6G AI-Native Integrated RAN-Core Networks

Deliverable D1.3
First periodic report

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Abstract

Technical work description of the first period (M1- M12) of the 6GARROW project, at the project level and at each Work Package (WP) level. This deliverable contains the technical contribution provided by each partner over the first reporting period, as well as an updated action plan and revised risk management plans.

Keywords

6GARROW, progress report, first period, objectives, expected results, technical contributions, action plan, work packages.

Disclaimer

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PU = Public

Executive Summary

This deliverable reports on the first year (M1-M12, Jan.-Dec. 2025) of the 6GARROW project, which aims to design, develop, and validate Artificial Intelligence (AI)-native, integrated Radio Access Network (RAN) and Core Network (CN) solutions for future Sixth Generation (6G) systems. During the reporting period, all work packages were successfully launched and executed according to plan, with no major deviations from the original work programme.

Key achievements include the definition of 6GARROW use cases, scenarios, Key Performance Indicators (KPIs) and Key Value Indicators (KVIs), and the development of an initial AI-native 6G system architecture, providing a solid foundation for subsequent technical developments. Significant State-of-the-Art analyses were completed on AI/Machine Learning (ML) techniques for enhanced device performance, RAN and CN optimization, and energy-efficient, semantic, and goal-oriented networking. Preparatory work was also carried out for experimental validation, including the design of testbed architectures and the initiation of European Union (EU)-Republic of Korea (ROK) joint Proof-of-Concept (PoC) activities.

Dissemination, standardisation, and exploitation activities during the first year fulfilled expectations of the project plan, with strong visibility achieved through publications, workshops, tutorials, and active engagement with international research and standardisation communities. Overall, the first year successfully established the conceptual, architectural, and collaborative basis required to deliver the planned innovations in the remaining project duration.

Acronyms and abbreviations

Term	Description
6G	Sixth Generation
AI	Artificial Intelligence
AIaaS	Artificial Intelligence as a Service
API	Application Programming Interface
CAPIF	Common API Framework
CN	Core Network
CRA	Cyber Resilience Act
CSI	Channel State Information
CQI	Channel Quality Indicator
DRX	Discontinuous Reception
DU	Distributed Unit
ER	Expected Result
ETSI	European Telecommunications Standards Institute
EU	European Union
F2F	Face-to-Face (meeting)
GDPR	General Data Protection Regulation
gNB	Next Generation Node B
KPI	Key Performance Indicator
KVI	Key Value Indicator
LLM	Large Language Model
MAC	Medium Access Control (layer)
MDAF	Management Data Analytics Function
ML	Machine Learning
MNO	Mobile Network Operator
NEF	Network Exposure Function
NETCONF	Network Configuration Protocol
NF	Network Function
NOMA	Non-Orthogonal Multiple Access
NRF	Network Repository Function
NWDAF	Network Data Analytics Function
O-DU	Open Distributed Unit
O-RU	Open Radio Unit
OPEX	Operational Expenditure

PHY	Physical (layer)
PoC	Proof of Concept
PQoS	Perceived Quality of Service
PTQ	Post-Training Quantization
QAT	Quantization-Aware Training
QoS	Quality of Service
RAN	Radio Access Network
RIS	Reconfigurable Intelligent Surface
SBA	Service-Based Architecture
SI	Study Item (3GPP)
SSLA	Semantic Service Level Agreement
SSRF	Semantic State Representation Function
TCO	Total Cost of Ownership
UE	User Equipment
UPF	User Plane Function
VPN	Virtual Private Network
WI	Work Item (3GPP)
WP	Work Package
YANG	Yet Another Next Generation (data modelling language)

1 Explanation of the work carried out by the beneficiaries and Overview of the progress

The first reporting period covers the initial year of the project, running from 1st January 2025 (M1) to 31st December 2025 (M12). During this period, all Work Packages (WPs) were launched in accordance with the GANTT chart of the project, which is shown below.

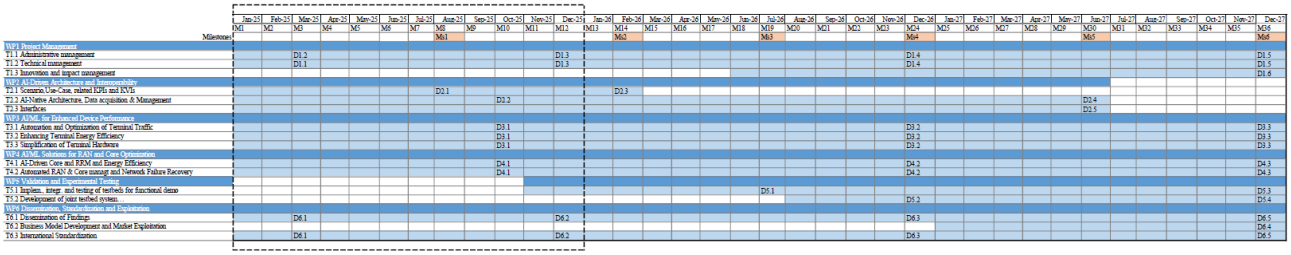

Figure 1: Gantt diagram illustrating the overall work plan of the 6GARROW project.

The project activities in the reporting period are summarized in the following list:

- **WP1 – Project management.** The activities in WP1 focused on administrative management (e.g., interaction with the PO and management of the Consortium Agreement), the financial management (distribution of initial payment), risk management (monitoring both anticipated and non-anticipated risks) and quality management (ensuring the technical quality of outputs and adherence to deadlines).
- **WP2 – AI-Driven Architecture and Interoperability.** Two fundamental deliverables were produced by WP2 during the first period. The 6GARROW use cases, scenarios and Key Performance Indicators (KPIs)/Key Value Indicators (KVIs) were defined in D2.1 and the initial architecture was provided in D2.2. In this latter deliverable, the project has provided an exhaustive state of the art on 6G architectures and a techno-economic vision of 6G.
- **WP3 –AI/ML for Enhanced Device Performance.** All partners involved in WP3 have started working as planned. WP3 has produced the first deliverable (D3.1) compiling all the avenues of research envisioned for enhancing device performance and the corresponding state of the art status. Periodic meetings have been also held for sharing technical presentations of the work and for starting discussions.
- **WP4 –AI/ML Solutions for RAN and Core Optimization.** All partners involved in WP4 have started their work as initially planned. The first deliverable (D4.1) that reviews the state of the art on AI-native and semantic 6G architectures, AI-driven resource usage, and automatic failure recovery across RAN and Core Network domains has been produced and delivered according to the plan. Periodic meetings have been arranged, in which partners have given technical presentations, promoting discussion on follow-up areas of collaboration.
- **WP5 –Validation and Experimental Testing.** In WP5, the functional requirements and system architecture have been studied to support the design of testbeds for demonstrating Artificial Intelligence (AI)/Machine Learning (ML) technologies, including physical-layer AI/ML techniques and cross-domain AI/ML coordination. Regular meetings have also been held among participants.
- **WP6 –Dissemination, Standardization and Exploitation.** In the first year, the activities of WP6 have successfully increased the visibility of the 6GARROW project by implementing the dissemination plan outlined in D6.1 through multiple communication channels. Overall, the

plan has been executed effectively and in line with first-year expectations and regular monthly meetings were held for keeping track of the updates.

Overview of the project results

The main achievements of the project in the first reporting period concern WP2, whereas the work performed in WP3, WP4 and WP5 is preparatory for the outcomes expected in the second and third years of the 6GARROW project timeline. Concerning WP6, big effort was put in the semantic communications related areas of the project, in which 16 publications were accepted and six more submitted for evaluation (i.e., currently under reviews or revision for resubmission) during the first period; the number of (accepted) publications is foreseen to increase in the forthcoming reporting period since the work done in technical WPs of the project (i.e., WP3, WP4 and WP5) will start producing new results very soon.

More in detail, the technical achievements can be summarized as follows.

Use cases, KPIs, KVIs and architecture (WP2)

1. Identification of families of use cases that can leverage an AI-native 6G network and benefit to end users and industry.
2. Identification of 6GARROW use cases. For each identified use case:
   - State of the art and gap analysis.
   - Relevant KPIs and KVIs.
   - Functional and non-functional requirements.
3. Development of the 6GARROW architectural framework, with the definition of the initial system architecture and functionalities. Including:
   - Techno-economics aspects of 6G.
   - State of the art on 6G network architecture.
   - Gap analysis with use cases defined earlier in the project.

AI/ML for Enhanced Device Performance (WP3)

1. State-of-the-Art Analysis. Conducted comprehensive reviews of existing AI/ML techniques for device performance enhancement, identifying key research directions in semantic communication, energy efficiency, and hardware simplification.
2. Research Framework Establishment. Defined a structured approach for developing AI-native solutions, focusing on terminal traffic automation, energy efficiency, and hardware optimization through semantic and goal-oriented communication techniques.
3. Technical Foundations. Laid groundwork for future developments by investigating representation learning, RIS-enabled resource optimization, and neuromorphic processing for efficient terminal operations.
4. Preparation for Implementation. Established the basis for subsequent deliverables (D3.2 and D3.3) that will develop and validate the proposed AI-driven solutions through analytical models and simulations.

AI/ML Solutions for RAN and Core Optimization (WP4)

1. Architecture and enablers. Investigation of the evolution of 6G architectures towards a semantic, AI-native and regulation compliant design, including the requirements that will be needed for the compliance with the forthcoming European Union (EU) AI Act.
2. AI-Native 6G Resource Usage. Study of AI/ML-driven algorithms for the optimization of energy efficiency and spectrum utilization at both network and physical layers.
3. Automation and Failure Recovery. Design of the end-to-end solution integrating distributed AI-agents into RAN, Transport and Core together with an AI-orchestrator in the Core Network for overall management, aiming at addressing proactive resilience and cross-domain AI coordination mechanisms for distributed 6G systems.

Validation and Experimental Testing (WP5)

1. Design of testbed for AI/ML-enabled physical technologies, including AI/ML application to the Open Distributed Unit (O-DU) High-PHY, configuration and operational validation of a 3GPP 5G-Advanced Open Radio Unit (O-RU)/O-DU High-PHY test environment, and comparative analysis of inference latency and power consumption across AI accelerators for AI/ML-based physical-layer technologies.
2. Design of RAN-CN integrated inference technologies, including generation of User Equipment (UE) mobility prediction input/output datasets compliant with 3GPP technical specifications to present highly standards-aligned technologies and demonstration scenarios.

Dissemination and standardisation activities (WP6)

1. Dissemination of the project results:
   - Accepted/Published publications:12 conference papers and 4 journal papers.
   - Submitted state/revision for resubmission: 2 journals, 4 conference papers
2. Organization of workshop: 2 Workshops (AI-RAN Summit and IEEE Globecom 2025).
3. Tutorial/Special Sessions: Workshop on EU Regulations (AI Act, Cyber Resilience Act, Data Act) at GEM, Grenoble, France.
4. Book on Digital Sustainability (Christophe Gaie and Markus Mueck): Completed, to be published, contributors from 6GARROW.
5. 6GARROW results discussed at multiple international events (Section 2.2.7.5 of D6.2).
6. Participation in 3GPP standardization activities and monitoring the current 6G discussions.

The work performed in each WP is further detailed in Section 1.2.

Deliverables and milestones

In the first reporting period, the following deliverables have been submitted:

Table 1: List of Deliverables.

Number WP	Deliverable name (Lead participant). Description	Type – Dissemination level Delivery date (in months)
D1.1 WP1	**Quality plan** (CEA/YONSEI). Detailed quality plan giving the project guidelines, communication practices, preparation and delivery of progress reports, among others.	R–PU M3
D1.2 WP1	**Data management plan** (CEA/YONSEI). Data management life cycle for the data to be collected, processed and/or generated by the 6GARROW project. D2.1 will be updated along the project.	R–PU M3
D1.3 WP1	**First periodic report** (AALTO/YONSEI). Technical work description of the first period (M1- M12) of the project, at the project level and at each WP level. Description of the technical contribution from each partner over the reporting period including action plan and revised risk management plans.	R–PU M12
D2.1 WP2	**6GARROW Scenarios, Use Cases and related KPIs/KVIs** (INTEL). Detail key scenarios, use cases and related KPIs/KVIs meeting the requirements for European and Korean application of AI/ML in cellular networks, and to be applied in WP3, WP4 and WP5.	R–PU M8
D2.2 WP2	**6GARROW Initial System Architecture** (AALTO). Initial 6GARROW architecture approach, including initial discussion on a relevant AI-native 6G architecture design.	R–PU M10

Number WP	Deliverable name (Lead participant). Description	Type – Dissemination level Delivery date (in months)
D3.1 WP3	**State of the art and challenges for AI/ML Enhanced Device Performance** (OULU). Exhaustive view on the State-of-the-Art relative to AI/ML Enhanced Device Performance and lists the challenges to be addressed. Common framework from WP2.	R–PU M10
D4.1 WP4	**State of the art on AI/ML Solutions for RAN and Core Optimization** (CEA). Exhaustive view on the State-of-the-Art relative to Energy Efficient Algorithms for Automation of Core Network and Resource Management in the Radio Access Network, including novel approaches for Network Failure Recovery. Common framework from WP2.	R–PU M10
D6.1 WP6	**Dissemination, standardisation and communication plans, and project website** (OULU). Plan for the dissemination, standardisation and communication activities, including the launching of the 6GARROW project website.	R–PU M3
D6.2 WP6	**Dissemination, Standardisation and Exploitation activity report Y1** OULU). First year status and update plans for dissemination, standardisation and exploitation.	R–PU M12

The following project milestone has been achieved, as planned in the Part-B of the submitted 6GARROW proposal:

Table 2: List of completed Milestones.

Milestone number Name	Related work package(s)	Due date (in month)	Means of verification
Ms1 6GARROW set-up	WP1, WP2, WP6	M8	• Dissemination, standardisation and communication plans set. • Project website online. • Quality and data management plans delivered. • Initial Scenarios, Use Cases and related KPIs/KVIs well defined.

Exploitable results

The following table reports the main exploitable results along their descriptions.

Table 3: Exploitable Results.

Exploitable Result	Means of exploitation
Identification of potential use cases and related requirements, and design of preliminary system architecture	The potential use cases and related requirements, as well as the preliminary design of the system level design of a AI-native 6G architecture with its functionalities can be exploited by: Telco operators: The identified use cases and preliminary architecture can guide operators in planning their 6G network evolution, helping

with required functionalities.	them prioritize investments in AI-native capabilities and semantic communication technologies. Operators can leverage the requirements and functional design to optimize resource allocation and improve energy efficiency in their networks. The preliminary architecture provides a roadmap for integrating AI-driven automation and semantic services, enabling operators to enhance network performance and reduce operational costs. Service providers: Service providers can use the identified use cases to develop new AI-as-a-Service (AIaaS) offerings, tailored to specific industry needs and compliant with regulatory frameworks. The preliminary architecture can help service providers in the design of solutions that leverage semantic communication and edge inference, improving service delivery and user experience. Providers can exploit the requirements and functional design to create innovative services, such as intercontinental robotic control or AI-driven resource optimization, which meet emerging market demands. Standardization bodies: Standardization bodies can use the identified use cases and preliminary architecture to inform the development of new standards for AI-native 6G networks, ensuring interoperability and compliance with regulations like the EU AI Act. The requirements and functional design provide a foundation for defining standardized interfaces and protocols, facilitating seamless integration of AI and semantic technologies across different network domains. The preliminary architecture can guide standardization efforts in creating unified frameworks for cross-domain AI/ML coordination, supporting the evolution of 6G networks toward more intelligent and autonomous systems.
AI/ML Framework for Physical Layer Optimization	The development of AI/ML techniques for physical layer optimization, particularly in beam management and Channel State Information (CSI) prediction, can be exploited by: Telco operators to enhance energy efficiency and spectral performance in their networks, reducing operational costs and improving the quality of service that can be provided to customers. Service providers to offer advanced AI-driven services that leverage real-time channel predictions and beam management for applications like high-precision positioning and ultra-reliable communications. Standardization bodies to inform the development of new standards for AI/ML integration in physical layer technologies, ensuring the interoperability and the achievement of performance benchmarks that are foreseen for future 6G networks.
Cross-Domain AI/ML Coordination Framework	The proposed framework for cross-domain AI/ML coordination between Radio Access Networks and Core Networks can be exploited by:

	Telco operators to achieve end-to-end network optimization, improving resource efficiency and service quality through seamless coordination between different network domains. Service providers to develop new services that require real-time, cross-domain data sharing and AI model coordination, such as intercontinental robotic control and AI-as-a-Service (AIaaS) offerings. Standardization bodies to establish protocols and interfaces for cross-domain AI/ML coordination, facilitating the integration of AI-native capabilities across heterogeneous network environments.

1.1 Objectives

The following subsections report the project objectives defined in Section 1.1 of Part-B of the 6GARROW proposal. Each objective refers to specific Expected Results (ERs). The paragraphs collect the description of the work performed in the reporting period towards each specific objective and list the related achievements.

1.1.1 Objective 1

Title: Define an AI-Driven Architecture and address Interoperability issues.

ER1.1: Overall system architecture that extends the state-of-the-art of 5G to fully integrate AI-native radio access systems and enable their operations.

- D2.1 (Scenarios, Use Cases, and KPIs/KVIs):
  - Identification of use cases that can benefit from an AI-native network design.
  - Functional architectural requirements for the identified use cases.
- D2.2 (Initial System Architecture):
  - Gap analysis with respect to the state-of-the-art architectures (from standardization, academic, industry initiatives).
  - Gap analysis with respect to the architectures required by use cases identified in D2.1.
  - Initial functional architecture with AI orchestration for joint Radio Access Network (RAN)–Core Network (CN) optimization.
  - Expected architectural extensions caused by native AI/ML in comparison to 5G:
    - Integrated data collection and analytics, 6G Network Data Analytics Function (NWDAF), which will likely result in a change in the RAN-CN interface and support of federated learning and distributed analytics.
    - Cross domain “Exposure Layer” that encompasses AIaaS in RAN, edge and CN. The “Exposure Layer” provides with metrics and information on the embeddings, e.g. embedding model or statistics with or without out task’s specifics to enable Semantic Layer.
    - AI Oracle or orchestrator that keeps track of distributed AI agents and associated resources.

ER1.2: Architecture suitable for highly distributed network topologies that leverage edge computing and learning frameworks to guarantee access to intelligence also to resource-constrained terminals and user devices.

- D2.2 (Initial System Architecture):
  - Functional architecture that introduces a framework for edge inference, in which AI/ML tasks are partitioned between the device and the edge server.
  - Incorporation into the architectural design of several functional requirements that stem from the key challenges associated with edge learning and inference, such as resource constraints, scalability and heterogeneity, orchestration of intelligence, and decentralized learning.
  - Functional architecture that supports collaborative edge inference, meaning that the devices such as User Equipment (UE) and the network collaborate to perform edge learning and inference tasks according to criterions that capture trade-offs between Key Performance Metrics (KPMs) (associated with AI/ML capabilities) such as: (i) training complexity; (ii) inference accuracy; (iii) AI/ML-related communication overhead; (iv) model generalization capability; (v) AI/ML performance; and (vi) inference latency.
  - Depiction of a functional architecture for semantic-aware edge inference in OPEN-RAN context.
  - Proposition to use internal Mobile Network Operator (MNO) data to train customized AI models tailored to the needs of individual users or user groups.
- WP5 (demonstration) / D2.1 (Scenarios, Use Cases, and KPIs/KVIs):
  - Aspects of semantic-aware edge learning and inference (and the associated use cases – D2.1) are reflected in the planned demonstration activities in WP5.
    - Semantic-aware device-edge co-inference for human-robot interaction
    - Physical layer AI/ML techniques.
    - AI/ML based Channel State Information (CSI) and Channel Quality Indicator (CQI) compression.
  - Aspects above were considered when designing the initial architecture.

ER1.3: Identification of new required functional components and interfaces at both the terminal and RAN sides, and on how these can be integrated with intelligent elements at the CN level.

- The initial 6GARROW architecture reported in D2.2 builds around semantic-aware edge learning and its supporting functionality: the semantic layer and related common AI orchestration for task-specific semantic operations.
- The functional architecture consists of following layers with:
  - Semantic layer in RAN and terminal to support semantic communications.
  - AI model management and model orchestration.
  - AI inference and service orchestration that hosts the task catalogue for edge inference tasks.
  - Cross domain co-ordination layer and service exposure.
- Support for semantic communication calls for new functionalities, such as semantic representations, semantic service level agreements, a new Quality of Service (QoS) concept that captures the meaning and relevance of information. The latter can be implemented as a new 5G QoS Indicator containing semantic descriptors to enable better coordination across RAN, CN and end user terminal.
- Since the AI-native operations work in a proactive manner, a concept of predictive QoS across different network domains has been introduced.

- The functional architecture highlights how AI-native capabilities can provide joint RAN-CN optimization possibilities, more specifically, through a semantic layer and common AI orchestration for task-specific semantic operations.

ER1.4: Architecture that streamlines information collection and sharing among network elements, as an enabler to intelligent network orchestration mechanisms and closed-loop QoS optimization.

- D2.1 (Scenarios, Use Cases, and KPIs/KVIs):
  - Defined the use cases that focused on collecting and sharing data efficiently between network elements to support smart orchestration.
  - Identified key performance and value indicators to measure how well the information flows help improve QoS in a closed loop fashion.
  - Examined how data sharing between CN and RAN can help the network react and adapt faster to changes.
  - Looked at what information that is needed for secure, real-time control of network resources.
- D2.2 (Initial System Architecture):
  - Proposed a functional architecture with a shared semantic layer to collect, understand, and distribute data across network elements.
  - Introduced protocols and Application Programming Interfaces (APIs) to synchronize and securely share metrics and states between RAN, CN, and Edge for flexible collaboration.
  - Defined AI-native functions for dynamic response and continuous adjustment based on collected data.
  - Supported intelligent agents and shared repositories to close the feedback loop for QoS control.
  - Included data governance and access controls to ensure secure and compliant information sharing.
- D4.1 (State of the Art on AIML Solutions for RAN and Core Optimization):
  - Studied AI/ML solutions to improve the flow of data between network parts using semantic representation and prediction models.
  - Introduced Semantic State Representation Function (SSRF) to standardize and share enriched information between distributed agents.
  - Described the use of digital twins and real-time analytics to monitor network conditions and improve intelligent control and QoS.
  - Presented an AI-driven architecture with distributed agents across RAN, CN, and Transport Network for ongoing data collection and quick reaction.
  - Detailed secure APIs for exposing network state data to operators and external services to support integration and resource control.

ER1.5: Intra-network intelligence made available to external parties via suitable APIs, extending the analytics exposure mechanisms supported by the Network Exposure Function (NEF) and the Network Data Analytics Function (NWDAF) in 5G.

- Deliverable D2.1 introduced the use cases that require exposing AI and analytics externally, including:
  - AIaaS for stakeholders, training the AI/ML model with MNO data without exposing raw datasets to third parties.
  - Semantic Communications Services for Agents (Semantic Service Level Agreements, embedding centric exchanges, codecs/metrics tailored to agent traffic).

- Value added data products (e.g., radio/service maps) and cross-domain coordination scenarios.

- Deliverable D2.2 defined a cross-domain Exposure Layer (generalizing NEF, Common API Framework-based) to expose:
  - Analytics and model artifacts (including semantic/embedding metadata) with policy, consent and access control.
  - AI/ML service provisioning (training/finetuning/inference) under governance, with predictive and semantic QoS concepts.
  - AI orchestrator ("AI oracle") as the coordinating point for distributed agents and exposed capabilities.
- Deliverable D3.1 identified agent-to-agent communication patterns (heterogeneous embeddings, zero-shot stitching) and semantic artifacts that inform what exposure primitives (e.g., embedding descriptors, semantic distortion metrics) are useful to external consumers.
- Deliverable D4.1 described architectural enablers for exposure:
  - Semantic State Representation Function (SSRF) as a semantic abstraction to present interpretable, machine-consumable network state.
  - Use of standardized northbound APIs (e.g., CAPIF: Common API Framework/TS 29.522 context) and cross-domain analytics (NWDAF: Network Data Analytics Function / MDAF: Management Data Analytics Function) as exposure backends.

ER1.6: Introduction of AIaaS features in the overall system and provision to external applications to facilitate the access to advanced AI functionalities, essential for the seamless operation of 6G networks.

- The introduction of AIaaS within the 6GARROW architecture enables external applications to access advanced AI models, inference services, and learning capabilities through standardized exposure interfaces.
- This extends the AI-native intelligence of the network beyond its internal domains and supports automation, optimization, and cross-domain orchestration in 6G systems.
- The architecture integrates an exposure layer that validates and governs access to AI functionalities. It also supports distributed AI agents, federated and edge learning, and model lifecycle management.
- Together, these mechanisms make network intelligence available as on-demand services while maintaining compliance, security, and interoperability requirements.

ER1.7: Efficient Interfaces for native AI/ML systems.

- D2.2 (Initial System Architecture):
  - Definition of a cross-domain Exposure Layer, generalizing the 3GPP Network Exposure Function (NEF) and based on CAPIF, enabling standardized and secure interfaces for AI/ML-native services across network, edge, and cloud domains.
  - Support for AI/ML capability exposure via APIs, allowing native AI agents and learning systems to request network intelligence, analytics, and control functions without relying on low-level protocol details.
  - Introduction of embedding-centric and semantic-aware interfaces, facilitating efficient exchanges tailored to AI/ML agent traffic rather than raw data streams, reducing overhead and improving task-oriented performance.
  - Enablement of semantic service negotiation and enforcement (e.g., SSLA: Semantic Service Level Agreement-oriented interactions), allowing AI/ML systems to specify performance

requirements in terms of inference accuracy, timeliness, or task success instead of traditional QoS metrics.
- Provision of interoperable northbound APIs that support multi-stakeholder access (applications, AI agents, orchestration platforms), ensuring scalability and extensibility for future AI-native 6G services.

ER1.8: Interoperable framework that allows different AI methodologies to be integrated and function cohesively within the network.

- The system architecture described in D2.2 includes the proposed framework to ensure multiple vendor specific AI methodologies, consisting of a distributed architecture where RAN, Transport and CN would have own AI agent optimized with their specific functionality.
- The AI agent would be interworking through standard discovery and management protocols (i.e. NETCONF: Network Configuration Protocol) and message structure (i.e. YANG: Yet Another Next Generation). This would allow each vendor to maintain own proprietary solution while exposing standard interfaces and management protocols to external components to ensure interoperability for end-to-end system.
- The baseline consists of having so called centralized AI oracle that has visibility of the specific independent AI modules designed for each specific component of the end-to-end 6G system.
- Moreover, the communication between the individual AI components and the AI oracle will follow standard transport protocols and data models such as NETCONF and YANG.
- With NETCONF a generic transport protocol is used to exchange configuration and instruct specific actions between diverse AI methodologies. In addition, YANG provides an extensive data model including AI data structures and commands to be exchanged with the AI oracle.

ER1.9: Setting of performance requirements and defining test procedures for validating AI-based performance enhancements, including the performance monitoring procedure, functionality / model management procedure, and the corresponding latency and interruption requirements.

- Deliverable D2.1 provided the KPI/KVI baselines per use case (e.g., U-plane/C-plane latency, reliability levels, energy metrics, positioning, semantic quality measures) to be used as acceptance criteria for AI-enabled functions.
- Deliverable D2.2 established an evaluation approach embedded in the architecture providing a:
  - Continuous validation through integrated data pipelines (6G NWDAF concept) and Exposure Layer governance (access control, consent, policy).
  - Predictive and semantic QoS notions to define measurable, end-to-end targets across RAN and CN.
- Deliverable D3.1 detailed measurement methods and targets at terminal side to validate AI-based gains considering:
  - Link level and system level simulation for compute/latency/energy tradeoffs (e.g., quantized receivers, semantic compression, device–edge co-inference).
  - Hardware-in-the-loop considerations (e.g., Power Amplifier impairment mitigation, waveform learning) and Block Error Rate and/or Bit Error Rate-centric validation under mobility and channel dynamics.
- Deliverable D4.1 outlined test and validation environments and procedures across domains, including:
  - Site-specific Digital Twin (Y-Twin) for controlled, repeatable PHY (Physical)/MAC (Medium Access Control) experimentation (5QIaware traffic, peruser decoded bits, mobility).

- Cross-domain analytics (NWDAF/MDAF) for runtime monitoring of AI functions and closed-loop control.
- Compliance and trust aspects (EU AI Act implications) as constraints on model evaluation, robustness and auditability.

1.1.2 Objective 2

Title: Enhance Device Performance with AI/ML.

ER2.1 Provide (joint) optimizations of data generation and transmission mechanisms

- Deliverable D3.1 contributed to the joint optimization of data generation and transmission by identifying semantic-driven data reduction mechanisms, cross-layer AI-based resource control, and Reconfigurable Intelligent Surfaces (RIS)-enabled adaptive transmission strategies that link how data is produced at the terminal with how it is sent over the air.
- These techniques will be further studied in the second and third year of the 6GARROW project.
- **Semantic-driven Data Generation & Compression:**
  - Representation learning techniques enabling terminals to extract only task-relevant data before transmission, reducing the amount of generated payload.
  - Goal-oriented semantic representations allowing terminals to adapt the format and granularity of generated data according to application objectives, enabling efficient joint control of what is generated and what is sent.
  - Semantic compression strategies based on separation of concerns, reducing local computation and transmission simultaneously.
- **Cross-layer Optimized Transmission:**
  - RIS-enabled power and traffic control mechanisms jointly optimize uplink transmission power and queue stability, therefore linking traffic generation (queueing) and transmission strategies.
  - Hybrid AI-based optimization for RIS-assisted Non-Orthogonal Multiple Access (NOMA) networks enables terminals to adapt transmission parameters based on network load and user clustering, directly coupling traffic behaviour and radio resource usage.
- **Distributed and Efficient AI Processing:**
  - Device-edge co-inference mechanisms reduce the amount of data that needs to be transmitted by splitting computation and minimizing redundant feature generation.
  - Semantic extraction combined with inference delegation allows terminals to produce only the necessary abstract representations, aligning data generation with transmission constraints.
- **Energy-Aware Protocols and Agent Communication:**
  - Inter-agent semantic protocol design to avoid unnecessary exchanges between terminals and network AI agents, reducing both message generation and over-the-air signalling.
  - Context-aware resource allocation and waveform learning jointly influence which data must be transmitted and how efficiently it is sent, closing the loop between traffic generation and transmission.

ER2.2 Significantly enhance terminal energy efficiency, either by a higher compression rate of the information, or by the deployment of optimized signal processing techniques that are resilient to lower channel quality

- Deliverable D2.1 framed the study of energy consumption with focus on use cases and requirements, considering:

- Highly efficient communications with light infrastructure (payload minimization, robust operation with constrained radio/compute).
- RAN/UE & RAN/CN cross domain coordination to translate link layer gains into end-to-end efficiency.

- Deliverable D3.1 consolidated terminal-side technical levers and evaluation, including:
  - Semantic/goal-oriented extraction and compression to reduce transmitted payload and RF on-time.
  - Device–edge co-inference (feature-level offloading, semantic caching) and lightweight AI (quantization/ PTQ: Post-Training Quantization/ QAT: Quantization-Aware Training, pruning).
  - Waveform learning and Discontinuous Reception (DRX)/power-saving L1/L2 strategies; AI-assisted Power Amplifier impairment mitigation to reduce backoff/baseband cost.
  - Methodologies for link/system simulation and Hardware-in-the-loop validation of compute/latency/energy trade-offs.
- Deliverable D4.1 complemented the energy efficiency study with network-side enablers that impact UE energy consumption, including:
  - Slice-aware AI-driven energy saving (ASM policies via rApp/xApp) and semantic-aware Radio Resource Management (RRM) considerations.
  - PHY AI techniques (beam mgmt., CSI prediction) to lower feedback/overhead; Digital Twin support for evaluating energy implications.

ER2.3 Contribute to the simplification of hardware in user devices, with a focus on ML models with controlled complexity that find a balance between model performance and energy efficiency, and with novel techniques for AI assisted hardware impairment mitigation.

- Several technical enablers have been investigated to achieve hardware simplification targets in user terminals and to evaluate performance of the proposed AI/ML-based algorithms.
- Initial State-of-the-Art review of planned contributions was carried out and published in D3.1, where “Section 4: Terminal Hardware Simplification” consists of the technical enablers and State-of-the-Art review corresponding to this objective. These contributions will be further developed in year 2 and 3 of the project. The work is carried out across two complementary directions.
- **AI-enhanced hardware impairment mitigation and efficiency enhancement:**
  - Addressed AI-assisted power amplifier impairment mitigation digital predistortion, developing low-complexity ML-models for terminal simplification.
  - Investigated a joint channel and impairment estimation framework, shifting the processing complexity from the UE to the system or base station side, resulting in simplified UE operation.
- **Semantic-aware hardware simplification with system-level AI integration**
  - Building on the device-edge co-inference and semantic communication solutions explored for terminal performance, traffic, and energy efficiency optimization, focusing on improving these approaches with explicit attention to terminal hardware simplification.
  - Addressed a broader system-level integration of AI processing within terminals, from architectural co-design to testbed deployment, which will be developed and implemented in the next two years of the project.

ER2.4: Frameworks ensuring that the diverse optimization processes can be run seamlessly and automatically, in association with the broader network infrastructure (incorporating the distributed nature of the processing functions between the device and the network, and the associated contextual and meta data exchange).

- The frameworks outlined in the initial architecture ensure that optimization processes across devices, edge nodes, and the broader network can operate seamlessly and automatically by relying on distributed AI capabilities, coordinated inference, and structured data exchange mechanisms.
- Deliverable D2.2 introduced an architecture in which intelligence is partitioned between terminals and the network, enabling AI tasks to be orchestrated dynamically according to resource availability, latency constraints, and contextual information.
- The design incorporates mechanisms for exchanging meta-data, semantic representations, and operational context between distributed processing entities, ensuring that optimization loops can run continuously and adaptively across heterogeneous components.
- This foundation supports automated decision-making, coordinated learning, and cross-layer optimization while preserving scalability and interoperability in highly distributed 6G environments.

ER2.5: Solutions that balance the computational load between the device and the network, with a clever separation of the processing functions focusing on device hardware simplification and energy efficiency.

- Deliverable D3.1 identified and analysed State-of-the-Art approaches and emerging research directions for balancing computation between devices and the network. It also outlined promising avenues for separating processing functions in a way that can simplify terminal hardware and improve energy efficiency.
- These insights provide a structured foundation for the research and developments to be carried out over the next two years within the project, including the investigation of:
  - Device-edge co-inference paradigms to split AI processing between terminals and the network, reducing on-device computational burden while preserving performance.
  - Semantic representation learning and extraction at the terminal, enabling an early abstraction of raw data and allowing the device to offload only compact, task-relevant information to the network.
  - Goal-oriented and semantic compression mechanisms to reduce the need for complex signal processing and large memory footprints at the terminal, contributing to hardware simplification.
  - Energy-efficient AI architectures (e.g., quantized models, lightweight Deep Neural Networks, neuromorphic-inspired processing) have been studied to minimize terminal-side inference cost before offloading or collaboration with the network.
  - AI-assisted radio and protocol optimization (including RIS-enabled schemes), shifting part of the optimization complexity to the network side to enable simpler terminal operation with lower energy consumption.
  - Semantic and agent-based communication frameworks, exploring how terminals can delegate reasoning and coordination tasks to network-side intelligence, limiting local computation while maintaining autonomy.

1.1.3 Objective 3

Title: Optimize RAN and Core based on AI/ML Solutions.

ER3.1: Energy efficient AI/ML algorithms for overall RAN and core optimization and automation that can exploit the network's AI nativeness to efficiently orchestrate and scale network functions and resources in distributed architectures under energy consumption constraints.

- Deliverable D4.1 established the State-of-the-Art foundation and research roadmap for energy-efficient AI/ML-driven optimization and automation across RAN and CN in distributed 6G architectures. This deliverable includes:

- A review on the State-of-the-Art published in the literature on energy-aware AI/ML techniques for RAN and CN optimization, including AI-driven scheduling, beam management, power control and PHY-layer adaptations.
- An identification of AI-native architectural enablers (e.g., analytics functions, AI/ML exposure, Digital Twins) that allow energy-aware decision-making across distributed network functions.
- An analysis of energy efficiency related topics across multiple time scales, distinguishing short-term radio-level optimization from long-term orchestration and automation strategies.
- Key highlights on the role of distributed architectures and the associated energy challenges, including scaling AI models, coordinating decisions across domains, and managing resource heterogeneity.
- A positioning of automation and orchestration as key research avenues, where AI can dynamically adapt resource allocation and network function placement under energy constraints.
- An identification of open challenges and research gaps, such as model scalability, energy-aware learning, explainability, and coordination across RAN and CN, guiding future algorithm design.

ER3.2: Semantic and goal-oriented radio resource management techniques, including coexistence between empowered and non-empowered users.

- **Direct Contributions.** Deliverable D4.1 explicitly addressed semantic vs. non-semantic user coexistence in the following ways:
  - Stating clearly the need to revisit RRM when introducing semantic communications, identifying:
    - Goal-driven vs. bit-level user requirements.
    - Potential conflicts in resource prioritization.
    - The necessity of semantic-aware schedulers.
  - Framing semantic communications as a key architectural enabler for 6G, not a peripheral feature, supporting the transition toward intent-driven networking.
  - Formulating explicitly the coexistence challenge of semantic and non-semantic users as a research problem, linking it to planned work in WP4 and fulfilling Objective 3 requirements.
- **Indirect / Supporting Contributions.** Deliverable D4.1 also positioned semantic reasoning as a foundational requirement for future AI-native core and RAN architectures.
  - Open research gaps identified by deliverable D4.1 include:
    - Semantic KPI exposure.
    - Mapping user intent to RAN decisions.
    - Hybrid user coexistence under different service profiles.
  - Deliverable D4.1 also established the State-of-the-Art background needed for developing semantic RRM, which is the expected first measurable result under Objective 3.

ER3.3: AI-driven platform for automated base station management, aiming to optimize network performance and efficiency in real-time.

- In the first year, 6GARROW has worked on an AI-driven architectural framework and control mechanisms for automated base station management.
- Initial contributions to the objective are:
  - Clarification of the architectural components required for AI-assisted and automated base station management, including analytics functions, AI modules, and RAN-CN interaction mechanisms.

- Review of the State-of-the-Art in AI-driven RAN control, covering energy-efficient scheduling, beamforming adaptation, and AI-assisted PHY-layer techniques relevant to base station automation.
- Identification of real-time and near-real-time control loops for base station management, distinguishing fast radio-level decisions from slower AI-driven optimization processes.
- Positioning of Digital Twins and cell-specific modelling as key enablers for safe development, training, and validation of AI-driven base station control mechanisms.

ER3.4: AI/ML service provision intra-network and externally, enabling consumers to access intra-network data and AI training capabilities for tailored AI models.

- Deliverable D2.1 (Scenarios, Use Cases, and KPIs/KVIs):
  - Introduction of use cases focused on offering AIaaS capabilities, allowing stakeholders to request customized AI models trained with confidential internal network data.
  - Identification of KPIs and KVIs related to the availability and quality of AI services, measuring user experience improvements through data-driven AI model refinement.
  - Description of business cases in which MNOs can monetize data by providing trained AI models without exposing raw sensitive data.
  - Definition of use cases, including collaboration scenarios where external and internal stakeholders utilize AI models trained on network data for improved decision-making and service personalization.
- Deliverable D2.2 (Initial System Architecture):
  - Proposal of a functional architecture that includes AI data management entities capable of handling requests for AI model creation and refinement using intra-network data.
  - Definition of secure interfaces between network internal components and external entities to allow controlled access to AI training resources and data.
  - Description of data repositories containing sensitive MNO data (restricted from raw sharing) and non-confidential public data, supporting AI processing while ensuring privacy.
  - Inclusion of AI model lifecycle management layer, capable of orchestrating AI training and inference tasks both inside the network and across trusted external platforms.
  - Emphasis on governance and compliance features to secure AIaaS provisioning, keeping it aligned with data privacy regulations such as General Data Protection Regulation (GDPR) and the EU Data Act.
- Deliverable D4.1 (State-of-the-Art on AI/ML Solutions for RAN and Core Optimization):
  - Overview of the State-of-the-Art in AI/ML service provisioning, including intra-network AI orchestrators exposing AI capabilities to external users.
  - Presentation of the Exposure Layer, evolving from the NEF to facilitate the exposing of AI models, analytics, and data to authorized consumers via standardized APIs.
  - Description of an AI orchestrator (or AI oracle) with system-wide visibility, able to dynamically allocate resources and control distributed AI agents to fulfil service requests.
  - Discussion of architectural enhancements enabling seamless AI model sharing and training with confidentiality preservation, leveraging federated learning and distributed analytics.
  - Coverage of compliance with upcoming regulations, including the EU AI Act, ensuring trustworthy and transparent AI/ML service delivery within and beyond the network.

ER3.5: Intelligent robustness and recovery mechanisms for CN functions in distributed architectures under QoS requirements.

- 3GPP has defined the Service-Based Architecture (SBA) that is leveraged for high availability, where multiple instances of the same Network Function (NF) can be registered in a Network

Repository Function (NRF) for load sharing. Robustness and availability in this context are delivered through containers or virtual machines where different instances of NF are deployed.

- 3GPP Release 17 also introduced the concept of Set-ID, which allows having multiple instances of the same NF to become part of a set. This group of NFs in the Set are providing redundancy and high availability since, if any of the single NF fails, the other NF part of the same set will take over the functionality without service disruption.
- This is a major improvement compared to 4G, where the failing of NF result in the devices to register and reestablish a new packet data session. In this context, 6GARROW aims at:
  - Leveraging the existing functionality of SBA for distributed NF and the concept of Set-ID.
  - Allowing a CN orchestrator to manage the deployment of NF part of the Set-ID in different locations (e.g. on-premises and on-cloud), based on the target levels of robustness that are set are requirements for the implementation.

ER3.6: RAN-Core integrated analytics and learning model management technology for cross-domain inference coordination which are geared to be exposed to network automation entities of each domain.

- Following the architecture defined in Deliverable D2.2 and the AI framework considered as part of the project, 6G-ARROW aims at utilizing the same methodology based on NETCONF and YANG models to retrieve the analytics from RAN.
- 3GPP defined the NWDAF to collects analytics from the CN. Based on it, 6GARROW aims at:
  - Designing the analytics repository where information from RAN and CN could be aggregated to carry out an end-to-end inference coordination.
  - The data collected in this repository will be exposed to network automation entities through the NEF, to be designed specifically with additional service endpoints to access the RAN-CN analytics.

1.1.4 Objective 4

Title: Develop and Validate Experimental Testbeds and Proof of Concept Platforms to Showcase the key 6GARROW Innovations.

ER4.1: demonstration of the proposed AI and ML concepts to be practical and effective in the context of the 6G network.

- Not addressed yet.

ER4.2: concepts assessed in a controlled environment, based on laboratory demonstrations and testbeds.

- Not addressed yet.

ER4.3: any potential issues identified, performance of the AI and ML innovations optimized, and guaranty that they can be successfully integrated into the 6G network provided.

- Not addressed yet.

ER4.4: collaborative demonstration between EU and ROK, showcasing the key concepts developed within the 6GARROW project.

- Aalto University (Finland) and Yonsei University (ROK) have initiated work toward a joint demonstration.

- A WireGuard-based Virtual Private Network (VPN) has been established between the two sites to enable testing of a local breakout scenario, in which:
  - The core network is hosted at Yonsei.
  - The UE is connected to the next-generation Node B (gNB) at Aalto, with the User Plane Function (UPF) instantiated locally at Aalto.

ER4.5: demonstration of the integrated system architecture, in a real-world scenario.

- Not addressed yet.

ER4.6: emphasized international collaboration and knowledge-sharing.

- During the first year of the project, strong emphasis was placed on initiating international collaboration and structured knowledge-sharing between European and Korean partners.
- Regular joint meetings, technical Face-to-Face (F2F) workshops, and collaborative development of core documents enabled early alignment on the 6GARROW vision.
- This initial phase established a shared understanding and common foundations, upon which closer technical cooperation, deeper integration, and increased joint authorship of scientific and technical outputs are expected to build in the coming project phases.

1.1.5 Objective 5

Title: Fostering collaboration between EU and ROK.

ER5.1: Exchange of best practice and lesson learned in European and Korean prototyping, lab trials and proof of concept (PoC).

- We have initiated the PoC work and exchanged details on the test-network configurations.

ER5.2: Joint development of solutions, techniques and components, architecture, interfaces and specific technological solutions that may have a direct impact on future business.

- Not addressed yet.

ER5.3: Establishment of mutual understanding and trust among European and Korean academics, industry, telecom operators to promote future collaborations in 6G and future networks markets.

- 6GARROW gathers four partners from ROK (i.e., two academic partners, one research centre and one industrial partner) and eight partners from EU (i.e., three academic partners, two research centres and three industrial partners).
- From its earliest stages, the project was shaped through joint efforts by ROK and EU partners. The Description of Work (i.e., Part-B of 6GARROW proposal) is the result of a closely coordinated effort between EU and ROK partners, whose combined contributions ensure a coherent intercontinental project.
- To strengthen this joint effort, an EU-ROK Coordination Agreement is now being prepared.
- Regular WP meetings brought together participants from both continents, supporting the project's goal of building trust and shared understanding among European and Korean stakeholders.
- The kick-off meeting project that took place in Grenoble (Jan. 2025), and the second F2F meeting that was organized in Seoul (Dec. 2025), provided valuable in-person exchanges, reinforcing collaboration and confidence between EU and ROK teams.

- The project organized a workshop at GLOBECOM 2025 featuring speakers and committee members from both Europe and Korea, further reinforcing its collaborative and intercontinental dimension.
- Industrial partners within the consortium actively exchanged their perspectives and jointly discussed the future of B5G networks, strengthening the project's shared vision and roadmap.

ER5.4: Joint EU-ROK publications in international journals and conferences.

- Joint vision paper published in IEEE EUCNC & 6GSUMMIT 2025 and presented by FhG.
  - E. C. Strinati et al., "AI-Native 6G Networks: The 6GARROW Integrated Device-Network Approach," in Proc. Joint European Conference on Networks and Communications & 6G Summit, Poznan, Poland, June 2025, pp. 115-120, doi: 10.1109/EuCNC/6GSummit63408.2025.11037138.
  - **EU authors:** Emilio Calvanese Strinati and Nicolas Cassiau (CEA-Leti, Université Grenoble Alpes, France); Pierre Dal Zotto (Université Grenoble Alpes, Grenoble INP, CERAG, France); Pierre Dal Zotto (Grenoble Ecole de Management, France); Nicola di Pietro and Davide Montagno Bozzone (HPE, Italy); Louis-Adrien Dufrène, Quentin Lampin, and Guillaume Larue (Orange Research, Grenoble, France); Thomas Haustein and Zoran Utkovski (Fraunhofer HHI, Berlin, Germany); Riku Jäntti, Petri Mähönen and Tanesh Kumar (Aalto University, Espoo, Finland); Matti Latva-aho, Dileepa Marasinghe, and Nandana Rajatheva (University of Oulu, Oulu, Finland); and Markus Mueck (Intel Deutschland GmbH, Germany).
  - **Korea authors:** Chan-Byoung Chae, Seong-Lyun Kim, Jemin Lee, and Jeonghun Park (Yonsei University, Seoul, Korea); Joongheon Kim (Korea University, Seoul, Korea); and TaeYeon Kim (Electronics and Telecommunications Research Institute, Korea).

ER5.5: Publication in social media and dedicated website.

- By the end of the first year of the project, 6GARROW has published 25 posts on both LinkedIn and X. This totals to 50 posts, meaning five times the promised amount.
- Activity on social media has driven traffic to the website and helped the project build a following on both platforms to effectively disseminate the progress and results of the project.
- In addition, the website itself has been updated regularly with new deliverables, news highlights, events, newsletters, and media mentions, ensuring a steady flow of traffic to the website and strong visibility on search engines.

ER5.6: Press releases.

- During its first year, 6GARROW published two press releases on the project website, which resulted in mentions on other news platforms, such as SNS JU Project News and 6G Flagship News.
- In addition, Yonsei University published an article on 6GARROW and AI-RAN on Digital Times, which can be considered a press release.
- Other notable media highlights included articles in SNS-JU Journal 2025, Nature Reviews Electrical Engineering, 6G Waves Magazine issue 9, and 6G Waves Magazine issue 11.

ER5.7: EU-ROK co-organization of workshops and schools.

- The project organized a full-day workshop at GLOBECOM 2025 (Taipei, Dec. 2025) featuring speakers and committee members from both Europe and Korea, further reinforcing its collaborative and intercontinental dimension.

- On 5 Dec. 2025, the 6GARROW consortium co-organised the AI-RAN Summit in Seoul, Republic of Korea, hosted at Yonsei University and held in conjunction with the F2F meeting in Seoul.
  - The summit was jointly organised by the Ministry of Science and ICT (MSIT), the AI Network Alliance (AINA), Yonsei University, and participating research projects, including 6GARROW.
  - The summit aimed at fostering global industry-academia-research cooperation on AI-RAN as a core technology for AI-native and 6G networks.
- A workshop on the European regulatory landscape relevant to digital infrastructure and 6G was held at Grenoble Ecole de Management (GEM) on 25 Nov. 2025.
  - The workshop was delivered by Dr. Markus Mueck (Intel, ETSI: European Telecommunications Standards Institute, and 6GARROW) and provided an overview of key EU regulations, their timelines, and their relevance to future 6G systems.

ER5.8: Joint demonstration of the 6GARROW key concepts.

- Not addressed yet

1.1.6 Objective 6

Title: Maximize the impact of 6GARROW with a highly targeted dissemination and exploitation plan to achieve a very high level of visibility of the results. Contribute to the global 6G standardization and create a lasting synergy for 6G research, innovation and commercialization.

ER6.1: Feed WP2-WP5 with latest rules on data legislation for AI and Data Management solutions, thus targeting compliance with regulation requirements (EU AI Act, Cyber Resilience Act (CRA), Radio Equipment Directive Articles 3(d/e/f) on Cybersecurity and Privacy, etc.).

- Deliverable D4.1 explicitly discussed the EU AI Act and its implications for AI-native architectures.
  - This deliverable outlined the requirements for general-purpose AI models with systemic risk and the obligations of providers, including model evaluation, adversarial testing, and cybersecurity protection.
  - The deliverable also proposed architectural approaches to meet these requirements, such as offering "trimmed down" versions of AI models to avoid additional regulatory burdens.
- Deliverable D2.1 emphasized the importance of security and privacy, including compliance with GDPR and other data protection regulations. It highlights the need for robust authentication mechanisms, granular access control, and privacy-preserving analytics.
- Deliverable D2.2 further elaborated on the need for secure data handling and communication, including encrypted transmission and privacy-preserving computation.
- Both Deliverable D2.1 and Deliverable D2.2 discussed the need for cross-domain coordination and data management, which inherently involves compliance with data legislation.
  - For example, the "Exposure Layer" should be designed to validate requests and ensure compliance with data protection regulations.
  - Both deliverables also mention the need for standardized interfaces and protocols to ensure secure and compliant data exchange across domains.
- Deliverable D4.1 included specific references to the EU AI Act and discusses the architectural implications of compliance with this legislation. It also mentions the need for cybersecurity protection and other regulatory requirements.

ER6.2: Support of the implementation process of EC regulations on AI and cybersecurity through standards to be developed by European Standardisation Organisations (ETSI, CEN, CENELEC).

- The architectures and interfaces proposed by 6GARROW will be designed to be compliant with emerging EC regulations (e.g., EU AI Act, GDPR, Cybersecurity Act).
- The architectural principles, compliance requirements, and security considerations identified in the project can be leveraged as technical contributions to ETSI, CEN, and CENELEC working groups, supporting harmonized standards for AI lifecycle management, cybersecurity, and cross-domain interoperability.

ER6.3: Coordination of related implementation approaches between EU and ROK.

- Aalto and Yonsei have begun planning a joint PoC. Although this collaborative work is still in an early stage, plan have been set up to continue with its implementation in the second year of the project.

ER6.4: Contribution to the 6G standardisation mainly in 3GPP and possibly in ETSI, focusing on current and future Study and Work Items in the 3GPP Releases 19 and 20, whilst preparing the scoping of 6G related SI and WI which are expected to be under discussion during the final phase of the project, corresponding to release 21 as the 1st official 6G release.

- 6GARROW aims at contributing to the technical insights, architectural concepts, and performance evaluations of ongoing 3GPP Study Item (SI) and Work Item (WI) in Releases 19 and 20, particularly in areas related to AI-native networking, advanced RAN–CN integration, and system-level optimizations.
- Based on 6GARROW results, candidate technical topics and architectural enablers will be identified and structured to support the scoping of future 6G-related SI and WI, anticipating discussions leading to Release 21 (first official 6G release in 3GPP).
- Relevant outcomes will be aligned with ETSI activities to ensure coherence between 3GPP system specifications and complementary European standards, facilitating a smooth transition from advanced 5G evolution to early 6G standardization.

ER6.5: Coordination of efforts in standardisation across Korean and European partners to approach standardisation in a cooperative way, e.g. by proposing particular aspects resulting from the project in new study/work items.

- Not addressed yet.

ER6.6: Promotion of technical and economic analysis towards vertical stakeholders.

- Not addressed yet.

ER6.7: dissemination.

- Deliverable D6.1 laid out a comprehensive plan for dissemination of the project results.
- Deliverable D6.2 includes the details of the dissemination activities of 6GARROW project during the first year. A summary of these activities is as follows:
  - Peer-reviewed journal and conference papers:
    - Published/accepted: 16.
    - Submitted/being revised: 6.
  - Number of publications uploaded to the 6GARROW Zenodo community: 7.
    - Some accepted publications still do not have a DOI, which will be added later.
    - URL: https://zenodo.org/communities/6garrow/records?q=&l=list&p=1&s=10

    - Link to Zenodo
  - Number of public deliverables made available online: 7.
    - URL: https://6garrow.com/results/
    - **Link to deliverables**
  - 6G ARROW tutorial on EU Regulations (AI Act, Cyber Resilience Act, Data Act, etc.)
    - Held on 14th Mar 2025 at 10:00 to 12:00 CET (Online).
  - IEEE MeditCom 2025 on 10th July 2025 panel, entitled *"AI-Assisted (6G) Communications – European Digital Legislations and Sustainability Challenges".*
    - Organised and moderated by Dr. Markus Mueck (Intel Deutschland GmbH), 6GARROW Innovation Manager.
  - Intel/GEM EU AI act and regulations workshop: 25th Nov. 2025.
    - The workshop was delivered by Dr. Markus Mueck (Intel, ETSI and 6GARROW) online, and provided an overview of key European regulations, their timelines, and their relevance to future 6G systems.
  - Participation to a Webinar organized by the AIOTI association. Intel gave the presentation "Edge IoT Industrial Immersive and Spatial Computing Applications. Ethics and Standardization aspects."
    - Activity done in collaboration with the EU-funded project MultiX.
  - EU-ROK workshop: AI-RAN workshop. Location: Yonsei University. Date: 5th Dec. 2025.
  - Co-organizing the IEEE GLOBECOM 2025 workshop in Taipei.
    - URL: https://globecom2025.ieee-globecom.org/workshop/ws-28-ai-native-communications-systems-towards-integrated-intelligent-and-highly-efficient
    - **Link to Workshop**
    - No. of submissions for evaluation: 35. No. of accepted papers: 12.
  - IEEE Globecom 2025: 6GARROW advertised at the booth from Yonsei University

ER6.8: assessment of the economic feasibility of AI and ML applications within the context of 6G networks.

- Deliverable 2.1 provided the use cases upon which with interview from projects members and verticals we will further develop suggested business models and value propositions.

ER6.9: strategic business vision and sustainable business model for innovative AI-native 6G networks.

- Deliverable D2.1 identified monetizable service avenues for:
  - The provision of AIaaS for internal/external stakeholders, including models built/refined on MNO data without exposing raw datasets to third parties.
  - Semantic services for agents (SSLAs, embedding codecs/protocols) and value-added data products (e.g., radio/service maps).
- Deliverable D2.2 defined architectural/business enablers and constraints, including:
  - Cross-domain Exposure Layer and AI orchestrator as the platform for AI capability exposure, under policy, consent and compliance controls.
  - Techno-economic analysis (cost/benefit, incremental evolution) and new QoS concepts (predictive/semantic) to underpin service differentiation.
  - Inter-operator Perceived Quality of Service (PQoS) concept to support dependable multidomain offerings.
- Deliverable D3.1 focused on device-side innovations contributing to sustainability, such as:

- Terminal energy-efficiency mechanisms (semantic extraction, co-inference, quantized/lite models, Power Amplifier mitigation, waveform learning) aligned with Operational Expenditure (OPEX) / Total Cost of Ownership (TCO) reduction and longer device lifetimes.

- Deliverable D4.1 discussed key architectural enablers that support commercialization, including:
  - EU AI Act considerations informing governance, model lifecycle constraints, and risk management for offered AI services.

1.2 Explanation of the work carried per WP

1.2.1 Work Package 1

WP1 is dedicated to administrative project management, technical and quality management and innovation and impact management.

Work carried out by each beneficiary involved

- CEA
  - Relation with the Project Officer
  - Coordination of the Consortium Agreement preparation.
  - Financial management
  - Project management team meetings (preparation, coordination, minutes).
  - Relation with SNS JU.
  - Edition of deliverables D1.1 (Quality Plan), D1.2 (Data Management Plan), D7.1 (Ethics).
  - Relation with Advisory Board.
  - Relation with Ethics Advisor.
  - Follow-up of Deliverables of other WPs (quality management).
  - Risk management.
  - F2F meetings (plenaries): preparation, animation, minutes.
- AALTO
  - Participation in F2F meetings.
  - Technical management.
- OULU
  - Participation to F2F meetings.
  - Coordination of project dissemination and visibility.
  - Development of internal reporting tools.
- GEM
  - Participation to F2F meetings.
  - Interviews with WP leader for research on international collaboration.
  - Support coordinator for SNS-JU questionnaire about 6G economics.
- YONSEI
  - Organizing and participating at the F2F meeting.

1.2.2 Work Package 2

WP2 develops a novel AI-native architecture for 6G networks, including new AI/ML and data management related entities and emphasizing the creation, integration and exposure of new interfaces at both the network and device levels. This WP provides the reference architecture, use-

cases, KPIs and KVIs for the validation (analytic, simulation-based or via testbeds) of key concepts developed in WP3 and WP4. The AI-native architecture is designed in accordance with the requirements of the novel EU AI Act.

Work carried out by each beneficiary involved

- CEA
  - Contribution to D2.1 (Scenarios and Use-Cases), with focus on the use case named *"reliable communications with light infrastructure."*
  - Contribution to D2.2 (Initial Architecture), providing support to the edition and visualizing the State-of-the-Art of SNS JU projects.
  - Task 2.2 leader, providing a follow-up of the contributions to the task.
  - Coordination of some of the periodic meetings.
- FhG
  - Contribution to Deliverable D2.1 (Scenarios and Use-Cases) and Deliverable D2.2 (Initial Architecture).
  - Participation in the regular meetings of WP2.
- AALTO
  - Contribution to D2.1 (Scenarios and Use-Cases), with focus on the section entitled *"Cultivating Radio Measurements into Value-Added Services for Spectrum Sharing"*.
  - Editor of D2.2 (Initial Architecture), coordinating the organization, development, and writing of the document in close cooperation with the project partners.
  - Contributed to D2.2 sections, including Introduction, Methodology and Principles, 3GPP, NG-RAN split architectures, ETSI, Core network considerations, Proposed functional architecture.
- INTEL
  - Contribution to D2.1 (Scenarios and Use-Cases), with focus on the section entitled *"AI-as-a-Service for stakeholders & creation of tailored AI models according to End User's needs."*
  - Contribution to D2.2 (Initial Architecture) on overall methodology on creating a functional architecture which is then instantiated according to specific use cases. Contribution to State-of-the-Art analysis, specifically on the 3GPP 5G CN Architecture.
- HPE
  - Activities related to Deliverable D2.1 (Scenarios and Use-Cases):
    - Editor of D2.1, coordinating the organization, development, and writing of the document in close cooperation with the project partners.
    - Leader of Sections 3.2.3 and 3.3.1, providing key contributions on two main topics.
    - Semantic and automated management of the core network through the SSRF based on Large Language Models (LLM).
    - Advanced strategies to reduce overhead in fault management and recovery using NLP/NLU techniques, designed for private 5G/6G networks.
    - Contribution in the definition and formalization of the main use cases of the project, grouped into functional families to support architectural and methodological development.
    - Introduction of new AI/ML methods for dynamic traffic prediction and automated recovery actions, improving energy efficiency and operational flexibility.
    - Development of specific metrics to evaluate the effectiveness of NLP models applied to the network, including accuracy, RMSE, and semantic similarity.
    - Gap analysis between the State-of-the-Art and the innovations of 6GARROW, showing the architectural and methodological improvements introduced.
    - Functional and non-functional requirements for the integration of the SSRF platform and for automated alarm and recovery management, ensuring compatibility with 3GPP standards.

- Activities related to Deliverable D2.2 (Initial Architecture):
  - Development and writing of section 4.7.2, focusing on semantic and goal-oriented architectures from the SNS JU perspective, with attention to semantic frameworks and new, smarter, and more efficient communication models.
  - Contribution to sections 5.3.2 and 5.4, covering core network considerations and proposals for functional architecture, with a focus on integrating AI-native functions and digital-twin systems into the network framework.
  - Contribution to Section 5.3.2, including analysis and integration practices between RAN and CN, with particular attention to automation, orchestration, and resilience strategies, essential for AI-based 6G networks.
  - In section 5.4, proposal of functional architectures to support AI-native capabilities, prioritizing interoperability, modularity, scalability, and security requirements, aligned with SNS JU guidelines and standardization trends.
  - Additional contributions were made to define how AI and digital-twin functionalities can coexist and be orchestrated in next-generation architectures, also supporting sustainability and adaptability goals.

- ORANGE
  - Contribution to D2.1 (Scenarios and Use-Cases), providing inputs for the definition of a use case on semantic service level agreement for agent-to-agent communications.
  - Contribution to D2.2 (Initial Architecture), contribution to the techno-economics analysis.

- YONSEI
  - Contribution to D2.1 (Scenarios and Use-Cases) across the following two sections:
    - Section 2, entitled *"methodology and structure"*, where a comprehensive list of KPIs and KVIs that have appeared in the relevant literature for 6G was discussed and tabulated.
    - Section 3, entitled *"use case families and use case taxonomy"*, where the following two use cases were discussed and detailed: (i) Ultra-reliable and low latency communications for machine vision-based robotic control; (ii) Dynamic resource allocation for international RAN-core.
  - Contribution to D2.2 (Initial Architecture) across the following two sections:
    - Section 2, entitled *"methodology and principles"*, where the methodology to create an architecture for the 6G networks was discussed.
    - Section 3, entitled *"techno-economic aspects"*, where the techno-economic costs and benefits were separately discussed and finally technoeconomic tools to assess the 6G technology financially were briefly mentioned.

- ETRI
  - Contribution to D2.1 (Scenarios and Use-Cases). Investigated and provided RAN/UE and RAN/CN cross-domain coordination use case, summarized with detailed descriptions in Chapter 3.1.2
  - Contribution to D2.2 (Initial Architecture). Investigated State-of-the-Art (SotA) of the O-RAN architecture and provided an initial functional architecture for a cross-domain intelligence coordinator, presented in Chapter 5.6.

1.2.3 Work Package 3

WP3 innovates in the field of AI/ML algorithms with the primary goal of optimizing user terminal traffic and enhancing device-network integration. This WP is dedicated to developing advanced AI/ML solutions that streamline automated traffic management, significantly boost energy efficiency, and contribute to the simplification of hardware in user devices. A pivotal aspect of this objective is to design algorithms that not only enhance the performance and user experience at the terminal level but also ensure seamless and efficient integration with the broader network infrastructure. Semantic

and goal-oriented techniques are explored to jointly optimize data acquisition and data transmission by selecting only the most informative, i.e. the most relevant data for the task in question. The focus is on creating solutions that balance operational efficiency with reduced complexity (both algorithmic and hardware), aiming to set new standards in device functionality and network interoperability in the emerging landscape of 6G technologies

Work carried out by each beneficiary involved

- CEA
  - WP leader.
  - Periodic online meetings: preparation, coordination, minutes.
  - Technical work:
    - Semantic and goal-oriented representations.
    - Semantic AI for terminal energy optimization.
    - Hardware evaluation of terminal traffic and energy efficiency optimization solutions.
  - Contribution to D3.1 (SotA on Device Enhanced Performance).
- FhG
  - Technical work:
    - Representation learning for on-device semantic extraction.
    - Device-edge co-inference and neuromorphic processing.
    - Edge inference system and complexity analysis.
  - Contribution to D3.1 (SotA on Device Enhanced Performance) on research objectives and relevant state of the art.
- AALTO
  - Participation in periodic meeting, including technical presentations and discussions on the contributing technical topics.
  - Technical contribution on semantic meta-split learning methods to transmit smashed data and gradients at the designated cut layer.
  - Contribution to the content of different sections of Deliverable D3.1 (SotA on Device Enhanced Performance).
- OULU
  - Task leader of Task T3.3 (Simplification of Terminal Hardware).
  - Editor of Deliverable D3.1 (SotA on Device Enhanced Performance). Deliverable D3.1 completed and published on 31st Oct. 2025.
  - Participated in periodic meetings including technical presentations and discussions on the contributing technical topics.
  - Technical work:
    - Semantic communications with generative AI.
    - Waveform learning for energy efficiency.
    - AI-assisted PA impairment mitigation.
  - Technical contributions to Deliverable D3.1 (SotA on Device Enhanced Performance).
- ORANGE
  - Task leader of Task T3.2 (Enhancing Terminal Energy Efficiency).
  - Contributions to Deliverable D3.1 (SotA on Device Enhanced Performance) on:
    - Semantic compression under separation of concerns. In actual communications, application and network share minimal information relative to the content of the data transported,

disabling many approaches from the semantic communications field. It was proposed to study alternatives paths, to keep leverage semantic techniques while respecting the separation of concerns.
    - Heterogeneous AI agents' communications. Aim is to define how to enable direct semantic communications between agents with different semantic/latent spaces. Focus was put on zero shot stitching approaches.
- YONSEI
    - Contribution to Deliverable D3.1 (SotA on Device Enhanced Performance) across three main novel research topics:
        - Hybrid AI for RIS-assisted NOMA networks.
        - DRL-based dynamic spectrum access.
        - Joint channel and impairment estimation framework.
    - In each case, research objectives were demonstrated, and relevant State-of-the-Art art was presented.
- KU:
    - Contribution to Deliverable D3.1 (SotA on Device Enhanced Performance) with Task T2.2 (AI-driven and RIS-Enabled Resource Optimization)
    - Specifically, leading the research on RIS-enabled energy-efficient uplink power optimization with user-traffic stabilization.
    - The research objectives were demonstrated, and relevant State-of-the-Art was presented.
- LGE
    - Contribution to Deliverable D3.1 (SotA on Device Enhanced Performance).
    - Participation in the regular meetings of WP2.

1.2.4 Work Package 4

To leverage the capabilities of AI/ML algorithms in revolutionizing the management of RAN and CNs, this work package focuses on transforming RAN and CN management, enhancing network energy conservation, and improving failure recovery processes. The key objective is to develop AI/ML based algorithms/mechanisms that will enable optimized and energy-efficient solutions for various key aspects at 6G radio and CNs which includes, for example, design of enhanced beam management techniques using AI/ML, development of AI/ML-enabled energy-efficient and sustainable network/radio orchestration and management mechanisms, intelligent data/service analytics and processing mechanisms at MEC/edge/cloud, and AI-based semantic and goal-oriented radio resource management techniques. This work is crucial in enhancing the operational efficiency, resilience, and sustainability of future wireless networks. To achieve this goal, two tasks are executed under WP4, focusing on optimization targeting energy efficiency and automated network management and network failure recovery.

Work carried out by each beneficiary involved

- CEA
    - Editor of Deliverable D4.1 (SotA on Enhanced RAN and Core): skeleton, follow-up of contributions, deadlines monitoring, meetings.
    - Main contribution to Deliverable D4.1 section entitled *"Co-Existence of Goal-Oriented and Legacy Users"*.
- AALTO
    - WP leader
    - Periodic online meetings: agenda, coordination, and preparation of minutes.
    - Presentation of WP4 status and future directions in the plenary F2F meetings of the project.

- Technical work:
  - AI-based application functions for RAN and Core Optimization.
  - Automated RAN & Core management and Network Failure Recovery
- Contribution to Deliverable D4.1 (SotA on Enhanced RAN and Core), with emphasis on the content of Section 4 entitled *"Automation and failure recovery"*.

- INTEL
  - Contribution to Deliverable D4.1 (SotA on Enhanced RAN and Core) on Section 2.2, entitled *"6G Architecture meeting the requirements of the EU AI Act"*, relating the work of 6GARROW to the implementation of the AI Act.
  - Introduction of the concept of offering the choice between a *"full"* and *"trimmed down"* version of an AI Model.

- HPE
  - All the following activities are part of Deliverable D4.1 (SotA on Enhanced RAN and Core):
    - Leader of Section 2, focusing on the integration of semantic and AI-driven intelligence into the network architecture design, in line with the vision of AI-native networks and compliant with the EU AI Act.
    - Writing of Section 2.3, which explains the transition from fragmented data to semantic reasoning in the 5G core, introducing the SSRF concept to interpret heterogeneous data and enable natural-language goal-based interactions and automated decisions.
    - Description in Section 2 of the coexistence between legacy users and goal-oriented users, with attention to energy efficiency and the use of technologies, such as RIS, to optimize the management of radio resources.
    - Writing of Section 4.3, focused on intelligent mobility management in next-generation networks, highlighting AI-native solutions that improve mobility optimization, efficiency, and quality of service in 6G networks.
    - Technical and research contributions that provide a foundation for the 6GARROW project's goal of optimizing RAN and CN through AI/ML solutions.
    - Focus on evolving architectures, intelligent resource usage, automation, and resilience, forming the basis for later development in the integration and validation phases.
    - Consideration of regulatory and compliance aspects, ensuring that AI-native solutions meet European requirements for transparency, reliability, and security.

- YONSEI
  - Extended contributions to Deliverable D4.1 (SotA on Enhanced RAN and Core):
    - Writing of Section 3.3, which details the design and implementation of 'Y-Twin'. This section introduces a research-centric digital twin framework that faithfully replicates the behaviour of a cellular RAN within the specific urban setting of the Sinchon district, utilizing NVIDIA's Sionna RT ray-tracing engine to overcome data scarcity in AI-native RAN.
    - Description of the PHY and MAC layer emulation capabilities within Y-Twin, emphasizing the transition from generic throughput modelling to 5QI-driven service differentiation. This includes the ability to produce per-user decoded bits and evaluate service-level objectives, creating a controlled *"evaluation sandbox"* for benchmarking new algorithms.
    - Introduction of *"BKNet"* (Bussgang-aided KalmanNet) as an AI-driven user tracking solution for energy-efficient low-resolution base stations utilizing 1-bit ADCs. This research employs a model-based deep learning architecture to ensure robust performance under severe quantization noise and serves as a representative study to be validated within the Y-Twin environment, demonstrating the platform's utility for bridging theoretical AI models with deployable architectures.
    - Development and integration of *"A-MMSE"* (Attention-aided MMSE) as a model-based deep learning baseline for OFDM channel estimation. Building on a two-stage frequency-

temporal Attention encoder and a rank-adaptive extension that learn an MMSE-equivalent linear filter and execute channel estimation via a single linear operation, A-MMSE/RA-A-MMSE provide a high-accuracy yet computationally efficient PHY benchmark within Y-Twin for comparing BKNet and other AI-native schemes under realistic 3GPP scenarios.

- ETRI
  - Contribution to D4.1 (SotA on Enhanced RAN and Core) on:
    - State-of-the-Art analysis of AI/ML-based physical-layer techniques for the 6G air interface in Section 3.2, focusing on 3GPP-standardized technologies such as CSI feedback and beam management, investigation of AI/ML approaches to address signalling overhead, latency, and channel adaptability limitations, and analysis of AI/ML-based techniques for CSI prediction, compression, and post-processing to improve wireless transmission performance.
    - State-of-the-Art analysis of cross-domain AI/ML coordination between RAN and CN in Section 4.4, targeting AI-native 6G architectures, including assessment of domain-specific AI functions (RIC and NWDAF) in current 5G systems, identification of limitations in inter-domain coordination for end-to-end optimization, and review of integrated AI/ML frameworks.
  - Development of algorithms:
    - AI/ML-based beam management and CSI feedback evaluation, based on system-level simulation results, including reduced beam management overhead with limited Reference Signal Received Power (RSRP) performance degradation, reduced Reference Signal (RS) overhead for beam measurement, improved CSI feedback accuracy with higher squared generalized cosine similarity compared to enhanced Type-2 codebook.
    - Implementation of initial UE mobility prediction algorithm, including development of initial domain-specific prediction models, based on PatchTST, to validate prediction feasibility, use of multi-channel time-series data as input and future UE location (e.g., coordinates, serving cell) as output, and design of an ensemble approach integrating RAN- and CN-domain models to enable cross-domain prediction.

1.2.5 Work Package 5

The primary goal of WP5 is to ensure that the proposed AI and ML concepts are both practical and effective in the context of the 6G network. By using laboratory demonstrations and testbeds, the work package can thoroughly assess the concepts in a controlled environment, considering their compatibility with the overall system architecture and their ability to enhance the performance of the algorithms from WP3 and WP4. This evaluation process allows the WP5 team to identify any potential issues, optimize the performance of the AI and ML innovations, and ensure that they can be successfully integrated into the 6G network. In WP5, a collaborative demonstration between EU and ROK is also planned, showcasing the key concepts developed within the 6GARROW project. This demonstration will highlight the successful implementation of the novel AI and ML concepts, along with the integrated system architecture, in a real-world scenario. By organizing this joint EU-ROK demonstration, WP5 aims to emphasize the international collaboration and knowledge-sharing aspect of the 6GARROW project.

Work carried out by each beneficiary involved

- CEA
  - Not stated yet.
- FhG
  - Not stated yet.
- AALTO

- Initial tests for a joint demonstration with Yonsei University, aiming at establishing a mobile network scenario in which the CN is hosted at Yonsei while the UE is connected to the gNB at Aalto, with the UPF instantiated locally at Aalto.
- Initial discussions on the preparation of a demonstration to test automation and failure recovery features involving the core network of Aalto and HPE.

- HPE
  - Initial discussions on the preparation of a demonstration to test automation and failure recovery features involving the core network of Aalto and HPE.
- YONSEI
  - Initial tests for a joint demonstration with Aalto University, aiming at establishing a mobile network scenario in which the CN is hosted at Yonsei while the UE is connected to the gNB at Aalto, with the UPF instantiated locally at Aalto.
- ETRI
  - Design of testbed for AI/ML-enabled physical technologies, focusing on AI accelerator analysis for AI/ML-based physical-layer implementation.
    - Aim is to cover a comparative evaluation of CPU, GPU, and NPU for Transformer-based CSI feedback and CNN-based beam management models in terms of inference latency, power consumption, and accuracy.
    - Also, the identification of edge NPUs as a suitable solution due to lower latency than GPUs and lower power consumption than data-centre NPUs without significant accuracy degradation.
  - Design of RAN-CN integrated inference technologies toward UE mobility prediction, including definition of cross-domain analytics scenarios addressing conflicts between domain-specific inferences.
    - Analysis and design of prediction objectives, input/output data specifications, domain-specific data characteristics and collection procedures for RAN and CN.
    - Analysis of 3GPP TR 37.817 and TS 23.288 for required input data.
    - Design and implementation of inference dataset generation using the commercial network simulator with automated scenario configuration, data preprocessing, and training, evaluation, and inference dataset creation.

1.2.6 Work Package 6

WP6 is committed to enhancing the visibility and impact of the 6GARROW project through various channels and avenues. This includes actively engaging in social media platforms, participating in scientific events, and contributing to standards and pre-standards bodies. The project is focusing on promoting its technical and economic analysis towards vertical stakeholders in the area of AI/ML-native networks. By engaging with these stakeholders, WP6 aims to foster a deeper understanding of the project's objectives and outcomes and encourage their involvement and support. In addition to these activities, WP6 is working on creating and sharing engaging content that highlights the project's achievements, milestones, and potential benefits. This will help attract a wider audience, generate interest, and inspire collaboration in the field of 6G technology.

Work carried out by each beneficiary involved

- CEA
  - Contribution to the 6GARROW *"project vision"* paper.
  - Participation to the submission and organization of the accepted workshop in GLOBECOM 2025 (with SNS phase 2 projects 6G-DISAC and 6G-GOALS).
  - Relation with SNS phase 3 projects 6G-LEADER and 6GMIRAI for the organization of a EuCNC 2026 workshop.

- Relation with the SNS projects 6G-LEADER and 6G ORIGAMI for a booth at MWC 2026.

- FhG
  - Contribution to the 6GARROW *"project vision"* paper.
  - Participation in the evaluation procedure of submitted papers of the 6GARROW workshop in GLOBECOM 2025.
  - Contribution to the content of Deliverable D6.1 and D6.2.

- AALTO
  - Contribution to the 6GARROW *"project vision"* paper.
  - Participation in the evaluation procedure of submitted papers of the 6GARROW workshop in GLOBECOM 2025.
  - Contribution to the content of Deliverable D6.1 and D6.2.
  - Participation in the regular monthly meetings of WP6.

- OULU
  - WP Leader.
  - Coordination of the regular monthly meetings for WP6.
  - Coordination of dissemination activities.
  - Project website and social media channel operation.
  - Creation of press releases, promotional materials.
  - SNS JU Communication Task Force liaison for 6GARROW.
  - Development of internal reporting tools.
  - Project presentation and deliverable templates.
  - Editor of Deliverable D6.1 (Dissemination, standardisation and communication plans, and project website) and Deliverable D6.2 (Dissemination, Standardisation and Exploitation activity report Y1).
  - Participation to the submission and organization of the accepted workshop in GLOBECOM 2025 (with SNS phase 2 projects 6G-DISAC and 6G-GOALS).
  - Relation with SNS phase 3 projects 6G-LEADER and 6GMIRAI for the organization of a EuCNC 2026 workshop.

- INTEL
  - Participation to the submission and organization of the accepted workshop in GLOBECOM 2025, including managing the call for scientific paper submissions, executing reviews of received paper submissions and selection of accepted papers, communication with workshop participants and paper authors.
  - Coordination of Springer Nature book *"Digital Sustainability - Legislations, Standards, Solutions and related case studies"* by editors Christophe Gaie, Markus Mueck.

- HPE
  - Participation in the following activities reported in Deliverables D6.1 and D6.2:
    - Active participation in the writing of D6.1, especially in Section 3, which covers dissemination, communication, and standardization plans, ensuring a structured and coherent approach to maximize the project's visibility and impact.
    - Coordination and definition of communication strategies for different targets (operators, industry, academia, policy makers), including management of the website, social media, publications, and events.
    - Contribution to D6.2 through the development of the annual report on dissemination, standardization, and exploitation activities, highlighting the results achieved in the first year in terms of engagement, social activities, and participation in scientific and industrial events.

    - Support to the international cooperation strategy, particularly between Europe and Korea, contributing to joint standardization activities and intercontinental PoCs.

- GEM
  - Contribution to the 6GARROW ‘project vision’ paper.
  - Organizations of workshops from Intel targeting master students.
  - Interviews with work package or task leader to gather data.
  - Ethnography of international collaboration ongoing.
- ORANGE
  - Keynote at MeditCom 2025 Workshop on Orange's vision of semantic communications.
  - Preparation and submission of an accepted conference paper at Globecom 2025 Workshop.
  - Contribution to the 6GARROW *“project vision”* paper.
- YONSEI
  - Preparation and submission of an accepted conference paper at Globecom 2025 Workshop.
  - Contribution to the 6GARROW “project vision” paper.
  - Contribution to the content of Deliverable D6.1 and D6.2.
  - Participation in the regular monthly meetings of WP6.
- KU
  - Participation in the evaluation procedure of submitted papers of the 6GARROW workshop in GLOBECOM 2025.
- ETRI
  - Contribution to the 6GARROW “project vision” paper.
  - Contribution to the content of Deliverable D6.1 and D6.2.
  - Participation in the evaluation procedure of submitted papers of the 6GARROW workshop in GLOBECOM 2025.
- LGE
  - Contribution to the 6GARROW “project vision” paper.
  - Contribution to the content of Deliverable D6.1 and D6.2.

2 Update of the plan for exploitation and dissemination of result

No change.

3 Update of the data management plan

No change.

4 Follow-up of recommendations and comments from previous review(s)

Not applicable.

5 Use of resources

Table 4 reports the PMs planned for the whole project (Total), planned for the report period (Planned) and spent in the reporting period (Spent) by each EU partner in each WP.

Table 4: Comparison between actual and planned PMs (EU partners)

Partner N°	Short Name	P/Ms	WP1	WP2	WP3	WP4	WP5	WP6	Total
1	CEA	Total	16	13	19	8	6	3	65
		Planned 1st year	4.5	3	7	1	0	0.5	16
		Spent 1st year	4.5	3	7	1	0	0.5	16
2	FhG	Total	0	5	16	0	13	10	44
		Planned 1st year							
		Spent 1st year	To be reported in next amendment / next reporting period*						
3	AALTO	Total	6	5	10	12	10	3	46
		Planned 1st year	1	1	2	3	2	1	10
		Spent 1st year	0.5	0.5	1	1.5	0	0	3.5
4	OULU	Total	1	0	28	0	0	10	39
		Planned 1st year	0	0	2.5	0	0	3.2	5.7
		Spent 1st year	0	0	2.46	0	0	3.2	5.66
5	INTEL	Total	2	8	0	7	0	6	23
		Planned 1st year	0.5	1.8		1.3		0.8	4.4
		Spent 1st year	0.42	1.58		0.65		0.59	3.24
6	HPE	Total	0	4	0	14	8	5	31
		Planned 1st year	0	2.5	0	4.7	0	1.3	8.5
		Spent 1st year	0	2.24	0	4.15	0	1.11	7.5
7	GEM	Total	3	0	0	0	0	6	9
		Planned 1st year	0.9					0	0.9
		Spent 1st year	0.83					0	0.83
8	ORANGE	Total	0	6	33	0	0	3	42
		Planned 1st year	0	1.8	4.7	0	0	0.5	7
		Spent 1st year	0	1.75	4.68	0	0	0.37	6.8
Total		**Total**	**28**	**41**	**106**	**41**	**37**	**46**	**299**
		Planned 1st year	**6.9**	**10.1**	**16.2**	**10**	**2**	**7.3**	**52.5**
		Spent 1st year	**6.25**	**9.07**	**15.14**	**7.3**	**0**	**5.77**	**43.53**

* At the time of submission, the PM consumption of FhG for Year 1 was not available. The coordinator has requested the data and will transmit it as soon as received.

6 Deviations from Annex 1 and Annex 2

6.1 Tasks

- **In WP3 *"AI/ML for Enhanced Device Performance,"* Task 3.2 "Enhancing Terminal Energy Efficiency,"** the partner ORANGE steered its contribution in a different way than originally planned.
  - The PMs are the same and an amendment has been submitted and accepted.
  - Below is the rationale for it:

  - The previous contribution focused on context-aware AI applications communication, examining how contextual information can enhance message exchange through compression at the transmitter and data augmentation at the receiver. This approach assumed communicating AI systems would share the same embedding / data representation model - a reasonable assumption when the proposal was initially drafted.
  - This topic remains scientifically relevant. However, the AI landscape has evolved dramatically over the past year, particularly regarding agents and multi-agent systems. We anticipated having several years before needing to address heterogeneous AI agent collaboration, but developments like Anthropic's MCP de facto standardization have accelerated this timeline significantly.
  - AI agents will be central components in future 6G networks, making them both fundamental to AI-native architecture and a primary use case for semantic communication when they collaborate. Moreover, from ORANGE perspective as a network operator, the impact of agent-to-agent communications on network capacity has emerged as a major research priority. These interactions, unconstrained by human response times, can occur at machine speeds - potentially generating orders of magnitude more frequent exchanges and fundamentally transforming network traffic patterns from traditionally downstream-heavy to more balanced or even uplink-heavy as edge agents continuously share data and collaborate. On the last aspect, this uplink data flow may have a significant impact on UE's energy consumption.
  - While the original research direction maintains its scientific merit, focus of ORANGE moved towards the heterogeneous agent communication challenge, due to its potential network impact and strategic importance for 6G development. Given the project's timeframe and our available resources, we cannot adequately address both research directions.
  - Consequently, ORANGE believes that this updated topic would be beneficial for the project, recommending the original text with the following: *"Develop algorithms and protocols enabling seamless and energy efficient communication between heterogeneous AI agents. As each AI agent operates with its own proprietary embedding model, establishing a universal representation framework becomes essential for effective inter-agent communication. While natural language (primarily English) currently serves as the default interchange format, this introduces inefficiencies through potential information loss. Our contribution will focus on zero-shot stitching, without requiring end-to-end training between communicating entities, thereby creating a more natural communication paradigm for AI systems."*

- Originally, Seoul National University (SNU) was planned to contribute to the project in all tasks of *WP3 "AI/ML for Enhanced Device Performance."* Due to Korean budget considerations, they finally did not engage in the project. All their tasks were re-allocated to Yonsei University, therefore keeping the scientific impact of the project unaffected.

- A request for a postponement of deliverable D2.3, *"6GARROW Refined Scenarios, Use Cases and related KPIs/KVIs"* has been made and accepted. This deliverable aims to refine the scenarios described in D2.1 based on the first findings from WP3 and WP4 as well as the outcomes of Task 1.3. The current due date is Month 14 (Feb. 2026).
  - We delivered the initial set of 6GARROW use cases and KPIs in D2.1 (M8, Aug. 2025), and work in WP3 and WP4 is progressing well. Deliverables D3.1 and D4.1 were submitted on time in M10 (Oct. 2025), providing research objectives and an overview of the State-of-the-Art. However, the algorithms and methods developed in these work packages are not yet mature enough to assess their impact on the use cases and related KPIs/KVIs in a meaningful way.
  - We believed that a three-month extension would allow us to deliver a far more relevant and technically sound document. The revised due date (M17, May 2026) still falls within the first reporting period. We also keep Milestone 2 at its original date (M14), as it marks the end of phase-1 and the initial architecture and research objectives will be available as planned.

6.2 Use of resources

- **INTEL.** Due to internal restructuring that caused previously involved personnel to leave the company, Intel spent slightly less effort than planned in the second half of the year. However, no negative impact of such reduction can be seen on any of the ongoing WPs. The situation is expected to improve and come back to normal along 2026.