitting and processing less information thanks to semantically-aware communication, HiFi cameras will be activated only at a fraction of time, thus saving camera energy.
PoC#2	Cost reduction of radio hardware.	30% reduction.	Leveraging simple RIS hardware technology instead of digital beamformer technology.
PoC#3	Number of direct conflicts.	50% reduction.	The 6G-LEADER conflict manager will handle and reduce O-RAN direct conflicts between xApps.

Table 4.15 provides a concise overview of additional measurement tools used within this project. It includes both open-source and proprietary software solutions. The QoE tool in srsRAN offers user- and cell-level network performance metrics such as throughput and PRB usage. The srsRAN JSON metrics tool focuses on real-time CPU and memory utilization of the RAN components, providing insights into resource consumption by the CU/DU. Lastly, dRAX is a proprietary software extension that enhances A1 policy frameworks by enabling collaborative conflict management, adding an advanced layer of control in network operations.

Table 4.15. Other measurement tools.

Name	Type	Ownership	Short Description
QoE (srsRAN E2 measurement) [9], [17] [ref]	SW	Open-source	Network performance (per user or per cell) based on Throughput, PRB
CPU and Memory utilization (srsRAN JSON metrics) [19], [23]	SW	Open-source	RAN CPU/memory utilization measurement (consumed by the CU/DU implementation) through run-time metric console reporting via JSON
dRAX [23]	SW	Proprietary	dRAX extension over A1 policies to create collaborative conflict management.

4.2.4 Validation steps and checkpoints

To ensure consistent progress monitoring across the five PoCs, a set of generalized validation steps and intermediate checkpoints is defined. These steps are aligned with the two-phase approach outlined in Chapter 3, and are designed to verify both functional readiness and performance improvements over time. Each checkpoint will make use of the tools and methodologies detailed in the measurement tools Subsection 4.2.3, enabling a first stage assessment of the relevant KPIs.

During phase A, an early integration and baseline validation are expected:

- **Checkpoint A1 (Mid-Phase A):** Initial functional validation of core system (mainly, software) components measurements for a subset of selected KPIs relevant to each PoC. Mainly, simulated and safe environments will be used.
- **Checkpoint A2 (End of Phase A):** Intermediate system-level validation and functional assessment, focusing on early performance gains and KPI trends.

During Phase B, instead, advanced integration and fine-tuned optimization will be carried out:

- **Checkpoint B1 (Mid-Phase B):** Integration of advanced features e.g., AI-enhanced components, with performance evaluation under more realistic or complex conditions. This includes the first-stage use of real testbeds with live traffic scenarios, targeting improvements in AI/ML accuracy, EMF power, scalability, or other PoC-specific KPIs.
- **Checkpoint B2 (End of Phase B):** Final validation and optimization of the complete PoC solution with real RUs, with full measurement campaigns covering all relevant KPIs, and demonstration of end-to-end gains supported by the tools outlined in the Subsection 4.2.3.

These checkpoints provide structured points for assessing intermediate results and guiding refinements within each PoC. The outcomes from each step will feed into the validation deliverables (i.e., D7.2 and D7.3), thereby ensuring that the progression from early prototypes to mature demonstrators is backed by data-driven evidence.

4.2.5 Readiness assessment of sub-components

This subsection outlines the readiness plan of **6G-LEADER**'s technical results. It defines the criteria and methodologies used for performance benchmarking, scalability evaluation, and risk analysis, ensuring that each outcome meets its technical objectives.

Technology Readiness Levels (TRLs) are standardized criteria used to assess the maturity of a particular technology or product. Such a criteria is widely adopted in the context of European projects. TRLs range from 1 (basic principles observed) to 9 (actual system proven in an operational environment). Each level reflects a stage in the development lifecycle:

- **TRL 1 – 3:** Conceptual and experimental stages (e.g., scientific research, proof of concept).
- **TRL 4 – 6:** Validation and demonstration in lab or relevant environments.

- **TRL 7 – 9:** System prototype demonstration to full deployment in operational settings.

In the context of the **6G-LEADER** project, TRLs are used to track the evolution of various technical components from early-stage research to validated prototypes. The overall, ultimate objective is a novel RAN design achieving TRL 5. This involves multiple technical Expected Results (ERs), each progressing through different TRL stages. Table 4.16 reports a summary of the key technical results and their TRL evolution:

Table 4.16. 6G-LEADER Expected Results and Maturity Level

ER id	Technical Expected Result	Initial TRL	Target TRL
ER1	AI/ML-driven channel prediction and PHY optimization	3	5
ER2	Spectral-efficient in non-orthogonal multiple access	3	5
ER3	Over-the-air computation (AirComp) schemes	3	5
ER4	Fluid antennas	2	4
ER5	Low-cost RIS-based beamformer	3	5
ER6	Semantics-empowered communications	3	5
ER7	xApps-based RAN control	3	5
ER8	dRAX-RIC	4	6
ER9	ORAN-native full-stack O-CU/O-DU solution	3	5
ER10	O-RAN O-RU SDR white-box system	4	6

In the following subsections , a dedicated discussion for each of the technical ERs is provided, including an estimated month of conclusion and integration within the project phases

4.2.5.1 AI/ML-driven channel prediction and PHY optimization

The technical expected result "*AI/ML-driven channel prediction and PHY optimization*" focuses on the design of AI/ML techniques for advanced wireless communication systems. In particular, this ER targets accurate channel prediction and dynamic optimization of physical layer parameters. This includes the integration of AI/ML methods to support complex features such as over-the-air computation, NOMA, and FAs.

The solutions depart from traditional well-studied AI/ML methods, by incorporation location uncertainty in channel modelling and prediction, and feedback mechanism for dynamic and fast adaptations to enhance the efficiency and adaptability of next-generation network deployments. The solution will be finally embedded in a third control loop through dApps at the CU/DU.

The TRL evolution for this result begins at TRL 3, where the core concepts are validated through analytical studies and lab-scale experiments, tuning the design of ML-based physical optimizations and confirming its feasibility. Two design phases are envisioned. During the first phase due to M12, a first version of the AI/ML-driven channel prediction and physical optimization frameworks will be provided. As the project progresses, the applications will reach TRL 4, with functional validation of the techniques in a controlled laboratory environment using testbed setups or simulated conditions due to M18. Ultimately, the technology is expected to achieve TRL 5,

demonstrating successful integration and validation into several PoC's (i.e., PoC#1, PoC#2, PoC#4, PoC#5) environments (M18-M24).

4.2.5.2 Spectral-efficient in non-orthogonal multiple access

The technical expected result "*Spectral-efficient in non-orthogonal multiple access*" aims to develop and evaluate novel random access and NOMA schemes designed to significantly enhance spectral efficiency across frequency bands ranging from FR1 to FR3. Using predictive AI/ML-based tools and novel contextual information, the proposed algorithms and techniques also focus on improving energy efficiency and minimizing EMF exposure, addressing both technical performance and environmental sustainability.

The TRL evolution of this result starts at TRL 3, where the foundational concepts of the proposed access schemes are designed and validated through theoretical analysis and simulation studies (M12). Progressing to TRL 4, the techniques will undergo functional validation in a laboratory environment through prototype xApp integrating AirComp for collaborative tasks and performance testing under emulated network conditions (M24). The development will culminate at TRL 5, where the schemes will be integrated and validated in PoC#5 through industrial-scale simulations/real-world tests confirming their applicability and effectiveness in near-operational settings (M36).

4.2.5.3 Over-the-air computation (AirComp) schemes

The technical expected result "*Over-the-air computation (AirComp) scheme*" focuses on enhancing AirComp techniques by integrating FL and semantic communication to enable efficient and scalable edge intelligence. The goal is to significantly reduce communication overhead, jointly optimize radio and task allocation, and thereby improve energy/spectral efficiency for distributed inference tasks at the network edge. By enabling simultaneous data aggregation and processing over the air, the proposed AirComp scheme supports advanced edge computing scenarios in next-generation networks.

This result starts at TRL 3, with the formulation and validation of key concepts through analytical studies and simulation-based evaluations of AirComp integrated with FL and semantic compression strategies (M12). At TRL 4, the solution will undergo functional validation in a controlled laboratory environment, using prototypes to demonstrate performance improvements in communication and inference workflows (M18). The project will advance to TRL 5 by validating the AirComp scheme in PoC#4 environment through integration simulated scenarios (or over-the-air testbeds), demonstrating its practical feasibility and readiness for real-world deployment.

4.2.5.4 Fluid antennas

The technical expected result "*Fluid antennas*" involves the advancement of a FA prototype, which will integrate AI/ML-driven predictive algorithms to enable dynamic FA reconfiguration. This will allow the antenna to maintain reliable coverage even while minimizing EMF, at reduced energy consumption. Additionally, the FA prototype operational capabilities will be extended to support the lower portions of the FR3 frequency band.

The TRL progression begins at TRL 2, where the conceptual FA design is formulated within early-stage hypotheses. Moving to TRL 3, the FA concept is subjected to experimental proof-of-concept through lab-scale evaluations and analytical studies demonstrating its technical feasibility (M18). By the end of the project, the development will reach TRL 4, with a validated prototype tested in PoC#5, confirming the functional performance of the ML-enhanced FA and its adaptability to FR3 band operation.

4.2.5.5 Low-cost RIS-based beamformer

The technical expected result "*Low-cost RIS-based beamformer*" focuses on the enhancement of a RIS prototype to support beamforming operations in the lower parts of the FR3 frequency band. The objective is to develop a low-cost, energy-efficient analog beamforming solution by integrating the FR3-capable RIS design into the MB radio unit, enabling near-field RIS-based beamforming. This approach aims to reduce hardware complexity and energy consumption while supporting advanced beam management in next-generation networks.

The TRL evolution starts at TRL 3. The low-cost RIS-based FR3-compatibility is initially evaluated both analytically and with first stage experiments (M12). In the next step, the RIS-assisted beamformer reaches TRL 4 and undergoes functional validation in a controlled laboratory environment, including early integration with MB radio units and a RF signal analyzer (M21). The technology will reach TRL 5 through validation in PoC#2, where the RIS-based beamformer is deployed in FR3 with all functionalities including beam sweep, proving its potential for practical, low-cost, and efficient FR3 beamforming deployment (M36).

4.2.5.6 Semantics-empowered communications

The technical expected result "*Semantics-empowered communications*" will introduce advanced communication schemes that leverage semantic awareness to achieve data-efficiency and robustness, and to enhance information efficiency by reducing irrelevant data exchanges. Moreover, the semantics-empowered communication needs to adapt to dynamic network conditions or requirements. By integrating novel AI/ML techniques i.e., generative AI and large-model, these technologies will account for multiple target KPIs. Also, the leveraged AI/ML techniques are incorporating location-aware channel modelling with spatial correlations and

feedback loops, applying Bayesian and other data-efficient algorithms to improve adaptation speeds and automate parameter tuning. The O-RAN architecture will be another key enabler to host semantics-empowered RAN intelligence and operations.

The TRL evolution of this result begins at TRL 3, with analytical and lab-based PoC demonstrations that establish the feasibility of semantics-empowered, predictive communication under controlled settings. The project will progress to TRL 4 as functional validation is conducted in PoC#1 and PoC#4, integrating AI-driven channel adaptation, semantic data handling, and distributed O-RAN apps under realistic, dynamic conditions (M18). By the end of the project (M36), it will reach TRL 5 through integration and demonstration in the O-RAN-compliant testbeds.

4.2.5.7 xApps-based RAN control

The technical expected result “*xApps-based RAN control*” focuses on leveraging semantically enhanced and AI/ML predictive capabilities (e.g., channel and traffic prediction) integrated into xApps to improve a variety of RAN processes, such as power control, beam management, and wireless for AI services. This solution addresses real-time challenges like learning channel parameters and predicting link quality under location uncertainty, as well as implementing feedback-driven and data-efficient optimization (e.g. Bayesian methods) for robust automated RAN adaptation. Within the O-RAN architecture, intelligent xApps and distributed dApps will enable dynamic control loops, seamless network monitoring, analytics, and self-organization. Conflict management will also be tackled to resolve conflicts between coexisting xApps under extreme performance requirements.

This result will progress from TRL 3, where core concepts and predictive algorithms will be verified via analytical and lab-scale experiments under simplified assumptions (M12). It will advance to TRL 4, demonstrating functional validation of the xApps and predictive models in a controlled environment that simulates key O-RAN components and RIC-based RAN control e.g., VIAVI RIC tester (M18). The work will end at TRL 5, with a prototype integrated into a relevant O-RAN environment that validates its automated control, conflict management, and E2E performance under realistic operating conditions, mainly in PoC#3.

4.2.5.8 dRAX-RIC

The technical expected result “*dRAX-RIC*” will focus on extending the dRAX-RIC platform by embedding semantic information to improve control-plane decision-making and by integrating a novel conflict management framework capable of resolving conflicts between xApps/rApps. To achieve this, dRAX-RIC platform will introduce an initial set of APIs to enable real-time RAN control based on semantics. The Conflict Manager will also include AI/ML capabilities to aid the process of conflict detection and solution. Also, the platform will integrate other technical results,

such as the AI/ML-driven channel prediction and semantic-based and goal-oriented communications to enable robust, predictive, and cooperative resource management across the RAN.

For the PoC#1, PoC#3, and PoC#4, dRAX RIC will start at TRL 4, the concept will initially be validated in a controlled O-RAN environment (M12). It will progress to TRL 5 as the prototype progresses towards a realistic RAN testbed with xApps/rApps and dApps embedded. By the end of the project, dRAX-RIC will reach TRL 6, successfully demonstrating the system in a relevant operational environment, validating its capabilities under dynamic network conditions (M36).

4.2.5.9 srsRAN: O-RAN-native full-stack O-CU/O-DU solution

The technical expected result “*srsRAN: O-RAN-native full-stack O-CU/O-DU solution*” will deliver a fully standard-compliant, beamforming-capable O-CU/O-DU supporting management based on xApps for near-real-time RAN control, and preliminary support for dApps for real-time control loops. Specifically, this result will enhance the srsRAN O-CU/O-DU to support beamforming-enabled O-RUs (split 7.2b), allow seamless coexistence of TDD/FDD FR1 operations alongside up to 100 MHz bandwidth in the lower FR3 band, and integrate low-cost RIS-based beamformer modules. Beyond hardware, the work will enable a new generation of distributed RIC-driven control loops – incorporating xApps, rApps, and dApps – leveraging AI/ML-driven predictive algorithms for dynamic resource allocation and semantics-based intelligence for enhanced communication. Together with enhanced RF flexibility from RISs and FAs, this will support ultra-reliable, low-latency, and highly spectral-efficient 6G communications across diverse deployment scenarios.

Starting at TRL 3, in PoC#1 and PoC#4, the technical principles of this fully open, AI-driven O-RAN-native O-CU/O-DU implementation will be analytically and experimentally validated in lab setups under simplified conditions, for PoC#1, PoC#4 and PoC#5. Progressing to TRL 4 (M18), the solution will undergo functional validation in a controlled environment, integrating FR3-capable RISs/FAs with real-time xApps and/or dApps and demonstrating autonomous reconfigurable beamforming and AI-driven resource management under realistic radio and network conditions. Finally, at TRL 5, the end-to-end O-CU/O-DU solution will be validated in a relevant, near-operational testbed.

4.2.5.10 O-RAN O-RU SDR white-box system

The “*O-RAN ORU- SDR white-box system*” is an advanced radio unit design that aims to enhance O-RAN capabilities in 6G by supporting the lower parts of the FR3 band and integrating an energy-efficient, O-RAN compliant analog beamforming architecture. It will introduce novel hybrid digital-analog MIMO technology specifically tailored for the 6G FR3 band. Its low-cost, white-box design will enable broad deployment across different use cases and will support high-throughput,

low-latency communications under dynamic wireless conditions. In addition, RISs and FA structures can be leveraged for further improvements in performance, energy efficiency, and adaptability.

Within the project, the TRL evolution of the O-RAN O-RU SDR white-box system will begin at TRL 4 (M12), where its functional validation is conducted in a controlled, laboratory environment with partial hardware-in-the-loop setups to verify analog beamforming and basic digital processing. Advancing to TRL 5 (M18), the system will be fully validated in an industrially relevant environment, integrated into partial end-to-end 6G network setups with simulation-driven testing under near-real conditions to optimize its reconfigurable radio components. Finally, the system will reach TRL 6, where a prototype will demonstrate its capabilities using real-world 6G radio interfaces and dApps/xApps.

4.3 Stakeholder alignment and feedback loops

PoCs play a central role for validating technological innovations and demonstrating their relevance in realistic scenarios. While PoC activities are still under development, a structured plan is in place to ensure strong alignment with key stakeholders and to establish continuous feedback and refinement mechanisms.

This subsection outlines how PoCs are planned to generate exploitable assets, how these outputs will be disseminated to create stakeholder value, and how structured feedback loops will be integrated throughout the project lifecycle.

4.3.1 Exploitable assets from PoCs

As the PoCs progress through their design and implementation phases, they are expected to generate a range of exploitable results, including:

- **Validated technology components:** Functional software or hardware modules that may serve as building blocks for future 6G deployments.
- **Reference integrated architectures:** Interoperable solutions across PHY, RAN, and ORAN domains, serving as blueprints for commercial or open-source adaptation.
- **Benchmarking and evaluation results:** KPI measurements from controlled trials or testbeds to support claims of technical feasibility and performance.
- **Reusable demonstration environments:** Testbeds and configurations designed with reusability in mind, enabling replication for future trials or demonstrations.
- **Deployment and operations guidelines:** Accompanying documentation and best practices to support stakeholder adaptation of PoC outcomes.

- **Awareness and training materials:** Public-facing assets (e.g., videos, brochures, demo kits) to support dissemination, onboarding, and educational outreach.

These outputs will feed into the identification and refinement of Key Exploitable Results (KERs).

4.3.2 Dissemination to stakeholders and value creation

To unlock the full potential of PoCs, **6G-LEADER** is implementing a proactive, multi-channel dissemination strategy targeting key stakeholder groups:

- **Targeted showcases and demonstrations:** PoCs will be presented at high-impact venues such as *EuCNC & 6G Summit* and *MWC*, enabling stakeholders, including operators, vendors, policymakers, and researchers to interact directly with live demonstrations and receive tailored briefings.
- **Strategic positioning in the ecosystems:** Active participation of consortium members in *6G-SNS JU*, *6G-IA*, and *O-RAN* will be leveraged to elevate PoC outcomes into broader industrial, research, and policy dialogues, thereby maximizing both visibility and influence.
- **Co-creation with operators and vendors:** All PoCs are being co-designed with industrial partners such as *Telefónica*, *Nokia*, and *Samsung*, who will provide domain-specific input throughout the development and validation.

Through these combined channels, PoCs are expected to become key enablers of stakeholder value whether via commercial application, contribution to policy and standardization, or cross-project knowledge transfer.

4.3.3 Linking exploitation assets to the stakeholders exploitation roadmap

Dissemination and stakeholder engagement activities are structured across the exploitation roadmap of the project to align with the maturation of PoC outputs and the progressive identification and refinement of KERs:

- **Year 1:** Initial PoC definitions and early-stage outputs will be refined and showcased at *EuCNC & 6G Summit 2025* and *MWC 2026*. During this phase, preliminary KERs will begin to be identified based on early PoC findings, supporting initial stakeholder exposure and feedback collection.
- **Year 2:** As PoCs mature, more advanced demonstrations will be presented at *EuCNC & 6G Summit 2026* and *MWC 2027*. The focus will include refining KERs with input from technical briefings, targeted evaluation discussions, and stakeholder engagement sessions to validate exploitation potential.
- **Year 3:** Final PoC outputs will be consolidated into demonstrators and mature KERs ready for broad dissemination at *EuCNC & 6G Summit 2027* and *MWC 2028*. Tailored outreach

to commercialization and standardization communities will facilitate adoption and integration into the wider 6G ecosystem.

All dissemination and engagement activities will be adapted to the intended audience, from strategic-level insights for decision-makers to detailed technical documentation for researchers and implementation partners. As a result, while PoC development is ongoing, **6G-LEADER** has laid out a detailed plan for stakeholder alignment, value-oriented dissemination, and structured feedback. These mechanisms are designed to ensure that PoCs evolve into mature, actionable exploitation assets with high potential for adoption, transfer, and long-term sustainability within the broader 6G ecosystem.

4.4 Resource and risk management

Effective risk and resource management of PoCs ensures that potential challenges are identified, assessed, and mitigated, thereby safeguarding success of the PoCs and the validation of the results. The aim is to be able to mitigate any potential risks at an early stage of the PoC development and before they have a significant impact on the validation process.

In particular, the following actions have been envisioned:

- Planning of the testbed shared resources usage and availability.
- Roles and responsibilities of participants participating in the PoCs have been clearly identified.
- Workflow plans have been identified per PoC, along with internal deliverables. PoC schedule follows the 2-Phase approach.
- KPIs per PoC have been identified, along with the measurements tools to ensure quality of the validation.
- Input from other technical WPs have been identified as well as expected ER TRLs.
- Mapping of PoC into the architecture.

Acknowledging that the interaction and information flow between partners is a fundamental element for effective risk management, WP7 will implement the following strategies:

- Maintain a registry for PoC level risk. When necessary, Brainstorming Sessions will be used to identify unforeseen risks (i.e., not identified before the start of the PoC) and prioritize them based on their impact and likelihood.
- Adopt a proactive approach to risk management, where each project partner contributes to the risk management plan. Additionally, to regular monitoring, internal milestones of the PoCs (identified in this document) in Phase A and Phase B will be used as check points. At the end of the first Phase an assessment will be conducted to assure the status of the risks.
- Regular WP7 meetings as well as PoC group meetings will be used to monitor and discuss the status of risks per PoC. A recurring practice is for the PoCs' leaders or their deputies

to report at WP7 meetings on the development of each risk in terms of its likelihood, impact, status and whether other mitigation actions should be taken as well as blocking issues external from the working group.

- Relevant risks will be discussed also during the regular Executive Board meetings, as well as risks that involve the interaction with other WPs.

4.4.1 Resource management

Identified resources required in the **6G-LEADER** PoCs can be divided as follows:

- **Effort:** Roles have been clearly identified. Efforts will be made to identify peaks in effort and appropriately plan activities in order to mitigate them.
- **Facilities and equipment:** PoC activity may include equipment that is not currently available in the testbeds. Early identification of the needs will be carried out as well as their acquisition programmed in time.
- **Shared Testbeds:** Activities will be carefully planned to avoid conflicts with other ongoing activities. Particular attention will be given to PoC#1 and PoC#4 that share the same testbed.
- **Validation tools:** Measuring tools have been identified.
- **Technologies:** Innovative technologies necessary for the realization of the PoCs come from the outputs of WP2-6. The ER development and their TRL readiness should be aligned with PoC implementation. Close interaction with other WPs will be kept leveraging on project internal communication tools (including Board Meetings, Plenary Meetings).

4.4.2 Monitoring of PoC activities

Table 4.17 maps the actions implemented in WP7 to assure that deviations from PoCs workplans are promptly identified and risks alerts are forwarded to “*Task 1.2: Quality, Security Risk and Delivery Assurance*” [27]. These actions are meant to complement those specified in the GA and to be additional to the mitigation actions already supporting project wide risks management impacting WP7.

Table 4.17. WP7 Monitoring and mitigation actions for risk management

Risk ID	Risk Description	Monitoring actions at WP7 level and Additional mitigation actions
R001	Partner resigning, or a radical change to its capacity to perform as expected or lacking expertise.	Specific roles and responsibilities (Section 3.2) have been mapped for each PoC, in order to quickly identify the uncovered areas and implement the mitigation strategy envisioned at project level.
R002	Partner cannot perform allocated work on time and with expected quality.	Roles and responsibilities will be continuously monitored to quickly detect any partner issues. A PoC-specific work

		breakdown structure, defined in T7.1, supports detailed tracking and checkpoints in both Phase A and Phase B.
R003	Resources are underestimated; part of the work cannot be completed according to plan.	To mitigate this risk, regular monitoring (telcos, WP7 and plenary meetings) will be conducted from the early stages of the PoC developments, to identify such problems in a timely manner. In case of detected difficulties, the work breakdown structure per PoC will be reviewed or resources rearranged.
R004	Interaction among WP's and Tasks is not satisfactory.	PoCs expected inputs from other technical WPs have been clearly identified. Interaction will be maintained both at a higher level, during regular Board Meetings, and at a lower level, since partners participating in PoCs also participate to technical WPs.
R005	Project milestones or deliverables are constantly delayed	Having set internal schedules and deliverables as well as clear roles for each PoC, helps mitigate this risk.
R006	Project schedule is partly not appropriate	In case the PoC individual schedules need corrections, and the resulting new schedule is incompatible with the project overall schedule, the WP leader will promptly inform the PC and TM for evaluation and possible corrective actions.
R007	The project lacks the resources to develop all topics as the project concept covers many topics.	PoCs in WP7 rely heavily on inputs from WPs 2–6. WP7 will coordinate with the respective WP leaders to define technical priorities and guide partners' efforts toward the key topics needed to build the PoCs and validate the Innovation Pillars.
R008	Conflicts over ownership	All conflicts that may emerge in WP7 and during PoCs deployment will be resolved at consortium level based on the GA and the agreed assets ownership and IPR management as envisioned in the GA.
R010	High-level architecture suggested for PoC integration is not suitable or adequate	Partners involved in PoC integration and evaluation will actively contribute to the architecture design from the start. PoCs have been mapped to the architecture to identify gaps and misalignments, with this process aligned to the two-phase design iterations and stakeholder feedback.
R011	Similar solutions with similar functionalities enter the market.	In case this risk should emerge, it will be resolved at consortium level as envisioned in the GA.
R012	Integration between distinct network segments and architectures is not possible	In the case of risk occurrence, the consortium may decide and activate the plan of various implementations of the same technology to determine if the issue was an implementation or a conceptual one and act accordingly.
R013	Failure to reach the project KPIs, unexpected external factors affecting the experimental KPI.	KPIs and validation methodologies for each PoC were defined during the initial phase of WP7 and WP3-WP6. The work package will continuously monitor outcomes to identify and address any external factors that could hinder the achievement of these KPIs.

Early risk detection has identified a potential implementation challenge for PoC#1 and its KPI4, arising from insights gained during the detailed integration planning stage. Specifically, validating this KPI within PoC#1 may be challenging given the current capabilities of the dRAX platform in managing lower PHY commands, which may not fully support the specific conditions required for

this scenario. To address this, we propose exploring KPI validation through simulations and/or another PoC. This will involve refining the PoC#1 schedule with targeted adjustments to ensure a clear plan for subsequent phases, potentially leveraging alternative approaches or platform capabilities that enable the necessary PHY parameter adjustments and channel estimates.

4.5 Scalability, security and manageability considerations

The advent of 6G networks represents a paradigm shift in connectivity, promising unprecedented speeds, ultra-low latency, and massive device connectivity. As the foundation of these networks, the Radio Access Network (RAN) architecture must be designed to address the unique challenges posed by 6G's ambitious goals. Scalability, security, and manageability are critical considerations that will define the success of 6G RAN implementations. These dimensions, emphasizing the requirements and strategies necessary to build a robust and future-ready 6G RAN architecture. Specifically, the evolution of the RAN architecture in 6G is driven by the need to meet escalating demands for connectivity, data throughput, and user experience. As networks expand to accommodate increasing user demand, network traffic, and device connectivity, scalability, security, and manageability emerge as critical considerations.

The **6G-LEADER** architecture emphasizes three key dimensions—scalability, security, and manageability—to deliver efficient and accessible solutions for future-ready RAN architectures. For instance, in PoC#4, AirComp and semantic information combined with control processing leverage AI/ML techniques to enhance the scalability of deploying solutions at edge nodes. PoC#1, on the other hand, employs split, inference, and localization not only to boost scalability but also to booster security for user information. Additionally, PoC#3 introduces manageability by implementing a conflict manager to prevent, resolve, or mitigate conflicts between different AI models. Furthermore, PoC#5 investigates scalability for FA, while the near-field RIS-based beamformer demonstrated in PoC #2 can be used to serve spatially separated users simultaneously in a scalable multi-user MIMO system by stacking several RIS modules at one base station

5 Conclusions and Future Work

This concluding chapter summarises the Deliverable D7.1 and outlines the planned next steps towards the project execution and validation phases as captured in D7.2 and D7.3. It consolidates the methodology, planning, and technical foundations established throughout the document and positions them as the starting point for the integration, testing, and demonstration activities that will follow in WP7. The insights presented here ensure continuity across the PoC lifecycle and establish a clear trajectory for performance evaluation, architectural feedback, and cross-WP coordination.

5.1 Summary of D7.1 outputs

Deliverable D7.1 presents the evaluation methodology and execution planning framework that governs the integration, testing, and validation of the five PoCs developed in the **6G-LEADER** project. It establishes a comprehensive methodology structured around three main components: a) Metric and KPI definition, b) Data collection and monitoring infrastructure, and c) Phased validation and demonstration processes. This methodology ensures consistency across all PoC deployments and alignment with the **6G-LEADER** innovation pillars, addressing stakeholder expectations and supporting a traceable and reproducible evaluation of the technical outcomes.

A key output of D7.1 is the alignment between the project's high-level architecture and the technical scope of each PoC. The document formalises a mapping between PoC objectives, functional components, and expected KPIs, ensuring that every evaluation is anchored in the broader system-level goals. Each PoC is analysed to extract its critical functionalities, targeted innovations (e.g. AI/ML integration, semantic communication, novel RF components), and associated testing needs. These are then translated into measurable evaluation criteria, with clear data collection strategies and defined success indicators. The approach ensures that KPIs are relevant, realistic, and aligned with regards to both technical feasibility and project ambitions.

D7.1 defines the implementation and evaluation strategy following a phased approach. Phase A covers early integration and testing, providing initial validation and architecture feedback, while Phase B focuses on complete demonstrator deployment and functional verification in realistic settings. A tailored development plan is provided for each PoC, including work breakdown structures, roles and responsibilities, testbed allocation, and risk management measures. The planning includes milestones such as intermediary PoC releases and validation checkpoints, which serve as inputs for future deliverables (D7.2, D7.3) and feedback loops to WP2–WP6.

From a technical execution perspective, the document details the specific test environments where the PoCs will be deployed. Each testbed (CNIT-ARNO, DICAT-SONIC Labs, UC3M, MB)

is characterised in terms of its capabilities, supported technologies, and alignment with innovation pillars. For example, DICAT supports RIC experimentation and conflict mitigation; CNIT enables semantic communication and edge computing; UC3M provides an environment for fluid antenna reconfiguration; MB supports RIS-based beamforming in FR3; and SRS platform enable low-level PHY-layer validation. This mapping ensures that the PoC activities are technically grounded and executed on fit-for-purpose infrastructure.

Another critical output of D7.1 is the specification of the monitoring, validation, and demonstration methodology. The document defines a three-stage process. In the first stage, KPIs and supporting metrics are extracted for each PoC and matched with corresponding data collection mechanisms. In the second stage, a monitoring framework is defined to track technical progress and performance evolution in relation to expected outcomes. In the third stage, the validation and demonstration processes are designed to validate that each PoC is meeting its objectives, under controlled conditions and with reproducible results. Each stage includes recommended tools, success criteria, and references to system maturity levels, allowing for component readiness tracking and architecture feedback.

D7.1 also introduces a risk-aware execution framework. It identifies risks that could affect the successful delivery of the PoCs, including integration delays, technical incompatibilities, or lack of cross-WP coordination. For each risk, mitigation actions are defined at both the PoC and WP7 levels. This supports project robustness and ensures that planning considerations are aligned with practical implementation constraints.

In conclusion, Deliverable D7.1 provides a technically rigorous foundation for the PoC development, integration, and assessment. It defines a unified methodology, maps innovations to testbeds, delineates evaluation phases, and sets clear criteria for performance verification. It ensures that the subsequent deliverables (D7.2 and D7.3) and tasks (T7.2 to T7.4) are grounded in a common reference framework, enabling a robust evaluation of **6G-LEADER** outcomes and their relevance to future 6G systems.

5.2 Next steps towards D7.2–D7.3

Deliverable D7.1 plays a pivotal role in enabling Task 7.2, which focuses on the integration and validation of PoCs during Phase A. The test environments and responsibilities defined in D7.1 guide the deployment and early-stage verification of each PoC within its designated testbed. Furthermore, D7.1 outlines the mechanisms to monitor progress, track the readiness of components, and assess early-stage performance against defined KPIs and KVIs. The results of these activities directly feed into D7.2, which will document the development status and evaluation outcomes of Phase A and channel the insights back to the technical WPs for refinement. Importantly, D7.1 sets the foundation for applying validation logic to continuous integration cycles, enabling risk mitigation and agile updates in the case of unforeseen technical issues.

Task 7.3 builds upon this foundation by extending the validation and demonstration activities into Phase B. The methodology defined in D7.1, particularly the structured mapping between PoC-level KPIs, architecture components, and performance indicators, is reused and expanded to guide the full-scale testing and operational validation of the **6G-LEADER** solutions. By applying the same traceability principles and evaluation logic used in Phase A, Task 7.3 ensures that results obtained from diverse PoC scenarios are comparable and verifiable. D7.1 also ensures that the performance feedback loop initiated in Phase A is sustained throughout the project lifecycle, thus feeding into final the architectural refinement and sustainability analysis.

This continuity enables WP7 to serve not only as a validation and demonstration layer but also as an iterative assessment and correction mechanism that enhances the technical robustness of the overall system. As a result, D7.1 acts as the backbone for all technical assessments carried out in Tasks 7.2 to 7.4, ensuring that the findings of the **6G-LEADER** project are supported by consistent methodology, well-structured evidence, and implementation-aware performance tracking.

6 References

- [1] 6G-LEADER, 'D2.1: Use case analysis, KPIS and requirements to RAN architecture design.', Sep. 2025.
- [2] O-RAN, 'WG1 TS "Use Cases Detailed Specification" R004 v17.00', Alfter, Germany, O-RAN ALLIANCE WG1, Jun. 2025. [Online]. Available: <https://specifications.o-ran.org/download?id=865>
- [3] 3GPP, 'TS 28.552: 5G, Management and orchestration; 5G performance measurements. Version 17.6.0 Release 17', 3GPP, Sophia Antipolis Cedex - FRANCE, TS 128 552, May 2022. [Online]. Available: https://www.etsi.org/deliver/etsi_ts/128500_128599/128552/17.06.00_60/ts_128552v170600p.pdf
- [4] 3GPP, 'TR 38.901: 5G; Study on channel model for frequencies from 0.5 to 100 GHz (Version 17.1.0 Release 17)', 3GPP, Sophia Antipolis Cedex - FRANCE, TR 138 901, Jan. 2024. [Online]. Available: https://www.etsi.org/deliver/etsi_tr/138900_138999/138901/17.01.00_60/tr_138901v170100p.pdf
- [5] M. Falcitelli *et al.*, 'Full-Scale Assessment of the "5GT System" for Tracking and Monitoring of Multimodal Dry Containers', *IoT*, vol. 5, no. 4, pp. 922–950, Dec. 2024, doi: 10.3390/iot5040042.
- [6] VIAVI Solutions, *Xgig® Exerciser*. [Online]. Available: <https://www.viavisolutions.com/en-us/products/exercisers-and-generators>
- [7] Spirent, *Ethernet & IP Testing*. [Online]. Available: <https://www.spirent.com/products/ethernet-ip-test-solutions>
- [8] Mathworks, *Matlab Communication Toolbox*. [Online]. Available: <https://www.mathworks.com/products/communications.html>
- [9] srsRAN, *O-RAN NearRT-RIC and xApp. e@ Interface*. [Online]. Available: <https://docs.srsran.com/projects/project/en/latest/tutorials/source/near-rt-ric/source/index.html#overview>
- [10] Python, *Python Time — Time access and conversions*. [Online]. Available: <https://docs.python.org/3/library/time.html>
- [11] Keysight, *S5040A Open RAN Studio Player and Capture Appliance*. [Online]. Available: <https://www.keysight.com/us/en/assets/3122-1431/data-sheets/S5040A-Open-RAN-Studio-Player-and-Capture-Appliance.pdf>
- [12] Massive Beams, *MODRAD-SC*. [Online]. Available: <https://www.massivebeams.com/>
- [13] Rohde & Schwarz, *R&S®FSW26 Signal and Spectrum Analyzer*. (2015). [Online]. Available: <https://www.testwall.com/media/catalog/product/file/FSW-Datasheet-101188.pdf>
- [14] Keysight, *FieldFox Handheld Spectrum Analyzers*. [Online]. Available: <https://www.keysight.com/us/en/products/spectrum-analyzers-signal-analyzers/fieldfox-handheld-spectrum-analyzers.html>
- [15] Rohde & Schwarz, *R&S®SMW200A Vector Signal Generator*. [Online]. Available: https://www.rohde-schwarz.com/nl/products/test-and-measurement/vector-signal-generators/rs-smw200a-vector-signal-generator_63493-38656.html
- [16] Amarisoft, *AMARI UE Simbox E Series*. [Online]. Available: <https://www.amarisoft.com/test-and-measurement/network-testing/network-products/amari-ue-simbox-e-series>
- [17] srsRAN, *O-RAN CU-DU Split*. [Online]. Available: https://docs.srsran.com/projects/project/en/latest/tutorials/source/cu_du_split/source/index.html

- [18] KinetiQ, *PPA2500 - Power analyzer*. [Online]. Available: https://www.idm-instrumentos.es/files/newton4/PPA2500-V6_A4.pdf
- [19] srsRAN, *Grafana Metrics GUI*. [Online]. Available: https://docs.srsran.com/projects/project/en/latest/user_manuals/source/grafana_gui.html
- [20] VIAVI Solutions, *TeraVM AI RSG*. [Online]. Available: <https://www.viavisolutions.com/en-us/products/teravm-ai-rsg>
- [21] Keysight, *Oscilloscope* | *Keysight*. [Online]. Available: <https://www.keysight.com/us/en/products/oscilloscopes.html>
- [22] Keysight, *Network Analyzers* | *Keysight*. [Online]. Available: <https://www.keysight.com/us/en/products/network-analyzers.html>
- [23] Accelleran, *dRAX xApp Dev Guide*. [Online]. Available: <https://accelleran.github.io/drax-xapp-dev-guide/v6.0/>
- [24] Cadtech, *CST Studio Suite*. [Online]. Available: <https://cadtech.es/soluciones/simulia/cst-studio-suite/>
- [25] Scikit-learn, *Machine learning in Python — 1.7.1 documentation*. [Online]. Available: <https://scikit-learn.org/stable/index.html>
- [26] Hugging Face, 'The AI community building the future.' [Online]. Available: <https://huggingface.co/>
- [27] 6G-LEADER, 'D1.1: Management handbook and quality plan.'

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