SNS JU JOURNAL /2026

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SNS CO-OP – SNS Collaborative Operations and Output Optimisation

SNS JU JOURNAL/2026

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Table of Contents

Foreword from the European Commission 6
Foreword from the Smart Networks and Services Joint Undertaking (SNS JU) 8
Introduction from the 6G Smart Networks and Services Industry Association (6G-IA) 10
Advancing Europe's 6G through the Smart Networks and Services Joint Undertaking 13

Projects' presentations by stream

Call 1 Projects 20

Stream A - Smart communication components, systems, and networks for 5G Evolution systems 21

5G-STARDUST 22
6GREEN 24
BeGREEN 26
NANCY 28
SEASON 30
VERGE 32

Stream B - Research for radical technology advancement 35

6G-NTN 36
6G-SHINE 38
6GTANDEM 40
ADROIT6G 42
CENTRIC 44
CONFIDENTIAL6G 46
ETHER 48
FLEX-SCALE 50
HEXA-X-II 52
HORSE 54
PRIVATEER 56
RIGOUROUS 58
SUPERIOT 60
TERA6G 62
TERRAMETA 64
TIMES 66

Stream C - SNS JU Enablers and Proofs-of-Concept (PoCs) 69

6G-BRICKS 70
6G-SANDBOX 72
6G-XR 74

Stream D - Large Scale Trials and Pilots with Verticals 77

FIDAL 78
IMAGINE-B5G 80
TRIALSNET 82

Coordination and Support Actions (CSAs) 85

SNS ICE 86
SNS OPS 88

Call 2 Projects 90

Stream B - Wireless Communication Technologies and signal processing 91

6G-CLOUD 94
6G-INTENSE 96
6G-TWIN 98
EXIGENCE 100
ORIGAMI 102
6G-DISAC 106
6G-GOALS 108
6G-MUSICAL 110
6G-SENSES 112
INSTINCT 114
iSEE-6G 116
6G-EWOC 120
ECO-eNET 122
OPTI-6G 124
PROTEUS-6G 126
ELASTIC 130
iTRUST6G 132
NATWORK 134
ROBUST-6G 136
SAFE-6G 138
6G-REFERENCE 142
FirstTo6G 144
TERAGREEN 146
6G-XCEL 150

Stream C - Complementary SNS JU experimental pan-EU federated infrastructure: SUNRISE-6G 153

SUNRISE-6G 154

Stream D - Large Scale Trials and Pilots with verticals-focused topic 157

6G-PATH 158
ENVELOPE 160

SNS JU Societal Challenges 163

6G4SOCIETY 164

Call 3 Projects 166

Stream B - Wireless Communication Technologies 167

- FLECON-6G 170
- UNITY-6G 172
- 6G-LEADER 176
- MULTIX 178
- AMBIENT-6G 182
- NEXASPHERE 184
- MARE 188
- XTRUST-6G 190
- 6G-MIRAI 194
- 6GARROW 196
- SUSTAIN-6G 200
- 6G-DALI 202

Stream C - SNS JU Microelectronics Lighthouse, X-TREME 6G 205

- X-TREME 6G 206

Stream D - SNS JU Large Scale Trials and Pilots with Verticals (IA) 209

- 6G-VERSUS 210
- AMAZING-6G 212

CSA: SNS CO-OP 215

- SNS CO-OP 216

HORIZON-ER-JU-2024-01 219

- FP2-MORANE 2 220

Calls 4/5 Projects 222

Stream B 224

- 6G-OPTICON 226
- AGENTIC6G 228
- MAGIC-6G 230
- PROSPERO 232
- SIXG 234
- IoT-ZERO 238
- OPTIMUS-6G 240
- PIONEERS-6G 242
- MULTIPLY-6G 246
- SHARC 248
- QUEST-6G 250
- 6G-NTN^2 Nexus 254
- 6G-CATS 256
- PAISES-6G 260
- SHIELD-6G 262

Stream C - 6G Telco Cloud and Service Provision enablers 265

- SOVEREIGN-6G 266

Stream D - SNS Trials and Pilots with Verticals 269

- 6G-CARE 270
- 6G-HOLONET 272
- GENIUS 274
- PRIME-6G 276

Appendices

- Steering and Technology Boards, SNS JU Working Groups 281
- Acronyms and abbreviations 282

Foreword from the European Commission

Thibaut Kleiner

Vice-chair of SNS JU Governing Board

Director for Future Networks, Directorate-General for Communications Networks, Content and Technology (DG CONNECT) European Commission



Europe's strength in mobile communications has been built on decades of innovation, collaboration, and strategic vision. From the early days of GSM, our continent has consistently shaped connectivity technology as a driver of economic growth and social progress. As we stand on the brink of the 6G era, Europe must once again play a major role shaping the next generation of networks around core principles: excellence, sustainability, security, and inclusiveness.

The Smart Networks and Services Joint Undertaking (SNS JU), a cornerstone of the EU's digital strategy on advanced connectivity, is the vehicle to deliver on this ambition. With €1.8 billion in combined public and private investment over seven years, the SNS JU has become a driving force behind Europe's 6G research and innovation. Since its inception, the initiative has launched 100 cutting-edge projects, fostering breakthroughs in areas like AI-native networking, non-terrestrial communications, ultra-reliable low-latency services, and energy-efficient infrastructure. These are not merely technical advancements, they are enablers of broader digital transformation, impacting concrete application areas like industrial automation, mobility, or healthcare.

This 2026 SNS JU Journal arrives at a pivotal moment. The global race toward 6G is intensifying, with standardisation efforts accelerating in 3GPP, large-scale trials underway, and the first commercial deployments expected at the end of the decade. Europe's assets in this race are strong, but competition is intense. To maintain our competitive edge, we must strengthen the bridge between research and market adoption. To achieve this, we must ensure that the most promising 6G technologies, many of which are showcased in these pages, are scaled, standardised, and commercialised to deliver tangible benefits to citizens and industries.

The projects featured in this Journal show how far we have come. From AI-driven network optimisation and quantum-secure communications to integrated terrestrial and satellite systems, European researchers and industry partners are pushing the boundaries of what is technically possible. Yet, the journey ahead presents major challenges:

- Standardisation: Europe's views must count in shaping global 6G standards, promoting in particular interoperability and fair competition.
- Security and resilience: As networks serve as the backbone of critical infrastructure, security by design and zero-trust architectures are non-negotiable.
- Sustainability: 6G must be the greenest generation so far, with energy-efficient designs and circular economy principles embedded from the outset.
- Global collaboration: While European players compete on the global market, they must also cooperate, aligning with partners from other countries on key choices regarding spectrum policy, research frameworks, and ethical AI governance.

The SNS JU's mid-term assessment review, conducted by the Commission, confirmed that we are on the right path, but the next phase will be decisive. We must accelerate trials, strengthen industry uptake, and foster cross-sector partnerships to ensure that 6G becomes a reality, not just in labs, but in factories, hospitals, and homes across Europe. The SNS JU Progress Assessment in this Journal provides a comprehensive overview of achievements, challenges, and strategic priorities, offering indications for the years ahead.

I extend my deepest gratitude to the researchers, engineers, and industry leaders whose dedication has positioned Europe at the forefront of 6G innovation. Their work today will define the digital landscape of tomorrow, one that is human-centric, secure, and sustainable.

As we move closer to 2030, let us remain bold in our ambition, collaborative in our approach, and firm in our commitment to a sovereign, competitive, and inclusive digital Europe.

Foreword from the Smart Networks and Services Joint Undertaking (SNS JU)

By 2030, 6G technology will transcend conventional connectivity to reshape Europe's digital landscape. This next-generation infrastructure will form an intelligent, programmable backbone for Europe's economy and society, seamlessly integrating artificial intelligence, cloud computing, space-based networks, and advanced sensing.

Since its establishment in 2021, the Smart Networks and Services Joint Undertaking's objective is to turn research into innovation and ensure that Europe's next generation of networks are secure, sustainable, and globally competitive by aligning public investment with industrial priorities. Supported by €900 million in EU public funds under Horizon Europe, this funding is designed to create a continuum, moving from exploratory research to technology building blocks, and from small-scale experiments to large-scale testbeds and vertical applications, for real-world pilots.

Erzsébet Fitori

Executive Director of the Smart Networks and Services Joint Undertaking



To date, we launched 5 calls for proposals to support 100 projects[1], delivering more than 2000 unique standards contributions to global standards. Our ecosystem comprises 5,415 researchers and mobilises Europe's entire innovation chain, from industrial leaders to SMEs and startups. Bridging the innovation gap, we have deployed Europe's first large-scale 6G experimental platforms and supported several trials and pilots across sectors like manufacturing, media, automotive, PPDR, and smart city.

2025 marked our first Top-10 Key Achievements selection, honouring outstanding 6G innovations in technology development, experimentation, vertical solutions, standards, and sustainability. This milestone inspires our journey towards research excellence and innovation.

Beyond funding, we are deepening our ties with key partners. The signature of the Memorandum of Intent with the European Space Agency (ESA) exemplifies this, delivering pilot facilities for seamless integration of terrestrial and non-terrestrial 6G networks to ensure ubiquitous coverage across Europe. Further collaboration with European programmes, including on the Strategic Deployment Agenda for Connected and Automated Mobility (SDA for CAM), and with Member States through our State Representative Group (SRG), are also vital for driving joint progress towards resilient, secure, energy-efficient and globally competitive 6G networks and services.

1. *100 projects with the FP-MORANE-2 project*

Yet, while these achievements signal progress, much lies ahead. Today's choices on standards, spectrum, security, and partnerships will determine whether Europe leads the 6G revolution or falls behind, especially as 3GPP standardisation has begun and other regions race ahead. This unprecedented opportunity is being shaped right now through the bold decisions and alliances we forge, strengthening Europe's technological leadership while keeping sustainability, inclusion, and societal value at the heart of our digital future.

I invite you to explore these pages not only as a summary of SNS JU's progress, but as a call to collective action. The future of connectivity lies in our hands. Together, let us ensure it is shaped by Europe, for Europe.

Introduction from the 6G Smart Networks and Services Industry Association (6G-IA)

Colin Willcock,

Chairman of the Board of the 6G-IA, Vice-Chairman of the SNS JU, Vice-Chairman of the ETSI Board.



The Smart Networks & Services Joint Undertaking (SNS JU) reached a peak in terms of active R&I projects in 2025 with 79 projects simultaneously running. The momentum of SNS JU will only increase with the imminent onboarding of another 20 projects from Calls 4 and 5 in 2026. This new wave of projects, will bring the total number of funded projects to over 100[1], and also signifies a shift for the SNS JU from early phase exploration, experimentation and innovation towards higher-TRL research and trails, bringing the development of true 6G technologies one step closer.

The first wave of projects (Call 1 and 2) are leaving behind impressive groundwork for 6G technology, with significant contributions across the board, as documented by the SNS JU Trackers & tools: more than 450 (vertical) Use Cases addressed and more than 260 Tests & Trials to evaluate them, more than 1100 standards contributions and broad knowledge dissemination via more than 1400 scientific publications and presence at more than 1300 events. Additionally, 188 Key Achievements have been identified from these projects within 2025, highlighting the impact of the SNS JU across different R&I aspects such as advanced technological development, B5G/6G experimentation, vertical and sustainable solutions development and more.

The continuity of the SNS JU programme and the multiple collaborative structures put in place, guarantees that the ongoing and new projects are building on top of this significant legacy, taking advantage of the results, insights and lessons learned by the predecessor projects. This is driving technology development foreword, keeping Europe at the forefront of the global 6G R&I landscape.

The complete project portfolio granted so far, amounting to approximately €630 million total funding, engages an impressive number of European experts from various fields including industry, academia, RTOs, SMEs, etc. This is proof of the significance of this endeavour for the European stakeholders and indicative of the impact it will potentially deliver. This trend continued in the Call 4 and 5 projects, starting in 2026, with a 28% of SME participation reflecting the importance of the SNS JU not just for the European R&I ecosystem, but for the overall economic and business development of the European Digital Technologies sector.

1. *100 projects with the FP-MORANE-2 project.*

The structured design of the SNS JU in phases, and the constant monitoring and adaptation of the work programme, has allowed for an impressive range of technologies, enablers and use cases to be already addressed in the initial phases of the SNS JU. The broad and diverse project portfolio has enabled EU researchers to spearhead technology development in critical technological areas including the envisioned 6G Architecture, AI native solutions, core and telco-cloud, Non-Terrestrial Networks (NTN), Optical communications, Security and Service provision, and novel devices and components, while at the same time driving forward sustainable 6G technologies. Moreover, the International Cooperation projects, bringing together experts from the EU, Japan, Korea and U.S.A., ensures that SNS JU research remains relevant, synchronised with global developments and part of the key ecosystem working towards the delivery of a single global 6G standard.

As we are well underway towards the 3rd and last phase of the SNS JU, it is important to look back at the accomplishments and achievements of the projects, which are summarised in this journal. From the technological requirements analysis, use case definitions, architectural designs, to the early insights for smart networks and services, the SNS JU has already achieved a lot. The monitoring and analysis of global 6G trends and innovative collaboration tools, delivered by the Coordination and Support Action projects, are proof that the SNS JU is definitely on the right track for impactful results.

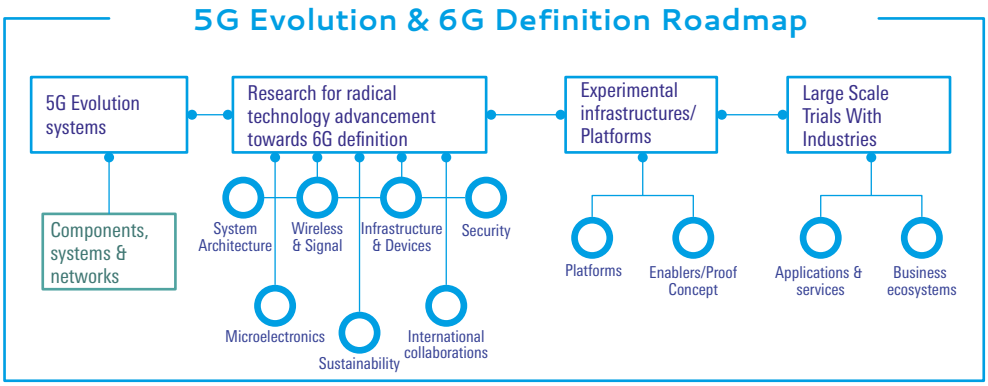
Advancing Europe's 6G through the Smart Networks and Services Joint Undertaking

The Smart Networks and Services Joint Undertaking (SNS JU) is the European public-private partnership responsible for steering research and innovation in smart networks and services. Established in 2021, it brings together resources from the European Union and industry to fund collaborative projects, coordinate large-scale experimentation, and prepare Europe for the standardisation and deployment of 6G.

The SNS JU overarching objective is to transform research into innovation and ensure that Europe's next generation of networks are secure, sustainable, and globally competitive. The SNS JU creates a continuum from exploratory research to technology building blocks, and from small-scale experiments to large-scale testbeds and real-world pilots for vertical applications.

The governance model of the SNS JU brings together the European Commission, public authorities to jointly define strategic agendas, investment priorities, and expected impacts. This approach ensures that innovation is aligned with both policy objectives and industrial needs. It also helps Europe act at scale, reduce fragmentation, and build critical mass in key domains such as spectrum, microelectronics, cloud and edge infrastructures, artificial intelligence, and integrated sensing and communication.

Through successive work programmes, the SNS JU supports a broad portfolio of activities ranging from fundamental research to trials and validation in real environments.



A PORTFOLIO OF 100 SNS PROJECTS

100 projects have been contracted to date (35 in Call 1, 28 in Call 2, 16 in Call 3, and 20 in Calls 4 & 5, and the FP-MORANE-2), generating strong momentum and a dynamic research ecosystem, as illustrated in the figure below, with total funding amounting to €630 millions of EU public funds. A 6th Call opened at the end of January 2026 and closed at the end of April 2026 with €22 millions of total budget for 5 projects. A 7th Call on front-end modules opened on 26 May 2026 with €14 million in EU funding and closed on 3 September 2026.

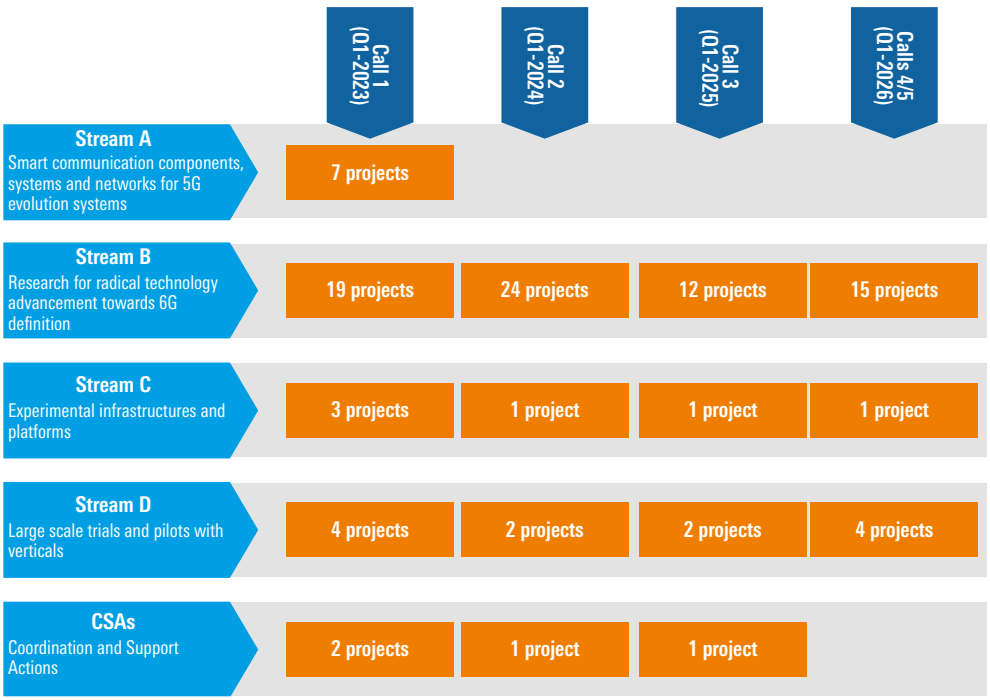
The portfolio is also organised into different technology streams and transversal topics:

- **Stream A: smart communication components, systems and networks for 5G evolution systems**
- **Stream B: research for radical technology advancement towards 6G definition**
- **Stream C: experimental infrastructures and platforms**
- **Stream D: large-scale trials and pilots with verticals**

SNS JU projects are steadily making outstanding progress and a concrete impact, as regularly highlighted in the SNS JU / projects websites and news[1]. They delivered more than 2,000 unique standards contributions to global standards. The SNS JU ecosystem comprises 5,415 researchers and mobilises Europe's entire innovation chain, from industrial leaders to SMEs and startups.

1. https://smart-networks.europa.eu/

Distribution of SNS JU Projects by call and stream – Project portfolio (100)





https://smart-networks.europa.eu/sns-ju-projects-key-achievements-2025/

THE SNS JU KEY ACHIEVEMENTS

Launched for the first time in 2025, the SNS JU Key Achievements initiative provides an opportunity for all Call 1 and Call 2 projects (63 projects in total) to showcase their most significant results. The process aims to identify and promote the most promising technological, experimental, and market-oriented innovations driving progress towards 6G.

The 2025 SNS JU Key Achievements edition features 188 results spanning advanced radio technologies, AI-driven and cloud-native networks, secure systems, sustainability, experimentation, vertical applications, and standardisation. These achievements demonstrate strong industrial relevance across sectors including manufacturing, transport, healthcare, ports, live events, and smart cities.

The selected Top-10 Achievements highlight the most tangible and mature outcomes as of 2025 across technology, experimentation, verticals, standards, and sustainability.

- The three main **technology development** include: i) time modulated arrays that support smarter, energy-efficient hardware combining communication and sensing, ideal for autonomous systems and AI-driven networks ii) high-capacity point-to-multipoint (P2MP) transmission introducing a cost-effective optical network design to enhance Europe's 6G transport sustainability and scalability, and iii) reconfigurable multi-mode IoT system offering battery-free IoT devices powered by light and radio energy, enabling sustainable connectivity across sectors like smart cities and healthcare.
- For **experimentation**, the three key achievements include: i) the experimentation infrastructure as a service (ElaaS) Toolkit, an open platform enabling remote testing of 6G innovations, accelerating collaboration in Europe, ii) multiple holographic communications in the 6G-XR testbed, marking the first holographic calls over a 6G network, unlocking new XR services and iii) a 6G federated portal, connecting 14 European testbeds,

simplifying experimentation and fostering innovation.

- **The two key vertical solutions** feature: i) real-world trials of 5G capabilities in port operations, enhancing safety and efficiency through real-time monitoring and AI, and ii) advanced XR capabilities during live events showcase high-speed, low-latency 5G, enriching fan experiences and safety.
- The most impactful **contribution to standards** refers to in-X architecture, integrating small, autonomous subnetworks in vehicles, factories, and classrooms, contributing to 3GPP standards for improved industrial applications.
- The **sustainable solution** selected highlights sustainable 6G use case families and zero-energy devices, defining sustainability principles and opening commercial opportunities across sectors leveraging greener 6G technologies.

SNS JU WHITE PAPERS

Finally, the **SNS JU White Papers**[1] compile key analyses and results from European projects, illustrating the maturation of 5G-Advanced and 6G technologies across strategic domains such as healthcare, AI-driven networks, media, sustainability, and artificial intelligence.

They provide a structured overview of scientific and technological progress while highlighting key challenges related to implementation, standardisation, and societal impact. By combining thematic studies with insights from trials and pilots, they help align research, industry, and policy stakeholders around the development of future network generations.

Trials and Pilots / Vertical engagement Tracker

Trials and Pilots

SNS JU trials and pilots validate advanced 5G, 5G-Advanced and future 6G technologies in real-world environments, demonstrating their practical value across industry and society. These large-scale experiments help assess performance, interoperability, scalability, resilience and sustainability while accelerating innovation and standardisation.

The activities cover key domains such as AI-native networks, NTN/TN convergence, edge computing, network slicing, XR, IoT, cybersecurity and digital twins, engaging vertical sectors including manufacturing, transport, healthcare, agriculture, education, media, ports, smart cities and public safety.

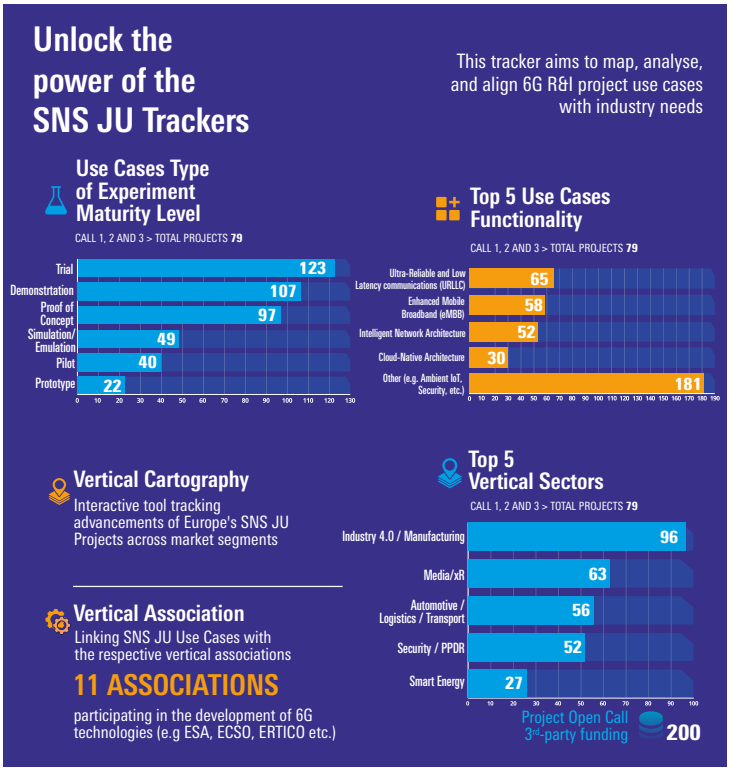
A snapshot of recent developments is presented in the two Trials and Pilots brochures highlighting 20 initiatives (8 trials and pilot champions in 2025, 12 in 2026) that demonstrate strong social relevance, economic potential, or the validation of groundbreaking services and applications. Industry 4.0,



Trials and Pilots brochure N°2

1. *https://smart-networks.europa.eu/sns-publications/*

Vertical Engagement Tracker



smart cities, and smart health are the top three preferred vertical sectors for Trials and Pilots. The results also show broad coverage across multiple vertical sectors, with significant overlap that enables cross-validation opportunities.

Vertical Engagement Tracker

To enable real-world validation, the SNS JU promotes trials and pilots through the Vertical Engagement Tracker (VET), which maps 415 initiatives, including 147 trials (TRL 5–7) across 11 sectors. It provides visibility on technology maturity and strengthens links between research and industry. Eight Stream D projects demonstrate impact in areas such as security/PPDR, industry 4.0/manufacturing, media/extended reality, robotics, smart mobility, immersive services, and smart health.

In addition, SNS JU Open Calls play a key role in expanding the ecosystem by bringing in new actors, ideas, and expertise. Open calls/Financial Support to Third Parties simplify access to funding and experimental facilities, enabling a broader range of stakeholders to contribute to Europe's 6G research and innovation ecosystem. They support targeted activities such as exploratory research, trials, and the use of SNS infrastructures, facilitating the participation of SMEs, start-ups, academia, and new actors in advancing future connectivity solutions. With more than 266 projects involving 366 stakeholders, including a strong participation from SMEs (representing 60% of stakeholders), these initiatives address key areas such as AI-driven orchestration, automation, security, sensing, and sustainability, strengthening Europe's 6G innovation ecosystem.

Projects' presentations by stream

Call 1 Projects

The 35 SNS JU Call 1 projects started in January 2023 with four streams and two Coordination and Support Actions (CSAs).

This section provides details on Call 1 SNS JU projects stream by stream and ends with the CSAs.

Stream A

SMART COMMUNICATION COMPONENTS, SYSTEMS, AND NETWORKS FOR 5G EVOLUTION SYSTEMS

The seven projects under this stream follow an evolutionary path towards the development of 6G networks. The selected projects demonstrate complementarity and have been selected in such a way as to create a complete system view. Research topics covered include energy efficient radio networks, adaptive Open RAN, integrated 5G-Non-Terrestrial Networks (NTN), AI-based edge platforms, and intelligent resource management ensuring security, privacy & trustworthiness.

5G-STARDUST

5G-STARDUST's ambition is to deliver a fully integrated 5G-NTN autonomous system with novel self-adapting end-to-end connectivity models for enabling ubiquitous radio access.

OVERVIEW

5G-STARDUST aims to demonstrate the feasibility of a fully 5G-capable non terrestrial system (NTN) leveraging gNB in space with regenerative payloads. The project builds on the main building blocks defined in the *3GPP Rel. 17-19*, with the ambition of shaping of 6G systems to incorporate NTN from day one. Key features have been validated through a dedicated proof-of-concept (PoC) using a lab testbed hosted by Thales Alenia Space France's premises in Toulouse.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The technology concept pursued a seamless integration of terrestrial (TN) and NTN networks at both the radio access and core network levels, enabled by a self-organised, software-defined network architecture built on a low earth orbit (LEO) satellite constellation. This approach provides native 5G-NR connectivity to users through advanced resource allocation and beamforming strategies.

Coexistence and cooperation between TN and NTN segments is achieved multi-link and multi-path strategies, supported by network slicing and orchestration frameworks that leverage AI-based functionalities to optimise performance in line with O-RAN architecture interfaces.

Furthermore, NTN evolution includes onboard applications, extended edge computing capabilities into space. By implementing necessary functionalities directly on the space segment, the project enables a ground-to-space edge services across terrestrial and satellite networks.

INNOVATIONS

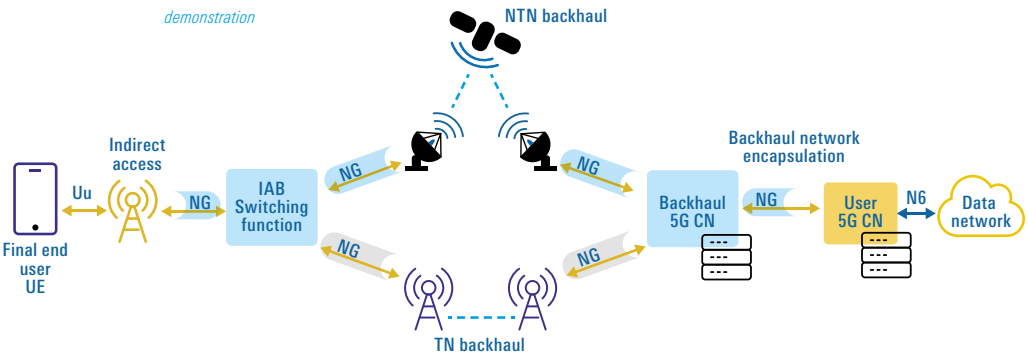
Based on the key pathways identified in the overall technology concept, the project developed **seven main innovation pillars:**

1. **Unified radio interface for TN and NTN operations**: Development of advanced user-centric beamforming and extended orthogonal time frequency space (OFTS)-waveform definitions
2. **Optimised radio-resource management**: Implementation of AI-based traffic prediction techniques to enhance spectrum efficiency
3. **Realistic space segment architecture**: Design of a space segment capable of hosting gNB and user plane function (UPF) blocks for 5G in space, including support for onboard applications
4. **Optimised multi-link strategies**: Development of multipath transmission control protocol (MP-TCP)/ multipath Quick UDP internet connections (MPQUIC) with an AI-driven path and data scheduling engine
5. **Handover and routing optimisation**: Validation of 5G-enabled LEO constellations, using a large-scale simulation environment (OpenLanes)
6. **AI-based slicing and orchestration**: Enabling efficient operations in integrated TN/NTN networks
7. **Support for in-space edge computin**: Leveraging onboard UPF and interfaces defined within 3GPP SA5 and ETSI ISG MEC standards

USE CASES/ TRIALS/ APPLICATIONS

The project addressed several use cases, largely aligned with the 3GPP roadmap, including connectivity for remote areas, mobile transportation, and public protection and disaster relief (PPDR) scenarios. The selection of final use cases for demonstration underwent multiple iterations, also considering the practical constraints of the proof-of-concept (PoC). Ultimately, the focus was placed on **in-flight connectivity** and residential broadband, which better capture the more interesting dynamics from a system integration standpoint and the most relevant options from a market exploitation standpoint. The scenarios have been demonstrated with real-world application in the so-developed realistic PoC, whose main aim has been to provide an in-depth validation of the functional architecture.

The 5G-STARDUST Proof-of-Concept demonstration



RESULTS / IMPACT

The importance of the work conducted according to the aforementioned seven innovation pillars has been recognised at dissemination level in terms of key publications and invitations to present results at the most relevant venues for NTN 5G/6G systems. Likewise, the main outputs of the conducted study activities have been fed into the main standardisation directions of 3GPP - namely with respect to RAN and SA areas. As such, the project eventually proved the potential of the NTN role in the overall European vision of forthcoming 6G system deployment and hence the prominent role of European industry in both TN and NTN domains.

Satellite And Terrestrial Access For Distributed, Ubiquitous And Smart Telecommunications

5G stardust

Coordinated by
Dr. Tomaso de Cola,
German Aerospace Center

January 2023–December 2025

Website: www.5g-stardust.eu

X: @5G_Stardust

LinkedIn: www.linkedin.com/company/5g-stardust/

Verticals: Automotive, transportation, residential broadband, PPDR, and governmental

Partners: German Aerospace Center, Thales Alenia Space France, Hispasat, Software Radio Systems, CTTC, Advanced Wireless Solutions and Services, CNIT, Fraunhofer FOKUS, Orange, MARTEL.

6GREEN

The 6Green project aims to create an innovative, service-based, and comprehensive ecosystem that promotes energy efficiency across the entire 5/6G value chain.

OVERVIEW

The goal of the 6Green project is to promote sustainability across the entire 5/6G value chain by enabling vertical applications and network slices to be dynamically, scalably, and autonomically deployed across the edge-cloud continuum, precisely when and where they are really needed by end-users, in order to minimise the resulting impact on the infrastructure layer. 6Green envisions the 5/6G ecosystem as a sustainable, interconnected, flexible and greener end-to-end intercompute system, capable of effectively interfacing stakeholders by means of latest generation intent-based and cloud-native paradigms, while facilitating their interactions under green economy business models and agreements. This vision is realised through an extended 5/6G service-based architecture (SBA) that leverages and extends state-of-the-art cloud-native technologies to enhance ecosystem – wide-flexibility, scalability and sustainability, and to enable all 5/6G stakeholders – from infrastructure and network platform providers to vertical industries – to reduce their carbon footprint by participating in a win-win green-economy business model and complying with a Decarbonisation Level Agreement (DLA).

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

6Green proposes an extended 5/6G SBA that leverages enabling technologies such as artificial intelligence, cloud-native approaches, and the edge-cloud continuum. Existing, 3GPP network functions (NFs) are enhanced to support new capabilities for information collection, decision-making, and the actuation of sustainability-driven configurations. In addition, new NFs are introduced to **i) collect detailed information on network and computing resources** across the edge-cloud continuum, **ii) predict and optimise the utilisation of computing resources and traffic load** together with their associated environmental impact, and **iii) address the business aspects of network management and slice reconfiguration** by enabling dynamic green business models between telecom operators and vertical stakeholders. Owing to its central role in the 5/6G ecosystem, the SBA is particularly well-suited to aggregate metrics, support informed decision-making, and facilitate the propagation of sustainability-related backpressure to other stakeholders.

INNOVATIONS

6Green has identified three multi-domain, multi-stakeholder technological innovations enabled by cutting-edge enabling technologies, such as artificial intelligence, that aim to align the diverse players of the 5/6G ecosystem around common sustainability objectives. These innovations are as follow:

1. **Edge Agility** provides smart, fast, and automated horizontal scalability to vertical applications and their associated slices across the 5/6G edge-cloud continuum triggered by user- or infrastructure-driven events such as user mobility or seamless workload migration). Application and slice instances can be rapidly scaled down to zero in unused segments of the continuum and promptly resumed when required;

2. **Green Elasticity** delivers of energy-aware, hardware-assisted acceleration for network functions and vertical applications, enabling intelligent vertical scalability across the entire 5/6G ecosystem. It leverages heterogeneous technologies including hardware accelerators, to offer multiple performance-energy trade-offs, which can be dynamically selected by exploiting standby and low power modes combined with optimal configurations and deployments;

3. **Energy-Aware Backpressure** introduces a set of cross-domain observability and analytics mechanisms, driven by hardware-level energy consumption metrics, to assess the energy use and carbon footprint attributable to a given vertical application or network slice. These metrics support the introduction of green business models designed to incentivise all stakeholders to adopt environmentally responsible behaviors through appropriate economic mechanisms.

USE CASES/ TRIALS/ APPLICATIONS

Green Technologies for 5/6G Service-Based Architectures

6Green

Coordinated by
Roberto Bruschi, CNIT

January 2023–December 2025

Website: https://www.6green.eu/

X: https://x.com/6GreenProject/

LinkedIn: www.linkedin.com/company/6green-project/

Verticals: Any verticals with sustainability needs

Partners: CNIT, Atos Spain, Ericsson Italy, Telenor, Telefonica ID, Telecom Italia, Orange Romania, Ubitech, Internet Institute, ININ, Oculavis, ICCS, Eurecom, CNR, Smile, HPE, Stam.

- **UC1: Critical Operation Maintenance during Energy-Constraint Disaster Scenarios**

  A critical infrastructure equipped with distributed computing capabilities, and relying on a non-public 5/6G network as the primary communication solution is impacted by an event that disrupts or interrupts connectivity to the central cloud. In response to the emerging risk situation, critical operations are preserved by dynamically deprioritising or suspending non-essential functions, ensuring service continuity under energy and connectivity constraints.

- **UC2: Energy-efficient Augmented Reality Remote Assistance System**

  Factory maintenance operations are supported by a remote assistant platform that leverages cloud-based servers for signaling and media management. When workers encounter machinery or equipment issues requiring expert intervention, remote specialists provide augmented reality-based visual guidance. This approach enables and successful task completion without on-site travel, thereby reducing associated CO_2 emissions.

- **UC3: Zero-Carbon Clientless Virtual Enterprise Desktop as-a-Service**

  The use case aims to deliver fully-featured virtual desktops accessible directly through standard HTML5 web browsers, eliminating the need for native clients and reducing the processing footprint on end-user devices. The service is deployed as containerised micro-service applications using Kubernetes manifests and supports workloads ranging from light office tasks to resource-intensive teleconferencing. The objective is to validate the platform's ability to provide a flexible, energy-efficient and sustainable desktop as a service (DaaS) solution, ensuring uninterrupted user access while minimising energy consumption and operational overhead.

RESULTS/ IMPACT

As the 6Green approaches its conclusion, nearly all artefacts have been completed with only a limited number of integration aspects still to be finalised. The project has already delivered several significant results and, as it enters its final year, the consortium will focus on integrating the outcomes achieved across the different layers of the 5/6G ecosystem. The main results can be summarised as follows: **(i) a comprehensive set of infrastructure-level enabling technologies**, including traffic offloading, power management and cloud-native orchestration mechanisms, network slice lifecycle management and optimisation techniques, and green observability and profiling capabilities; **(ii) the complete design of the 6Green network function sets** and their integration in a fully operational service-based architecture; **(iii) the formalisation of the DLA concept**, which embeds sustainability metrics and indicators directly into customer vertical and network-level requests, together with a set of refined green business models and advanced mechanisms for application-aware network orchestration and renegotiation.

BeGREEN

BeGREEN brings forward the design of energy-efficient solutions into radio access, edge, network functions and management.

OVERVIEW

BeGREEN addresses the growing energy demands of B5G and future 6G networks by placing energy efficiency at the core of radio access network (RAN) design and operation. It combines AI/ML-driven optimisation, O-RAN-based programmability, and hardware and architectural innovations. Through cross-domain orchestration across RAN, edge, and core, it shows how intelligent control can cut energy consumption without compromising performance, supporting sustainable and scalable mobile networks aligned with Europe's green and digital ambitions.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

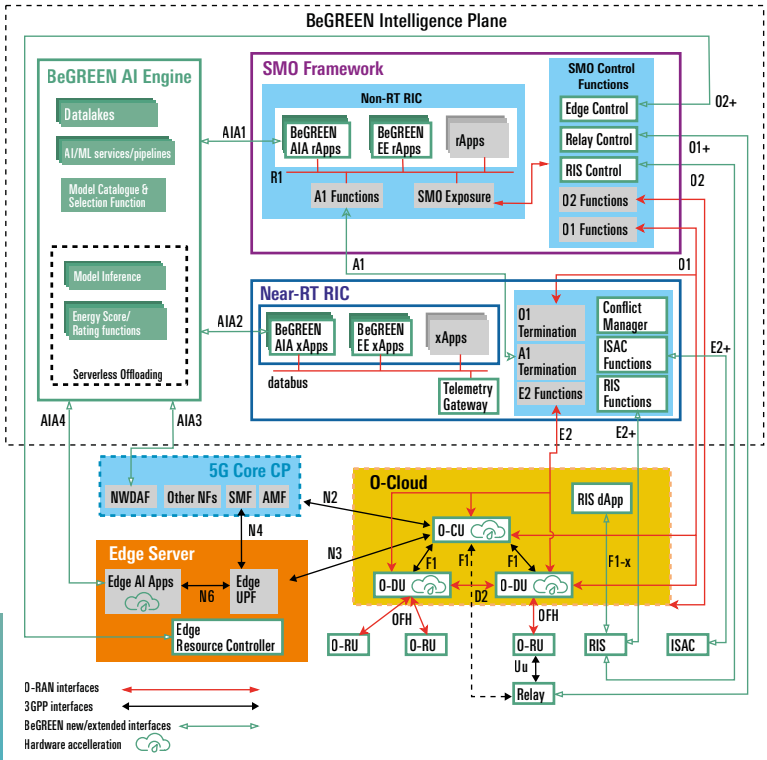
The BeGREEN Intelligence Plane is a cross-domain AI/ML-driven framework integrated with Open RAN (O-RAN) to enable energy-aware monitoring, control, and orchestration across RAN, edge, and core. It decouples AI model lifecycle from control logic and supports reusable non-real-time/near real-time applications (rApps/xApps). The architecture incorporates technologies such as reconfigurable intelligent surfaces (RIS), relays, and integrated sensing and communication (ISAC), along with enhancements in open radio unit (O-RU), open distributed unit (O-DU), and open centralised unit (O-CU). It also includes energy-efficient compute strategies, such as hardware acceleration and advanced risk machines (ARM)-based deployments, and introduces energy KPIs (e.g. energy score and energy rating) for closed-loop optimisation.

INNOVATIONS

BeGREEN introduces a cross-domain approach to energy-efficient RAN design through its intelligence plane, a unified AI/ML framework enabling coordinated control across RAN, edge, and core. It advances O-RAN programmability by decoupling AI model execution from control applications, enabling scalable and reusable optimisation workflows. The project combines architectural innovation and practical implementations, including AI-driven carrier on/off switching, compute-aware virtual RAN (vRAN) and user plane function (UPF) optimisation, reconfigurable intelligent surface (RIS)- and relay-assisted coverage, and integrated sensing and communication (ISAC)-based sensing for resource allocation. At the hardware level, it demonstrates gains via graphics processing unit (GPU) acceleration, ARM-based deployments, and radio frequency (RF) techniques such as power amplifier (PA) blanking, digital predistortion (DPD), and envelope tracking. A key contribution is the shift from RF-centric optimisation to holistic energy management that accounts for compute and AI workloads, positioning BeGREEN as a reference for sustainable 6G system design.

USE CASES/ TRIALS/ APPLICATIONS

BeGREEN validates its concepts across representative scenarios covering RAN, edge, and core domains, reflecting realistic B5G and pre-6G deployments. In the RAN domain, scenarios include dense urban and indoor environments with coverage gaps and traffic hotspots. RIS and relay technologies are assessed to extend coverage and improve energy efficiency without



Beyond 5G Artificial Intelligence Assisted Energy Efficient Open Radio Access Network

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January 2023– June 2025

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Partners: Accelleran, Gigasys Solutions, IHP, Telefónica, BT, Ericsson Ireland, Parallel Wireless, Fundació Privada i2CAT, NEC Laboratories Europe, Universitat Politècnica de Catalunya, ARM Microprocessor, RunELL.

BeGREEN architecture

additional base station deployments. AI/ML-based control identifies optimal relay placement, activation, and RIS configurations, adapting to traffic and propagation conditions. Carrier on/off switching and traffic offloading are also explored in multi-layer (e.g. non standalone) deployments, using real operator data to optimise energy consumption while preserving quality of service. ISAC-enabled scenarios further enhance efficiency by leveraging sensing for user detection, beamforming and resource allocation. On the compute side, BeGREEN explores vRAN and edge scenarios where resources are shared across services. AI-driven mechanisms dynamically adapt CPU and accelerator usage for virtualised base stations and UPFs, reducing over-provisioning and energy consumption. Joint orchestration of vRAN and edge AI services highlights performance-energy trade-offs. Additional scenarios address platform optimisation, including x86 vs ARM deployments and GPU acceleration for Layer-1 processing, demonstrating how hardware–software co-design improves energy efficiency.

RESULTS/ IMPACT

20-35% energy savings can be achieved through a combination of AI-driven optimisation, architectural innovation, and hardware-aware design. At the RAN level, RIS-based solutions can provide up to 80% energy-efficiency improvements under favourable conditions, while relay-assisted approaches achieve 35–70% reductions in coverage-challenged scenarios. RF-level techniques deliver additional savings, with PA blanking enabling up to 64% PA power reduction.

At the compute level, GPU acceleration improves energy efficiency by more than 10× for selected Layer-1 tasks, while ARM-based deployments reduce power consumption by up to 10–33% depending on workload. AI-driven optimisation of vRAN and UPF resources achieves 20–30% energy savings.

NANCY

Focusing on energy-efficient wireless networks, adaptive Open Radio Access Networks, AI-based edge platforms, and intelligent resource management ensuring security, privacy, and trustworthiness.

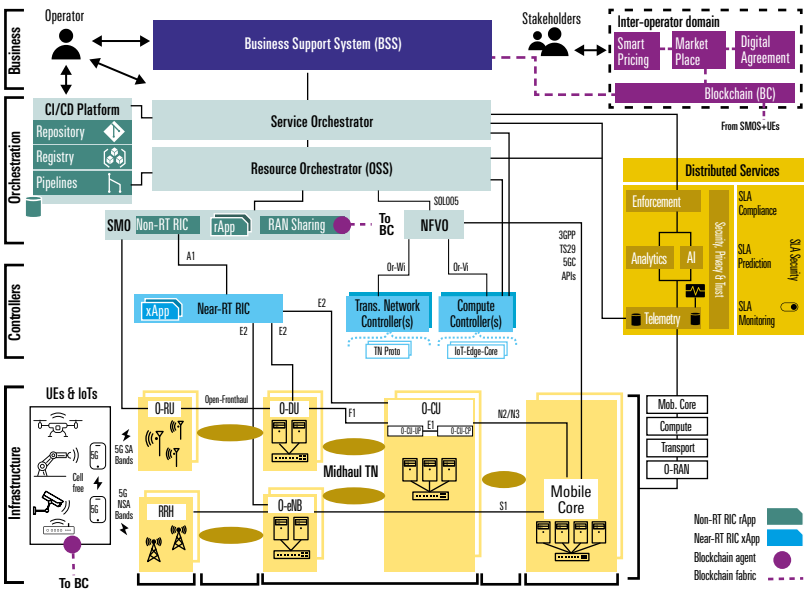
OVERVIEW

The aim of NANCY was to introduce a secure and intelligent architecture for next-generation wireless networks. By leveraging blockchain and artificial intelligence, NANCY developed flexible networking schemes, and intelligent resource management mechanisms with a focus on energy efficiency, security, privacy, and trustworthiness. The consortium consisted of 9 Research Institutes, 5 industrial organisations, and 10 SMEs from 9 European countries.

ARCHITECTURE

The figure illustrates the functional and deployment view of the NANCY architecture. In more detail, the **Infrastructure** layer is comprised of distributed and heterogeneous physical devices that span across multiple interconnected domains. The controllers layer consists of a set of infrastructure controllers that manage the underlying domain resources. Furthermore, the **Orchestration** layer provides end-to-end service and resource management within an operator's realm, as well as continuous integration and delivery of the operator's own or customer services. Finally, the **Business** layer includes the network operators' components to manage products and interact with other operators to exchange products, services, and resources through a secure inter-operator domain.

NANCY architecture



an artificial iNtelligent Aided unified Network for seCure BeYond 5G long term evolution

NANCY

Coordinated by
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January 2023–December 2025

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Verticals: Automotive, Transport and Logistics, Media and entertainment

Partners: University of Western Macedonia, UBITECH, TECNALIA, NEC, I2CAT, Italtel, Netcompany-Intrasoft, 8BELLS, Thales, Draxis, Dreven, OTE, Virtual Open Systems, Institut Jozef Stefan, Consortium for the Research in Automation and Telecommunication in Italy, Ericsson Italy, Innocube, Greek Centre for Research and Technology, Sidroco Holdings, university of Murcia, Scuola Superiore Sant'Anna, MetaMind Innovations, university of the Basque Country.

INNOVATIONS

Key technical innovations include:

- **O-RAN** integration with AI-based blockchain-RAN (B-RAN) orchestration for dynamic spectrum access, interference management, and service delivery.
- **AI-powered orchestration** for B5G service management across edge–cloud–radio access network (RAN) domains, featuring self-evolving model repositories and reinforcement learning-based resource allocation.
- **Quantum-safe security mechanisms**, including post-quantum cryptography (PQC) and quantum key distribution (QKD).
- **Blockchain-based distributed security infrastructure** for trustworthy service exchange, self-sovereign identity, and immutable transaction records.
- **Advanced resource management** via computational offloading, user-centric caching, resource elasticity, and semantic communication schemes to reduce latency and energy use.
- **Smart pricing and marketplace mechanisms** using by auction and game theory to enable decentralised multi-stakeholder participation.
- **Self-healing and self-recovery mechanisms**, including anomaly detection frameworks with explainable AI for resilient network security.

USE CASES/ PROOFS-OF-CONCEPT

The technical innovations were validated across six real-world proofs-of-concept (PoCs) testbeds and demonstrations in Greece, Italy, and Spain:

- **Greek In-Lab Testbed**: Validated the micro-operator concept, NANCY Marketplace for inter-operator resource sharing, and blockchain-based service level agreement (SLA) establishment.
- **Italian In-Lab Testbed**: Confirmed edge resilience with secure hardware partitioning, AI-driven anomaly detection, and quantum-safe service authorisation using PQC digital signatures.
- **Spanish In-Lab Testbed**: Achieved seamless connectivity via dynamic operator selection and task offloading, with privacy-preserving semantic communications for smart urban infrastructures.
- **Italian Massive IoT Demonstrator**: Showcased self-healing, self-recovery, and PQC-based secure communication on Ericsson's commercial-grade 5G infrastructure.
- **Spanish Outdoor Demonstrator**: Demonstrated reliable, low-latency unmanned aerial vehicle (UAV)-assisted multi-hop scenarios to extend network coverage
- **Greek Outdoor Demonstrator:** Validated the NANCY architecture in real 5G environments with edge orchestration for extended reality applications.

RESULTS/ IMPACT

NANCY's outcomes show how future wireless networks can provide secure digital services, enhance threat protection, optimise resources, and support demanding applications.

- **Telecom Operators**: Greater control over network slicing and AI-driven resource optimisation, reducing costs and improving cybersecurity.
- **European Industry and Manufacturers**: A B5G architecture with quantum-ready security and open standards, enhancing interoperability.
- **Society**: Mobile networks with digital identity protection and energy-efficient connectivity, supporting sustainable development.

SEASON

An innovative Multi-Band over Space Division Multiplexing (SDM) optical network infrastructure, spanning the access, aggregation, and metro/long-haul segments.

OVERVIEW

SEASON provides a foundational infrastructure for 6G by integrating multi-band (C+L+S) transmission and spatial division multiplexing (SDM). The project targets a drastic reducing in energy consumption and capital expenditures (CapEx) while scaling network capacity up to 120x through automated, "zero-touch" management.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

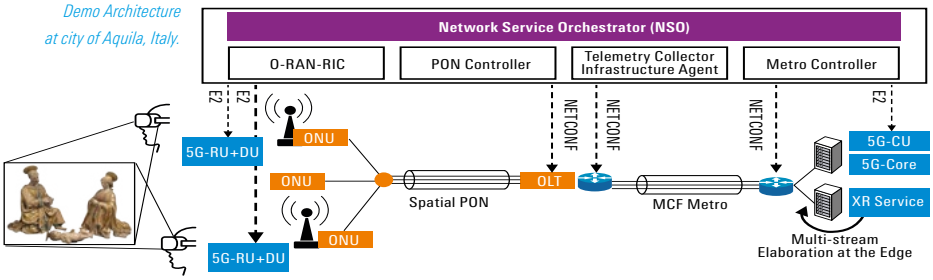
The SEASON architecture establishes a high-capacity foundation for 6G by pioneering an integrated optical-packet transport network. It overcomes traditional C-band capacity limits through a combined **Multi-Band (S+C+L)** and **spatial division multiplexing (SDM)** data plane, enabling a shift from legacy point-to-point links to a flexible, mesh-based core. By directly integrating **IP-over-DWDM (IPoDWDM)** and **point-to-multipoint (P2MP)** coherent transceivers into high-speed packet switches, SEASON removes redundant hardware layers, significantly reduces energy consumption per transmitted bit.

INNOVATIONS

SEASON innovations represent a major shift from static, single-band optical links to a dynamic, multi-dimensional infrastructure. By combining advanced digital signal processing with novel physical-layer hardware, the network becomes **an intelligent, programmable asset**, allowing operators to scale capacity on-demand while decoupling traffic growth from energy use and hardware complexity.

Key innovations include: **Multi band over space division multiplexing (MBoSDM) switching**: First modular node prototype capable of switching traffic across multiple spectral bands and spatial cores simultaneously, **Spatial passive optical network (PON)**: Energy-efficient access solution dynamically activating fibre cores based on real-time traffic demand, **Open extended reality (XR) point-to-multipoint (P2MP)**: Coherent optics reducing required transceivers by up to 50% in metro aggregation, **Predictive Telemetry**: Streaming telemetry framework achieving a 10:1 data compression ratio for network monitoring.

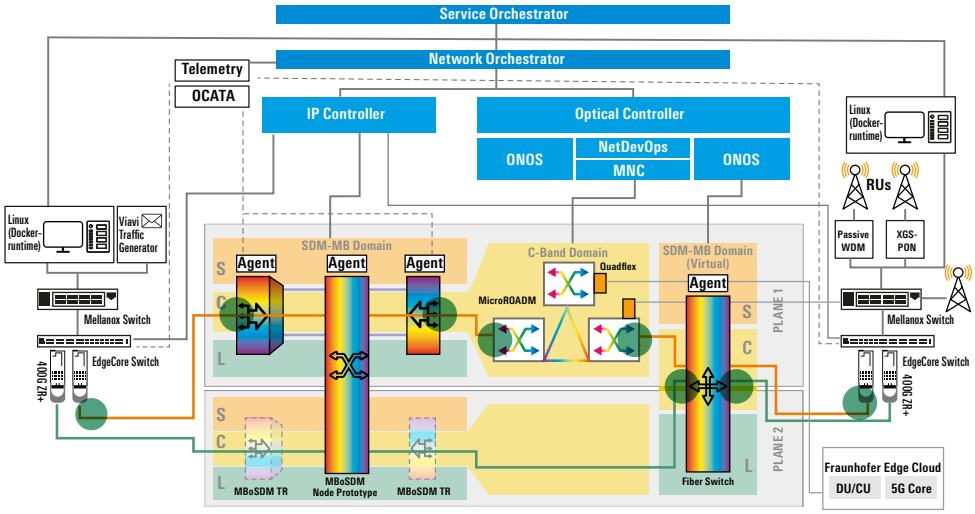
Demo Architecture at city of Aquila, Italy.



USE CASES/ TRIALS/ APPLICATIONS

Field Trial 1: **Core XR Field Trial**. The flagship experiment in L'Aquila city demonstrated SEASON's ability to handle high-demand extended reality (XR) traffic through a fully integrated orchestration chain. By combining open radio access network hubs with coherent optics, the trial achieved **sub-1ms latency**, confirming the network's capability to support immersive XR and real-time industrial automation. Continuous telemetry monitoring traffic growth as new XR users joined, validating the system's dynamic performance.

Field Trial 2: **Self-healing multi-band optical Demo**. Tested across multi-vendor testbeds, this trial showcased the **self-healing** capabilities of the SEASON control plane. When a fibre cut was simulated in the C-band, the optical control and telemetry assistant (OCATA) Digital Twin automatically re-routed critical traffic to the L-band within seconds, maintaining uninterrupted service without human intervention.



Self-healing in an IP-over-WDM network with dual protection for video streaming traffic.

RESULTS/ IMPACT

The project has demonstrated tangible benefits across capacity, sustainability, and economic performance:

- **Capacity Scaling**: Validated a roadmap to increase network throughput from 10x to 120x compared to legacy C-band systems.
- **Sustainability**: Achieved a 38% reduction in energy consumption in the access-metro segment through dynamic lane aggregation.
- **Economic Viability**: Demonstrated a 50% CapEx saving by adopting open, disaggregated hardware and DPU-based virtualisation.
- **6G ready performance**: SEASON meets all requirements for high capacity and ultra-low latency, without proportionally increasing costs or carbon footprint, providing a scalable and sustainable foundation for 6G networks.

Self-Managed Sustainable high-capacity Optical Networks

SEASON

Coordinated by
Filippo Cugini, CNIT

January 2023–December 2025

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Verticals: Augmented reality (AR) service for user-driven immersive experiences

Partners: CNIT, Ericsson, CTTC, ADVA, Telefonica ID, Universidad Carlos III de Madrid, Fraunhofer HHI, Telecom Italia, SSSA, UPC, INF-G, INF-P, WEST Aquila, Accelleran, WINGS ICT, FiberCop.

VERGE

The EU-funded research project VERGE aims to deliver an AI-empowered, flexible and modular edge platform, unifying communication and computation resources into an edge-cloud compute continuum that is seamlessly integrated within B5G.

OVERVIEW

VERGE proposes an open, modular, and distributed edge architecture, designed to integrate seamlessly with the edge-to-cloud compute continuum. The overall VERGE concept has been built around three conceptual pillars:

1. **Edge for AI** (Edge4AI), responsible for enabling the unified compute continuum environment, encompassing the heterogeneous pool of computing resources from the edge to the cloud;
2. **AI for edge** (AI4Edge), a portfolio of AI methods to optimise and automate different aspects of the computing and network performance in diverse and dynamic B5G/6G environments;
3. **Security, Privacy and Trustworthiness for AI** (SPT4AI), addressing relevant challenges on robustness, privacy, safety, and explainability of the developed AI models, targeting to enhance their overall trustworthiness.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The VERGE architecture illustrated in the figure, highlights the interactions between its three pillars: i) Edge4AI, comprising the Orchestration, Management, and Control (OMC) layer, the cognitive framework, and the programming models; ii) the AI4Edge; and iii) the SPT4AI. An edge-to-cloud compute continuum underpins the architecture, abstracting all the compute resources used to execute and orchestrate applications, services and intelligent algorithms. Below this, 5G/6G network components, including RAN, core, and transport, are shown. The VERGE Open Dataspace provides access to an open repository of datasets for AI/ML model training.

This complex ecosystem involves multiple stakeholders, including telecom operators, edge and cloud infrastructure providers, equipment manufacturers, and end users from vertical industries. Among them, software developers such as application and network function developers and AI/ML model owners, play a key role in designing applications, networks, and AI-enabled services for this heterogeneous infrastructure.

INNOVATIONS

The project has selected six innovations for the Innovation Radar:

1. **Advanced AI solutions** to manage and optimise services across edge and cloud environments;
2. **Cognitive Framework** to enable intelligent decision-making and automation;
3. **Hololight Space Extended Reality (XR) with product life management**, allowing immersive, interactive 3D design reviews directly in CAD tools like NX;
4. **Real-time streaming of 3D product models** (Jupiter Tessellation format) to XR devices over 5G enabling seamless multi-site collaboration;
5. **Verification-as-a-Service for Reinforcement learning (ReLVaaS)** to assess the reliability and trustworthiness of AI models based on reinforcement learning;

6. **Hierarchical Edge-to-cloud orchestration** to efficiently deploy and manage cloud-native services.

USE CASES/ TRIALS/ APPLICATIONS

VERGE use cases target two vertical domains:

1. **XR-enabled industrial use case**, aims to deliver immersive XR services with minimal latency and overall high quality of experience. The use case supports industrial processes, such as collaborative product design and prototyping by remote engineering teams, as well as XR-assisted remote robotic control;
2. **Autonomous tram use case**, focuses on safety services running both on-board an autonomous tram and at the edge infrastructure. It leverages multiple sensor (e.g., cameras, LiDAR) to enhance the driver's situational awareness.

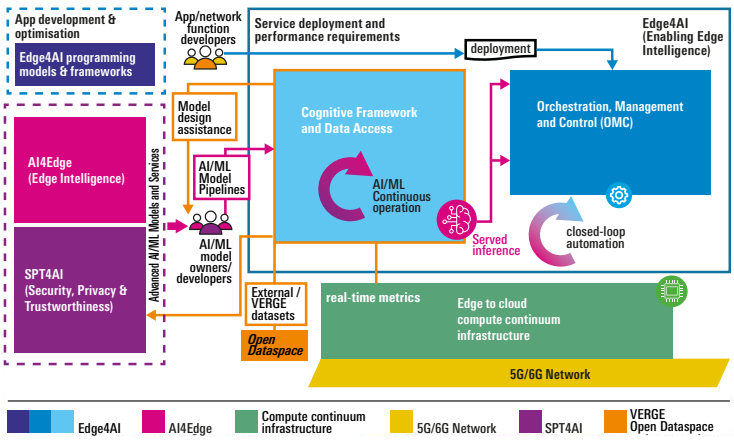
RESULTS/ IMPACT

VERGE has introduced an open, modular, distributed architecture to support edge computing evolution for Beyond 5G (B5G) and 6G, as detailed in D1.3 *"VERGE's final system architecture"*. Comprehensive results for each pillar are reported in dedicated deliverables: Edge4AI in D2.2 *"Final Report on VERGE Edge4AI design"*, AI4Edge in D3.2 *"Final Report on VERGE edge intelligence and network management"* and SPT4AI in D4.2 *"Final design and performance assessment of the VERGE solutions for security, privacy and trustworthiness for AI"*.

VERGE's open dataspace includes a variety of datasets generated by the project – a detailed description is provided in D1.4 *"Report on VERGE's open dataspace (v2)"*. The project also defined eight demonstrations, with results reported in D5.3 *"Showcasing VERGE Proof-of-Concept"*. Several demonstrations were showcased live at EuCNC'25 and at the VERGE final event on 25th June 2025 at Turkcell's premises in Istanbul. Video recordings of all demonstrations are publicly available at **https://www.verge-project.eu**.

In terms of impact, VERGE implemented planned measures to maximise dissemination, communication, exploitation, standardisation and knowledge management. Key quantitative achievements include 36 conference papers and 20 journal papers published, 40 participations in conferences, exhibitions and events, including keynote speeches, 10 open-source contributions and 21 formal contributions to standardisation bodies including ETSI MEC, ETSI RRS, ETSI OpenSlice and 3GPP.

VERGE architecture



AI-powered eVolution towards opEn and secuRe edGe architEctures

Coordinated by Oriol Sallent, Universitat Politècnica de Catalunya

January 2023–June 2025

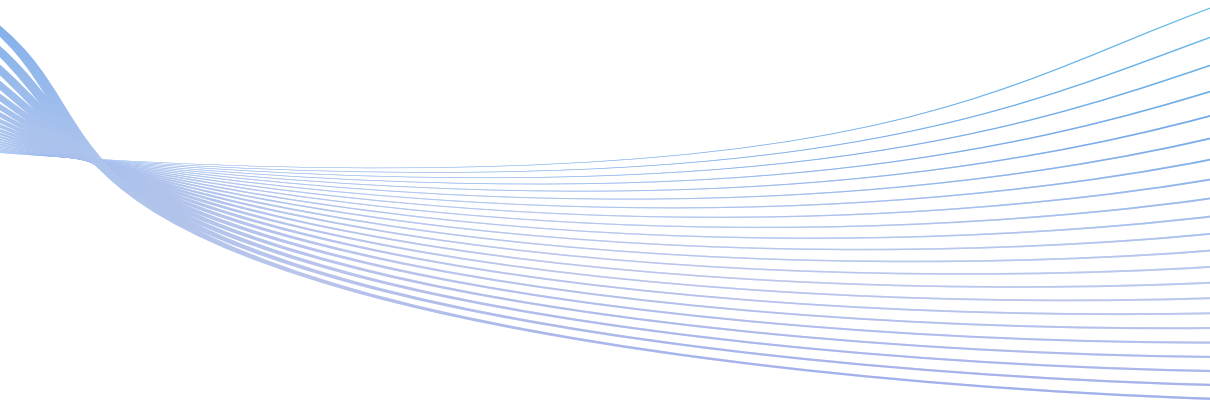
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Verticals: Industry: Factory & process automation, Smart Cities: People mobility

Partners: Universitat Politècnica de Catalunya, CTTC, King's College London, University of Oulu, Barcelona Supercomputing Center, Samsung UK, Intel, Ericsson Sweden and Türkiye, Turkcell, Nearby Computing, Hiro Microdatacenters, Ground Transportation Systems Italia, Arcelik, Holo-Light.



Stream B

RESEARCH FOR RADICAL TECHNOLOGY ADVANCEMENT

in preparation for 6G and radical advancements of IoT, devices and software

The focus of Stream B is on novel technologies that are expected to be adopted in commercial networks within a mid- and/or long-term timeframe. Research topics considered in the 19 retained projects include, inter alia, novel 6G system architectures, advanced wireless and optical communication technologies, advances in Non-Terrestrial Networks, secure development of URLLC applications.

6G-NTN

The 6G-NTN project brings together high-level representatives from the mobile communication, satellite, and research communities to identify technical, regulatory, and standardisation enablers for the NTN component of 6G.

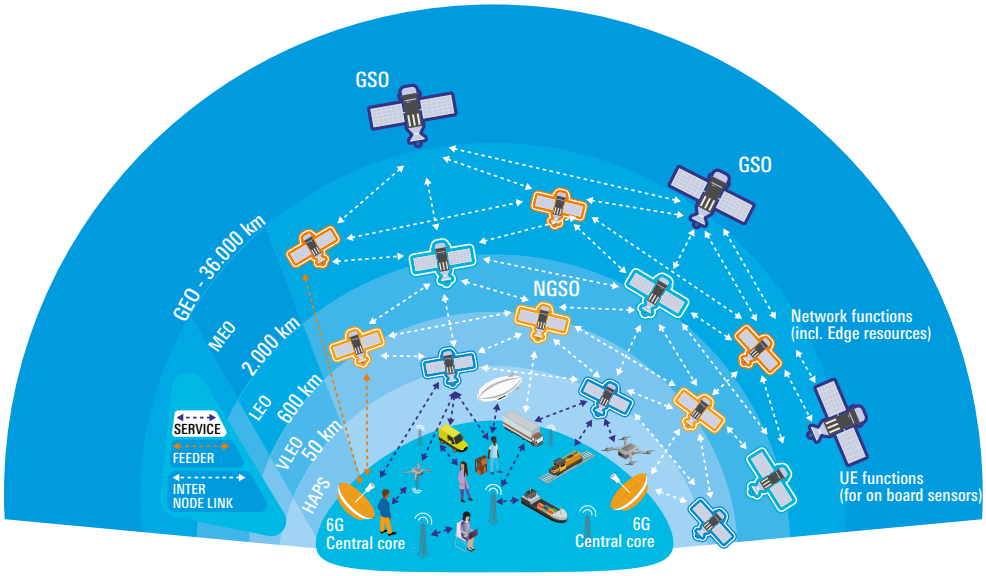
OVERVIEW

6G-NTN developed and validated the technical, regulatory, and standardisation enablers for integrating non-terrestrial networks (NTNs) with terrestrial networks (TNs) in 6G. The project focused on multidimensional infrastructure, multi-constraint radio access networks, and multi-user terminals, providing foundational knowledge and tools to support NTN–TN integration.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The project implemented a 3D, multilayered, multiband, multiterminal architecture combining satellites in geostationary (GEO), medium (MEO), and low earth orbit (LEO) with high-altitude platform stations (HAPS). These are interconnected via optical inter-satellite links (OISLs) and RF feeder links to ground stations. The system supports multiple frequency bands (C and Q/V) and a wide range of terminals, including handheld devices, drones, vehicles, and fixed ground stations.

6G NTN architecture



INNOVATIONS

6G-NTN introduced a suite of innovations enabling a transformative leap beyond 5G: improved performance over 5G NT, spectrum coexistence between TN and NTN, 3D integrated network architecture, seamless service continuity, mettre global navigation satellite system (GNSS)-independent positioning, flexible software-defined payloads, AI-enhanced RAN intelligent controller (RIC) and virtual network function (VNF) orchestration, rapid traffic adaptation, integrated edge computing, compact in-vehicle terminals, public protection and disaster relief (PPDR) support, light-indoor connectivity, and enhanced throughput.

USE CASES/ TRIALS/ APPLICATIONS

Seven representative use cases were defined, spanning enhanced mobile broadband, mission-critical services, aerial and maritime connectivity, and underserved or remote areas. User requirements were derived for handheld, drone, and mounted terminals, considering performance targets, mobility, latency, and device constraints, providing a robust foundation for architectural and technological design.

RESULTS/ IMPACT

6G-NTN established a comprehensive foundation for integrating NTNs into 6G, delivering outcomes across use-case definition, 3D multi-layered architecture, spectrum and regulatory analysis, air interface evolution, sustainability, and AI-driven network intelligence. The 3D architecture integrates HAPs, LEO (400–800 km), and GEO satellites. Two LEO designs—homogeneous and distributed service/feeder satellites—were evaluated, with the distributed system maximising throughput while enabling in-space RAN and potential core network functionalities.

Payload and terminal work focused on Q/V-band antennas, while regulatory and spectrum studies addressed coexistence challenges and proposed interference mitigation and multi-orbit exclusion strategies. Candidate air interface waveforms—including CP-OFDM, WOLA-OFDM, DFT-s-OFDM, F-OFDM, BF-OFDM, UFMC, and OTFS[1]—were evaluated for spectral efficiency, Doppler resilience, latency, and implementation complexity, informing future standardisation.

AI-enabled network intelligence was developed via an AI-driven RIC managing terrestrial and non-terrestrial segments with hierarchical learning, split learning, and coordinated training. AI-based VNF orchestration and network forecasting enable proactive resource allocation across multi-orbit satellites and terrestrial infrastructure.

Sustainability was a core objective, with metrics covering environmental footprint and societal benefits. 6G-NTN demonstrates that NTNs are essential for 6G, providing flexible, intelligent, and resilient networks that extend coverage, support new services, and lay the groundwork for global deployment, standardisation, and sustainable digital inclusion.

6G Non-Terrestrial Networks

6GNTN

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January 2023–December 2025

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Verticals: Maritime, Automotive, Transportation, Public Protection and Disaster Relief, Direct Communication over Satellites

Partners : University of Bologna, Thales Alenia Space, Martel, Greenerwave, Thales, Ericsson Sweden and France, CTTC, German Aerospace Centre (DLR), Orange France, SES Techcom, Qualcomm communications, Digital for Planet.

1. These are waveform and modulation schemes used in wireless communications, especially in 4G, 5G, and future 6G systems:
-Cyclic prefix orthogonal frequency division multiplexing (CP-OFDM)
-Windowed overlap-add OFDM (WOLA-OFDM)
-Discrete Fourier transform-spread OFDM (DFT-s-OFDM)
-Filtered OFDM (F-OFDM)
-Filter bank / band-filtered OFDM (BF-OFDM)
-Universal filtered multi-carrier (UFMC)
-Orthogonal time frequency space (OTFS)

6G-SHINE

The 6G-SHINE project will pioneer the main technology components for wireless in-X subnetworks, short range low-power radio cells to be installed in industrial, vehicular and consumer entities.

OVERVIEW

6G-SHINE focused on designing key technology components for wireless in-X subnetworks—short-range, low-power radio cells at the edge of the 6G "network of networks"—to enable pervasive connectivity with unprecedented performance. These subnetworks can be embedded in robots, vehicles, and consumer devices to support advanced industrial and immersive applications. As a low-technology readiness level (TRL) (2–4) initiative, 6G-SHINE validated its most promising concepts through laboratory demonstrations.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

In-X subnetworks are expected to support services with data rate, latency, and reliability requirements that significantly exceed the capabilities of existing technologies, including 5G. Meeting these demands requires substantial innovation across the physical layer, medium access control, and radio resource management. While these subnetworks should be capable of standalone operation, they can also benefit from connectivity to a parent 6G network. In this context, 6G-SHINE develops cost-effective and scalable methods for the seamless integration of subnetworks into the broader 6G ecosystem, enabling efficient management of traffic, radio, and computational resources.

INNOVATIONS

6G-SHINE defined the architectural building blocks for in-X subnetworks, and their integration in the 6G "network of networks" (see figure). Physical layer research leveraged the short-range nature of in-X subnetworks to support high-performance communication with low energy consumption. Key technologies included **beamforming and beamfocusing, reconfigurable intelligent surfaces (RIS), and self-conjugating metasurfaces** for retro-directing signals and reducing beam-tracking delays. Reliability under blockage was addressed through cooperative communication and network coding. At the medium access control (MAC) layer, the project investigated **predictive, context-aware scheduling** to proactively allocate radio resources and reduce signaling overhead. To cope with high subnetwork density, 6G-SHINE explored **distributed radio resource management**, sharing control between subnetworks and the parent 6G network and leveraging AI where beneficial. The project also developed **short-range channel models across sub-6 GHz**, millimeter-wave, and sub-THz bands, tailored to the target deployment scenarios.

USE CASES/ TRIALS/ APPLICATIONS

Within the project, thirteen use cases for in-X subnetworks were defined across consumer, industrial, and in-vehicle domains. Consumer use cases include:

Immersive education: Enhancing interactive learning for groups of students and teachers through rich media content and extended reality (XR) technologies,

XR interactive gaming: Enabling immersive multiplayer gaming experiences in indoor environments equipped with XR gaming infrastructures.

Industrial use cases include: **Robot control**: Coordinating multi-axis robots to fully exploit their available degrees of freedom and movement capabilities, **Visual inspection cells**: Supporting quality assurance in manufacturing processes through high-resolution video streams, **Subnet coexistence**: Enabling task distribution among swarms of small, specialised robots configured for specific functions.

In-vehicle use cases include: **Wireless zone electronic control units (ECUs)**: Sensors and actuators within a vehicle zone connect wirelessly to a local ECU responsible for their coordination, **Collaborative wireless zone ECUs**: Addressing automotive systems that require collaboration or function offloading among sensors, actuators, and processing units located in different vehicle zones.

RESULTS/ IMPACT

The 6G-SHINE project significantly advanced the concept of **in-X subnetworks** as short-range, low-power cells at the extreme edge of the 6G "network of networks." The project delivered novel models, architectures, and methods across the physical, MAC, and resource management layers, laying the foundations for the realisation and integration of in-X subnetworks in future 6G systems. From an industrial perspective, 6G-SHINE made a tangible impact on standardisation by introducing the subnetwork concept into 3GPP, contributing to ETSI ISAC, and providing inputs to IEEE and ETSI RIS and THz groups. Notably, the **in-vehicle subnetwork use case** was included in 3GPP TR 22.870, positioning the project to influence emerging 6G standards and strengthen Europe's industrial competitiveness. Societally, 6G-SHINE supported a sustainable and human-centric 6G vision through localised processing, reduced cabling, and new applications in education, industry, and mobility. The project also contributed to SNS JU and 6G-IA vision activities, with **its work on in-X subnetworks recognised among the Top 10 Key Achievements of 2025 in the SNS JU Work Programme**. Overall, 6G-SHINE established in-X subnetworks as a credible 6G building block, bridging early-stage research and standardisation while enabling future industrial and societal adoption.

6G SHort range extreme communication IN Entities

Coordinated by Gilberto Berardinelli, Aalborg University

March 2023 – August 2025

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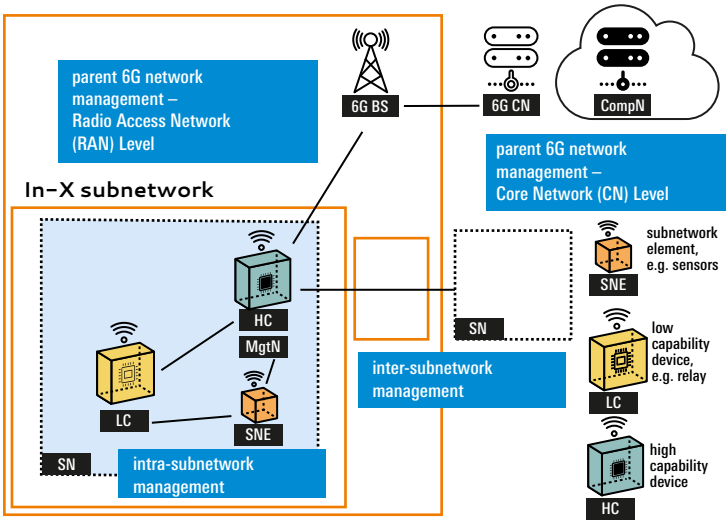
X: @6gshine

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Verticals: Industry, automotive, media and entertainment

Partners: Aalborg university, CNIT, university Miguel Hernández de Elche, Apple, Sony, Bosch, Interdigital, Fraunhofer IIS, IMEC, Keysight, Nokia Denmark, Cogninn.

6G-SHINE architecture blueprint.



6GTANDEM

By co-designing novel dual-frequency operation and an innovative highly integrated and distributed radio stripe system, 6GTandem will create superior value in energy consumption, service availability and system cost.

OVERVIEW

The 6GTandem project pioneers a dual-frequency multiple antenna system, integrating sub-THz and sub-10GHz signals to meet future 6G application needs. Sub-THz frequencies enable ultra-high data rates but face significant propagation losses, while sub-10GHz signals are less affected by obstacles like walls providing robust coverage and support devices with no extreme high data rate requirements. By combining these frequencies and densifying sub-THz deployments, 6GTandem ensures high throughput and reliable coverage. The project advances scalable 6G radio access network (RAN) evolution in Europe, co-designing communication algorithms and radio frequency (RF) hardware.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

6GTandem will provide **low-cost and lightweight radio stripes that enable flexible deployment**, addressing challenges from the design of hardware components, such as chips ensuring the seamless operation of the entire system. Our primary focus revolves around the dense deployment of sub-THz radio units to deliver high data rates, complemented by sub-10GHz radio coverage to ensure a reliable connection. To deploy sub-THz frequencies, the project employs plastic microwave fibre (PMF), a cost-effective and flexible solution for indoor applications. Sub-THz radio units, interconnected via PMF and configured as "radio stripes," are installed on walls and ceilings. This arrangement brings the radio units closer to users, addressing challenges such as blocked line-of-sight and limited transmitted power.

INNOVATIONS

6GTandem combines innovative hardware and system design to address sub-THz transmission challenges. **At the system level**, the dual-frequency architecture is optimised to enhance reliability and adaptability through a modelling framework. **On the hardware side**, novel chips, fabricated in silicon-germanium (SiGe) bipolar complementary metal-oxide-semiconductor (BiCMOS) technology (B12HFC) are co-designed with antennas and couplers to seamlessly integrate with low-loss plastic PMF tailored for the sub-THz D-band. The breakthrough "radio stripe" concept revolutionises sub-THz infrastructure, offering a compact, and easily deployable solution that supports network densification.

USE CASES/ TRIALS/ APPLICATIONS

The 6GTandem project explores future societal and industrial needs by analysing use cases that leverage its dual-frequency, high-capacity, and reliable network architecture. Key deployment scenarios include large venues, industrial sites, healthcare facilities, transportation hubs, and educational institutions. Use cases fall into four groups: **augmented, virtual and extended reality (AR/VR/XR)** for immersive healthcare, training, and events; **ultra-reliable low latency communications (URLLC)** for real-time applications, AI, and digital twins in smart manufacturing; **positioning/tracking** for logistics and crowd management; and **High Throughput** for privacy-conscious video surveillance using federated learning.

These solutions deliver energy-efficient, secure, and high-performance connectivity, enabling smarter healthcare, education, manufacturing, and public environments.

RESULTS/ IMPACT

6GTandem has significant strides toward high-capacity, reliable 6G connectivity. A key milestone is the successful demonstration of an integrated **D-band transceiver in embedded Wafer Level Ball Grid Array (eWLB)** packaging, preserving signal quality at very high data rates, achieving **100 Gbps over a 1m polarisation maintaining fibre (PMF) link**. This confirms the feasibility of compact, high-speed sub-THz modules for future networks. The test leveraged a novel circular-core PMF with low loss (2.5 dB/m), enabling efficient signal distribution in dense deployments and validating **sub-THz radio stripes** as a scalable solution for dual-frequency multi-antenna systems.

To address mobility and reliability challenges in immersive applications, we conducted a **real-world XR measurement campaign** with a wireless connection and sensors mounted on a head-mounted display. The study revealed frequent and rapid rotational movements that severely disrupt the links, highlighting the limitations of single-band systems. This motivated the dual-frequency tandem approach, combining sub-THz for ultra-high data rates with sub-10 GHz for robust control and fallback connectivity.

In parallel, we developed **a hardware-aligned modeling and simulation framework** that integrates realistic propagation, hardware constraints, and mobility patterns. This framework supports the design and optimisation of distributed radio architectures interconnected via PMFs and coordinated across sub-THz and sub-10 GHz bands. It enables evaluation of advanced algorithms for cross-band coordination, beam selection, and dynamic resource allocation, ensuring robust performance under real-world conditions. Impact: These achievements collectively advance the 6GTandem vision by validating critical building blocks for energy-efficient, high-capacity, and mobility-resilient wireless systems. They pave the way for the upcoming laboratory demonstration of sub-THz communication over integrated antenna-in-package (AiP) radio stripes and establish a strong foundation for future deployments.

A Dual-frequency Distributed MIMO Approach for Future 6G Applications

6GTandem

Coordinated by Barbara Gaggl, Technikon

January 2023–June 2026

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Verticals: Industry, automotive, media and entertainment

Partners: Technikon, Ericsson, KU Leuven, Chalmers university of Technology, Linköping university, Lund university, Huber + Suhner, Infineon Technologies Germany and Austria.

ADROIT6G

A distributed AI-enabled framework for the management of next-generation 6G architectures.

OVERVIEW

As the world transitions from 5G to the 6G era, mobile networks must be architected differently to meet stringent requirements of innovative, future-looking applications that cannot be supported by existing 5G systems. Looking toward the next decade, when 6G is expected to be widely deployed, 5G application types will evolve, redefining the classical service classes of ultra-reliable and low-latency communications (URLLC), enhanced mobile broadBand (eMBB), and massive machine-type communications (mMTC) and introducing entirely new services. ADROIT6G proposes disruptive innovations in 6G network architecture that will fundamentally transform how networks are designed, implemented, operated, and maintained.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The ADROIT6G architecture comprises three cooperative inter-domain frameworks that operating over a programmable inter-computing and inter-network infrastructure. Distributed computing nodes – located at the far edge, edge, and cloud domains - each with distinct characteristics and capabilities, are used to deploy virtual functions of the software-defined, disaggregated radio access and core network, virtual applications, and AI agents. These elements are dynamically orchestrated as part of the overall network control and management strategy.

INNOVATIONS

ADROIT6G proposes disruptive innovations in the architecture of emerging 6G mobile networks that will fundamentally transform how networks are designed, implemented, and operated, and maintained. Key innovations include:

1. **AI/ML-powered optimisations across the entire network**, enabling high performance and automated operations;
2. **Cloud-native network transformation**, allowing the cellular network to be implemented across diverse edge-cloud platforms, including non-terrestrial networks, with security built integrally into the network user plane;
3. **Software-driven, zero-touch operations**, ultimately automating every aspect of the network and the services it delivers.

The innovations and performance of ADROIT6G will be validated through three representative extreme 6G use cases (UCs) via proofs-of-concept (PoCs).

USE CASES/ TRIALS/ APPLICATIONS

ADROIT6G innovations, functionalities, and performance are validated through three extreme 6G use cases (UCs), namely the **holographic telepresence, Industrial IoT, and collaborative robots/drones** via corresponding PoCs on a number of well-established 5G testbeds, which are upgraded to support ADROIT6G innovations and architectural elements.

The purpose of the PoCs is to validate the capabilities of both the 6G technology and representative UCs of vertical industries requiring 6G-level performance. These validations take place in lab environments over suitable testbeds, ensuring the technological readiness of the solutions for commercial exploitation within 4-5 years after the project's conclusion.

During the project, each PoC will deploy a layered testing practice to guide development, including extensive representative tests, verifications, and validations. This encompasses UC-specific tests covering all service classes relevant to targeted vertical industries and measurements ,testing, validation and demonstrations of PoCs in lab settings.

Research is conducted with users rather than on users, and continuous improvements are driven by feedback from PoC roll-outs. This iterative process provides a foundation for information sharing, operational learning and ongoing improvement of the technologies.

RESULTS/ IMPACT

ADROIT6G advances the state of the art by designing a novel 6G system architecture in which **distributed AI is natively embedded across communication, computation, and control**. This AI-native approach enables autonomous network operation, real-time adaptation, and efficient resource management across cloud, edge, and device layers, while evolving the cellular infrastructure to fully integrate deep-edge devices as active participants in both communication and computation.

The project introduces an AI-driven **Management, Orchestration, and Control framework** capable of handling the scale and complexity of future 6G networks. Secure and decentralised crowdsourcing AI, extended to Device-to-Device communications, enables collaborative intelligence without centralising data, while energy-aware multimodal representation learning ensures sustainability across resource-constrained devices. Data plane acceleration and hardware–software co-design further support the performance demands of AI-native networking.

ADROIT6G also enables highly reliable connectivity for Industrial IoT through the integration of non-terrestrial networks, extending coverage and resilience. Its innovations are validated through laboratory-based proofs of concept, demonstrating tangible user and system-level benefit. To maximise impact, the project actively disseminates results, contributes to standards and open-source communities, and supports the establishment of globally recognised key value indicators to guide the evaluation and adoption of future 6G systems.

Distributed Artificial Intelligence–driven open and programmable architecture for 6G networks

ADROIT6G

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January 2023–May 2026

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CENTRIC

Using AI for wireless network design meet users' communication needs and environmental constraints.

OVERVIEW

CENTRIC aims to leverage AI techniques through a top-down, modular approach to wireless connectivity placing the users' communication needs and environmental constraints at the core of the network stack design.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

CENTRIC promotes a 6G communication approach in which the application's requirements serve as the starting point for designing the underlying protocol stack. The AI-native air interface (AI-AI) proposed by CENTRIC enables forth a level of physical layer and protocol stack customisation unprecedented in communication engineering. Leveraging the AI-AI, each user receives the type and amount of connectivity they need, whenever and wherever they need it. By delegating the design and implementation of communication systems to the AI-AI, application-layer developers are freed from managing complex stacks and can focus on their products. The resulting communication solutions will be application-specific and adaptable to the target scenarios.

INNOVATIONS

The CENTRIC project is pursing several technical innovation areas, each focusing on specific advancements, as outlined below:

E2E-learned waveforms and modulations

- Novel waveforms for pilotless communications and short packet transmission
- Methods for user-tailored modulation learning

AI-empowered MIMO communications

- Deep learning methods for multi-user multiple input multiple output (MIMO)
- Learning frameworks for channel state information (CSI) acquisition, and MIMO precoder selection
- AI methods for user-centric, sensing-aided beam operations in mmWave networks

Application- and scenario-specific learned protocols

- AI methods for emerging multiple-access protocols for specialised services
- Methods for transmission-mode selection in dense deployments:

Sustainable and human friendly RRM

- Caching methods for distributed learning
- Radio resource management (RRM) techniques for cell-free massive MIMO networks targeting electromagnetic fields (EMF) exposure reduction
- Multi-objective AI methods for RRM performance-energy trade-offs

Novel AI-computing hardware and real-time optimisation

- New digital complementary metal-oxide-semiconductor (CMOS) in-memory computing architecture
- Mixed analog-digital memristor-based in-memory computing architectures

Towards an AI-native, user-centric air interface for 6G networks

CENTRIC

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January 2023-June 2025

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- Computing platform designs based on neuromorphic paradigms
- Methods for graphics processing unit (GPU) acceleration of deep learning algorithms

Training and monitoring environments for AI models

- Theoretical guidelines for the management of AI-AI models
- Algorithms and procedures for managing AI-AI models

AI-suitable testing frameworks and Proofs-of-Concept (PoCs)

- Novel methodologies for benchmarking and testing AI in 6G
- PoCs demonstrating AI-AI concepts

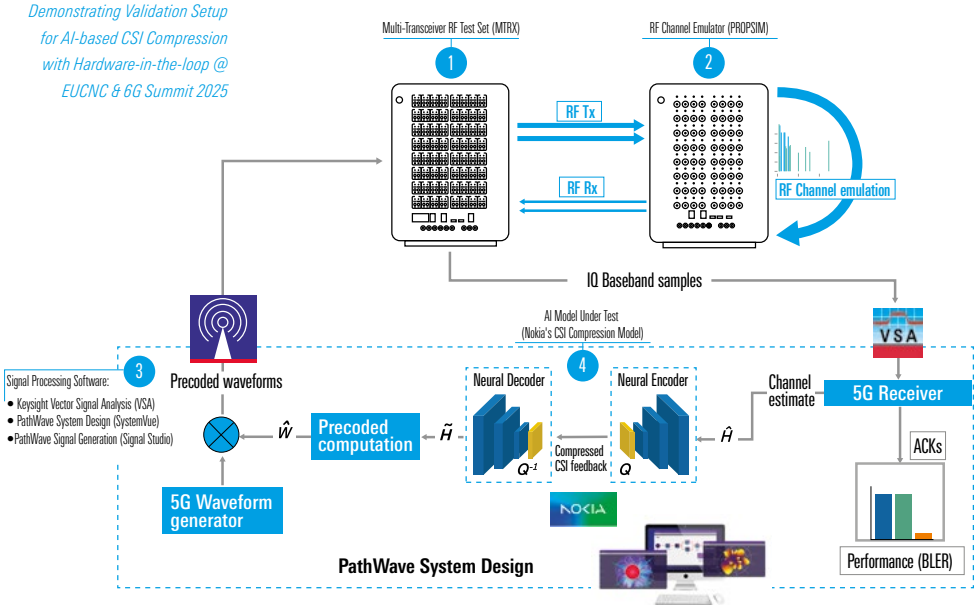
PROOFS-OF-CONCEPT

The CENTRIC project demonstrated novel AI-AI concepts through the development of laboratory PoC implementations. These PoCs validates the expected gains and provide insights on the feasibility and cost of implementation. They also help identify issues or unforeseen effects that may arise when operating the newly designed solutions.

In this context, **the CENTRIC project developed three testbeds**; Sub-THz Over-The-Air (144 GHz), an O-RAN commercial testbed (for multi-user MIMO (MU-MIMO) NRx and sensing), and closed-loop MIMO testbed (CSI feedback), which were used to establish the following PoCs:

- AI-based sub-THz channel estimation,
- Site-specific MU-MIMO neural receiver,
- AI-based sensing with 5G new radio sounding reference signal (NR SRS),
- CSI feedback compression.

Demonstrating Validation Setup for AI-based CSI Compression with Hardware-in-the-loop @ EUCNC & 6G Summit 2025



RESULTS/ IMPACT

The CENTRIC project consolidated new research paradigms, including protocol emergence and AI-native physical layer. It developed and validated several enablers for the AI-AI concept, building on the innovations described above, and contributed to the open-source community by providing multiple training environments and datasets generated from the project experiments.

CENTRIC produced 27 conference and 19 journal peer-reviewed publications. The project filled 41 patents and provided 32 contributions to various standardisation bodies.

CONFIDENTIAL6G

Ensure secure and private computation in the cloud-edge continuum of 6G by developing modern cryptographic techniques, tools, and libraries.

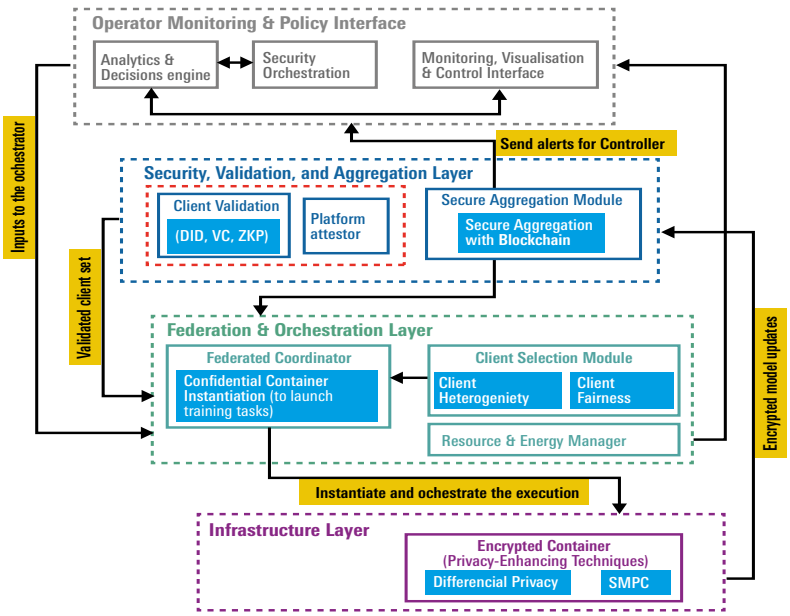
OVERVIEW

CONFIDENTIAL6G developed advanced cryptographic, confidential-computing and networking mechanisms to ensure end-to-end data protection in future 6G networks. Addressing the privacy and security challenges of the cloud–edge continuum, the project enables secure, privacy-preserving computation and communication among multiple stakeholders. By combining post-quantum cryptography, trusted execution, and privacy-preserving algorithms, CONFIDENTIAL6G supports confidential AI/ML collaboration and lays the groundwork for trustworthy, resilient and regulation-compliant 6G services.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

CONFIDENTIAL6G developed a distributed confidential computing and networking architecture for 6G that protects data across its entire lifecycle -at rest, in transit, and in use. It integrates **trusted execution environments at cloud and edge** with privacy-preserving cryptography, including secure multi-party computation, homomorphic encryption, zero-knowledge proofs, and post-quantum cryptography. A confidential orchestration layer enables **automated attested deployment across heterogeneous infrastructures** while a distributed ledger layer ensures identity management, access control, integrity, and traceability of data and model exchanges.

Federated AI/ML framework



Confidential Computing and Privacy-preserving Technologies for 6G

Coordinated by Vera Stavroulaki, WINGS ICT Solutions

January 2023–December 2025

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INNOVATIONS

CONFIDENTIAL6G utilises **fully homomorphic encryption (FHE)**, tailoring relaxed functionalities for specific AI applications and designing efficient encryption functions. It explores **secure multi-party computation (SMPC) protocols** and architecture-agnostic trusted execution environments (TEEs) with remote attestation. **Post-quantum cryptographic (PQC) protocols** will be developed for secure 6G applications, including transport layer security (TLS). Blockchain privacy is enhanced with **zero-knowledge proof (ZKP)** and FHE to protect smart contracts, while DLT is applied to sovereignty and authentication using decentralised identifiers (DIDs) and anonymous verifiable credentials. Federated learning (FL) challenges are addressed by scaling algorithms for hierarchical networks and edge computing, accommodating device heterogeneity and TEE capabilities. The project also develops field programmable gate arrays/graphics processing units (FPGA/GPU)-accelerated FHE and PQC algorithms for far-edge nodes, with cryptographic acceleration for constrained devices.

USE CASES/ SCENARIOS

CONFIDENTIAL6G validated its technologies in three pilot use cases (UC).

UC1 – Predictive Maintenance: Federated learning across airline stakeholders preserved data locally with encrypted model updates and blockchain-enabled traceability maintaining accuracy and full data-sovereignty compliance.

UC2 – Telecom Cloud Confidential Computing: TEE-enabled multi-vendor platforms (AMD SEV-SNP, Intel TDX) used TLS attestation and automated orchestration, shielding data and code with minimal overhead and millisecond-scale attestation times.

UC3 – Intelligent Connected Vehicle: Federated learning on heterogeneous vehicle and infrastructure data preserved model utility, enhanced robustness to adversarial updates, and used decentralised identity with ledger-verified over-the-air updates, ensuring near-real-time verification and compliance with data-sovereignty rules.

RESULTS

A major outcome of CONFIDENTIAL6G is a **comprehensive analysis of post-quantum cryptography and a structured toolkit** aligned with National Institute of Standards and Technology (NIST) standards, enabling quantum-safe networking primitives for future 6G protocols. The project delivered a unified software interface and orchestration framework for trusted execution environments, supporting portable confidential computing across cloud and edge infrastructures. CONFIDENTIAL6G advanced confidential AI by evaluating ML algorithms on encrypted data using full homomorphic encryption and multi-party computation, validated on industrial and mobility datasets. Federated learning frameworks were combined with confidential-workload orchestration and attestation mechanisms, while zero-knowledge proofs addressed verifiability in encrypted computation and federated analytics. The project also designed a secure decentralised data-sharing framework integrating distributed ledgers, confidential computing, FHE and MPC to ensure trusted exchange, auditability and access control - forming deployable building blocks for regulation-compliant, multi-stakeholder 6G services.

ETHER

ETHER is going to provide a framework for the terrestrial/non-terrestrial network ecosystem that involves efficient and zero-touch resource management, provides solutions for key RAN challenges, and identifies the business opportunities for potential stakeholders.

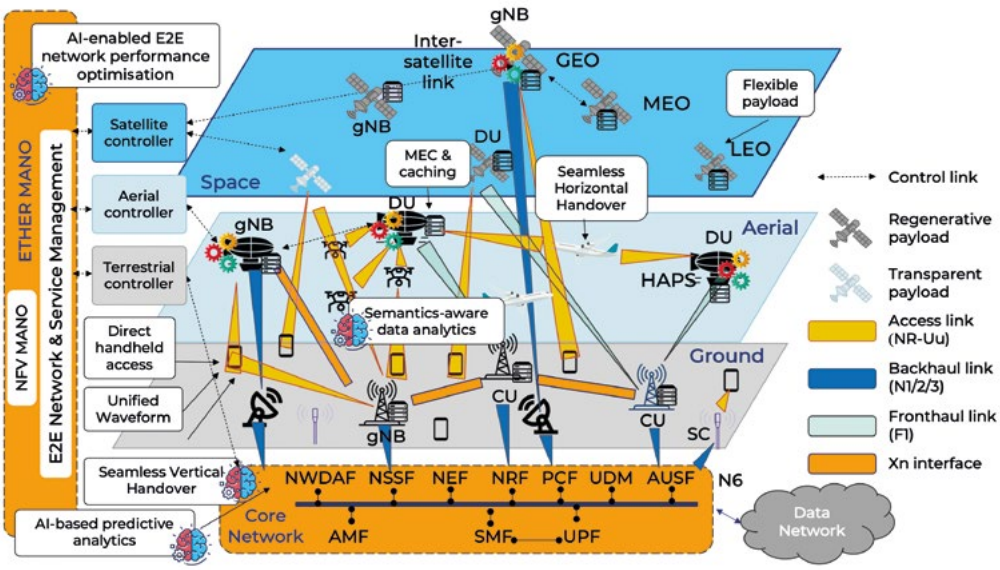
OVERVIEW

The ETHER project unifies **terrestrial and non-terrestrial networks (NTNs)** into a sustainable 3D radio access network (RAN), enabling AI-driven, zero-touch resource management. It deliver full coverage, ultra-high reliability, 3x energy efficiency, and up to 95% lower total cost of ownership than terrestrial-only networks. With a **fully programmable, multi-layered edge architecture and self-evolving network slicing**, ETHER accelerates NTN integration for future-ready connectivity.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The ETHER project presents a cost and energy-efficient **3D architecture** integrating terrestrial and non-terrestrial networks. It supports direct handheld access, unified waveform, flexible payloads, and seamless handovers. AI-driven, automated management and orchestration (MANO) combined with edge computing and analytics enabled a self-evolving, scalable, next-generation communication network.

ETHER 3D network.



INNOVATIONS

The ETHER project advances innovation across three pillars:

1. **Unified RAN**: Enabling global broadband with direct handheld devices, unified waveforms, and seamless handovers across radio access technologies (RATs);
2. **Intelligent 3D Resource Management**: using AI-driven, zero-touch optimisation and software-defined payloads to deliver adaptative, KPI-aware networks;
3. **Distributed 3D Computing and Caching**: deploying multi-layer edge-architectures to reduce latency and cloud load support future 6G requirements.

USE CASES/ TRIALS/ APPLICATIONS

ETHER focuses on three key use cases:

1. **Service Provisioning for Delay-Tolerant IoT**: Leveraging low earth orbit (LEO) satellites, ETHER provides global coverage for delay-tolerant massive machine type communications (mMTC) IoT applications. Flexible, software defined payloads support diverse devices and technologies, reducing vendor dependency and enabling seamless multi-system integration, fostering innovation and market expansion;
2. **Unified RAN for Direct Handheld Access**: ETHER bridges TN and NTN to provide seamless broadband to handheld devices. Distributed LEO satellite beamforming and high gain, energy-efficient antennas ensure robust signal delivery, enabling a unified RAN for high-speed, reliable connectivity anywhere;
3. **Air-Space Safety Critical Operations**: By integrating terrestrial networks, HAPS, and LEO satellites, ETHER ensures persistent connectivity for safety-critical air and space operations, supporting real-time coordination and continuous data exchange between control centers and operational hubs.

RESULTS/ IMPACT

ETHER has finalised its innovations and incorporated them into demonstration activities aligned with these use cases.

- **UC1** (Delay-Tolerant IoT) was demonstrated at the 5th NTN Workshop organised by Fraunhofer Fokus. It showed how IoT devices maintain NB-IoT connectivity in sparse satellite constellations. Software-defined satellite payloads and semantics-aware information handling reduced IoT device energy consumption by up to 75%, lowering constellation complexity and improving service quality[1].
- **UC2** (Unified RAN) was demonstrated at EuCNC & 6G Summit 2025 in Poznan, Poland. A standards-compliant vertical handover between a terrestrial 5G gNB-distributed unit and a LEO satellite gNB-DU was executed using OpenAirInterface and an field-programmable gate array (FPGA)-based channel emulator simulating realistic LEO conditions (high Doppler, varying link quality). This first-of-its-kind 3GPP-compliant demonstration attracted significant community interest, including high-level SNS JU representatives, and paves the way for 6G unified terrestrial-non-terrestrial coverage in remote areas[2].

These demonstrations highlight ETHER's impact in enabling unified terrestrial-non-terrestrial networks and sustainable, large-scale IoT deployments.

1,2. https://ether-project.eu/2025/11/11/5thntnworkshop/

sElf-evolving terrestrial/ non-Terrestrial Hybrid nEtwoRks

ETHER

Coordinated by Konstantinos Ntontin, university of Luxembourg

January 2023–March 2026

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Verticals: Telecommunications, Aerospace, Aviation, Defense, PPDR, Agriculture, Smart Cities, Logistics

Partners: University of Luxembourg, Aristotle university of Thessaloniki, Collins Aerospace, Avanti Communications, Sateliot, Ubiwhere, I2CAT, Nearby Computing, National Centre for Scientific Research-"Demokritos", Linköping university, Orange Poland, Martel, Net AI.

FLEX-SCALE

Future 6G networks will rely on large-scale deployments of smart MIMO antennas in both small-cells and cell-free RAN architectures.

OVERVIEW

FLEX-SCALE developed a new class of 6G x-haul optical transport networks that combine ultra-wideband fibre transmission, space-division multiplexing and energy-efficient photonic devices to scale capacity from tens of terabits per second per interface to over 10 petabits per second per node. Targeted front-, mid- and back-haul segments, the project enables cost- and energy-efficient connectivity between dense radio sites, edge clouds and core data centres.

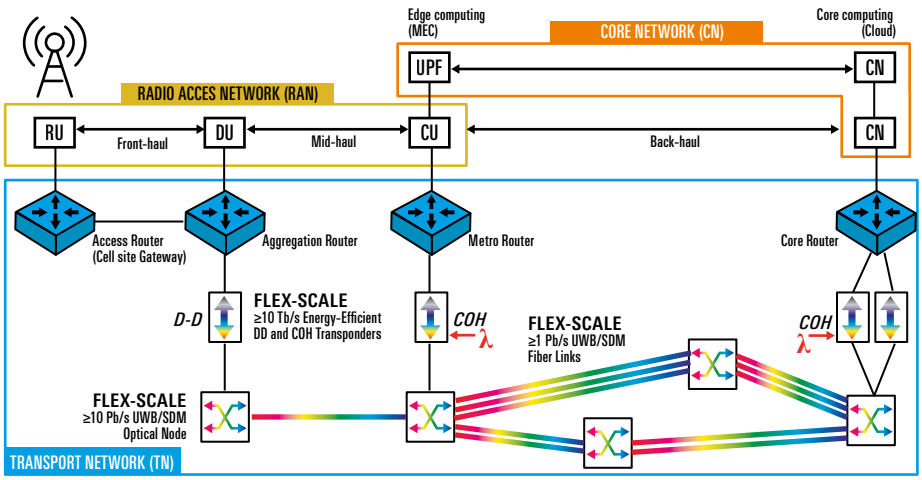
At the system level, FLEX-SCALE introduces multi-granular optical switching nodes that steer traffic at the fibre, waveband and wavelength levels, alongside plasmonic transceivers with optical digital-to-analog converter (oDAC) that replaces power-hungry electronic DACs. A sustainable SDN-based control plane coordinates packet and optical layers to minimise energy use while ensuring quality of service, aligning with the SNS JU vision on ultra-high-capacity, ultra-low-energy 6G transport networks.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The FLEX-SCALE architecture is on multi-granular optical nodes (MG-ONs) and ultra-wideband S/C/L-band fibre links with space-division multiplexing, interconnecting RAN, edge and core routers as illustrated in the figure below. Each MG-ON integrates a WaveBand-Selective Switch (WBSS) on a silicon-nitride photonic integrated circuit (PIC) together with wavelength selective switch (WSS) and optical cross-connect (OXC) fabrics, enabling fibre-, band- and wavelength-level switching with low energy consumption and microsecond-scale reconfiguration.

On the transceiver side, monolithic plasmonic PICs provide dual-polarisation coherent interfaces targeting 1 Tb/s per wavelength over S/C/L bands. They use oDAC based on plasmonic

Transport Network (TN)



Mach–Zehnder modulators to generate high-order optical constellations without requiring ultra-fast electronic DACs.

A transport software-defined networking (SDN) control plane jointly manages both internet protocol/optical transport network routers and the ultra wideband/space division multiplexing optical layer, leveraging open information models and modern southbound protocols for configuration and telemetry.

INNOVATIONS

FLEX-SCALE introduces three main innovations tightly linked to 6G x-haul needs:

1. **Plasmonic oDAC-based transceivers**: A monolithic plasmonic platform integrates ultra-compact modulators and detectors with over 200 GHz electro-optic bandwidth on a ~25 mm^2 PIC, enabling dual-polarisation 1 Tb/s coherent channels across S, C and L bands. Its novel oDAC architecture generates high-order optical **pulse/quadrature amplitude modulation (PAM/QAM) constellations** directly in the optical domain using only non-return-to-zero or PAM-4 drivers, eliminating the need for ultra-fast, high-resolution electronic DACs and targeting <10 femtojoule/bit switching energy;
2. **WaveBand-Selective Switch and multi-granular node**: A WBSS on a silicon-nitride PIC flexibly slices the 21 THz S+C+L band into programmable wavebands and routes them with microsecond-scale reconfiguration and low energy per switched bit. This forms the core of a multi-granular optical node (MG-ON) that supports fibre, band and wavelength-level switching;
3. **Energy-aware SDN control and monitoring**: A transport SDN framework jointly manages packet and UWB/SDM optical layers, exploiting MG-ON flexibility to bypass routers and groom traffic, aiming to reduce transport-network energy consumption by up to 50% under realistic 6G traffic. Non-intrusive optical performance monitoring based on coherent-receiver probes and optical channel monitors feeds quality of transmission estimation and ML-based analytics.

RESULTS/ IMPACT

At the European Conference of Optical Communications (ECOC) 2025, a parallel plasmonic oDAC was presented for the first time, using two plasmonic Mach–Zehnder modulators and tunable splitters compatible with both IM/DD and coherent receivers, achieving line rates up to 360 Gb/s oPAM-4, 420 Gb/s oPAM-8 and 128 Gb/s oPAM-16—a roughly 2.5× symbol-rate gain at similar driver complexity. By selecting appropriate power-splitting ratios, the setup generated coherent bipolar optical oPAM-4/8/16 and unipolar amplitude shift keying (ASK)-4 with clean eye diagrams, confirming the linearity needed for high-order constellations. Complementing this achievement, at **the Optical Fiber Communications Conference (OFC) 2025**, FLEX-SCALE demonstrated the multi-layer SDN control orchestration of these transceivers over multi-granular optical networks, validating end-to-end integration with intelligent packet-optical coordination and proving that energy-efficient high-capacity 6G transport can be operationally managed through adaptive software-defined control planes.

Within FLEX-SCALE, these results directly support the design of a dual-polarisation 1 Tb/s coherent transceiver targeting <10 fJ/bit and <10 dB fibre-to-fibre loss over S, C and L bands. System-level studies show that such architectures, combining analog photonic and electronic signal processing, enable higher data rates with improved energy efficiency per bit. This can yield around **30% transmitter-side power savings** and relax extinction-ratio and bit error rate-vs-distance constraints for 16QAM and 64QAM signals, making oDAC-driven plasmonic transceivers **a key enabler for energy-efficient multi-Tb/s 6G transport interfaces.**

Flexibly Scalable Energy Efficient Networking

FLEX-SCALE

Coordinated by Ioannis Tomkos, University of Patras

January 2023–December 2025

Website: 6g-flexscale.eu/

LinkedIn: www.linkedin.com/company/flex-scale/

Verticals: Communication Infrastructure Technologies and Devices

Partners: University of Patras, CNIT, CTTC, Fraunhofer HHI, the Hebrew university of Jerusalem, LioniX, Opsys Sensing, PICadvanced, Ericsson Italy, Telefoncia ID, Universidad Carlos III de Madrid, Ubitech, VPIphotonics, Federal Institute of Technology Zurich, Huber+Suhner.

HEXA-X-II

Hexa-X-II is the SNS JU 6G flagship project, providing a holistic view of the concepts and enablers to define a 6G end-to-end system that will deliver the future 6G digital services.

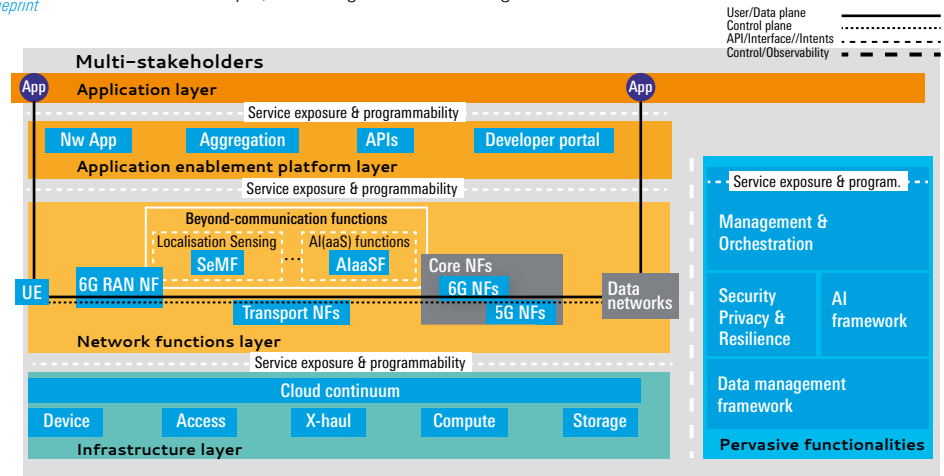
OVERVIEW

Hexa-X-II was Europe's flagship research project during 2023-2025, bringing together partners from across the value chain, including network and device vendors, operators, research institutes, academia and SMEs. With a strong focus on environmental, economic, and social sustainability, the project developed use cases (UCs), enabling technologies, and an end-to-end 6G system blueprint, providing significant input to the early stages of 6G standardisation. As a flagship project, Hexa-X-II interacted with all Call 1 and several Call 2 projects to analyse the wide range of technical enablers.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

Hexa-X-II developed an end-to-end 6G system blueprint (see figure below), that lays the foundation for the recently started 6G standardisation. Notable architectural innovations include the cloud continuum in the infrastructure layer, enabling seamless integration of physical resources and the application enablement platform layer, which provides tools to expose network functionalities for enhanced configuration and optimisation in a multi-stakeholder environment.

Hexa-X-II end-to-end 6G system blueprint



INNOVATIONS

The Hexa-X-II project developed a wide range of technical enablers, spanning use cases, sustainability metrics, radio protocols, intent-based management, security, network architecture. These also include integrated sensing and communication, compute offloading, AI-based radio interface, distributed massive multiple input, multiple output (MIMO), reconfigurable intelligent surfaces, sub-THz transceivers, multi-radio access technology spectrum sharing, non-terrestrial networks, 6G device classes, system-on-chip architectures, energy-neutral devices, and advanced network management incorporating real-time zero-touch control loops, network programmability or multi-domain federated learning.

USE CASES/ TRIALS/ APPLICATIONS

HEXA-X-II

Coordinated by
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January 2023–June 2025

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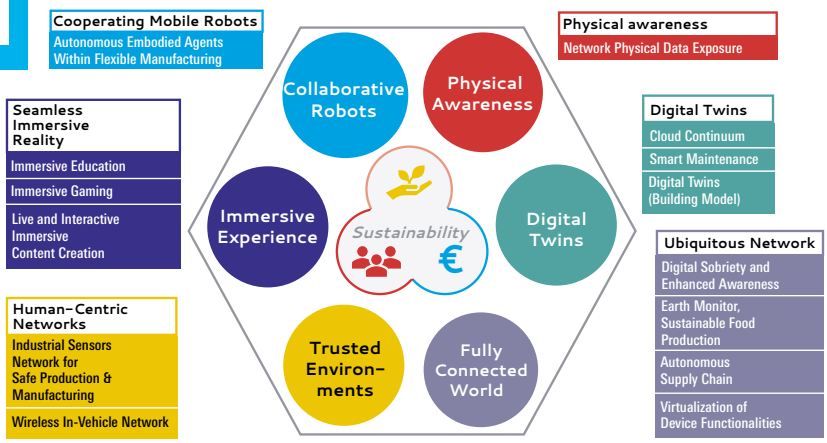
LinkedIn: linkedin.com/company/hexa-x-ii/

Partners: Nokia (Finland, France, Germany, Denmark) Ericsson (Sweden, Finland, Turkey), Aalto University, Apple, Atos (IT Solutions, Spain), CTTC, Chalmers university, ICCS, IMEC, Luleå Technical University, TNO, Nextworks, Optare, Orange (France, Poland), Oulu university, PIU, Qamcom, Qualcomm, SAS IDATE, Sequans, Siemens (Finland, Germany, Austria), Sony, TU Dresden, VTT, Telecom Italia, Telefonica, Telenor, Ubiwhere, UC3M, Vodafone, Wings, Barkhausen Institute, NXP, Rheinland-Pfalzische Technical University.

Hexa-X-II developed 21 different use cases, grouped into six distinct use case families (figure below). For each of the use case family, a representative UC was selected and analysed in more detail.

- **Immersive experience**: Building on the 5G extended reality applications, 6G will enable seamless interactions between physical and digital objects while on the move.
- **Collaborative robots**: The AI revolution will enable agentic AIs controlling virtual and physical entities leveraging 6G for reliable connectivity and control.
- **Physical awareness**: By integrating sensing and communication, 6G will provide aggregated positioning and sensing information from a wide range of devices enabling enhanced situational awareness.
- **Digital Twins**: Digital representations of physical entities will support large scale monitoring and prediction of complex systems, such as factories, or smart cities.
- **Fully connected world**: 6G aims to bridge the digital divide by providing ubiquitous connectivity to people across the globe.
- **Trusted environments**: 6G will enable highly trusted environments with strong privacy, reliability, and security guarantees, supporting for essential human-centric services, such as real-time vital health monitoring ensuring without any data misuse.

Hexa-X-II Use Cases with Highlighted Representative Use Cases



RESULTS/ IMPACT

The Hexa-X-II project has positioned Europe at the forefront of 6G research with a strong presence at high profile conferences, e.g., MWC, EuCNC, and VTC. It has also carried out ten different proof-of-concepts incuding AI-based air interface, zero-energy devices, and smart network management, as well as three iterations of a system-level PoC presented annually at EuCNC. In addition, five of Hexa-X-II's UCs have been agreed to be used in 3GPP SA1.

6G will offer a more sustainable way to deliver existing services as well as enabling novel beyond-communication services such as sensing and compute offloading. The innovations in e.g., AI, sensing, non-terrestrial networks, and zero-energy devices will enable previously unimaginable new services and applications.

HORSE

HORSE proposes a novel human-centric, open-source, green, sustainable, coordinated provisioning and secure evolutionary platform.

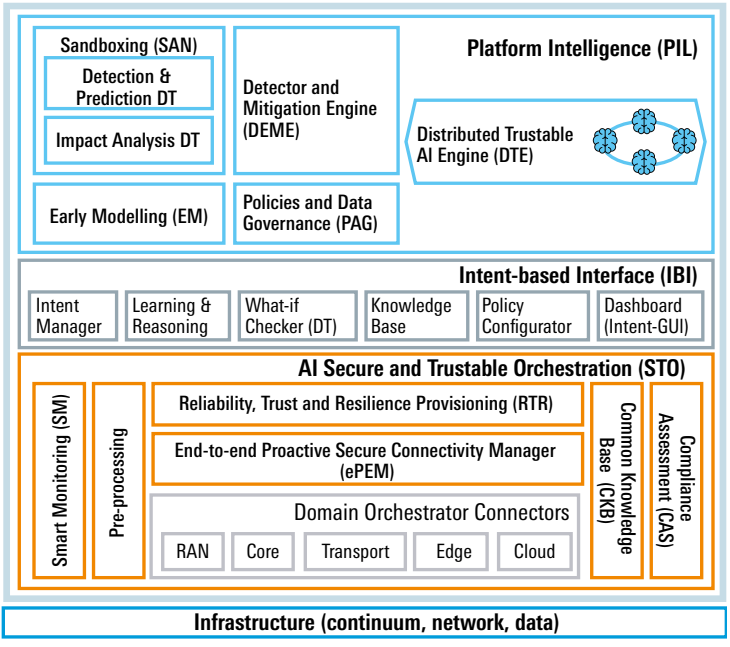
OVERVIEW

The HORSE project aimed to demonstrate how applications can leverage emerging 6G capabilities while also addressing unforeseen challenges through its evolutionary protection platform.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The HORSE reference architecture for 6G delivers a human-centric, end-to-end security framework. It adds a smart, adaptive layer leveraging AI for early threat detection, vulnerability correction, and resilience. Key components include an intent-based interface for user interaction, platform intelligence for predictive security strategies, and AI-driven orchestration that ensures reliable, trustworthy deployment of services and resource management across the 6G infrastructure.

HORSE Architecture



INNOVATIONS

The key HORSE innovation sits on proposing an end-to-end proactive solution for cybersecurity protection in 6G ecosystems leveraging several technological domains, including AI, predictive approaches, digital twin proactive analysis, intent-based, etc. This key innovation may be summarised as: **a specific set of intelligent functionalities** (Sandboxing, early modelling, etc.) used to replicate the entire 6G landscape (infra and potential attacks), to conduct both an analysis of the attack impact and a preliminary analysis of the candidate actions to be deployed, to maximise effectiveness, a **novel strategy responsible for detecting threats in a predictive form**, proactively acting towards either removing or mitigating the impact of the foreseen threat, **an intent-based human-centric approach**, mapping high-level intents into security workflows able to react to security threats and vulnerabilities, and **an adaptive, dynamic and proactive security services orchestration strategy** supporting recursive deployment of many functional components for multi-tenancy, high device heterogeneity (virtualisation), and end-to-end resource self-configuration, spanning across multiple domains and applications.

USE CASES/ TRIALS/ APPLICATIONS

The light rail and metro scenario ensures high availability, secure communication, and resilient orchestration, managing trams, stops, and command centres while enhancing disaster recovery, remote/cloud operations, traffic and security monitoring, and vehicle-to-control communications.

The XR industrial scenario enables secure, multi-site collaboration in virtual or mixed environments, supporting 3D object manipulation for design reviews, prototyping, and process monitoring, with robust connectivity and security for data-intensive applications.

RESULTS/ IMPACT

The HORSE project delivers a comprehensive framework for secure 6G service orchestration, combining advanced monitoring, AI-driven preassessment, and proactive security. Its key components include:

1. **HORSE Platform**: full-featured 6G orchestration;
2. **Distributed AI Engine for Services Preassessment**: sandboxed AI models to evaluate orchestration strategies;
3. **Smart Monitoring**: collects data and tracks resource usage across domains;
4. **Threat Detection and Mitigation Engine (DEME)**: identifies and mitigates threats;
5. **Intent-based Secure Cross-Domain Orchestrator**: maps high-level intents into security workflows for coordinated orchestration;
6. **End-to-End Proactive Secure Connectivity Manager (ePEM)**: central orchestration and observability for secure services;
7. **Network Digital Twin (NDT)**: simulates 6G networks and traffic for predictive testing and validation.

Holistic, Omnipresent, Resilient, Services for future 5G Wireless and Computing Ecosystems

HORSE

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January 2023–December 2025

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PRIVATEER

PRIVATEER is to pave the way for 6G "privacy-first security" by studying, designing and developing innovative security enablers for 6G networks, following a privacy-by-design approach.

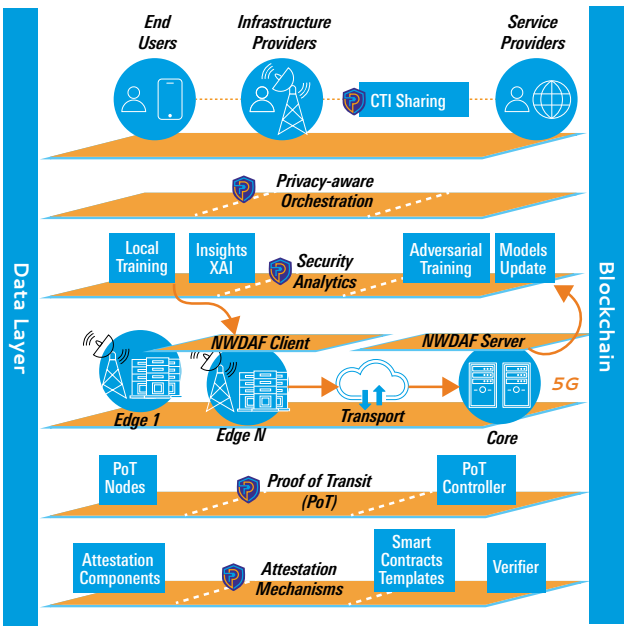
OVERVIEW

Privacy is a cornerstone of EU research and development efforts for 6G, recognised as a critical societal priority in the European 6G vision. PRIVATEER's mission is to advance "privacy-first security" in 6G by researching, designing and developing innovative security enablers based on a privacy-by-design approach.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

PRIVATEER's security and privacy-enabling framework is structured in multiple layers, each containing distinct components that interact to protect the network from attacks while safeguarding end-users' privacy, as illustrated in the figure below.

PRIVATEER's Security and Privacy Enabling Framework



PRIVATEER's architecture is based on four major pillars:

- **Privacy-Aware Orchestration**: AI-driven mechanisms and blockchain technology are used for VNF placement and trust assessment. Proof of transit (PoT) mechanisms ensure traffic integrity and order, enhancing network trustworthiness.
- **Decentralised Security Analytics**: The edge domain enhances performance through FPGA accelerators and utilises network data analytics functions (NWDAFs) in a federated learning deployment for intrusion and anomaly detection, ensuring data privacy.
- **Privacy-friendly Attestation**: Bootup and runtime attestation mechanisms verify virtualised environments and maintain system integrity. Distributed Identification introduces verifiable credentials (VCs) and decentralised identifiers (DIDs), registered on a Distributed Ledger, to authenticate users without third-party reliance.
- **Privacy-friendly CTI Sharing**: Establishment of a network for confidential and efficient threat data exchange among stakeholders, utilising a secure, distributed index and proxy system.

INNOVATIONS

PRIVATEER innovation potential lies in addressing critical privacy and security challenges in the transition from 5G to 6G networks. The project pioneers a **privacy-by-design approach** to develop advanced security enablers, leveraging cutting-edge technologies such as federated learning, explainable AI, and blockchain-based decentralised identifiers. PRIVATEER advances the state of the art by decentralising security analytics, enhancing privacy-aware network slicing, and implementing privacy-friendly mechanisms for cyber threat intelligence sharing. Its innovative methodologies, including **adversarial AI robustness, multi-party computation, and privacy-preserving data pipelines**, contribute to a cutting-edge integrated approach to privacy-first security. By integrating these advancements into a coherent, demonstrable 6G framework, PRIVATEER sets a new benchmark for privacy and security in next-generation networks.

USE CASES/ TRIALS/ APPLICATIONS

The PRIVATEER framework addresses critical security and privacy challenges across Intelligent Transport Systems (ITSs) and Smart Cities, focusing on safeguarding private networks, orchestrating secure logistics, and enhancing public transportation with privacy-centric solutions. **For road operators**, the framework enables robust defenses against edge service compromises through advanced detection and AI-driven analytics. **Logistics operations** benefit from secure network resource orchestration, leveraging PRIVATEER's privacy-preserving mechanisms to ensure data integrity and secure communications. In the field of **public transportation**, a citywide network slice supports privacy-secure journey planning and AI-assisted functionalities, illustrating the framework's utility in managing sensitive data across multiple service providers. **Smart city initiatives** include the deployment of a "neutral host" edge network by a municipality, emphasising the importance of infrastructure integrity and the need for distributed analytics to prevent security breaches.

RESULTS/ IMPACT

PRIVATEER has successfully concluded, delivering a comprehensive suite of software enablers for privacy-first security in 5G/B5G networks publicly available on zenodo. Key outcomes include:

1. **federated learning-based multi-modal intrusion detection techniques**, robust against adversarial attacks;
2. **explainable AI tools** to communicate threats,
3. **streaming pipelines for data anonymisation;**
4. **trusted and secure hardware acceleration platforms for federated learning**;
5. **open annotated datasets for machine learning testing;**
6. **an intent-based manager tool for privacy preservation;**
7. **a privacy-aware orchestrator;**
8. **privacy-aware proof-ot-transit mechanisms;**
9. **privacy-preserving cyber threat intelligence sharing;**
10. **decentralised Identifiers for securing the 6G ecosystem**.

The project also produced reports on the 6G threat landscape overview and generated a comprehensive dataset covering various types of denial of service attacks in B5G networks.

PRIVATEER

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January 2023–December 2026

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Verticals: Intelligent Transportation, Smart Cities

Partners: Space Hellas, NCSR "Demokritos", Telefonica ID, RHEA System , INESC TEC, Infili Technologies, Ubitech, Complutense university of Madrid, ICCS, Norwegian Defense Research Establishement, IQuadrat, Polytechnical Institute of Porto, ERTICO ITS.

RIGOUROUS

The RIGOUROUS project aspires to identify and address the major cybersecurity, trust and privacy risks threatening the network, devices, computing infrastructure, and next generation of services.

OVERVIEW

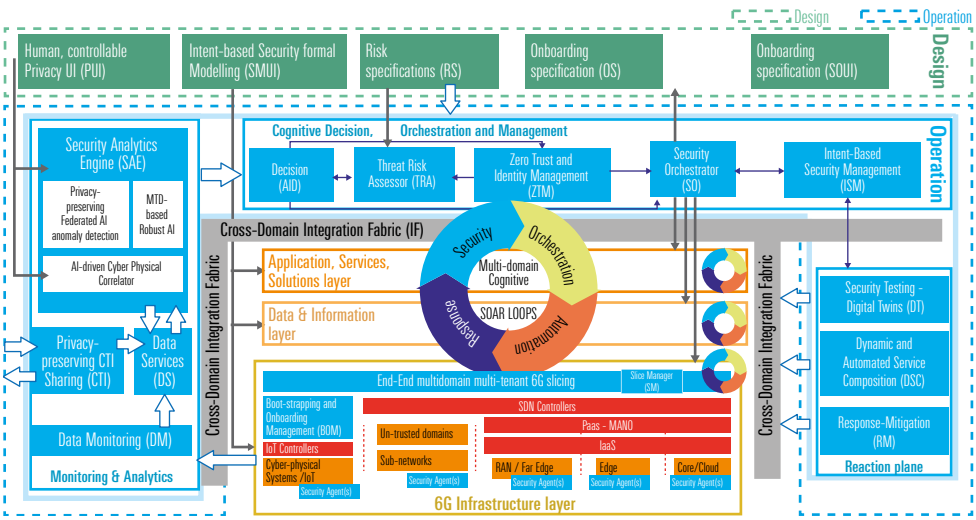
RIGOUROUS is addressing cybersecurity, trust, and privacy risks across 6G networks, devices, computing infrastructures, and next-generation services. The project adds a **human-centric dimension** to future networks, combining security and privacy by design with a smart service framework powered by **AI and ML**. This framework incorporates cognitive Security Orchestration, Automation, and Response (SOAR) loops to respond dynamically to evolving cyber threats in real time.

RIGOUROUS aligns with the Smart Networks and Services Joint Undertaking (SNS JU) vision and collaborates with other European initiatives including HORSE, PRIVATEER, and HEXA-X-II, strengthening Europe's leadership in secure and trustworthy 6G technologies.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The RIGOUROUS framework is designed to provide a **secure, trusted, and privacy-aware foundation** for 6G and continuum computing services across diverse networks. It integrates Development, Security and Operations **(DevSecOps) principles** to ensure continuous, secure delivery and automated policy enforcement, while leveraging **AI-driven orchestration and anomaly detection** to identify and respond to threats in real time. By combining **automation, dynamic management, and human-in-the-loop design**, RIGOUROUS enhances operability and resilience, validating its approach through industrial-scale use cases in real-world environments.

RIGOUROUS Architecture



INNOVATIONS

RIGOUROUS will introduce a range of **groundbreaking advancements** to strengthen security, privacy, and trust across the 6G and cloud–edge–IoT ecosystem, including: **Intent-based modelling** for defining and enforcing security and privacy requirements, along with secure onboarding specifications, **AI-driven orchestration** of security processes across multiple network domains and segments, **Cross-domain 6G slicing** with zero-touch, automated network security management, **Zero Trust-based security enhancements** tailored for 6G architectures, **Secure IoT device initialisation** and trusted application onboarding, **Comprehensive end-to-end threat and risk analysis**.

USE CASES/ TRIALS/ APPLICATIONS

RIGOUROUS has developed four main uses cases (UCs).

- **UC1 – RIGOUROUS platform validation**: This UC tackles the transformative challenges of 6G by applying a DevSecOps approach, integrating security throughout the development lifecycle. Performance is assessed through a series of threat scenarios, demonstrating the platform's effectiveness in identifying, responding to, and mitigating complex cyber threats to 6G infrastructures.
- **UC2 – IoT-Based Smart City Platform**: This UC manages diverse IoT data from city-wide gateways, supporting communications while addressing unauthorised access and economic Denial of Service (DoS) attacks.
- **UC3 – Utilities Management and Security**: This UC focuses on data security in utilities management, covering threat scenarios such as Distributed Denial of Service (DDoS) attacks, data and code injection, and challenges arising from outdated systems.
- **UC4 – Public Protection and Disaster Relief (PPDR)**: This UC highlights correlations between assets and critical elements at risk, featuring scenarios such as PPDR operations, team provisioning, potential intrusions and the exposure of device vulnerabilities.

RESULTS/ IMPACT

RIGOUROUS has produced several enablers to enhance **privacy and security** in 6G networks, with use cases and design plan documented in multiple publications and deliverables at https://rigourous.eu. Some of the project's key achievements include:

- **Security Orchestration in Beyond 5G Networks**: The Security Orchestrator, forms the core of the RIGOUROUS architecture, enforcing interoperable security policies by automatically deploying and configuring chains of Virtual Network Security Functions (VSF).
- **RIGOUROUS Network Self-Protection**: Developed by the University of the West of Scotland, this solution introduces an innovative approach to securing 5G/6G multi-tenant infrastructures through automated, fine-grained traffic control and dynamic network slicing.

secuRe desIGn and deplOyment of trUsthwoRthy cOntinUum computing 6G Services

RIGOUROUS

Coordinated by Antonio Skarmeta Gomez, University of Murcia

January 2023–December 2025

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Verticals: Smart Cities, PPDR, Industry

Partners: University of Murcia, Orange Romania, Lenovo, RHEA Group, eBOS, WINGS-ICT, OneSource, ICT-FI, Starion Group, University of Oulu, Instituto de Telecomunicações, Aston University, University of the West of Scotland.

SUPERIOT

SUPERIOT aims at demonstrating, advocating and further promoting the concept of truly sustainable IoT systems.

OVERVIEW

The SUPERIOT project advances genuinely sustainable IoT systems through a reconfigurable architecture combining optical and radio technologies. These technologies jointly provide wireless connectivity, energy harvesting, and precise positioning within one integrated system. Sustainability is strengthened through printed electronics, supporting environmentally friendly, batteryless IoT devices. The resulting system is highly flexible, able to operate across diverse scenarios and adapt to changing requirements. SUPERIOT's goals include developing and demonstrating a fully reconfigurable, broadly sustainable IoT system at device and network levels. Four proof of concept demonstrators were delivered to validate the practical value and performance of the developed technologies.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The project applies a **holistic sustainability approach throughout design, implementation, use, and disposal**. This is achieved through the combined and flexible use of radio and optical technologies, reconfigurable nodes and networks, and sustainable fabrication methods. **The system architecture includes four main elements**: reconfigurable radiooptical IoT nodes; infrastructure for connectivity, energy, and positioning; network intelligence; and services and applications. The joint use of optical and radio networks provides a strong basis for nextgeneration IoT, meeting diverse communication requirements. Bluetooth Low Energy is used for radio links and narrowband visible light communication for optical links, with both technologies also supporting positioning and energy harvesting.

INNOVATION

SUPERIOT introduces an innovative IoT concept with advances across several fields. The joint use of radio and optical communication enables **dynamic selection of the most suitable technology** for connecting nodes to access points. Architecturally, the main novelty is unifying optical and radio communication, wireless power transfer, and sensing and location functions within one system. Key innovations include **a holistic architecture for resource constrained, sustainable nodes**, supported by optimised algorithms for seamless handovers and system-level optimisation at node and network layers. These advances are validated through demonstrations. The project also brings printed electronics into IoT, enabling sustainable node fabrication.

USE CASE/ SCENARIOS

In the initial phase, SUPERIOT defined three main operating scenarios:

- smart tags and labels,
- large scale sensing and actuation,
- enhanced IoT communications.

Twenty-four potential applications were identified and mapped to the four demonstrators. For each application, key requirements, dual mode connectivity, sensing and actuation, positioning, privacy and security, energy autonomy, recyclability, cost, and more, were evaluated for importance, feasibility,

expected maturity, and suitability for the demonstrators. Based on this analysis and SUPERIOT's capabilities, the use cases and requirements for the four demonstrators were established.

Demonstrators 1 and 2, the most extensive, address industrial material flow, logistics, distribution, and patient monitoring.

RESULTS

The four project demonstrators developed by SUPERIOT are briefly presented.

- **Demo 1** showcases a sustainable smart tag operating in a scaled industrial material flow scenario. It validates bidirectional communication using both optical and radio links, with dynamic reconfigurability between them. The system demonstrates positioning through visible light communication and integrates environmental sensing for temperature, humidity, gas parameters, and pressure. It also supports actuation of an e-paper display and the optical and radio transmitters. Energy autonomy is achieved through energy harvesting and storage, including printed micro supercapacitors. Overall, the demonstrator confirms that the SUPERIOT solution meets all required features for industrial smart tag applications.
- **Demo 2** demonstrates two complementary scenarios for medical environments. The first, a real sized setup at the Vitality Hub, demonstrates reliable dual mode localisation using visible light for room level accuracy and radio channel sounding for precise indoor positioning, combined with sensing, dynamic communication mode switching, and actuation through e-paper displays. It is fully integrated with a software platform for real-time data use and visualisation. The second, a scaled scenario, highlights sustainability and energy autonomy through hybrid optical and radio energy harvesting, using simultaneous wireless information and power transfer (SLIPT) and simultaneous light information and power transfer (SWIPT) with printed electronics. It compares organic photovoltaics and amorphous silicon under realistic indoor conditions. Together, the demonstrator confirms SUPERIOT's potential to deliver sustainable, reconfigurable, dual mode solutions for future medical applications.
- **Demo 3** focuses on creating a very simple, limited capability IoT node built entirely from printed components. The node uses gravure printed organic solar cells and reverse offset printed transistors to achieve full energy autonomy, harvesting all required power without any battery. It receives information through pulsed red, green, and blue light, where colours provide system clock and a two bit address signal, and optical filters ensure wavelength selectivity. The printed solar cells act as both energy harvesters and information receivers, while the output is a voltage pulse that can drive a printed indicator, an e-paper display, or modulate a backscattering antenna. The work confirms that fully printed electronics can support minimal IoT functionality and are ready for further development without fundamental technical barriers.
- **Demo 4** showcases a large area IoT repeater node based on a Reconfigurable Intelligent Surface (RIS) integrated into the SUPERIOT platform. It combines localisation, real time RIS control on an embedded microcontroller, and a monitoring interface that visualises system state and computes beam steering angles. These elements form a closed loop system that dynamically redirects signal reflections toward a moving IoT node, enabling adaptive and sustainable indoor connectivity. The demonstrator was validated at IMEC's Vitality Hub, confirming reliable integration, fast beam steering updates, and stable remplacer par reconfigurable intelligent surfaces operation.

Truly Sustainable Printed Electronics-based IoT Combining Optical and Radio Wireless Technologies

SUPERIOT

Coordinated by Marcos Katz, University of Oulu
January 2023–December 2025
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Verticals: Industry, Health, Energy, Smart Cities, Transport and Logistics

Partners: University of Oulu , INES TEC, VTT, NOVA, IMEC, Lightbee, MPICOSYS, KU Leuven, University of Bristol, Vivid Components, WAVECOM.

TERA6G

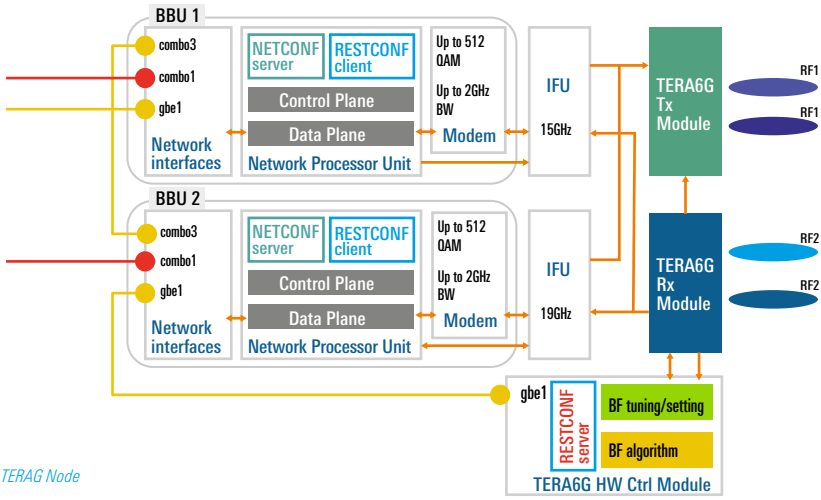
TERA6G is advancing connectivity with cutting-edge transceivers.

OVERVIEW

TERA6G leverages advanced hybrid photonic integration to develop groundbreaking wireless transceiver modules capable of terabit-per-second data throughput. These modules enable fully programmable, end-to-end orchestrated communication networks, by exploiting the reconfigurability of photonic components, thereby supporting network slicing and dynamic, automated management of multi-beam wireless system resources.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The TERA6G project pursues the "**Fiber over the air" concept**, bringing the information capacity of optical fibres to wireless links. By operating in higher regions of the electromagnetic spectrum above 100 GHz - where vast bandwidth is available – **the project enables significantly increased transmission speeds** while using low-complexity coding schemes to reduce latency. Microwave photonics techniques combining the strengths of photonic and radiofrequency (RF) technologies, are employed to deliver ultrawide RF frequency tuning, ultra-broadband bandwidth and low loss RF distribution and signal processing. These capabilities support multi-beam generation with advanced beamforming and beamsteering functionalities. In addition, the reconfigurability of photonic components is a key enabler of intelligent or "smart" management.



TERAG Node

INNOVATIONS

TERA6G builds on a range of key innovations.

At hardware level, the project advances integration technology, such as the chiplet concept - developing modular functional building blocks that can be replicated and combined to scale transmission capacity without

changing the underlying architecture. It also pushes hybrid integration technologies to enable unique functions including integrated optical isolators. In parallel, innovative lensing schemes are developed to support two-dimensional antenna arrays based on dielectric waveguide antennas.

At the network level, TERA6G exploits the reconfigurability of photonic components to develop wireless transceiver modules that enhance user throughput and overall network capacity. These modules enable the integration of mobile objects into network architectures, and support diverse service-level agreements as well as network slicing.

USE CASES/ TRIALS/ APPLICATIONS

TERA6G use cases are focus on two main multiple Point to Point (mPMP) scenarios.

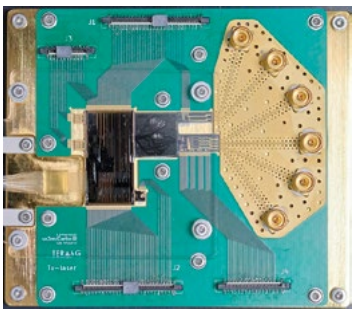
The first scenario addresses x-Haul for mobile small cell densification in outdoor public networks, responding to the growing demand for scalable mobile infrastructures in which small cells are deployed to enhance network coverage and capacity. This outdoor scenario is well suited to high-frequency operation, given the short-range links typical of dense urban areas.

The second targets indoor private networks, enabling high-throughput connectivity for industry 4.0 applications. It addresses the requirements of adaptive manufacturing, which demands robust, low-latency connectivity for a higher density of remote nodes and dynamic physical layouts, allowing on-the-fly reconfiguration of production lines.

RESULTS/ IMPACT

TERA6G has developed **groundbreaking wireless transceivers based on hybrid photonic integration**, combining silicon nitride, indium phosphide and polymer chips. These technologies are used to implement an optical heterodyne RF generation system capable of supporting a scalable number of independent beams operating at a tunable carrier frequency. The assembled chips and the resulting packaged module are shown below.

TERA6G has also developed the **building block and control architecture** for an end-to-end orchestrated communication network, based on its wireless transceiver modules. This architecture enables dynamic management of network nodes within a fully automated network framework. The baseband unit (BBU) is a key element, allowing dynamic allocation of multi-beam wireless system resources through fully programmable end-to-end orchestration, supporting energy efficiency, network resiliency and adaptable capacity.





TERAhertz integrated systems enabling 6G Terabit-per-second ultra-massive MIMO wireless

TERA6G

Coordinated by
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January 2023–June 2026

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Verticals: Industry: factory & process automation

Partners: Universidad Carlos III de Madrid, ICCS, Fraunhofer HHI, LioniX International, PHIX, University of Piraeus Research Centre, University of Oulu, Cumucore, Intracom Telecom, Telefonica ID, Polytechnical University of Madrid, Leapwave Technologies.

TERRAMETA

TERRAMETA aims to examine revolutionary 6G technologies and demonstrate the feasibility of multi-functional THz reconfigurable intelligent surfaces (RISs) to support very high data rates in wireless communications networks.

OVERVIEW

Over the next decade, 6G mobile communications are expected to enable novel applications, such as the internet of senses, that rely on billions of wireless devices transmitting sensor data for AI inference. Existing communication technologies cannot meet the extreme requirements of these services. The TERRAMETA project therefore explores disruptive 6G solutions, demonstrating the feasibility of multi-functional Terahertz (THz) reconfigurable intelligent surfaces (RISs) to support ultra-high data rates. The project develops dedicated hardware as well as advanced control and optimisation methods for RISs, which are validated through real-world demonstrations in factory automation and telecommunications infrastructure.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

THz frequencies offer massive bandwidth enabling future wireless services with data rates of up to 1 Tbps. However, their practical use is limited by high path loss and susceptibility of blockage. TERRAMETA addresses these challenges by developing novel THz and reconfigurable intelligent surfaces technologies that overcome such limitations through electromagnetic wave shaping.

The project pioneers the **design and fabrication of RISs operating at 140 and 300 GHz**, targeting wireless communications, sensing, and localisation, as well as their system-level integration. These RISs can be deployed to create virtual line-of-sight paths, enabling robust, high-throughput connectivity in challenging environments.

INNOVATIONS

TERRAMETA has achieved **system-level innovations spanning both RIS hardware and signal processing**. Multiple reconfigurable RIS platforms were developed, including a 24×24 memristor-based reflective RIS (R-RIS), a hybrid 12×12 Schottky diode R-RIS with semi-automated assembly, a gallium arsenide based transmissive RIS (T-RIS) with monolithically integrated Schottky diodes, a hybrid T-RIS based on phase change materials and complementary metal-oxide-semiconductor packaging, and a microfluidic 1-bit R-RIS demonstrating successful beam scanning. Together, these platforms enable scalable, low-power beam control at 140 and 300 GHz. To complement these hardware advances, the project proposed advanced algorithms for RIS-enabled beam management, including biconvex channel estimation under dual-wideband fading, near-field codebook design, and curved beam synthesis using Airy beams. Cell-free multi-RIS communication strategies were also investigated, along with user scheduling and distributed beamforming under imperfect channel knowledge. Integrated sensing and communication (ISAC) capabilities were further advanced through full-duplex metasurface antenna architectures and RF imaging based on physics-informed neural networks. Collectively, these innovations validate TERRAMETA's co-design approach to THz hardware and signal processing, enabling robust, high capacity 6G connectivity.

USE CASES/ TRIALS/ APPLICATIONS

TERRAMETA focuses on two key use-case domains: factory automation and telecommunications.

- **Factory scenario**

  In Industry 4.0 environments, RIS-enabled THz links support mobile robots performing real-time simultaneous localisation and mapping (SLAM) and AI-assisted control. RIS elements deployed on factory pillars and mobile units ensure reliable, low-latency connectivity in dynamic industrial settings. A dual validation approach is adopted:

- **large-scale ray-tracing** simulations based on detailed 3D factory models;
- **real-world demonstrations**, in which RIS hardware has been integrated with mobile robots provided by industry partners.

- **Telecom Scenario**

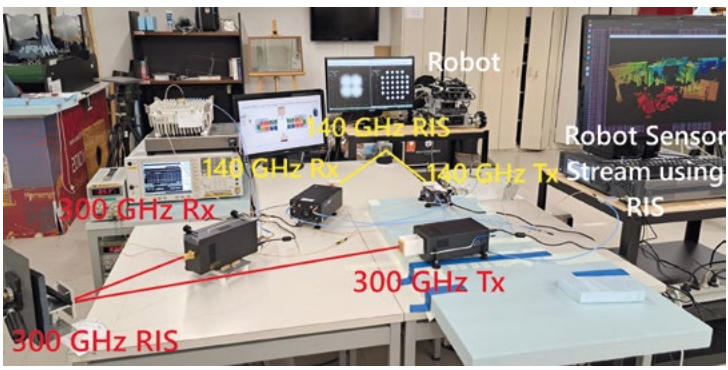
  In the telecommunication domain, RIS technology is integrated with Open RAN (O-RAN) architectures to enhance 6G connectivity in urban and dense network environments. RIS helps mitigate THz path loss and blockage, enabling non-line-of-sight communication and supporting diverse use cases, including high-capacity xHaul. RIS modules are deployed on urban infrastructure (e.g., lamp posts) to improve end-user connectivity and enable intelligent, energy-efficient beam steering. A full system trial at BT's research campus is planned for the spring of 2026.

RESULTS/ IMPACT

TERRAMETA achieved a world-first demonstration of full-duplex RIS-enabled wireless links at 140 and 300 GHz, integrated with a mobile robot use case streaming high-bandwidth 3D point cloud data. The system delivered 8.5 Gbps at D-band (140 GHz) over a 70cm + 70cm bidirectional RIS-aided link (robot uplink), and 2.1 Gbps at 300 GHz over 30cm + 70cm configurations (robot downlink). Simplex transmissions reached 5 Gbps over 4.2m at D-band, with extended 42m links currently under development.

TERRAMETA's breakthroughs demonstrate that THz RIS technology can overcome severe path loss and blockage with innovative designs and intelligent beam steering, enabling ultra-reliable, multi-gigabit full-duplex connectivity. This capability is essential for next-generation 6G use cases, including smart cities, real-time industrial automation and future demanding AI-driven robotics applications.

Full-duplex RIS link architecture for 140 GHz and 300 GHz configurations, transmitting and receiving real sensory data.



Terahertz Reconfigurable Metasurfaces for Ultra-High-Rate Wireless Communications

TERRAMETA

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Verticals: Industry, Smart Cities

Partners: INESC TEC, National and Kapodistrian university of Athens, university of Oulu, Instituto de Telecomunicações, Intracom Telecom, CEA Leti, university of Luxembourg, Dell Technologies, technical university of Braunschweig, ACST, Nova university of Lisbon, university of Hertfordshire, BT.

TIMES

The vision of TIMES is a THz-based smart radio ecosystem working in complex scenarios with many heterogeneous devices, capable of offering similar performance as wired networks in terms of data rate (Tb/s), ultra-low latency, sensing, and reliability.

OVERVIEW

TIMES enhances 5G to achieve wired-like performance by combining Terahertz (THz) communications, advanced channel measurements, intelligent mesh networking, and smart wireless control. It targets industrial applications demanding ultra-high performance, reliability, and sensing, such as cooperative robotics, predictive maintenance, and real-time control.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

TIMES explores THz communications in industrial environments, focusing on links between machinery and mobile robots. It develops advanced THz channel models, intelligent mesh networking, and high-definition integrated sensing and communication (ISAC) and validates solutions through a real-world proof-of-concept (PoC) demonstrator based on ultra-wideband communications, intelligent mesh networking and ISAC.

INNOVATIONS

To address these challenges, TIMES will carry out extensive measurement campaigns in industrial environments using a **300 GHz channel sounder**, enabling the development of accurate and application-relevant THz channel models. Given the stringent requirements of THz propagation, advanced antenna and radio front-end designs are essential. Accordingly, the TIMES proof-of-concept demonstrator will leverage **novel THz prototype front-ends, beam-steering capable antenna systems**, and **reconfigurable intelligent surface (RIS)** technologies to ensure robust, high-performance communication.

In terms of THz channel modeling TIMES has introduced several novel contributions:

- **Near-field extensions to 3GPP standardised model** to account for spherical wavefront effects at short distances and large arrays;
- **RIS-assisted channel models** validated with measurements at 300 GHz, including a distance-adaptive radar equation for near-field RIS links;
- **ML-based line of sight (LoS)/non line of sight (NLoS) classification** achieving 97% accuracy, along with automated clustering of multipath components.

USE CASES/ TRIALS/ APPLICATIONS

The TIMES project has identified 15 use cases for THz communication systems across **six application areas**, including predictive maintenance, mobile robot management, flexible and modular factory, highly dynamic control, augmented and virtual reality (AR/VR) and digital twins, and seamless field bus substitution. Each use case (UC) has been analysed to derive its specific **communication and sensing requirements**.

In the context of **manufacturing and logistics**, the project has defined UCs for stationary production machines and moving robots, classified into short-term (~3 years), mid-term (3-5 years), and long-term (>5 years) horizons.

Among these, TIMES will demonstrate 2 PoCs: the first focusing on THz-based machine connectivity in an industrial environment, and the second showcasing a THz link with a mobile receiver.

RESULTS/ IMPACT

TIMES aims to develop a THz-based smart radio system capable of operating in complex scenarios with many heterogeneous devices. The envisioned system will deliver very high data rates, ultra-low latency, sensing, and reliability. **Key building blocks include THz front ends, antennas, and RIS**. The project has evaluated multiple antennas with beam-steering capability and RIS technologies, and is currently finalising the first prototypes. Two dedicated measurement campaigns have already been conducted to assess system performance with initial results published in two conference papers.

6G technology is expected enhance wireless systems to enable accurate sensing, imaging, and localisation capabilities. These features are essential for industrial environments, where higher bandwidth, reliability, low latency, massive device connectivity, and advanced machine communication are critical enablers for future automation and control systems.

A major hardware outcome of the project is a **compact THz Indoor Unit** for nextgeneration ultrahighdatarate wireless links. Using Fraunhofer IAF's 35 nm InGaAs mHEMT technology, the unit integrates transmit and receive frontends, a medium power amplifier, and phase-locked loop (PLL)based local oscillators in a single manufacturable platform. The system operates **over the 270–330 GHz with 60–90 GHz intermediate frequencies (IF)**. The waveguidebased design employs precision computer numerical controlmilled, goldplated housings and lowloss Eplane transitions for broadband performance. Measurements demonstrate receiver conversion gains of approximately 10–13 dB and typical transmitter output powers exceeding 7 dBm. The integrated PLL enables agile channel selection and support future features such as beam steering and frequency hopping. Overall, the validated **260–330 GHz coverage**, stable IF performance, and repeatable linearity provide **a robust, industry relevant hardware platform** for upcoming THz communication demonstrators and industrial mesh network trials under the TIMES project.

These THz front-end units are now in integration and final testing phase at CNRS and TU Braunschweig (TUBS) in preparation for PoC demonstrations. CNRS will establish a fixed RIS-enabled NLoS THz link, to be demonstrated at AETNA factory in February-March 2026. A first RIS operational demonstration was already conducted at CNRS last year, validating an initial NLoS data link in the THz band. With all building blocks being now validated, the full TIMES demonstrator is close to completion and will be showcased at CNRS before deployment at AETNA factory. In parallel, TUBS is preparing mobile THz link use cases based on beam-steerable antenna systems. Both PoCs feature end-to-end IP connectivity over THz frequencies, bringing THz communication closer to practical industrial applications.

System verification experiments have successfully demonstrated interoperability with various commercial millimetre wave modems, operating in both time division duplex and in frequency division duplex modes. Over-the-air measurements confirm sufficient margin and bandwidth to support fully IP-connected, real-time links using frequency agile leaky-wave antennas and RIS-assisted propagation.

THz Industrial MEsh Networks in Small Sensing and Propagation environments

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January 2023–December 2025

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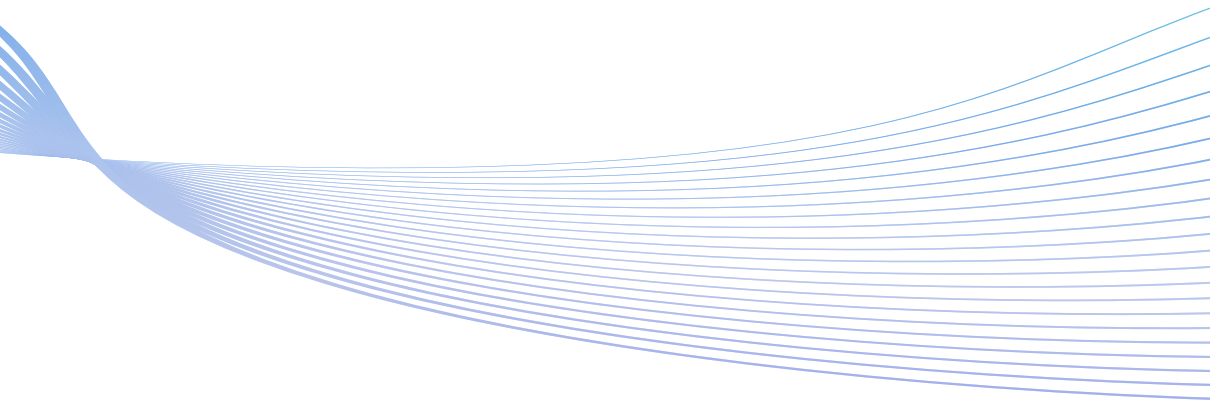
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Verticals: Industry

Partners: CNIT, Aetna Group Spa, Anteral SI, BI-REX Big Data Innovation & Research Excellence, CNRS, Fraunhofer Gesellschaft, Huawei Technologies Duesseldorf Gmbh, Technische Universität Braunschweig, Telenor Asa, University of Stuttgart.



Stream C

SNS JU ENABLERS AND PROOFS-OF-CONCEPT (POCs)

including development of experimental infrastructure(s)

The three projects in stream C aim to develop EU-wide experimentation platforms that can incorporate promising technical 6G enablers for their further validation. Key aspects for the projects are the reusability and ability to evolve of the experimental platforms over the lifetime of the SNS JU programme. Accessibility and openness with well-defined and clearly documented technological and business interfaces are also considered key assets of the infrastructures to be developed.

6G-BRICKS

6G-BRICKS offers breakthrough enablers, explainable AI models and open interfaces for a truly modular and open RAN compliant end-to-end 6G experimentation facility.

OVERVIEW

6G-BRICKS providers experimenters with the capability to remotely test breakthrough radio access network (RAN) devices, going well beyond typical parameter adjustments. For the first time, users can contribute custom implementations of core system components as O-RAN xApps. Based on a "LEGO Bricks" concept, the platform also offers reusable, self-contained testbed components lowering barriers to experimentation and enabling interdisciplinary validation of emerging 6G technologies.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The 6G-BRICKS delivers an open 6G experimentation platform that integrates cell-free architectures, OpenAirInterface (OAI), and Reconfigurable Intelligent Surfaces (RIS) through a modular, software-defined design. The facility's architecture is structured into the following tiers:

1. **Experimentation Plane:**

   This serves as the entry point to the 6G-BRICKS Facility, enabling intent-driven, human-in-the-loop experimentation.

2. **Management & Orchestration Layer:**

   This layer, deployed at each facility site, offers a unified controllability framework through the Domain Management and Orchestration (DMO) framework. It uses Explainable AI to unify policies and provide feedback to experimenters about potential issues during experiments.

3. **6G RAN Infrastructure Domain:**

   This domain incorporates advanced 6G RAN technologies into modular components with O-RAN interfaces for reusability. The KU Leuven site features a Distributed Cell-Free RAN for enhanced network densification and the Eurecom site uses the OpenAirInterface O-RAN stack, integrated with a reconfigurable intelligent surface (RIS).

INNOVATIONS

1. **Integration of breakthrough 6G technologies and federation of to testbeds** under a unified set of experimentation tools.
2. **Validation and demonstration of advanced use cases**, including holographic communication, metaverse, and digital twinning, leveraging 6G technologies and architecture.
3. **Support for disaggregated and programmable software-defined infrastructures** (SDIs) with virtualisation, softwarisation, and O-RAN compliant interfaces for modularity and reusability.
4. **Decentralised management plane** enabling zero-touch orchestration through explainable artificial intelligence (XAI).
5. **Compute Continuum abstraction** supporting disaggregated wireless X-Haul.
6. **Breakthrough 6G RAN technologies**, including distributed cell-free and RIS.

7. **Secure and trusted Experimentation** via software defined perimeters (SDP).

USE CASES/ TRIALS/ APPLICATIONS

The following use cases showcase how 6G technologies can transform work and industrial environments by enabling immersive experiences and highly efficient operations.

UC1: Metaverse as an enable of a Modern Workplace:

- PoC1: Holoconferencing in a virtual meeting room
- PoC2: virtual team building activities

UC2: 6G applications for Industry 4.0

This use case focuses on Industry 4.0 applications, showcasing how 6G enablers can enhance operational efficiency through autonomous robots, digital twins, and extended reality (XR).

- PoC1: Autonomous robots in Industry 4.0
- PoC2: AR inspection of Industry 4.0 digital twin on site.

RESULTS/ IMPACT

6G-BRICKS progressed from system integration to experimental validation and open access. The project completed the **deployment and configuration of key enablers across the 6G testbeds** and validated the facility through extensive dry-run testing of the experimentation plane, orchestration, security, and RAN-related components. Building on this validated infrastructure, 6G-BRICKS also **successfully executed its first Open Call experimentation cycle**. In terms of impactful outcomes, 6G-BRICKS delivered two end-to-end O-RAN compliant solutions, each integrated with a key 6G technology:

- An O-RAN compliant CFmMIMO solution was implemented and deployed at KUL, improving spectral efficiency by >2x at the inter-cell region.
- A RIS control framework integrated with the OpenAirInterface O-RAN solution.
- An experimentation framework based on xApps, enabling experimenters to remotely test 6G devices, and even enhance core sub-systems such as precoding and scheduling.

Building Reusable testbed Infrastructures for validating Cloud-to-device breaKthrough technologieS

6G BRICKS

Coordinated by Christos Verikoukis, ISIS/ATH

January 2023–June 2026

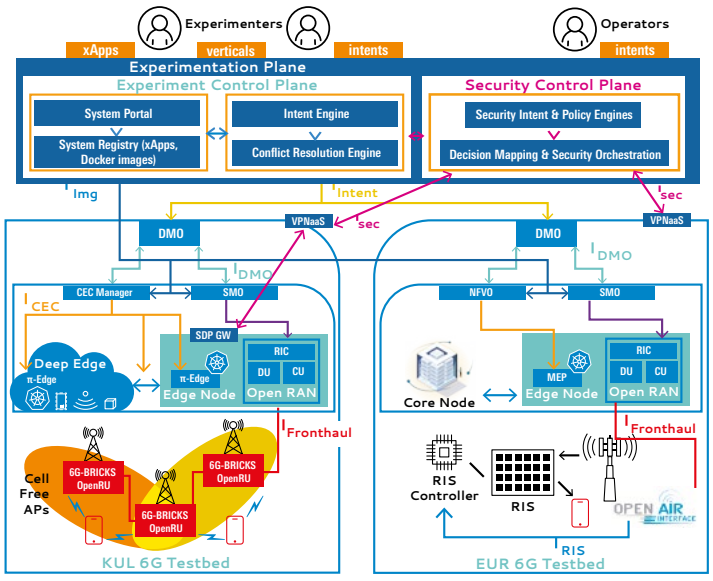
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Verticals: Industry, Logistics, Media and Entertainment, Education

Partners: ISI/ATH, Iquadrat, KU Leuven , CEA, Eurecom, National Instruments Germany, ISRD, Ericsson Ireland, Intracom, I2CAT, Brainstorm, Space Hellas, OTE, Satways, eBOS, Ektacom, Lenovo.



6G-BRICKS architecture

6G-SANDBOX

The 6G-SANDBOX project addresses the need for an experimentation facility that guarantees modularity, openness, reusability, innovation, and sustainability.

OVERVIEW

6G-SANDBOX provides a modular European experimentation facility, enabling configurable trial networks that integrate virtual, physical, and emulated resources to validate 6G technologies and key performance indicators. Four platforms in Athens, Malaga, Berlin, and Oulu host end-to-end trial networks, while the shared 6G-library allows experimenters to deploy them modularly on demand.

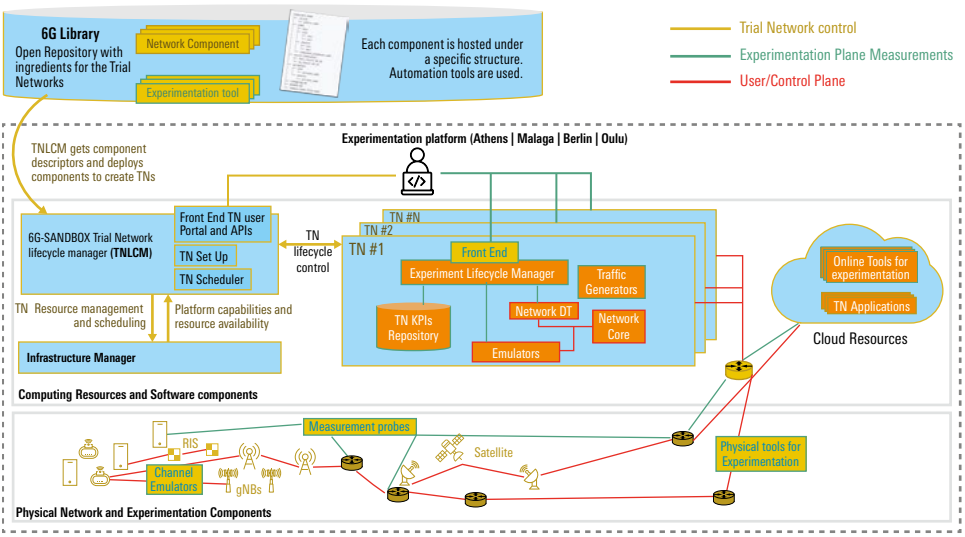
CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

6G-SANDBOX offers an innovative experimentation framework for beyond 5G and 6G technologies, built on a modular architecture (see figure below) structured around three main planes:

- **User/Control Plane**, which manages interactions, connectivity, and data exchange among network components;
- **Experimentation Plane**, which supports the design, execution, and monitoring of experiments;
- **Trial Network Plane**, which supports the deployment and configuration of trial networks, manages the related resources and provides interfaces to the trial network users.

Together the three planes form a core framework that integrates beyond-5G technologies, such as O-RAN, reconfigurable intelligent surfaces, joint communication and sensing, satellite links, deterministic networking, and digital twins -while its open and modular design allows seamless integration of additional 6G technologies.

6G-SANDBOX reference architecture



INNOVATIONS

6G-SANDBOX introduces a set of innovations structured around **ten technological ambitions** including: disruptive wireless communications, fixed/radio access network/satellite integration, deterministic networking, network openness (core network exposure), artificial intelligence/machine learning-driven network evolution, security as a service, the edge-cloud continuum, digital twins, and mixed extended reality-haptics applications. Across all these areas, the project delivers research outcomes and software components that demonstrate measurable advances beyond the state of the art.

The project establishes a new experimentation paradigm where **isolated testbeds are instantiated on a shared network and compute infrastructures** and offered to third parties for configuration, technology validation and key performance indicator (KPI) measurement. Experimenters gain access to cutting edge technologies and network digital twins integrated across four geographically distributed platforms in Europe.

Going beyond current approaches, 6G-SANDBOX maximises replicability and reusability by releasing its complete software stack as open source through the 6G-SANDBOX toolkit. Moreover, for the first time within a single project, such a wide and comprehensive set of measurement tools is offered to experimenters, covering almost any network KPI that a third party may require.

USE CASES/ TRIALS/ APPLICATIONS

The project has built an **experimentation facility that is agnostic to the vertical industry** requesting technology validation and 6G KPI measurements. The project completed successfully its Open Call programme, where **32 sub-projects have been funded** and brought their own use cases into the 6G-SANDBOX experimentation facility. The 6G-SANDBOX facility has been expanded with various components, including NEF & NWDAF implementations, Digital Twin enablers, as well as RIS & NTN interfaces. Beyond this programme, the project welcomed third parties for technology validations and measurements, gathering experience and valuable inputs on 6G experimentation methodology. Currently, the project welcomes large scale trials in four key areas, namely non-terrestrial networks, reconfigurable intelligent surface, Frequency range 3 (FR3), and deterministic networking.

RESULTS/ IMPACT

The project is the main code contributor to the ETSI Software Development Group OpenCAPIF and has released a stable version of the 6G-SANDBOX toolkit. It realises an experimentation infrastructure as a service (ElaaS) model and was selected among the SNS JU 2025 Top-10 Key Achievements! The consortium has also submitted a substantial number of contributions to 3GPP and to ITU-T Study Groups, with more than 20 of these contributions already approved.

In parallel, 6G-SANDBOX has signed **three Memoranda of Understanding** with major organisations, including ESA, SLICES and ITRI, and has established four company-level collaborations with industrial partners. Within this framework, a new 6G experimentation laboratory has been created in Malaga, which will remain operational beyond the end of the project. Finally, leveraging the extensive set of measurement tools offered to experimenters, thorough the project has conducted thorough KPI assessments and technology validation activities. The corresponding results are documented in *Deliverables D5.3* and *D5.4*.

SAND BOX

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January 2023–June 2026

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6G-XR

6G eXperimental Research's ambition is to strengthen European leadership in 6G technologies by enabling next-generation XR services and infrastructures that will provide beyond-state-of-the-art capabilities in the run-up to the 6G era.

OVERVIEW

The 6G-XR project designs, deploys, and validates an advanced experimental infrastructure for immersive extended reality (XR) applications over 5G and 6G networks. It integrates innovations across networks, edge, and cloud to support demanding use cases such as holographic communication, immersive augmented and virtual reality (AR/VR), and real-time digital twins, leveraging programmable network control, edge computing, and open application programming interfaces (APIs).

Through large-scale experimentation across multiple testbeds, 6G-XR shows how next-generation mobile networks can dynamically optimise performance, latency, resource use, and energy consumption to deliver high-quality XR experiences while addressing sustainability, standardisation, and real-world exploitation.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

Concept and Architecture. 6G-XR is built on a modular, end-to-end reference architecture that tightly integrates XR applications with programmable 5G and 6G networks, edge computing, and cloud resources. XR applications - including AR/VR, and holographic communication - are network-aware, exposing their performance needs to the infrastructure. A cross-domain orchestration layer dynamically places media functions such as rendering, encoding, and synchronisation, close to users. Control and user planes are separated yet coordinated, enabling real-time session setup, quality adaptation, and resource allocation across distributed test sites.

Technologies. 6G-XR combines advanced XR media pipelines including volumetric video capture, remote rendering, and multi-user synchronisation, edge and cloud computing for ultra-low-latency processing, and programmable network capabilities via open APIs. These include quality of service (QoS) control, edge discovery, and orchestration frameworks able to react dynamically to congestion, mobility, and service demands. The project also integrates IP multimedia subsystem (IMS) communication, WebRTC and DASH delivery, as well as AI-assisted monitoring to optimise performance and sustainability. Together, these elements illustrate how future 6G systems can evolve beyond best-effort connectivity toward intelligent, adaptive infrastructures that natively support immersive XR services at scale.

INNOVATIONS

Main Innovation. A flagship innovation of 6G-XR is the world's first network-native holographic call, jointly demonstrated by Telefónica, Ericsson, and MATSUKO. For the first time, real-time holographic communication was integrated directly into a standard smartphone dialer using the IP multimedia subsystem (IMS) data channel, enabling users to place and receive 3D holographic calls without relying on third-party applications. The solution combines MATSUKO's AI-driven single-camera technology to reconstruct lifelike 3D holograms, Ericsson's IMS data channel capabilities, and Telefónica's 5G network, allowing holographic content to be streamed in real time to XR devices with a strong sense of presence. This breakthrough demonstrates that holographic communication can operate on existing mobile

infrastructure in a scalable, secure, and operator-ready manner. It opens the way for telecom operators to deliver immersive services such as advanced collaboration, training, and remote assistance, while laying foundations for future 5G evolution and 6G business models. Beyond this milestone, 6G-XR has delivered advances across multiple domains. In XR technologies, achievements include red, green, blue, depth (RGBD) Sensor Calibration, the XR Capturer as an inspection tool, thermal compensation for plenoptic cameras and a QoS-aware adaptive multimedia pipeline. In the RAN area, techniques the project developed equalisation techniques for doubly dispersive channels and high-frequency transceiver designs. For control and management, innovations include a trial controller, a congestion detection function and an energy-aware QoS-driven end-to-end controller. In programmable networking, the project delivered a set of operational application programming interface (APIs), compliant with CAMARA open standards.

USE CASES/ TRIALS/ APPLICATIONS

Five use cases have been demonstrated:

1. **Resolution Adaptation or Quality on Demand**: Dynamically adjust application resolution or traffic prioritisation to maintain user experience during network congestion.
2. **Routing to the Best Edge**: Deploy applications on the most suitable edge node and use the closest user plane function (UPF) based on service requirements, location, and available resources.
3. **Control Plane Optimisations**: Utilise an IMS platform that integrates holographic communications directly into the mobile phone dialer.
4. **Collaborative 3D Digital Twin-like environment**: Enables users to review 3D objects in a digital twin environment before printing them in the real world.
5. **Energy Measurement Framework for Energy Sustainability**: Use precise energy measurement data to optimise end-to-end energy consumption across the mobile network infrastructure.

Open Call projects have leveraged the 6G-XR infrastructure and trial controller to deploy and evaluate their own XR solutions, demonstrating how external innovators can efficiently experiment with, validate, and scale next-generation XR applications in a realistic 5G/6G-ready environment.

RESULTS/ IMPACT

6G-XR 6G-XR has shown that **immersive XR services**—such as real-time holographic communication, interactive digital twins, and multi-user collaboration—**can be delivered in a network-native, scalable, and operator-controlled** way by integrating applications, edge/cloud computing, and programmable mobile networks. Key outcomes include validated end-to-end architectures, open and reusable XR enablers, and large-scale experiments showing how latency, bandwidth, reliability, and energy use can be dynamically optimised to meet stringent XR requirements.

These findings underscore the need for 6G: current networks struggle to consistently support sub-10 ms latency, high uplink capacity, precise synchronisation, and deterministic quality of service: 6G capabilities—native edge intelligence, fine-grained network exposure, deterministic performance, and sustainable operation—are essential to scale XR from isolated demos to mass-market services, enabling new societal and industrial applications and human-centric digital experiences.

6G eXperimental Research to enable next-generation XR services

Coordinated by Jussi Haapola, University of Oulu

January 2023–December 2025

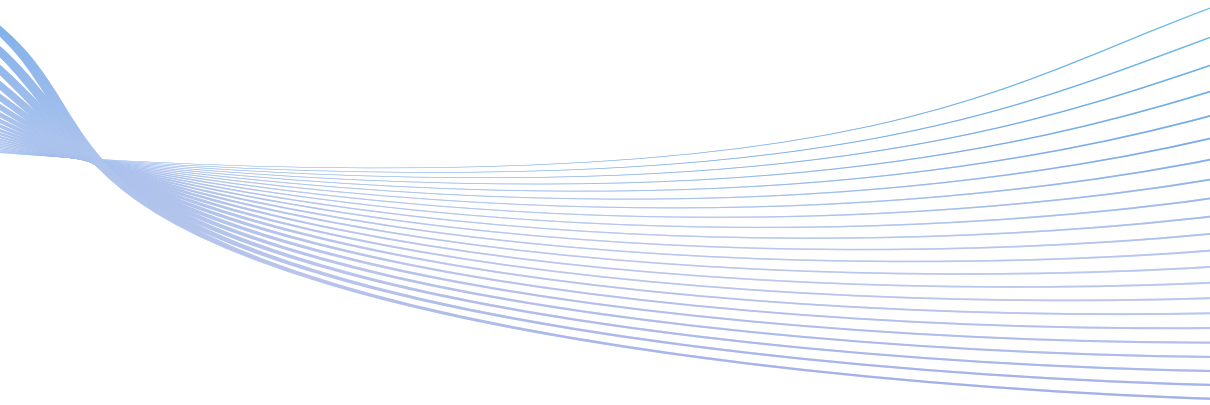
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LinkedIn: www.linkedin.com/company/6g-xr/

Verticals: Media/XR

Partners: University Oulu, Instituto de Telecomunicações, Ericsson, InterDigital, i2CAT, Vicomtech, VTT, Martel, Matsuko, Raytrix, Capgemini, Intel, Nokia, Telefonica, IMEC.



Stream D

LARGE SCALE TRIALS AND PILOTS WITH VERTICALS

including the required infrastructure to explore and demonstrate technologies, advanced applications and services in vertical domains

Four projects are implementing large-scale SNS JU trials and pilots with specific verticals of high economic and societal importance. The aim is to explore and demonstrate 5G/6G technologies, advanced applications and services in vertical sectors such as energy, construction, automotive, manufacturing, eHealth, culture, and media.

Additionally, these large-scale trials aim to serve as catalysts for the creation of viable business ecosystems. Stream D projects incorporate technologies that are currently key enablers for 6G networks, including AI/ML, cybersecurity, cloud/edge and advanced IoT solutions etc.

FIDAL

FIDAL is targeting the augmentation of human capabilities, allowing vertical industry players to perform advanced technological and business validation in large-scale field trials.

OVERVIEW

FIDAL meets the increasing demand from verticals and enterprises for rapid development of advanced services by testing beyond 5G capabilities. It provides a future-proof 5G test infrastructure and supports innovative Media and public protection and disaster relief (PPDR) applications through large-scale trials. By enabling both technological and business validation and contributing to standardisation, FIDAL facilitates high-impact SNS JU trials, ultimately advancing the advancement of future 6G technologies.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

Key technologies investigated and integrated into the FIDAL framework include: **Maestro** for standardised service management applications programming interfaces (APIs), **Open Slice** for cross-domain slice management, and **Monitoring and Analytics** services that gather data from testbeds, applications, and use cases (UCs).

INNOVATIONS

Within FIDAL, partners drive innovation in their areas of expertise to achieve maximum impact. A central element of this work are the three FIDAL testbeds (Malaga, Patras, Telenor) which foster wireless advancement through validation, experimentation, and collaboration.

USE CASES/ TRIALS/ APPLICATIONS

In 2025, FIDAL entered Phase 3 of its lifecycle, focused on executing iterative cycles of large-scale trials (LST). Four the FIDAL UCs have already completed several trial iterations, while the LST's for the remaining UCs are planned for 2026.

USE CASE	DESCRIPTION	OBJECTIVE
UC1: Internet of Senses	Testing the high-speed and low latency capabilities of beyond 5G through an almost instantaneous sensory experience using the OWO (Boreal) haptic suit. The trial involved university students	Collection of data on network application connection capacity and latency
UC2: Digital twins for first responders	Simulation of a fire scenario using automatic hazard-monitoring algorithms to continuously keep first responders updated on the evolving crisis	Demonstrate end-to-end early fire detection, coordinated emergency response, enhanced situational awareness and decision-making

fidal field trials beyond 5G

Coordinated by
Ioannis Markopoulos, NOVA

January 2023–June 2025

Website: fidal-he.eu

X: x.com/project_FIDAL/

LinkedIn: www.linkedin.com/in/fidal-project-b21227262/

Verticals concerned: PPDR, MEDIA

Partners: NOVA, eBOS technologies, ISI/ATH - RESEARCH & INNOVATION INFORMATION TECHNOLOGIES, PIUU, Iquadrat, FORTH, Telenor, Ektacom, Airbus, PSCEuropeFORUM, P-NET, Emerging Networks and Verticals, university of Patras, UBITECH, Telefonica ID, university of Malaga, APPART, Satways, Boreal technology and investments, ORama, Ericsson Greece.

UC3: City security event	Investigation of a technology for PPDR smart situational awareness, enhancing effective, resilient, and secure collaboration and real-time information sharing for PPDR personnel. The trial involved the Malaga Police	Push To Talk application enabling video and audio communication even when a large number of users are connected to the same network
UC6: XR-assisted services for public safety	The LST tested two scenarios: **extended reality (XR)-based technology** to support first-aid responders in pre-hospital treatment skills of (UC6.1) and augmented reality (AR)-based technology to deliver instant data enabling safer, smarter decision-making for law enforcement agents (UC6.2). The trials involved the Hellenic Rescue Team	Testing of defined KPIs (e.g. network stress, throughput, bandwidth allocation), key value indicators (KVIs) and user experience assessment

RESULTS/ IMPACT

The project has delivered an advanced, future-ready beyond 5G infrastructure comprising three testbeds labs and three large-scale infrastructures integrated with end-to-end Evolved 5G facilities. Both third-party use cases and FIDAL core UCs have been integrated, tested and validated – including **7 FIDAL UCs, 19 UCs from Open Call Round 1, 9 UCs from Open Call Round 2**.

FIDAL's architecture enables the requesting and provisioning of network services through open-source components such as OpenSlice and TeraFlowSDN. The testbeds now offer comprehensive interfaces, services, and tools for resource control, with **six network applications** leveraged for real-world validation. The project has also defined and applied KVIs to capture societal and business challenges, ranging from the digital divide to privacy and trust. Additionally, the FIDAL repository service has been enhanced with curated datasets, complete with test case descriptions and metadata, making them readily available to the wider community.



IMAGINE-B5G

Imagine-B5G is working to provide an advanced and accessible end-to-end (E2E) 5G platform for large-scale trials and pilots in Europe.

OVERVIEW

Imagine-B5G delivers an advanced and accessible end-to-end (E2E) 5G platform enabling large-scale trials and pilots across four 5G experimental facilities in Norway, Spain, Portugal, and France.

The platform supported rigorous testing of emerging core technologies and future network architectures, fostering the development of innovative services and unlocking new business opportunities for Beyond-5G (B5G) vertical applications.

Through three Open Calls (OCs), the facilities onboarded third parties – including SMEs, industry, and researchers. Selected participants collaborated on vertical experiments (VEs) and platform extensions (PEs), advancing real-world 5G use cases while contributing to the technical evolution of the underlying infrastructure.

USE CASES/ TRIALS/ APPLICATIONS

IMAGINE-B5G launched three Open Calls (OCs) to accelerate the development, validation, and adoption of innovative Beyond 5G solutions across a wide range of verticals, including public protection and disaster relief (PPDR), media and entertainment, transportation and logistics, industry 4.0, education, agriculture and forestry, and eHealth. Successful applicants were granted direct access to the Imagine-B5G experimental facilities, together with technical mentoring and structured project support.

The Open Calls programme proved highly effective. Across the three calls, 184 proposals were submitted and a total of 45 projects were selected – 15 per call – covering both vertical experiments and platform extensions. Projects from OC1 and OC2 projects were presented in the two most recent SNS JU Journal editions. OC3 projects, presented below, ran for six months and focused exclusively on vertical experiments.

Norway Facility:

- **PULSE-5G**: *Predictive Utilisation of cloud Logic and Sensors for Efficiency with 5G* by Simtera, is an Industry 4.0 project focused on enhancing industrial automation through 5G, AI, and cloud-based control systems.
- **5G4Reha**: *5G-driven tele-rehabilitation combining extended reality (XR) and biomechanical tracking* by Nissatech, develop a system to support remote rehabilitation exercises while capturing and analysing patient movement biomechanics.
- **SCANNER**: *Smart Component Analysis through Novel XR Environments and Robotics* by Finwe, developed new methods for inspecting industrial components, integrating micrometer-level 3D scanning, XR, robotics, and 5G.
- **5GPace**: *Optimising 5G Network for Efficient Video Production by Pacing* by Technical University of Darmstadt, aims to enhance support for time-critical applications, notably video streaming like remote production.

Spain Facility:

- **AbySS-5G**: *Autonomous Boat for Safety & Security with 5G* by UTEK, demonstrated the effective use of the 5G-connected autonomous boat "Kaluga" for human safety, surveillance, and environmental monitoring.
- **PORTSAFE-B5G**: *Proactive Observation and Real-Time Traffic and Surveillance Analysis for Facility Enhanced Security leveraging B5G* by WINGS,

Advanced 5G Open Platform for Large Scale Trials and Pilots across Europe

Imagine B5G

Coordinated by David Gomez-Barquero, Polytechnical University of Valencia

January 2023–March 2026

Website: https://imagineb5g.eu/

X: @B5gImagine

LinkedIn: www.linkedin.com/showcase/imagine-b5g

Youtube: www.youtube.com/@Imagine-B5G

Verticals: PPDR, media and entertainment, transportation and logistics, industry 4.0, education, agriculture and forestry, eHealth

Partners: Polytechnical University of Valencia, Telenor, Telefonica, Altice Labs, Nokia Finland and Spain, Capgemini, Samsung UK, Keysight, Ubiwhere, Airbus, Port of Valencia, Eurecom, Telecommunications Institute, Oslo University, South East Technological University, Athens University of Economics and Business.

was implemented to enhance port security and logistics using 5G standalone and Multi-Edge Computing (MEC) analytics.

- **OPS5G**: *Cyber-physical Environment for Real-time, Efficient, Sustainable 5G enabled Farming Operations* by Xilbi, uses 5G's high speeds and low latency to transform farming with an Environmental Digital Twin and AI decision support.
- **HoloMEd**: *Multiuser XR holo-portation trials for immersive media education over B5G scenarios* by I2CAT, introduces an affordable holo-portation platform allowing up to ten people to interact in real time as life-sized 3D holograms.
- **SMATRA-5G**: *Smart Transport with Dynamic Virtual On-Board Units Powered by 5G* by OdinS, is advancing transport technology with its Virtual On-Board Unit (vOBU) experiment, boosting connected car capabilities through 5G integration.

Portugal Facility:

- **ADS-5G**: *Autonomous delivery service using 5G and GNSS localisation fusion* by YouShip, aims to improve localisation accuracy and continuous positioning by combining 5G and GNSS for an autonomous delivery robot.
- **5G-EVER**: *5G Edge V2X Ecosystem for Revenue Collection* by A-to-Be, tested 5G V2N (vehicle-to-network) payments, enhancing convenience, sustainability, and V2X (vehicle-to-everything) services via cellular technology.
- **NEURONET**: *iNtelligent Energy Usage-awaRe platfOrm for sustaiNable grEen networking* by OmniumAI, creates an energy-aware platform using artificial intelligence and machine learning, enabling experimentation with environmental impacts on energy efficiency.
- **WINGS**: *WIreless 5G time-sensitive NetworkinG for Smart factories* by University of Sheffield, shows how Time-Sensitive Networking and private 5G deliver deterministic end-to-end connectivity and reliable performance for Industry 4.0.

France Facility:

- **AIRWAY**: *Expanded situational awareness on the use of different aerial means in firefighting* by Digital Aeronautics, proposes capturing drone data at different heights and visualising meteorological risk for safe aerial operations.
- **5G-FIRE**: *5G Firefighters' Instant Remote Eye* by AzurIA, aims to enhance firefighting operations by integrating 5G technology into its existing CamIA fire detection and alert case.

RESULTS/ IMPACT

Imagine-B5G demonstrates the potential of next-generation network technologies to transform critical infrastructure and industrial operations across multiple sectors. The project supports the adoption of private 5G networks, enables more sustainable and autonomous operations, and reinforces Europe's leadership in advanced digital and industrial technologies.

By expanding and optimising its experimental facilities, Imagine-B5G has significantly enhanced infrastructure readiness for future pilots, research collaboration, and continued innovation, paving the way for impact beyond individual industries or locations.

TRIALSNET

TrialsNet is deploying B5G large-scale trials over wide coverage areas and with the involvement of extended sets of real users targeting a holistic evaluation of the KPIs and KVIs of 6G applications in different domains, encompassing various network deployments and solutions.

OVERVIEW

TrialsNet targeted a series of technical, performance and productivity objectives designed to significatively shape the evolution of today's ecosystem towards 6G. Building on this foundation, the project conducted an extensive trials campaign aimed at:

- identifying the potential limitations of current network technologies to derive requirements for the next generation mobile network and
- assessing end-user acceptance of the proposed applications by engaging new vertical sectors, thereby supporting broader 5G adoption in Europe.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

Two technological frameworks were developed:

- **TrialsNet Baseline 5G Technology (Bs5G)**, representing the initial deployment of project infrastructures and serving as the base line for experimentations;
- **TrialsNet Advanced 5G Technology (A5G**), incorporating cutting-edge network technologies to support the final trials.

Notable achievements within A5G include the **mmWave standalone (SA) private network** deployed at the Movistar Arena (recognised as one of the SNS JU Top-10 Key Achievements), an **Innovative Orchestrator** tested in Pisa to manage end-to-end (including the transport network) quality of service (QoS) for concurrent eHealth services -even in mobility- via slicing, and the implementation of a **Zero Touch Management Service** (part of the project's contribution to the 3GPP Workshop on 6G) in Romania to support the related trials.

Building on these infrastructures, TrialsNet also developed a range of applications across the three project domains:

- Infrastructure, Transportation, Security, and Safety;
- eHealth and Emergency;
- Culture, Tourism, and Entertainment. These applications leveraged numerous technologies, including XR, cobots, IoT, AI, digital twins, and more.

Finally, TrialsNet implemented solutions specifically targeting sustainability, improving metrics such as energy consumption, a key objective for large scale trials.

INNOVATIONS

Through the application of the three-stage process — **Discovery, Generation and Development** –, TrialsNet identified **15 innovations** (8 driven by the consortium and 7 by the Open Call cohorts) that the project considers significant advances in 6G-enabled applications across its three domains. Each innovation was assessed not only during the use case design phase, but also throughout the trials and in post-trial evaluations.

The **value propositions** of the innovations were evaluated based on the number of enabled use cases and their performance against Key Value Indicators (KVIs), ultimately framing their potential impact in relation to the **Sustainable Development Goals (SDGs)**.

In this context, the **large-scale trials** demonstrated real-world applicability and user acceptance, providing concrete proof points of innovation potential. Notably, the project's innovations also encompassed process definitions, not just technological aspects, such as the KVI framework established for the trials.

USE CASES/ TRIALS/ APPLICATIONS

TrialsNet conducted over **20 large-scale trials** (covering 13 use cases) by consortium partners and an additional 50+ trials (over 24 use cases) through Open Call sub-projects, across four European clusters in Italy, Spain, Romania, and Greece as well as 24 additional sites from the Open Call. These trials provided robust experimental evidence of the performance and applicability of next-generation networks thorough a variety of innovative applications.

The trials engaged thousands of end users (distributed according to the three domains), multiple vertical sectors, and a wide range of device types. This heterogeneity was key to validating the adaptability of the tested technologies and applications under real-world conditions and across varying deployment environments – including commercial, private, and experimental infrastructures – using a consistent data set of around 850 publicly available (https://zenodo.org/records/17392665) measurements and KVIs.

RESULTS/ IMPACT

By applying a clearly defined evaluation framework and process that enabled uniform and comparable data collection and analysis across all trials, TrialsNet conducted an extensive assessment of the collected **KPIs and KVIs**. On one hand, the trials highlighted limitations in the current network landscape -heavily optimised for downlink intensive applications- revealing the need for improved support for **high-uplink throughput and low-latency requirements**. On the other hand, the results showed a consistently positive perception among end users regarding the impact of TrialsNet, strongly endorsing the project's contribution to **society, the economy, and the environment** within the context of sustainability objectives.

Overall, TrialsNet advanced its objectives across all dimensions, including **technical validation, value creation, dissemination, exploitation, and innovation**. By bridging the gap between technological capability and societal value, the project not only contributed to the **state of the art in 5G and B5G networks** but also laid the foundation for a **sustainable, inclusive, and innovation-driven 6G network.**

Trials Supported By Smart Networks Beyond 5G

Coordinated by
Silvia Provvedi, Ericsson Telecomunicazioni SPA

January 2023–December 2025

Website: https://trialsnet.eu/

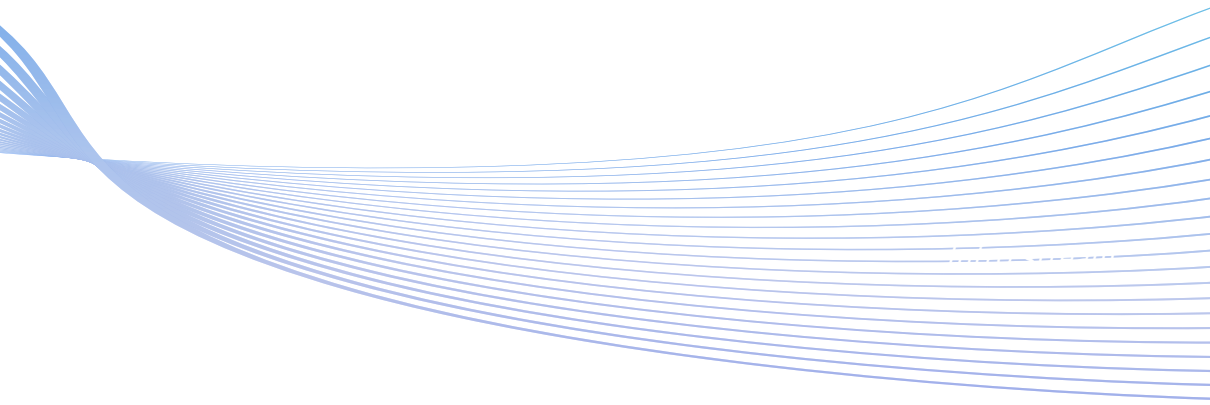
X: @trialsnet

LinkedIn : www.linkedin.com/company/trialsnet/

BlueSky : https://bsky.app/profile/trialsnet.bsky.social

Verticals: Infrastructures, Transport, Security and Safety/ eHealth and Emergency/ Culture, Tourism and Entertainment

Partners: Ericsson Italy and Spain, Telecom Italia, Orange Romania, Nextworks, Wings ICT, Information and Communication Technologies IKE, Universidad Carlos III de Madrid, Imec, Yerba Buena VR Europe, CNIT, Telefónica ID, Italian Institute of Technology Foundation, Athens International Airport, Santa Anna School, PIIU, City of Turin, Gheorghe Asachi Technical University of Iasi, Prosegur, Crossmedia, DAEM, CNR, CERTH, Real Wireless.



COORDINATION AND SUPPORT ACTIONS (CSAs)

The project portfolio includes two Coordination and Support Actions focussed on internal operational aspects of the SNS JU Partnership as well as on establishing dialogues with EU initiatives (e.g., related partnerships, national initiatives, etc.) and promote SNS JU results and achievements at a global level while working towards the formation of global standards.

SNS ICE

The SNS ICE project provides the collaboration environment for dialogue amongst European and global stakeholders involved in the preparation of 6G smart networks and services.

OVERVIEW

The SNS ICE project served as a coordination and support action initiative under the Smart Networks and Services Joint Undertaking (SNS JU), advancing Europe's vision for 6G networks on a global scale. It facilitated collaboration and knowledge exchange among European, Vertical and international stakeholders preparing for 6G smart networks and services. The project captured and analysed emerging technological trends and reports on B5G and 6G research and innovation (R&I) activities within the SNS JU community. Additionally, it disseminated the outcomes of SNS JU projects globally, creating a collaborative platform for dialogue and exchange. The work of SNS ICE aimed to strengthen Europe's leadership in next-generation networks and to foster a unified approach to global 6G development.

PROJECT ACTIVITIES/ HIGHLIGHTS/ INNOVATION

The SNS ICE project engaged in strategic activities to capture the latest innovations and discussions in B5G/6G development, analysing global and vertical landscapes while promoting the vision of SNS JU. Key highlights of the project include:

Alignment on EU stakeholder priorities for 6G Use Cases & common EU front in Standardisation

SNS ICE led efforts to unify European stakeholders (Industry, Academia, SMEs, SNS JU Projects, National Initiatives) on 6G Use Cases prioritisation within standardisation bodies. Through multiple alignment meetings and feedback rounds, detailed Use Cases (families, requirements, KPIs) were defined. For the first time, EU stakeholders presented a unified front at a 3GPP SA1 Workshop in May 2024, significantly boosting European influence and impact on future 6G standards.

Vertical Engagement & Trends Analysis (Claudio)

The SNS ICE project actively engaged stakeholders from vertical sectors, associations, standardisation and regulatory bodies, aiming to understand the trends and the uptake of technology developed for the benefit of society. MoUs/LoIs fostered joint actions and events, including a 2024 questionnaire for vertical associations which helped refine the 2023 SNS ICE trend analysis[1]. The Vertical Engagement Tracker (VET)[2] tool developed in 2023 to systematically map and monitor SNS JU use cases, was updated with 247 use cases from 52 SNS JU projects, and allows to draw a comprehensive birds-eye view of the current state of the art of the SNS JU research landscape while identifying gaps and guiding future policy[3].

Global 6G Landscape Analysis & Worldwide Collaboration

SNS ICE has been instrumental in strengthening the SNS JU's position in global fora, through the organisation of more than 30 international events

1. *SNS ICE Deliverable D3.2, Initial Trends Analysis in Vertical Sectors, January 2024, https://smart-networks.europa.eu/csa-s/#SNS-ICE*
2. *https://verticals-tracker.sns-ju.eu/*
3. *SNS ICE Deliverable D3.3 Updated Trends Analysis in Vertical Sectors, January 2025, https://smart-networks.europa.eu/csa-s/#SNS-ICE*

Smart Networks and Services International and European Cooperation Ecosystem

Coordinated by
Kostas Trichias, 6G-IA

January 2023-March 2025

Website: https://smart-networks.europa.eu/csa-s/#SNS-ICE

LinkedIn : www.linkedin.com/company/sns-ice/

Partners: 6G-IA, CTTC, TNO, Trust-IT, Commpla, Telecom Italia, Nokia Solutions and Setworks, EUrescom, electronic communications office of Latvia (VASES).

Workshops[4], realising the commitments of the 8 MoUs that have been signed with international associations. Moreover, project partners further enhanced and updated the SNS ICE 6G global landscape survey[5] focusing on:

- envisioned / prioritised 6G enabled Use Cases;
- key 6G enabling technologies (enablers);
- performance targets for the primary 6G Key Performance Indicators (KPIs). The extracted insights suggest that Europe's 6G roadmap is well aligned with global priorities, including key enablers like AI-native networks, energy efficiency, and integrated sensing.

EU Research Environment & National Initiatives

SNS ICE further advanced collaborations with European National initiatives, analysing research priorities across nine EU initiatives and capturing stakeholders' views on 6G. The project also provided a thorough analysis of the EU cloud initiatives around Europe which has been highlighted as a key collaboration topic by almost all EU stakeholders[6].

4. SNS ICE Deliverable D4.3, Final Dissemination Communication and Exploitation Report, March 2025, https://smart-networks.europa.eu/csa-s/#SNS-ICE

5. SNS ICE Deliverable D1.2, Impact analysis and SNS promotional report 2.0, December 2024, https://smart-networks.europa.eu/csa-s/#SNS-ICE

6. SNS ICE Deliverable D2.2, Findings and Trends from European 6G R&I initiatives, December 2024, https://smart-networks.europa.eu/csa-s/#SNS-ICE

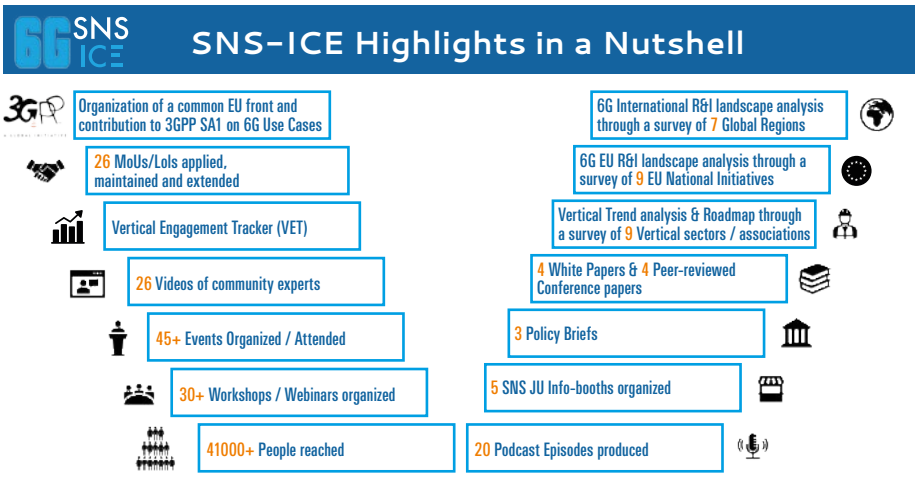
RESULTS

The SNS ICE partners facilitated meaningful connections with the SNS JU and the global community and engaged in extensive outreach activities throughout the project duration[7] to raise awareness about SNS JU activities and promote the results of the Phase 1 and Phase 2 projects, in order to maximise the programme's impact. The figure provides and overview of SNS ICE's impact and highlights:

- Presentation of a common EU front at 3GPP SA1 and adoption of most of the EU priorities in 3GPP TR22.870.
- Update & Evolution of SNS JU collaborative Trackers / tools including the Vertical Engagement Tracker, Standards Tracker and KPI Radar.
- Detailed 6G Landscape analysis on Global, EU & Vertical stakeholders.
- Multiple impactful publications including targeted Policy Briefs
- Successful dissemination of SNS JU vision, work and results via a large variety of printed and online materials.

7. SNS ICE Deliverable D4.3, Final Dissemination Communication and Exploitation Report, March 2025, https://smart-networks.europa.eu/csa-s/#SNS-ICE

SNS ICE Highlights / Impact



SNS OPS

The SNS OPS project is devoted to supporting the operations of the 6G Smart Networks and Services Joint Undertaking (SNS JU).

OVERVIEW

The SNS OPS project supported the operational activities of the 6G Smart Networks and Services Joint Undertaking (SNS JU). The work was to facilitate and strengthen the European SNS JU Initiative. This included:

- Supporting for the Smart Networks Services Joint Undertaking (SNS JU) institutionalised European partnership and the associated programme governance.
- Organising SNS JU as a coherent and coordinated programme, with clear links to the 6G-IA and the European Commission and the SNS JU Office.
- Maximising the impact and exploitation of SNS JU project results in key areas such as standardisation and spectrum, through structured and managed co-operation among projects.
- Enabling coordination and joint actions across Joint Undertakings (JUs).

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The approach and structure of the SNS OPS project are designed to operate the SNS JU infrastructure and facilities, while ensuring continuity and the transfer of European ICT research leadership activities from the 5G PPP to the SNS JU. Building on the achievements of the predecessor Coordination and Support Action (CSA), 6GStart, the project aims to carry forward the momentum and leadership established under the 5G PPP and apply them to the new challenges of the SNS JU under Horizon Europe.

The project was organised into five core work streams that operate in continuous dialogue with one another, and with the peer CSA, SNS ICE. This close interaction ensured a clear and up-to-date view of the SNS JU community progress, which is regularly fed back into actions to refine and improve the programme across its successive phases.

INNOVATIONS

SNS OPS has in its final year continued to work on all 5 core streams of activities and achieved all planned results, even going beyond target KPIs.

In the stream on SNS JU assessment and planning, a "monitoring and analysis framework" of the technological KPIs, societal KVIs, and other relevant work aspects targeted at the SNS JU projects has been developed. Questionnaires have been developed for Call 1, 2 and 3 projects. While the questionnaire for newly started projects was about collecting information on project positioning and plans, the questionnaire for ongoing projects collected information on the progress of projects in their past year. The thorough analysis of the responses yielded valuable insights that were published and presented in a webinar and further used e.g. in the SNS JU Work Programme generation process which SNS OPS partners have supported and made various contributions to. The project responses showed e.g. that all specific objectives of the SNS JU Work Programme are well matched by the projects, showing a healthy balance and complementarity among the projects.

In the second stream SNS JU Outreach: Dissemination and Communication,

Supporting the SNS JU Operations

6G SNS OPS

Coordinated by
Uwe Herzog, Eurescom

January 2023–March 2025

Website: https://smart-networks.europa.eu/csa-s/#SNS-OPS

Partners: Eurescom, 6G-IA, Nokia Solutions and Networks, Ericsson, Thales, Telenor, Orange France, IDATE, Nokia Networks France, Southeast Technological University, Australo, Trust-IT, Instituto de Telecomunicacoes, Martel, University of Surrey.

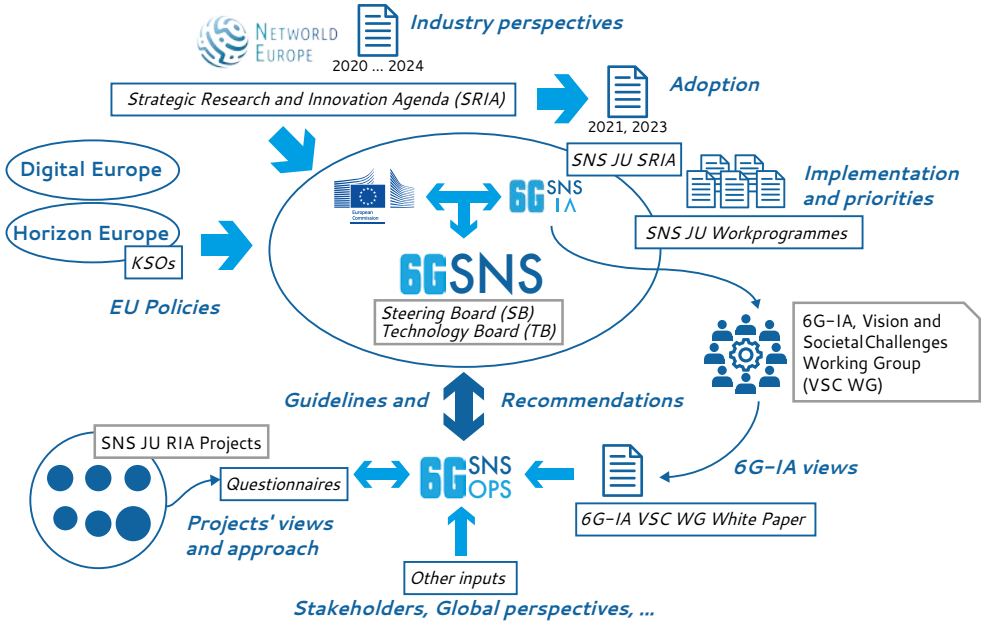
SNS OPS has deployed online and offline communication measures to reinforce the SNS JU brand. The SNS JU website which SNS OPS maintains continues to serve as a central information hub and has experienced a strong interest and engagement from the community. In terms of social media on platforms like LinkedIn and X the SNS JU outreach has further grown, and a SNS JU Mastodon channel has been added to reach out also to this new emerging community. This demonstrates the SNS JU's ability to engage a wider audience.

In the third stream SNS OPS organised and supported the SNS JU programme organisation and orchestration. This work focused on supporting the main SNS JU initiative bodies; -the Steering and Technology Boards-, while ensuring efficient collaboration across the SNS JU projects. With the addition of Call 3 projects the Boards expanded to 79 SNS JU project members, significantly increasing the effort to organise and manage their activities. In addition, SNS OPS continued to manage the SNS JU Collaboration Agreement among projects, integrating both SNS JU Call 2 and Call 3 projects.

The fourth stream focused on Stakeholder Engagement and Working Group Support, aiming to foster global stakeholder involvement and interaction. To maximise the value and impact of the SNS JU programme, the strategy included tailored activities for key stakeholder groups, such as verticals and complementary domains, SMEs, Working Groups (WGs), and peer Partnerships, Initiatives and Associations. Several events were organised – for example targeting Digital Innovation Hubs, Microelectronics and Security – with goal of assessing the relevance and impact of the SNS JU within specific- domains and gathering feedback on stakeholder expectations.

The fifth stream – Events logistics and IT infrastructure – has managed the provision of the SNS JU working IT infrastructure and the preparation for SNS JU events. The goal has been to ensure that every event is organised professionally way, maximising value for participants. Notable examples include the EuCNC & 6G Summit 2024 and an SNS JU Session at MWC 2024 and 2025. Regarding the "IT infrastructure", SNS OPS has overseen the organisation, production and maintenance of the SNS JU's operational IT systems, covering everything from mail servers and repositories to the brokerage service and the SNS JU website at https://smart-networks.europa.eu.

SNS JU Vision and Programme process, stakeholders and reference documents



Call 2 Projects

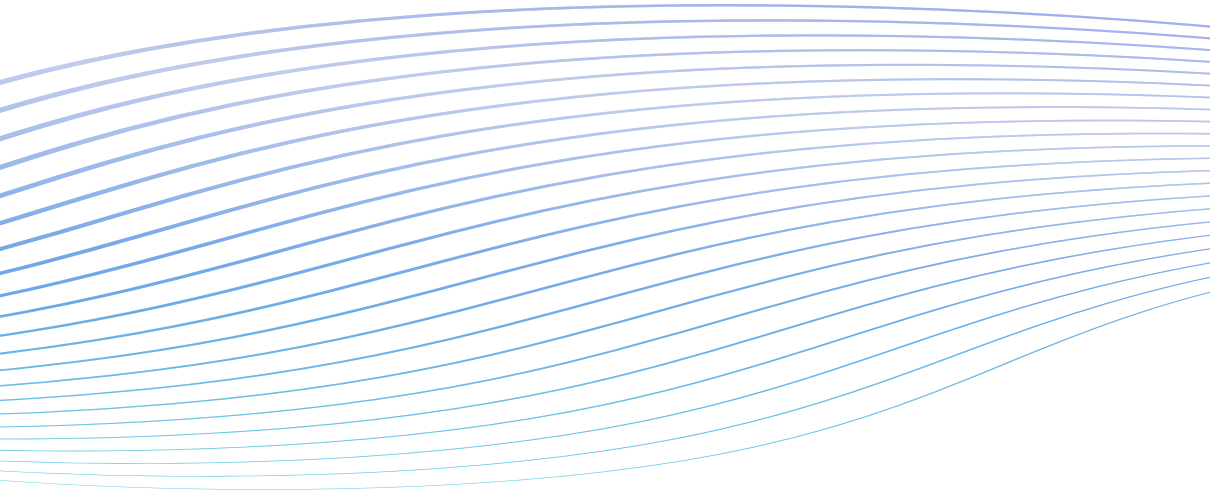
The 28 SNS JU Call 2 projects started in January 2024 or March 2024 in three streams or sub-streams and one CSA.

Stream B

WIRELESS COMMUNICATION TECHNOLOGIES AND SIGNAL PROCESSING

The stream B covers research for revolutionary technology advancements, in preparation for 6G and revolutionary advancements for IoT, devices and software.
The stream targets low to medium Technology Readiness Level in WP2023, with the objective of delivering innovative solutions towards real life networks, in a long-term time-period.
It also includes targeted international cooperation with the USA centred on Artificial Intelligence.

The stream B is broken down into six sub-sections encompassing i)System Architecture (B1, 5 projects), ii)Wireless Communications Technologies and Signal Processing (B2, 6 projects), iii)Communication Infrastructure Technologies and Devices (B3, 4 projects), iv)Reliable Services and Smart Security (B4, 4 projects), v)Microelectronics-based solutions for 6G networks (B5, 3 projects), and vi)the EU-USA 6G R&I Cooperation (B6, 1 project).



Stream B1

SYSTEM ARCHITECTURE

The selected projects demonstrate complementarity and have been selected in such a way as to strengthen the structure of 6G networks for increased robustness, adaptability, and efficiency to cater for the expected extreme 6G use cases and their requirements.

6G-CLOUD

An initiative aimed at developing an AI-driven and cloud-compatible architecture for 6G networks.

OVERVIEW

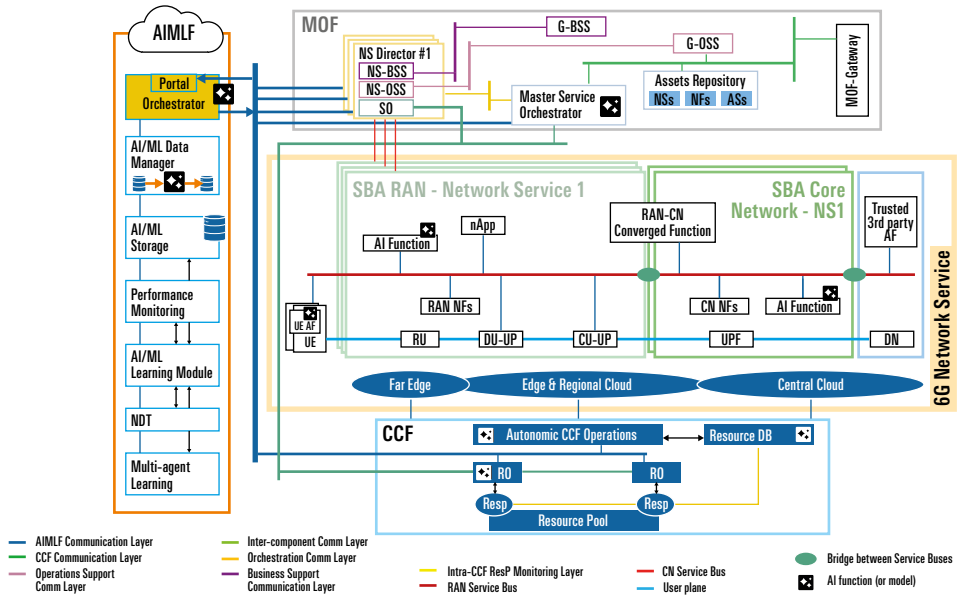
6G-Cloud develops and validates key technologies for an AI-native, cloud-friendly 6G architecture across the cloud continuum, extending 5G with a service-oriented design supported by distributed control and management from extreme edge to central clouds.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The 6G-Cloud architecture adopts a cloud-native, end-to-end service-based approach (SBA) that extends beyond the core (CN) into the radio access network (RAN) and management domains. It unifies network services, management and orchestration (MOF), cloud continuum (CCF), and artificial intelligence/machine learning (AI/ML) through standardised interfaces across the cloud–edge–far-edge continuum.

A dedicated 6G management and orchestration layer separates service lifecycle management from infrastructure optimisation, enabling latency and bandwidth-aware function placement over a unified resource pool. The RAN is implemented as a service-oriented component with disaggregated control and user planes, supporting flexible composition with core functions. Native-AI services enable close loop automation, while dynamic scaling and relocation of functions ensure service level agreements (SLA) compliance across the physical continuum.

6G-Cloud service-based architecture blueprint



INNOVATIONS

6G-Cloud has developed the following key innovations:

- **A comprehensive end-to-end service-based architecture blueprint** for realising cloud-native 6G networks and services across cloud continuum.
- **An AI-driven management and orchestration framework, cloud continuum framework**, together with associated business interfaces, to support flexible and scalable 6G network deployment in multi-stakeholder environments.
- **A service-based AI/ML framework** providing AI-as-a-service for 6G network functions and for the operations of the 6G-Cloud management and orchestration frameworks.
- **Methods, network apps and intelligent algorithms** for network service composition and network exposure across converged service-based 6G RAN and CNs.
- **A Network Digital Twin** supporting AI/ML model training and validation, resource orchestration verification and network performance optimisation.
- **Enablers for a "network of networks" concept** built on a unified cloud infrastructure to support diverse 6G use cases across multiple vertical sectors.

USE CASES/ APPLICATIONS

6G-Cloud targets a broad variety of 6G use cases grouped into Enhanced Human Communication, Enhanced Machine Communication, and New 6G Enabling Services. Within these categories, the project focused on developing several key use cases, including on-demand onboarding of converged RAN-Core networks on the cloud for industry environments, and elastic network resource provisioning for high-density public venues such as stadiums. The project also addressed the deployment of non-public networks using "Network of Networks" concepts to support public protection and disaster relief (PPDR) operations. To validate these applications, the project successfully implemented three proofs-of-concept (PoCs), demonstrating system capability and performance across the cloud continuum.

RESULTS/ IMPACTS

The project has successfully finalised the overall architecture and developed system PoCs, results documented in several public deliverables. The service-based RAN design delivers a control fabric that enables RAN-Core convergence and seamless onboarding of intelligent network applications (nApps). The management and orchestration framework incorporates refined workflows and decentralised mechanisms to manage distributed resources across heterogeneous cloud domains. The proposed AIMLF provides modular pipelines for AI-native automation, supporting intelligent function placement and resource optimisation. These technical achievements are further strengthened by the integration of network digital twins (NDTs) for network performance optimisation providing a solid foundation for truly cloud-native, AI-driven 6G systems.

Service-oriented 6G network architecture for distributed, intelligent, and sustainable cloud-native communication systems

6G CLOUD

Coordinated by Tao Chen, VTT Technical Research Centre of Finland

January 2024 – June 2026

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Verticals: Industry, PPDR, Smart Cities, Transport and logistics.

Partners: VTT, National Centre For Scientific Research "Demokritos", university of Murcia, Warsaw university of Technology, Orange Poland, ATOS Spain, Thales Six GTS France, Lenovo, BubbleRAN, Ubiwhere, Four Dot Infinity.

6G-INTENSE

Shaping the future of 6G with sustainable, AI-powered smart services and advanced network-compute integration.

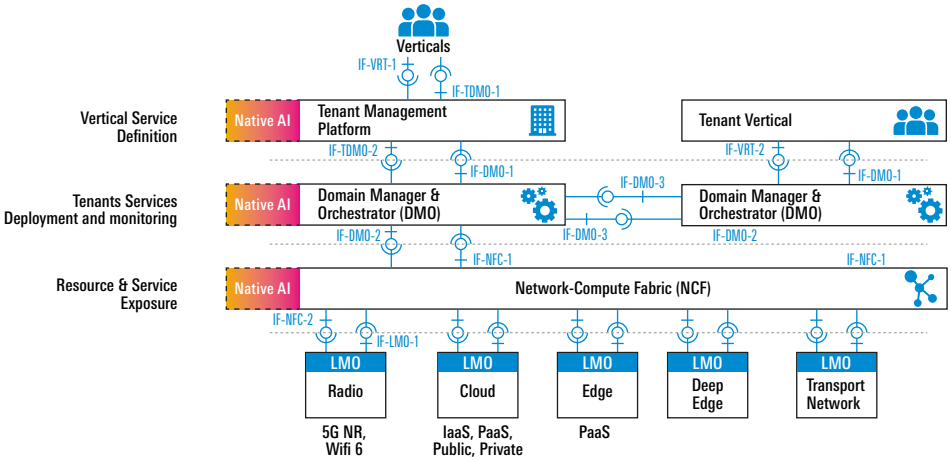
OVERVIEW

The 6G-INTENSE project aims to advance future 6G networks through intent-driven AI and collaborative ecosystems. It develops a distributed management and orchestration plane to reconcile multi-stakeholder intents, an abstraction framework for 6G network-compute fabric, and a scalable software defined wide area network (SD-WAN) compute interconnection to support autonomous service meshes. The project also delivers an AI-native toolkit and a federated AI plane, for privacy-preserving joint communication and sensing at the edge, complemented by strong dissemination, exploitation, and standardisation activities.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The 6G-INTENSE Distributed Intent-driven management and orchestration (DIMO) architecture addresses the complexity of federated, multi-stakeholder 6G infrastructures with a layered, intent-driven, and AI-native design. It comprises three abstraction layers: **tenant domain management and orchestration (t-DMO), domain management and orchestration (DMO), and network compute fabric (NCF)** - separating business, service, and resource management. High-level business intents expressed in natural language, are translated into service intents by the DMO and into resource intents by the NCF. The NCF abstracts heterogeneous radio, cloud, edge, deep edge, and transport resources via local manager and orchestrators (LMOs), enabling dynamic federation and scalability. Native AI, supported by an AI-native toolkit (ANT), large language models (LLMs), Reinforcement learning from human feedback (RLHF), and hierarchical reinforcement learning (HRL), enables autonomous intent translation, assurance, and continuous optimisation, ensuring service level agreement (SLA) compliance and robust operation at internet-scale 6G environments.

6G-INTENSE General Architecture



INNOVATIONS

The project presents a Native AI–based automation architecture, distributed intent-driven management and orchestration (DIMO), enabling intent-driven decision-making across autonomous domains for scalable 6G management. Key innovations include the separation of service and resource management via domain management and orchestration (DMO), network compute fabric (NCF), and local manager and orchestrators (LMOs), enhancing modularity across heterogeneous infrastructures. Advanced sensing boost the reliability of deep edge deployments.

Scalable service delivery is supported by a hierarchical tenant management layer (t-DMO) enabling zero-touch operations. Native AI manages the intent lifecycle through language-based intent handling and closed loops optimisation using reinforcement learning from human feedback (RLHF). The project also advances programmable overlay networking for compute inter-connection (CIC) using SD-WAN, enabling flexible connectivity across distributed compute resources.

USE CASES/ TRIALS/ APPLICATIONS

The 6G-INTENSE project features two proofs-of-concept (PoCs) demonstrating its key innovations. The first, **Distributed Continuum for Pervasive Computing**, validates the abstraction framework through AI model training, and integration with compute and communication platforms. It showcases micro-service orchestration across the network-compute fabric, joint communication and sensing (JCAS) at the deep edge, SD-WAN based interconnection of points of presence, dynamic resource integration, and SLA assurance via intent monitoring and edge intelligence.

The second PoC, **Metaverse**, demonstrates JCAS-based user tracking for location awareness while balancing accuracy and energy efficiency, alongside fully autonomous service management through native AI for intent negotiation and adaptive orchestration based on sensing inputs.

Together, the PoCs evaluate key performance indicators (KPIs) like high throughput, low latency, and reliable distributed orchestration, as well as business KPIs including AI-driven service management, and automated SLA guarantees.

RESULTS/ IMPACT

Key results include the definition and validation of the **DIMO framework** and overall system architecture (*D2.3, D2.5*), the separation of service and resource management through **DMO, NCF, and LMOs** (*D4.1, D4.3*), and the implementation of a **hierarchical tenant management** layer enabling zero-touch service management (*D2.4, D3.2*). The project also advanced **Native AI** capabilities for intent handling and closed-loop optimisation (*D3.1, D3.2*), **SD-WAN–based compute inter-connection** (*D4.1*) and enhanced **deep edge dependability** through sensing (*D4.2*). These results highlight the critical role of 6G in supporting ultra-low latency, reliability, scalability, and integrated compute communication sensing services.

Intent-driven NaTive AI architecturE supporting Network-Compute abstraction and Sensing at the Deep Edge

6G-INTENSE

Coordinated by Coordinated by Christos Verikoukis, ISI/ATH

January 2024 – December 2026

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Partners: ISI/AT, Eurecom, Ericsson, Intracom, Orange Romania, OTE, CNIT, Iquadrat, university of Oulu, eBOS, RealWorldIquadrat, University of Oulu, eBOS, Realworld.

6G-TWIN

AI-based architecture for the upcoming 6G network, focusing on using Network Digital Twins (NDTs) for real-time optimisation.

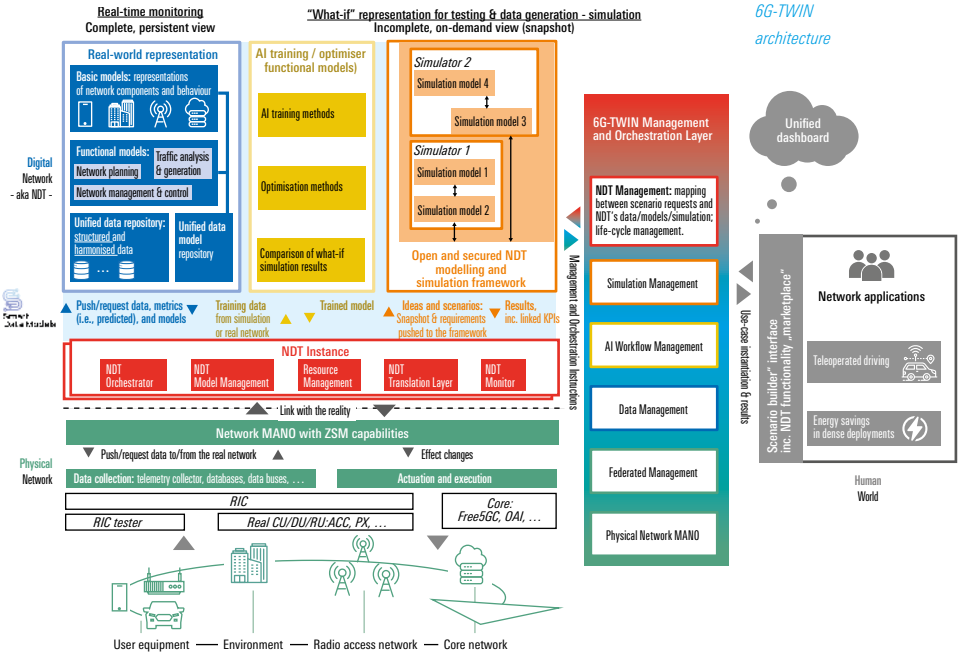
OVERVIEW

As networks become more complex and distributed, 6G – expected around 2030 – demands architectures with built-in intelligence and automation. Network digital twins (NDTs) are emerging as a key enabler - allowing network scenarios to be predicted, tested, and optimised before deployment, while supporting real-time adaptation during operation.

6G-TWIN lays the foundation for an AI-native reference architecture that integrates NDTs as a core mechanism for end-to-end, real-time optimisation, management, and control of highly dynamic network scenarios.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

6G-TWIN develops methods, models, and simulation tools to design and manage multi-layered virtual representations of networked systems across heterogeneous domains (e.g., edge, fog, and cloud) and communication technologies (e.g., cellular, optical, and non-terrestrial). Its functional architecture integrates real-time data collection from the physical network, NDT data and model management, AI training, and an on-demand simulation, all orchestrated by a unified management layer that enables seamless integration, lifecycle management, and closed-loop feedback between real-world operations and simulation insights.



INNOVATIONS

The 6G-TWIN NDT framework introduces a multi-layered architecture that bridges real-world network operations with predictive, simulation-driven decision-making. A key innovation is the formalisation of the NDT concept through a structured, AI-native framework tailored to 6G networks, ensuring clarity, scalability, and scientific rigour. By providing a dynamic and controlled environment for testing and optimisation, this approach accelerates the development of intelligent, scalable, and cost-effective systems, setting a new benchmark for NDT's in 6G and beyond.

USE CASES/ TRIALS/ APPLICATIONS

The project's solutions are being validated through two use cases addressing mobility and energy-efficiency challenges:

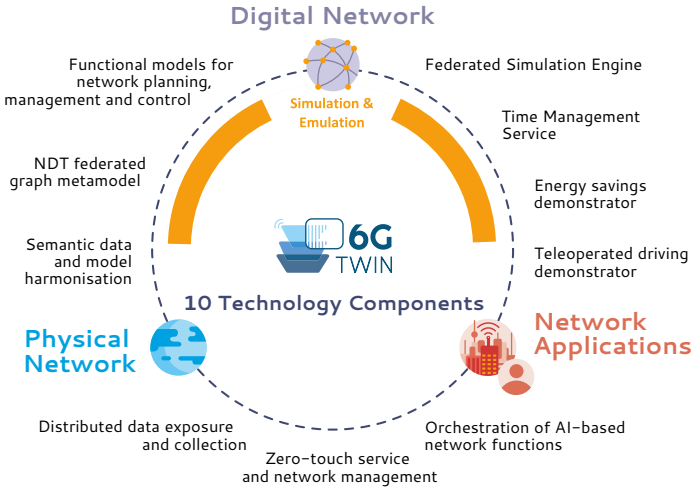
- **Teleoperated driving** where predictive NDTs anticipate network behaviour before departure to ensure end-to-end quality of service and resource availability, and
- **Energy savings** where reactive NDTs optimise network energy efficiency in real time. Both use cases rely on low-technology readiness levels, lab-scale demonstrators and open approaches to maximise impact.

RESULTS/ IMPACT

The project will deliver ten technology components, including an AI-native network reference architecture integrating multiple NDTs - already available on Zenodo and the website, functional models for optimising network performance with AI-driven orchestration, and an open modelling and simulation framework.

By mid-term, 6G-TWIN has made this vision tangible through a solid architecture baseline and nine public deliverables, and initial working prototypes – demonstrating that the technology can be built, connected, and reused beyond the project.

6G-TWIN's technology components



Integrating Network Digital Twinning into Future AI-based 6G Systems

6G TWIN

Coordinated by Sébastien Faye, Luxembourg Institute of Science and Technology (LIST)

January 2024 – December 2026

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Verticals: Automotive, Energy

Partners: LIST, IMEC, Polytechnical university of Bari, Technical university of Dresden, Bourgogne university, Accelleran, Ericsson, Proximus NXT, R2M Solution, Ubiwhere, VIAVI Solutions.

EXIGENCE

Devise & explore a novel approach for energy consumption and carbon footprint reduction of ICT services in the era of next-generation mobile telecommunications (6G).

OVERVIEW

To reduce energy consumption (EC) and carbon emissions (CE) in the 6G era, EXIGENCE adopts an innovative approach based on measuring, analysing, and optimising EC/CE at the ICT service layer. Unlike previous work, this approach actively involves service users into the reduction effort, creating new degrees of freedom: rather than merely reallocating resources to minimise EC/CE within service level agreement constraints, EXIGENCE can dynamically incentivise users to choose specific service variants when this yields systemic EC/CE gains. By raising user awareness and enabling participation – supported by carbon market mechanisms – EXIGENCE bridges technological and socio-economical sustainability. Treating EC/CE as costs and ICT services as utilities, the approach balances both, providing a robust technological and economic foundation for sustainable ICT operations.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The project leverages service-level EC/CE data to enable each domain along the service delivery path – from the end user to every subservice endpoint – to optimise the balance between its energy consumption, associated costs and delivered service quality. To achieve this, EXIGENCE introduced the measure, optimise, incentivise (MOI) concept and adopts the service function chain (SFC) model.

In the developed architecture, each "enabled domain" (i.e., subservice domain, technology or administrative unit) is represented by an agent capable of collecting and exposing EC/CE for each relevant service session. These agents reside within their respective domain, which must provide functions and reference points to supply the agent with energy information - or receive it – related to locally provided or consumed services.

Analysis of typical candidate domains (3GPP, IETF, ETSI) shows that most relevant technology domains already support the necessary functionality. Any novel functionality, such as **green orchestration**, is directly linked to the innovations planned in EXIGENCE. The inter-domain exchange of EC/CE data introduces new standardisation requirements for standard-setting organisations including metrics, data collection and attribution methods, functions, reference points and module/ interfaces.

INNOVATIONS

The latest version of 3GPP TS 22.261 incorporates requirements derived from several use cases introduced by EXIGENCE into 3GPP SA1. Following a new work item initiated by the project within ETSI PDL ISG, multiple GS documents have been produced. In the field of green orchestration, extensions to management and orchestration (MANO) and notably open-source MANO (OSM) are currently being finalised. Additionally, EXIGENCE maintains an active draft in IETF GREEN WG.

USE CASES/ TRIALS/ APPLICATIONS

Developed in 2025, the EXIGENCE prototype demonstrates key architectural components and achieves **TRL-4**. It showcases end-to-end eco-data exchange in a realistic setup, including a 5G non-public network (NPN), transport network and service infrastructure for various service scenarios (single-node, video streaming, distributed AI). The system integrates software energy probes, physical power meters with message queuing telemetry transport (MQTT)-based collection, and real-time energy visualisation. The prototype was demonstrated at EUCNC 2025, IETF 123 (Hackathon), and the **one6G Summit**, where it won the **Best Demo Award.** At EUCNC, EXIGENCE secured one of the 18 demo booths; and was selected as one of only two to be presented live to a **high-level European Commission delegation**.

RESULTS/ IMPACT

In essence, EXIGENCE develops **live eco-labels for ICT services**, domain-specific resource management mechanisms, and supports **user involvement** by defining incentives to reduce energy consumption and CO_2e impacts during service use. The project outcomes aim to verifiably lower EC/CE, particularly in the context of 6G. In 2025, EXIGENCE achieved its formally stated optimisation goals:

- **Factor 3 (or higher) savings in AI model training** through runtime scheduling of AI workflows.
- **Factor 3 savings in video streaming** via carbon-aware service endpoint (variant) selection, supported by user incentives.
- **Factor 5 savings in AI inferencing service provisioning**, which requires strict latency guarantees, by selecting service endpoints (variant) selection by energy/carbon criteria.
- **Zero CO_2 emissions for AI training tasks**, while ensuring fast convergence and improved accuracy, by scheduling AI tasks on computation resources powered by green energy source.

These results have been published in top-tier journals and conferences such as **IEEE TGCN, ACM EEnergy, and TMLR**. In the remaining project period, efforts will focus on further validating the architecture and integrating user incentivisation mechanisms.



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January 2024 – June 2026

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ORIGAMI

ORIGAMI aims at advancing the architectural models of next-generation mobile networks by exploring Global Service-Based Architecture, Zero-Trust Exposure Layer and Compute Continuum Layer.

OVERVIEW

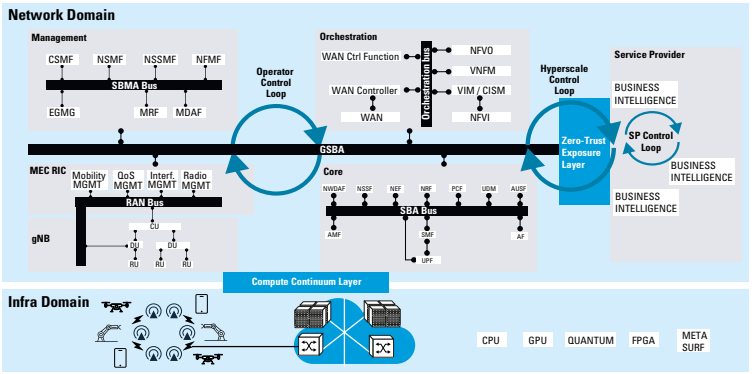
ORIGAMI aims to advance mobile network technology by enhancing 5G architectures to enable 6G. Current 5G models lack support for global operations and limit virtualisation and programmability which could constrain 6G performance. ORIGAMI seeks to develop a cross-plane 6G architecture that removes these barriers, promotes energy-efficient systems, and supports disruptive business models.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

ORIGAMI aims at achieving this goal by designing:

- **Global Service-Based Architecture (GSBA)**: fostering interoperability across data, control, management, orchestration, and Network Intelligence (NI) planes,
- **Zero-Trust exposure Layer (ZTL)**: enabling unprecedented levels of network customisation for verticals, including other mobile network operators,
- **Compute Continuum Layer (CCL)**: providing streamlined control over virtualised functions at very fast timescales.

These enablers advance the network architecture beyond the current 5G SBA. Building on the innovations illustrated in the figure, ORIGAMI develops novel, tangible, verifiable, and measurable NI solutions and digital services demonstrating the feasibility of its vision in realistic use cases.



The ORIGAMI architecture innovations enables next-generation global services and NI functionalities

INNOVATIONS

ORIGAMI aims to collaboratively design and develop innovative network architectural extensions that ensure synergistic operation, address key challenges, and leverage them through specific network intelligence algorithms that exploit newly created closed loops.

The Operator Control Loop extends existing domain-specific control loops, like those in the radio access (RAN) or core network, to achieve a holistic network view. The GSBA unifies these domains, allowing intelligent algorithms to operate under network operator policies. This integration supports operations like global RAN resource orchestration, which standard 5G architectures cannot achieve due to the need for tight interdomain coordination.

Meanwhile, the ZTL introduces the **Hyperscale Control Loop**, enhancing service providers and network operators. This expands network capabilities and enables service customisation, allowing operators to offer diverse services and monetisation models like those of software as a service (SaaS) companies. To realise this vision, various NI functionalities and services will leverage these closed loops, building on ORIGAMI's architectural innovations.

USE CASES/ SCENARIOS

Optimised Resource Integration and Global Architecture for Mobile Infrastructure for 6G

ORIGAMI

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Verticals:ORIGAMI provides horizontal solutions and innovations to all verticals but will realise implementation in the IoT vertical.

Partners: Telefonica ID, NEC Laboratories Europe, Telecom Italia, EMnify, Fogus Innovations & Services, CUMUCORE, ISRD, NET AI TECH, Delt University, Universidad Carlos III de Madrid, IMDEA Networks and i2CAT Foundations, Delt Technical, FIBERCOP.

ORIGAMI considers the following use cases to address technological barriers:

Data-driven task offloading for reliable virtual RAN (vRAN) acceleration. To address Barrier #1 (Unsustainable RAN virtualisation), ORIGAMI proposes a vRAN approach, focusing on resource pooling and opportunistic offloading to the most efficient computing resources.

Enhancing management, stability, and security in the 6G architecture. ORIGAMI employs advanced Machine Learning (ML) models for network management in Open RAN architectures, addressing Barrier #2 (Poor interoperability of RAN components).

Integration of novel compute paradigms and robust NI. ORIGAMI aims to develop a comprehensive NI toolbox for 6G networks, focusing on scalable learning algorithms, hybrid learning approaches, deep learning-based optimisation, and Bayesian and Quantum computing-assisted optimisation to address Barrier #3 (High latency and unreliable NI).

Effective, distributed, and streamlined access to u-plane computing capabilities. Addressing Barrier #4 (Underutilised modern programmable transport), ORIGAMI proposes solutions for integrating ML models into user plane programmable hardware, developing distributed solutions for heterogeneous user planes, and streamlining the development and deployment of user plane intelligence.

Enabling the global operator model. ORIGAMI leverages Distributed Ledger Technology (DLT) to enable dynamic ecosystem partnerships, focusing on real-time billing, automated dispute resolution, trust, and confidentiality. A blockchain-based solution for direct interaction among mobile operators addresses Barriers #5 (Lack of global service APIs) and #6 (Obsolete trust model hinders performance).

Anomaly detection. ORIGAMI integrates real-time anomaly detection functionalities, especially for machine-to-machine platforms, to address Barrier #7 (Inadequate networking data representation).

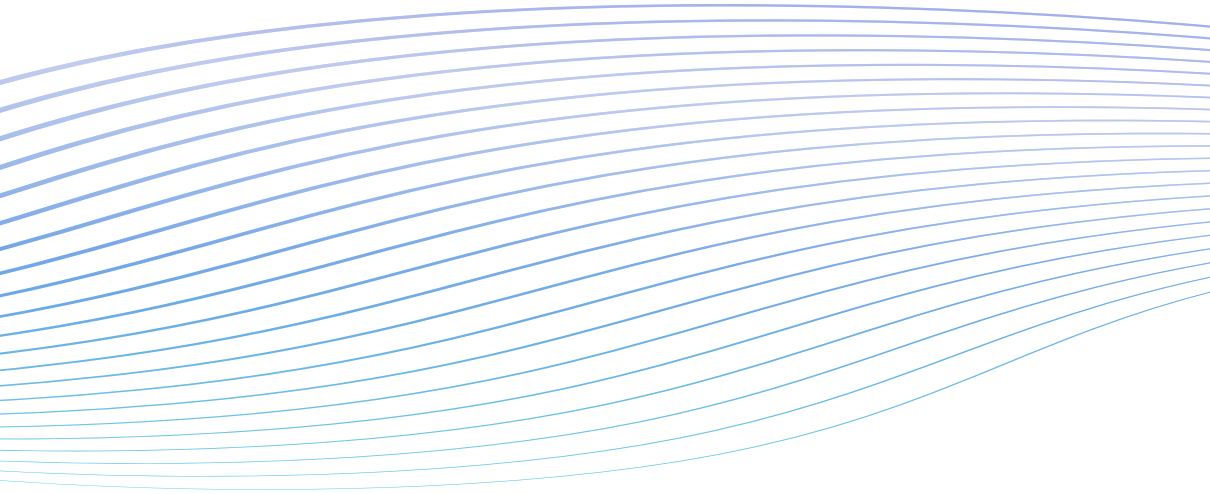
Network Core traffic analysis and optimisation. ORIGAMI reduces Barrier #8 (high volume of control plane signaling) through a service control point-enabled 6G core, using ML techniques for traffic optimisation.

RESULTS

During the first two years, ORIGAMI has already defined and consolidated a **6G-oriented system architecture** built around three core components: the Global Service-Based Architecture (GSBA), the Compute Continuum Layer (CCL), and the Zero-Trust Exposure Layer (ZTL). These components were specified through **23 use cases** addressing eight clearly identified barriers in current mobile networks, each with explicit functional and non-functional requirements and KPI targets. The resulting architectural blueprint extends the 3GPP service-based architecture across network and compute domains, enabling scalable network intelligence, cross-domain resource orchestration, and new trust and exposure mechanisms.

A key achievement is ORIGAMI's **strong and early standardisation impact**. The project has already exceeded its contribution target to **3GPP (SA5), the O-RAN Alliance, and ITU-T,** providing concrete technical inputs on service-based architectures, AI-native network management, interoperability, and zero-trust models for 6G. Use cases were systematically mapped to standardisation gaps, reinforcing their relevance and potential adoption.

In parallel, **9 out of 12 KPIs** were validated and several use cases progressed toward **TRL 4–5**, demonstrating the technical feasibility and maturity of the proposed concepts.



Stream B2

WIRELESS COMMUNICATION TECHNOLOGIES AND SIGNAL PROCESSING

The selected projects explore advances such as novel 6G RAN technologies and integrated communication-sensing paradigms.

6G-DISAC

The 6G-DISAC project is aimed at realising Integrated Sensing and Communication (ISAC), surpassing typical standalone scenarios.

OVERVIEW

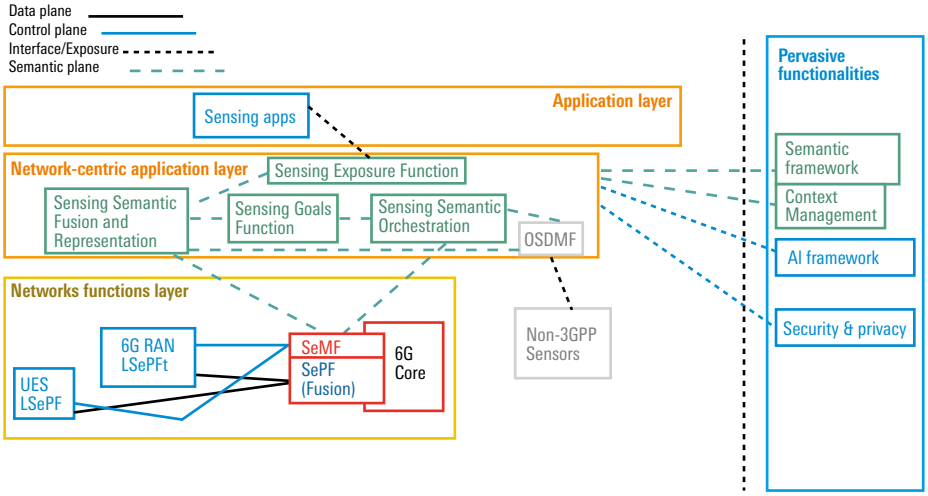
6G-DISAC develops and validates a distributed intelligent sensing and communication (DISAC) approach, enabled by heterogeneous 6G nodes, that cooperatively sense the environment, and a distributed processing combined with adaptative radio sensing and AI/ML-driven orchestration, to deliver context-aware services instead of just connectivity.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The 6G-DISAC framework introduces a distributed architecture that moves intelligence to the network edge, overcoming centralised ISAC limitations. It proposes a layered design: a network functions layer (NFL) for radio/sensing control, a network-centric application layer (NCAL) for semantic intelligence, and a unifying semantic plane with three key functions: semantic sensing orchestration (SSO), translating high-level application requirements into sensing goals; semantic sensing goals (SSG) refining directives and filtering data; and semantic sensing fusion and representation (SSFR), consolidating multi-modal data streams into coherent semantic outputs.

The distributed sensing protocol coordinates heterogeneous nodes, while transmission (STx) nodes send orthogonal probing signals to minimise interference and reception (SRx) nodes capture echoes and act as local sensing processing functions (LSePF), performing edge-based feature extraction, and sending compressed semantic features to the central SePF (CSePF) for fusion, reducing data transmission.

6G-DISAC architecture



INNOVATIONS

6G-DISAC delivered innovations to make distributed ISAC practical and scalable. It optimised adaptive waveform and physical layer-parameters for sensing and localisation, including AI-native cooperative designs leveraging RIS. Receiver-side inference enabled real-time distributed localisation and tracking of passive objects and users, with simultaneous localisation and mapping-oriented processing. Sensing outputs enhanced communications, such as beam management, handover, and full-duplex adaptation while protocols and orchestration coordinated heterogeneous sensing roles, reduced beam-search overhead, and supported learning-based operation.

USE CASES/ TRIALS/ APPLICATIONS

6G-DISAC validates distributed ISAC in mobility and industrial scenarios, providing reliable perception as a network service. Key applications include

- **shop-floor automation**, where automated guided vehicles require low-latency awareness of humans and machinery, and
- **smart intersections**, where vulnerable road users (VRUs) are robustly detected via infrastructure sensors and 6G connectivity.

A flagship trial on infrastructure-assisted parking demonstrates operation in global navigation satellite system-denied operation, multipath-rich, and occluded environments.

The sensor-rich demonstrator (radar, LiDAR, cameras, and optional RIS) connects to an edge-hosted fusion server (figure). The trial has two phases: first, vehicle identification and authentication via an inaudible multitone ultrasound detected by 120 GHz radar; second, distributed perception and guidance, where each node outputs ISO 23150–compliant object lists and the central fusion performs time alignment, association, multi-sensor fusion, parking-slot detection, and generates collective perception message-like guidance via 3GPP/V2X. RIS panels mitigate occlusions by "illuminating" low visibility areas, without extra transmitters.

RESULTS/ IMPACT

To support distributed ISAC, multiple DISAC protocols were defined for heterogeneous devices - including passive targets, connected devices, and autonomous agents - enabling sensing-aided communication, semantic data/model exchange, and distributed learning. Resource allocation balances latency, accuracy, and energy while key outcomes include cooperative sensing, RIS-assisted opportunistic sensing, and federated/over-the-air learning for low-power devices. Dynamic spectrum management across multiple RATs, improves energy efficiency while compromising performance.

6G-DISAC outcomes produced 53 published papers in top journals and conferences, 44 communication actions including keynotes, 34 contribution items to standardisation (3GPP and ETSI ISAC), and 9 patent applications.



6G-DISACTrial

6G for Distributed Intelligent Sensing and Communication

6G DISAC

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6G-GOALS

6G-GOALS marks a leap towards intelligent and goal-oriented communication, integrating AI to revolutionise network design and data transmission.

OVERVIEW

The 6G-GOALS project contributes to the SNS JU program by providing theoretical, numerical and proof-of-concept validations on how **semantic and goal-oriented principles** can be applied to future 6G and beyond networks and services to enhance **efficiency, sustainability, and reliability**.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

To enable scalable and efficient **Semantic Communication (SemCom),** 6G-GOALS introduced an **open radio access network (O-RAN)–enhanced architecture** with semantic-aware entities, interfaces, and protocols for goal-oriented communication in 6G networks.

End-to-end SemCom relies on two key components: the **Semantic Module** and the **Semantic Extractor**, deployed at the user equipment and at the edge or cloud (e.g., multi-access edge computing). The Semantic Module compresses and filters context information exchanging only relevant data, while the Semantic Extractor uses AI techniques, including generative models, to derive high-level semantic representations from raw data.

A Semantic RAN intelligent controller (RIC) guides retransmission and resource decisions based on semantic importance, enabling efficient communication between user equipment and edge applications. O-RAN provides an open and interoperable platform with Near-real time and non-real-time RICs hosting xApps and rApps, while the **Y1 interface** can be extended for semantic configuration, key performance indicators exchange, and feedback, supporting semantic-aware policy enforcement, real-time RAN adaptation, tighter MEC integration, and advanced AI-driven optimisation at the network edge.

INNOVATIONS

The core innovation of 6G-GOALS is a **semantic-aware 6G architecture**, enabling distributed intelligence across the RAN, edge, and core, where communication, computation, and control adapt dynamically to task objectives rather than raw data delivery. The project established **theoretical and practical foundations** for semantic-aware communication, particularly for constrained environments such as robotic control and model delivery. It also developed **resource-aware, and actionable communication protocols** and algorithms laying the groundwork for intelligent, cross-domain orchestration that aligns system behaviour with semantic utility, resource efficiency, and application-level goals. These innovations are validated through proofs-of-concept (PoCs) on software defined radio-based and AI-accelerated platforms, including a flagship demonstration of **semantic-communication-enabled cooperative robotics**, demonstrating feasibility and performance gains under realistic wireless conditions.

USE CASES/ TRIALS/ APPLICATIONS

The project's **semantic-driven and AI/ML-assisted innovations** will be demonstrated through two closely linked demonstrators: an in-lab proofs-of-concept and a real-world field trial.

The **in-lab demonstrator** builds an end-to-end industrial-grade testbed integrating user equipment, Open RAN, core network, and application layers. It enables controlled validation of semantic communication, joint source–channel coding, AI-assisted protocols, and orchestration mechanisms under realistic wireless conditions and industrial workflows such as autonomous navigation, cooperative transport, mapping, and collaborative robotics. It supports interoperability testing, key performance indicator-driven benchmarking, and technology readiness level (TRL)-5 validation.

The **field-trial demonstrator** focuses on semantic communications–enabled cooperative robotics in logistics and warehousing. It involves over 20 multi-sensory, graphics processing unit-enabled robots capable of local semantic processing and ML-based encoding. The network combines a 5G core and semantic-aware Open RAN enhanced with a Semantic State Representation Function (SSRF) and Semantic RIC for semantic-driven policy control, resource orchestration, and quality of service adaptation. A hybrid control architecture balances low-latency local robot decision with centralised semantic coordination, semantic mapping, and task allocation.

Across both demonstrators, **comprehensive KPIs**—including latency, reliability, energy efficiency, semantic relevance, and task performance—quantitatively assess benefits over state-of-the-art solutions. Together, these demonstrations validate the **feasibility, scalability, and real-world impact** of data-efficient, goal-oriented, and intelligent 6G communication systems.

RESULTS/ IMPACT

The project has made significant early progress in **semantic communication, protocol design, and network orchestration**. Key achievements include the development of **semantic-aware communication models** that go beyond raw data transmission by incorporating task relevance, perception, and inference utility, supported by semantic information-theoretic frameworks and learning-based compression techniques. **Semantic and goal-oriented KPIs**, such as value of information and task completion efficiency, enable performance evaluation beyond classical throughput and latency-based metrics.

In parallel, **goal- and time-aware protocol concepts** address semantic alignment, urgency, and causal reasoning to ensure transmitted information is meaningful and actionable. At the theoretical and algorithmic levels, the project advances **semantic information theory** and develops learning-driven semantic representation, compression, and **goal-aware joint source–channel coding**.

Complementing these advances, the project has established the foundations for **AI-native control and orchestration**, including joint multi-domain resource management and the design of a **Semantic Radio Intelligent Controller**, enabling coordinated optimisation of communication, computation, and sensing resources in line with semantic utility and application goals and enabling cross-layer, goal-oriented control of network operations.

6G GoalOriented Ai-Enabled Learning And Semantic Communication Networks

Coordinated by Emilio CalvaneseStrinati, CEA-Leti

January 2024 – December 2026

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Verticals: Automotive, Industry, Energy, Smart cities

Partners: CEA Leti, CNIT, NEC, TOSHIBA, university of Aalborg, Eurecom (EUR), Imperial College London (ICL), TIM, HPE, HPE IT, University of Singapore (SUTD).

6G-MUSICAL

6G-MUSICAL explores innovative approaches for tightly integrating communication and radio-sensing, paving the way for a paradigm shift towards a perceptive network.

OVERVIEW

6G-MUSICAL aims to advance 6G networks by **integrating radio communication with high-precision sensing and localisation**, equipping 6G edge nodes with radar-based sensing and communication components for accurate object detection, tracking, centimetre-level positioning, 3D imaging, and enhanced data throughput and spectral efficiency.

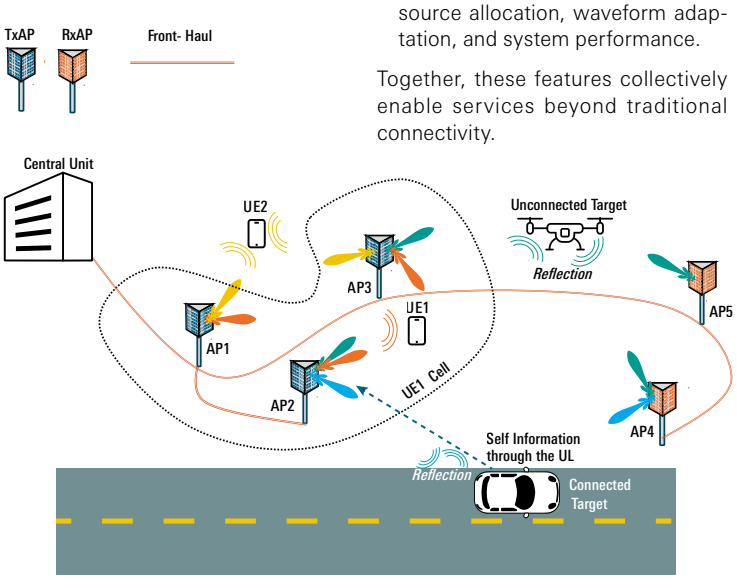
CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

6G-MUSICAL integrates radio communication and radar-based sensing in 6G edge nodes to enable **joint communication and sensing** (JCAS) allowing nodes to transmit data while simultaneously sensing their environment. Multi-node cooperation with precise **optical-electronic synchronisation** enables centimetre-level localisation and 3D imaging of both connected and unconnected objects. Advanced JCAS waveforms, algorithms, and machine learning optimise communication, sensing, and resource use, creating a perceptive 6G network.

Key technologies include:

- **Integrated radio frequency/radar elements**: Transmit data while sensing across multiple frequency bands;
- **Synchronised multi-node cooperation**: Enables high-resolution tracking and localisation;
- **JCAS waveforms and algorithms:** Ensure reliable communication and accurate sensing;
- **Optical and electronic references**: Provide timing and carrier synchronisation for cooperative sensing;
- **Machine learning**: Optimises resource allocation, waveform adaptation, and system performance.

Together, these features collectively enable services beyond traditional connectivity.



6G-MUSICAL Vision

INNOVATIONS

The main innovations of 6G-MUSICAL include:

- **Joint Communication and Sensing** (JCAS): A unified framework supporting both high-rate data transfer and sensing, replacing separate communication and radar systems.
- **Cooperative Multi-node Sensing**: Synchronised multi-node radar enables centimetre-level localisation and 3D imaging of connected and unconnected objects.
- **Optical-Electronic Synchronisation**: Ultra-stable optical references provide reliable timing and frequency across edge nodes for network-wide sensing.
- **AI-Assisted Resource Management**: Intelligent spectral allocation and dynamic waveform adaptation balance communication, sensing, and energy efficiency.

USE CASES/ TRIALS/ APPLICATIONS

6G-MUSICAL targets several application domains where precise situational awareness and high data connectivity are critical:

- **Industry & Logistics**: Cooperative localisation and tracking of assets, robots, and inventory in factories and warehouses with sub-decimetre accuracy.
- **Smart Cities & Transport**: Infrastructure-embedded sensing for traffic monitoring, pedestrian detection, and efficient mobility management.
- **Automotive**: Supporting connected vehicle applications that require integrated communication and high-precision sensing for advanced driver assistance and eventual autonomy.

Laboratory proof-of-concept (PoC) testbeds are underway to validate key technologies including multi-node synchronisation, joint waveforms, and high-resolution 3D imaging. These demonstrations highlight the practical potential of integrated communication and sensing and provide early insights into performance and scalability in controlled environments.

RESULTS/ IMPACT

6G-MUSICAL has developed and validated the foundational architecture for ISAC networks. Initial joint waveforms, cooperative sensing algorithms, and optical-electronic synchronisation methods have been prototyped and tested. Laboratory PoC trials demonstrate high-resolution localisation, object tracking, and 3D imaging capabilities.

These results underscore the need for embedded sensing in 6G: current wireless systems cannot support centimetre-level sensing, environment mapping, or simultaneous communication and sensing at scale.

By merging communication with sensing and localisation, 6G-MUSICAL lays the foundation for perceptive networks that support industrial automation, smart cities, connected transport, and context-aware services, advancing both technology and future 6G standards.

6G-MUltiband Wireless and Optical Signalling for Integrated CommunicAtions, Sensing and Localisation

6G-MUSICAL

Coordinated by Atílio Gameiro, Instituto de Telecomunicações

January 2024 – December 2026

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Verticals: Smart Cities, Industry / Automation, Transport & Logistics

Partners: Instituto de Telecomunicações, University College London, Fraunhofer-IZM, eBOS , University of Oulu, IMEC, Orange Romania, WASEDA University, Menhir Photonics.

6G-SENSES

6G-SENSES proposes Cell-Free Massive MIMO and Integrated Communication and Sensing for advanced 6G connectivity.

OVERVIEW

6G-SENSES is building a next generation wireless infrastructure aiming to both achieve advanced performance towards the International Mobile Telecommunications (IMT) 2030 vision, outperforming key performance indicators (KPIs) of current networks, while progressing research towards fully perceptive networks. The project considers a multi-technology radio access network (RAN) ecosystem integrating sensing technologies within an integrated sensing and communication (ISAC) framework to provide accurate environmental representation and precise user localisation.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

6G-SENSES promotes a novel 6G architecture that integrates sensing and communication services, connecting a multi-technology ISAC-capable RAN to core network (CN) domains via an advanced transport network. Leveraging new physical layer (PHY) technologies, the framework enhances inter-technology cooperation to improve sensing precision. It integrates 6G RAN innovations such as cell-free multiple-input multiple-output (CF-MIMO) and ISAC within the 3GPP and Open RAN (O-RAN) architecture, while reconfigurable intelligent surface (RIS) design, optimisation, and modeling further strengthen communication and sensing. Sensing data will feed the O-RAN framework to enable optimisation and support the creation of digital network twin (NDT).

INNOVATIONS

6G-SENSES introduces several key innovations beyond the state of the art:

- Development of a multi-technology RAN ecosystem for ISAC, including 5G new radio (NR), Wi-Fi, Sub-6 (non-3GPP non-Wi-Fi), mmWave (60 GHz), using orthogonal frequency-division multiplexing (OFDM) and orthogonal time Frequency space (OTFS) modulation.
- Deployment of RIS infrastructures to complement ISAC and CF-MIMO developments.
- Design and fabrication of a scalable mmWave (60 GHz) MIMO front-end for ISAC.
- Integration of such heterogeneous RAN within 3GPP/O-RAN-like frameworks.
- Exploitation of sensing functionalities and distributed antenna schemes for improved communication and energy efficiency.
- Extension of O-RAN radio intelligent controllers (RICs) and control plane intelligence.
- Development of AI/ML models for network management, configuration and optimisation.

USE CASES/ TRIALS/ APPLICATIONS

6G-SENSES is developing three proofs of concept (PoC):

PoC 1: Multi-Technology ISAC Platform: Develops a small-scale end-to-end (E2E) prototype to demonstrate performance gains in a multi-technology ISAC environment. By leveraging multiple wireless access technologies (WATs) as sensing inputs, and integrating real-time RAN and CN extensions, it validates dynamic and intelligent network adaptation.

PoC 2: CF-MIMO Prototype: Enhanced with real-time control, demonstrating distributed signal processing, tight synchronisation, time division duplexing (TDD) reciprocity calibration, and efficient transport network integration.

PoC 3: NDT via RAN sensing: Uses RAN sensing to build up a NDT via telemetry from O-RAN RICs. Sensing data informs network planning assessments and generates datasets for optimisation, with a focus on energy efficiency.

RESULTS/ IMPACT

On the **user plane**: 6G-SENSES evaluates ISAC-enabling technologies to improve 6G communication, leveraging sensing, localisation and tracking across sub-6 and mmWave bands. This includes distributed and scalable signal processing techniques to support efficient CF-MIMO operation, addressing practical challenges such as energy consumption and reciprocity calibration. Evaluations quantify impacts on key performance indicators including positioning and sensing accuracy, delay, and resource utilisation.

On the **control plane**: the project implements a structured assessment to verify the O-RAN RICs compliance with standards, including interface and service model validation, and control-loop latency profiling. Advanced control mechanisms are independently evaluated, such as feedback Service Management and Orchestration (SMO) control enforcing sensing delay and freshness are near real-time applications combining non-3GPP sensing with 3GPP native quality of service (QoS) data.

At the **end-to-end (E2E) level**: AI/ML-driven automation is assessed for orchestrating ISAC services across the network. For example, a Deep Reinforcement Learning (DRL)-based slice orchestration framework is evaluated for balancing energy efficiency with service-level performance for concurrent communication and sensing slices. Additionally, a system-wide techno-economic evaluation framework assesses deployment cost, scalability, and sustainability, complementing technical performance analysis with economic insights.

SEamless integrationN of efficient 6G wirelesS tEechnologies for communication and Sensing

6G SENSES

Coordinated by
Jesús Gutiérrez Terán, IHP– Leibniz Institute for High Performance Microelectronics

January 2024 – June 2026

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Verticals: Industry, Smart Cities

Partners: IHP, Institute of Accelerating Systems and Applications, university of Cantabria, Accelleran, OTE, Sapienza university of Rome, Technical university Braunschweig, BubbleRAN, Barkhausen Institute, Intel Germany, Notthingham Trent university.

INSTINCT

INSTINCT focuses on developing three technological pillars to achieve a more sustainable, interactive, and intelligent 6G connectivity.

OVERVIEW

The INSTINCT project is aimed to enable globally sustainable, interactive, immersive, and intelligent 'beyond communications' 6G connectivity by developing three complementary but critical breakthrough technology pillars:

- "Sense-to-communicate": to improve radio spectrum usage by leveraging sensing information for supporting of 'beyond communications' use cases.
- "Communicate-to-sense": to transform the wireless network into a smart 'sense the world' platform, capable of providing joint communication and sensing (JCAS) as-a-service functionalities towards a wireless radio 'beyond transmitting bits', capable of sensing, detecting, mapping, and 'understanding' semantics.
- Multi-functional JCAS Network Intelligence: to optimise the architecture, resources, propagation and waveforms aided by AI for wireless JCAS systems.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

INSTINCT aspires to deliver the theoretical framework and relevant key performance indicators (KPIs), waveforms, protocols and hardware design of an innovative beyond communications 6G architecture, which combines the benefits of sensing-assisted communications, communications-assisted Sensing and the co-design of sensing and communications, leveraging Reconfigurable Intelligent Surfaces (RIS) and artificial intelligence/ machine learning (AI/ML). INSTINCT, by means of its 3 pillars is establishing the foundations along with the enablers as well as new architectures and, thus, offer the cornerstones of a new information communications and sensing technologies era, where IoT meets ICT.

INNOVATIONS

INSTINCT adopts an interdisciplinary approach built around a 3-phase methodology theoretical studies, ecosystem development, demonstration with key performance indicator (KPI) evaluation. This approach produces multiple hardware and software demonstrators enabling interactive, immersive and intelligent connectivity across three 6G use cases.

The relevance and impact of INSTINCT stem from its direct alignment with 6G technologies and recent regulatory and standardisation developments, addressing key gaps identified in prior EC-funded research, particularly under the SNS JU call 1 framework.

USE CASES/ TRIALS/ APPLICATIONS

INSTINCT use cases are grouped in three general categories: sensing-aided connectivity, sensing-able connectivity and multifunctional JCAS intelligence. For their simulation-based evaluation, existing deterministic and statistical channel models will be enhanced with a focus on integrating of reconfigurable intelligent surface (RIS) models and JCAS performance metrics. These enhancements will enable the quantification of achievable performance and provide benchmark the final demonstrations.

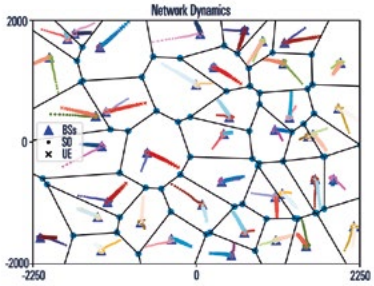
RESULTS/ IMPACT

The main results are highlighted below:

- **Hardware demonstrator I - JCAS in a sub-6GHz network infrastructure**: Two complementary hardware platforms, CortexLab and HermesPy were successfully established to demonstrate JCAS in sub-6GHz networks. An image of the FR1 RIS setup in Cortex Lab is shown below (left).
- **Hardware demonstrator II - RIS-aided JCAS using mmWave link (28 GHz)**: AI-driven opportunistic JCAS was implemented using RIS to infer user positions from RIS configurations.
- **Hardware demonstrator III - UAV-supported 5G&GNSS Fusion-based Localisation Framework**: A two-stage demonstrator for unmanned aerial vehicles-based search and rescue operations including AI-based optimisation of 5G and global navigation satellite system for robust localisation.
- **Software simulation platform**: An AI-based coverage map prediction tool was developed at TID using graph neural networks. A snapshot of stochastic geometry simulator, which evaluates JCAS performance in large networks considering base stations, sensed objects and user equipment is shown below (right).

Hardware demonstrator I (left) and Software Demonstrator (right)





At EUCNC 2025, INSTINCT partners contributed to 5 workshops, several special sessions and papers along with a booth with multiple hardware and software demonstrators.

Instinct partners in EUCNC 2



Joint Sensing and Communications for Future Interactive, Immersive, and Intelligent Connectivity Beyond Communications

INSTINCT

Coordinated by Padmanava Sen, Barkhausen Institute

January 2024 – December 2026

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Verticals: Wireless Communication Technologies and Signal Processing, Joint communication and sensing

Partners: Barkhausen Institute, university of Piraeus - Research Center, Bosch, Aalto university, Fraunhofer HHI, Greenerwave, NEC Laboratories Europe, Institut National de Recherche en Informatique et Automatique, Institut National des Sciences Appliquées de Lyon, i2CAT foundation, Oulu university, Centralesupelec, Telefónica ID, Telefónica.

iSEE-6G

iSEE-6G aims to integrate Communications, Computation, Sensing, and Power Transfer into a unified 6G RAN framework.

OVERVIEW

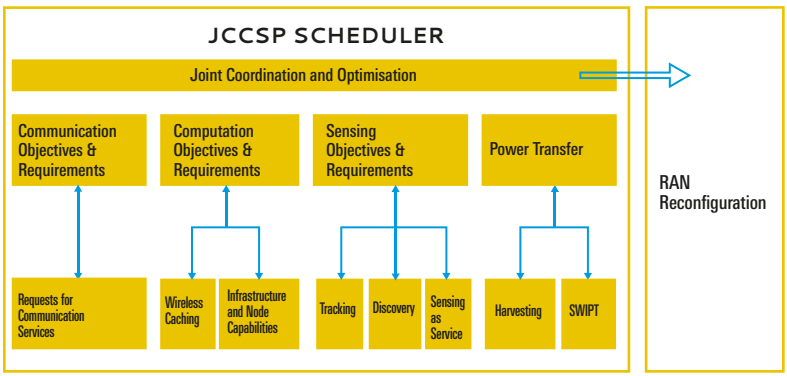
Joint resp. Integrated Communication and Sensing (JCAS resp. ICAS) is set to transform wireless systems and Radio Access Networks (RANs). iSEE-6G extends this with a unified joint communication, computation, sensing, and power transfer (JCCSP) radio platform using 6G technologies. Its framework features reconfigurable antennas surfaces, a JCCSP-optimised physical layer aligned with Open RAN, cross-layer service-oriented design, and system-level solutions for cell-free 6G networks. Proof-of-concept studies explore JCCSP in unmanned aerial corridors and vehicular scenarios, leveraging edge computing for enhanced positioning and mapping in Public Protection and Disaster Relief (PPDR) scenarios.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

iSEE-6G integrates **Communications, Computation** (RAN disaggregation and edge offloading for intensive functions), **Sensing** (object and motion detection via radio), and wireless **power transfer** into a unified 6G JCCSP RAN framework, focusing on:

- Radio channel evaluation.
- Intelligent surface and antenna array design.
- Waveform and transmission optimisation.
- Network sensing and beamforming for the cell-free 6G.
- Cross-layer designs, multiple access techniques for JCCSP. and stochastic geometry-based system-level performance analysis.
- AI application for modelling, optimisation, and decision-making.
- New service components for edge-based positioning and topology management.
- An intelligent unit to coordinate the operation of the system model and the components, the JCCSP scheduler.

JSCCP Scheduler



Integrated SEnsing, Energy and communication for 6G networks

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Verticals: agriculture, automotive, smart-city, drone OEMs, health, telecommunication, industrial automation, PPDR

Partners: IMST, university of Piraeus Research Center, technical university Berlin, Airbus DS, IMEC, KU Leuven, WINGS ICT, university of Cyprus, Orange Romania, Agricloud, NVIDIA, DirekOrange Romania, Agricloud, NVIDIA, Direk.

INNOVATIONS

iSEE-6G introduces a groundbreaking framework for JCCSP, extending traditional ISAC capabilities by:

- Proposing novel physical layer designs, including optimised waveforms, and intelligent beamforming techniques.
- Performing advanced channel modelling tailored to ISAC channel particularities.
- Integrating and developing innovative antenna systems for ISAC operation and aerial applications.
- Integrating cutting-edge technologies - reconfigurable intelligent surfaces, mmWave and multi-band communication, and full-duplex operation - for JCCSP.
- Introducing AI and learning for the multi-functional physical layer.
- Exploring emerging services of JCCSP for PPDR applications.

iSEE-6G focuses on Unmanned Aerial Vehicular (UAV) applications, enabling energy-efficient wireless power transfer, enhanced sensing, and secure communications, while using machine learning for dynamic network optimisation and supporting multi-band operations for seamless service across diverse environments.

USE CASES/ SCENARIOS

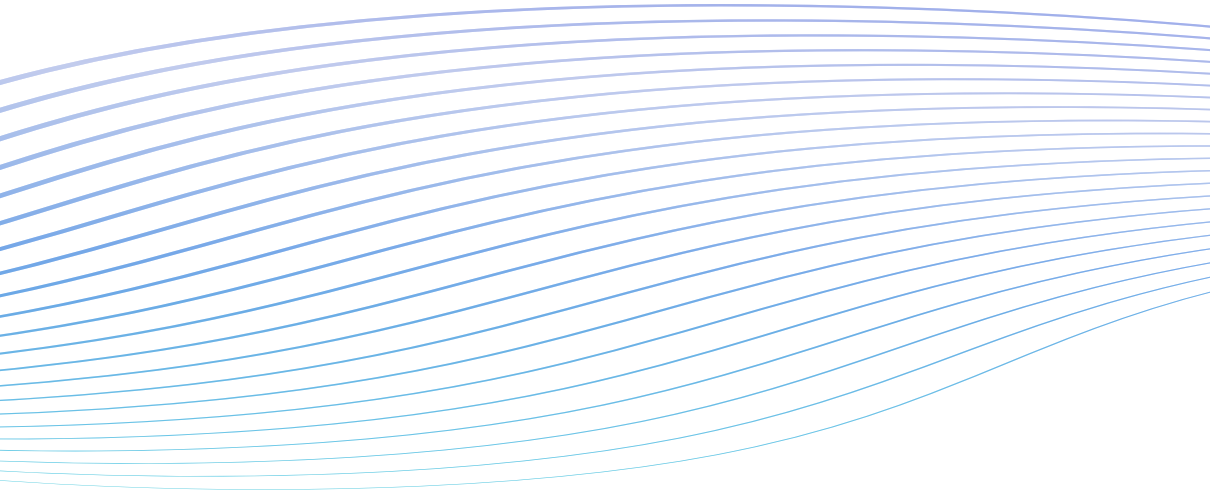
iSEE-6G investigates six use cases of JCCSP enhancing the system's efficiency and performance:

- **JCS in a 6G Cell-free environment**: Demonstrates the applicability of network Multiple Input Multiple Output (MIMO) and highlights the practical advantages of the ORAN architecture through seamless integration of sensing and communications frameworks.
- **UAV corridors management**: Coordinates UAVs with various networking and functional roles.
- **Safety enhancement**: Combines 6G JCCSP capabilities with UAV versatility to enable proactive safety measures.
- **Agricultural industrial IoT**: Uses UAVs for environmental sensing, and precision interventions, boosting agricultural productivity, resource efficiency, and sustainability.
- **Connected and cooperative autonomous mobility**: UAVs with advanced sensing and B5G/6G communications enhance coordination and collaboration among autonomous vehicles.
- **Energy harvesting**: UAVs serving as radio frequency signal sources enable sustainable operation of Internet of Everything networks and introduce new possibilities for wireless power transfer.

RESULTS

The expected JCCSP outcomes of iSEE-6G include:

- 6G-enabled use case scenarios with aerial corridors.
- Channel measurements and modelling for aerial systems and ISAC.
- Novel waveform designs, multiple-access schemes and physical layer framing.
- Hybrid beamforming schemes optimising achievable Degrees of Freedom.
- Deep neural network-supported beamforming for JCCSP.
- Wireless edge caching techniques for JCCSP-enabled 6G networks.
- Multi-access edge computing for enhanced positioning and mapping.
- AI-enabled collaborative positioning algorithms integrating European Global Navigation System fusion supporting PPDR operations.
- mmWave beam-scanning antenna arrays and RIS prototypes for UAV and terrestrial radio units.
- Proof-of-concept demonstration testbeds.



Stream B3

COMMUNICATION INFRASTRUCTURE TECHNOLOGIES AND DEVICES

The projects have been selected to fortify and expand the physical and virtual infrastructure to support 6G technologies, e.g. on optical and wireless.

6G-EWOC

6G-EWOC focuses on advancing 6G for autonomous driving, improving road safety and efficiency.

OVERVIEW

6G-EWOC envisions open, shared, safer mobility powered by 6G. Its mission is to support autonomous and connected driving by providing real-time, high-quality data to all road users – vehicles, pedestrians and infrastructure – enhancing collective perception and safety. 6G-EWOC aims to connect vehicles and road users via high-speed, low-latency optical wireless and fibre links, democratise situational awareness, regardless of individual sensor capabilities, enable real-time data fusion and decision-making through edge computing and AI, support safe, efficient and responsive mobility, even in complex urban environments.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

6G-EWOC's multi-layered architecture combines optical communications, sensing and AI to support connected and automated driving, sharing real-time information with all traffic participants. Optical Wireless Communication (OWC) provides up to 10 Gb/s access for sensor-to-user data exchange while 100 Gb/s low-latency coherent fibre fronthaul connects to near- and far-edge datacenters for real-time data fusion. AI-driven software-defined networking (SDN) ensures efficient resource provisioning across the system.

INNOVATIONS

Key innovations include: **(i) Optical wireless for Gb/s-grade access** to roadside users via compact beamformers and free-space optical links, extending fibre capacity over Fi-Wi-Fi bridges where fibre is not available. Vehicular lighting is also leveraged for visible light communication (VLC), supporting broadband vehicle-to-vehicle data exchange; **(ii) Connected LiDAR/RaDAR** systems, using simplified laser and radio detection, capture high-resolution scenery data and enable instantaneous information sharing; **(iii) High-capacity fronthaul** delivers 100 Gb/s connectivity between remote radio heads and edge processing nodes using low-complexity quasi-coherent fibre-optic transceivers and optical switches built on photonic integrated circuit (PIC) technology; **(iv) AI-driven SDN orchestration** enables efficient programmability, rapid service provisioning and improved energy efficiency; **(v) AI-powered sensor application** leverage 6G-enabled crowd-sourced data fusion for accurate simultaneous localisation and mapping, supporting informed decision-making for safe and efficient autonomous driving.

USE CASES/ TRIALS/ APPLICATIONS

The migration to advanced mobile and road infrastructure networks with enhanced performance and reliability enables fully autonomous vehicles equipped with collective perception capabilities. 6G-EWOC addresses key road transportation use cases: **(i) Safety**: ensuring seamless, collision-free navigation through complex or busy intersections, even in the presence of vehicles with varying autonomy levels, vulnerable road users (pedestrians, cyclists or e-scooters) and dynamic obstacles. 6G provides participants

with a comprehensive understanding of their surroundings, including the ability to see through obstructions, capture hidden objects, predict trajectories and process data near the event to enable realistic digital-twin representations; **(ii) Transportation efficiency**: optimising of roadside traffic flows by leveraging collective perception to steer or influence vehicle movements in smart city environments. This reduces congestion, travel times and CO_2 emissions, improving citizens' quality of life. AI-driven information processing at the city-level supports coordinated regional traffic management and large-scale rerouting to minimise delays; **(iii) Emergency response**: prioritising routes for emergency vehicles to ensure the fastest possible arrival at their destination, even across multiple busy intersections.

RESULTS/ IMPACT

6G-EWOC has successfully demonstrated both wireless and wired communication modes in access and fronthaul scenarios. Its OWC segment achieved outdoor demonstrations featuring optical beamforming and turbulence mitigation in free-space optical Fi-Wi-Fi bridges delivering 10 Gb/s per wavelength via simplified optical remote radio heads, real-time LiDAR point-cloud transmission over 100 m through vehicular lighting, and hybrid RF/OWC schemes resilient to severe weather. Traditional LiDAR and RaDAR technologies were enhanced with communication capabilities to enable joint communication and sensing for connected mobility.

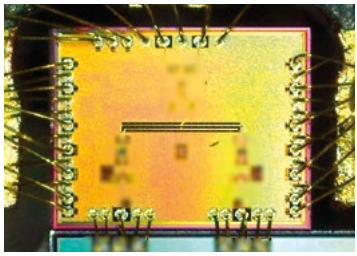
The project advanced its fronthaul by testing first-generation 50 Gb/s quasi-coherent application-specific integrated circuit (ASIC), while progress in III-V/silicon PIC manufacturing supports fully integrated receivers. Initial prototypes of a 16x16 thin-film Lithium-Niobate switch were produced, with ongoing verification of the SDN-enabled time-slotted operation achieving sub-microsecond reconfiguration.

AI-driven network orchestration is being pioneered through a disaggregated SDN control system, already demonstrating sub-10s service provisioning and targeting a 50% reduction in energy consumption via deep reinforcement learning. These advancements underpin the cooperative perception framework, where sensor-fusion algorithms for autonomous vehicles surpass current benchmarks in object detection accuracy.

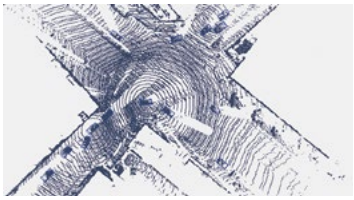
By combining intelligent resource management with vehicular connectivity, 6G-EWOC validates the feasibility of autonomous, energy-efficient 6G ecosystems. The final testbed will include a fully operational 5G distributed network supported by optical links connecting the sites at UPC (Barcelona) and CTTC (Castelldefels), and connectivity with the OTE Labs (Athens).



(a) Connected LiDAR prototype



(b) fronthaul receiver ASIC



(c) LiDAR data fusion.

AI-Enhanced Fibre-Wireless Optical 6G Network in Support for Connected Mobility

Coordinated by José Antonio Lázaro, Polytechnical University of Catalunya

January 2024 – December 2026

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Verticals: Automotive: Connected car – V2X and Autonomous driving, Smart Cities: People mobility, Transport and logistics: Efficient mobility of people and goods

Partners: Univertitat Politechnica de Cataluyna BarcelonaTech, CTTC, AIT Austrian Institute of Technology, III-V Lab, Ligentec, Beamagine, Bifrost Communications, Nokia Bell Labs, Nvidia, Magna, Cosmote.

ECO-eNET

The ECO-eNET project pioneers in 6G transmission technologies, merging optical and radio transport for an efficient edge network.

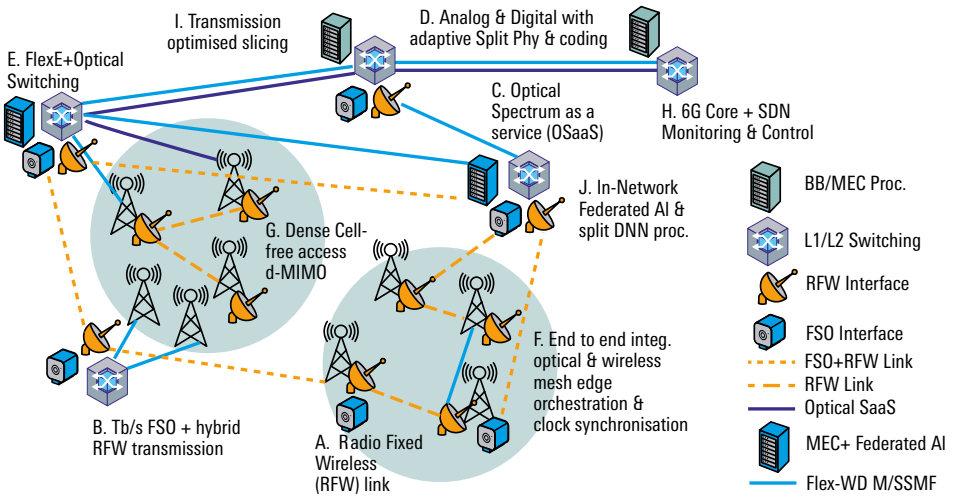
OVERVIEW

The ECO-eNET project aims to establish confluent networking as a scalable, efficient platform for 6G, by integrating optical and wireless transmission technologies with advanced orchestration and control. Its goal is to deliver high-capacity, ultra-energy-efficient, and low-latency mesh networking at the edge, managed by AI-enhanced orchestration across mobile, confluent, and compute domains.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

ECO-eNET's confluent networking integrates radio fixed wireless, free space optical (FSO), and flex-grid DWDM fibre optics for xhaul networks, with a focus on mesh networking. The project aims to develop a confluent mesh edge network interoperating with RAN structures - Cell free / distributed MIMO (CF/D MIMO), O-RAN - to meet 6G requirements for reliability, peak data rate, and low latency. Its layered architecture advances infrastructure, control, sensing, and management by combining fibre, optical wireless, and radio fixed wireless. Beyond simple convergence, AI-driven orchestration enables flexible operation, forming a scalable 6G platform. This "network confluence" lies at the heart of ECO-eNET's vision.

Confluent mesh networking including ten technologies investigated in ECO-eNET



INNOVATIONS

ECO-eNET has made significant strides in establishing confluent networking as a new paradigm for 6G. Key advances include plasmonic sub-THz components, photonic adaptive optics for free space optical (FSO) links, and fibre sensing. Converged xhaul transmission was validated on the HEAnet production network, demonstrating the coexistence of mmWave, sub-THz and coherent optical signals. The project also delivered a unified control and monitoring framework spanning RAN, core, and transport domains, AI-enhanced orchestration for slice provisioning, and initial results on federated AI orchestration.

USE CASES/ TRIALS/ APPLICATIONS

ECO-eNET use cases cover various service provisioning roles, stakeholders, and envisioned vertical services:

- **UC1: Optical Network for hyper reliable low latency communications (HRLLC) Scenarios** focuses on a confluent network in the 6G transport segment, leveraging sensing technologies to predict malfunctions, outages, and intrusions in fibre optical networks. Trials will emulate transport network conditions and assess the network's response.
- **UC2: Wireless Transport Network for High Capacity & HRLLC** explores extended confluent solutions using sub-THz and FSO bands for high-capacity, low-latency networks. It integrates transport communication and sensing to detect link failures and enables confluent mesh networking for enhanced reliability via an intelligent management plane. Trials will evaluate complex transport network deployments.
- **UC3: CF/D-MIMO Structures for IC and HRLLC** integrates CF/D-MIMO RAN structures into the ECO-eNET mesh transport network, enhancing scalability and flexibility. This supports "Seamless Immersive Reality" and "Ubiquitous and Resilient Networks." Trials will assess 6G technologies in an E2E deployment.
- **UC4: AI-Optimised Confluent Mesh for Energy and Latency** develops AI/ML algorithms to optimise energy efficiency and minimise latency in 6G x-haul networks, balancing energy efficiency, computational overhead, and prediction accuracy for ISAC services. Trials will assess the intelligence of the complete ECO-eNET solution.

RESULTS/ IMPACT

ECO-eNET has made substantial progress across its objectives. In transmission technologies, plasmonic sub-THz links have been designed to reach 1 Tbps over 1 km with energy consumption below 40 picojoules per bit. Simulations confirmed feasibility with a signal-to-noise ratio of around 20 dB. Optical wireless links advanced through adaptive optics based on photonic lanterns and integrated photonic circuits, with first prototypes fabricated. Fibre sensing was implemented via telemetry-as-a-service platform, achieving an F1 score of approximately 93% in anomaly detection. Confluent xhaul experiments demonstrated coexistence of multi-gigabit radio-over-fibre signals and 400 Gb coherent optical channels in metro and passive optical networks, validated in a live trial on the HEAnet production network.

On the orchestration side, a unified monitoring framework spans RAN, core and transport domains, integrating energy and performance metrics via open-source tools such as Prometheus and Grafana. AI-based orchestration methods were developed for integrated access and backhaul networks, centralised RANs and optical fronthaul switching, with initial results published. Preliminary work on federated AI orchestration explored balancing computation between edge and central cloud and applied neural architectures inspired by natural language processing to optical quality-of-transmission estimation.

Efficient COnfluent Edge NETworks

ECO eNET

Coordinated by Paolo Monti, Chalmers University of Technology

January 2024 – December 2026

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Partners: Chalmers University of Technology, Trinity College Dublin, Institute of Accelerating Systems and Applications, OTE, Accelleran, mBryonics, Tallinn university of technology, Adtran Networks, ETH Zürich, Polariton Technologies, university of Bristol.

OPTI-6G

OPTI-6G's ambition is to design, develop and exhibit the operation of a radio optical 6G.

OVERVIEW

A Private 5G Network is designed for deployment in dedicated areas and supports high performance ultra reliable low latency communication (URLLC) applications. In OPTI-6G the private network architecture integrates the Sparq-2025- network in a box (NIB) and open RAN radio unit (ORU), operating in 3.5GHz/mmWave bands and enhanced by replacing the radio interfaces with infrared optical wireless communication. The network supports the ORAN split PHY architecture option 7.2 category B with a standard O-RAN Interface between the ORU and the NIB. The NIB integrates all core 5G network components, including the O-RAN distributed unit (O-DU), central unit (CU), next generation (NG) core and multi-access edge computing (MEC), spanning functionality from high PHY (OSI layer-1) to the application layer (OSI Layer-7). This architecture enables evaluation of cell-free 5G operation in the optical domain, as an alternative to conventional microwave-based systems at 3.5GHz (n78).

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The OPTI-6G architecture is a hybrid system integrating a 5G O-RAN with an optical wireless communication (OWC) layer under a novel cell-free paradigm. The figure below illustrates the generalised block diagram, comprising the NIB, radio units, radio frequency (RF)-to-optical transducers, optical transmitters and receivers and commercial 5G user equipments.

OWC network block diagram

The system is designed to provide ultra-reliable, high-speed, and seamless connectivity, alongside precise localisation, for demanding industrial applications such as autonomous guided vehicles (AGVs) in complex indoor environments.

This interface supports cell-free operation, allowing a single UE to be served simultaneously by multiple RUs over OWC links. By eliminating hard cell boundaries and handovers, the system improves reliability, reduces latency, and enhances spectral efficiency, with intelligent signal combining at the DU ensures seamless and robust connectivity.



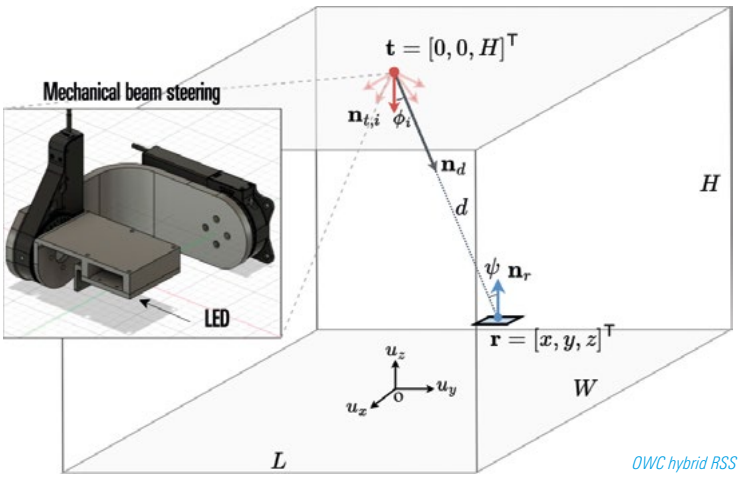
Development and Testing Process

INNOVATIONS

Beyond high-speed communication, OPTI-6G introduces highly precise localisation capabilities, essential for applications such as AGV navigation. This is achieved by exploiting received signal strength (RSS) measurements directly within the OWC system.

A dedicated power detector at the UE's OWC receiver enables accurate optical signal power measurements, which are collected from multiple RUs and processed (e.g., via trilateration) to estimate the UE's position.

Furthermore, a novel hybrid OWC positioning method combining RSS and angle-of-arrival (AoA) beamsteering has been developed. By dynamically steering a Lambertian optical source in successive directions, multiple virtual source positions are created, enabling accurate localisation using conventional RSS techniques. While currently implemented using a hardware Gimbal, this approach can be extended to solid-state beam steering technologies.



OWC hybrid RSS and AoA beamsteering-based positioning

USE CASES/ TRIALS/ APPLICATIONS

The time-difference of arrival (TDoA) positioning method was tested in the sub-6 GHz domain achieving 4-7 cm accuracy in central labs areas. Tests will be repeated with optical RUs to integrate an optical TDoA system into the final OPTI-6G demonstrator, alongside the RSS and hybrid RSS and AoA-based positioning.

RESULTS/ IMPACT

The first experimental results from the proposed beamsteering-based positioning system has been shown a global root mean square error (RMSE) of 2.66 cm, an average positioning error of 2.35 cm, and a 90th percentile error of 4.32 cm.

OPTI-6G

Optic 6G Cell-Free Networks (OPTI-6G)

Coordinated by Adam Kapovits, Eurescom

January 2024 – December 2026

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Zenodon: https://zenodo.org/communities/opti-6g/

Verticals: Industry 4.0

Partners: Eurescom, BRUNEL University of London, université de Versailles Saint-Quentin-en-Yvelines, RunEL NGMT, Oledcomm.

PROTEUS-6G

PROTEUS-6G aims to design and develop a dynamic, flexible, scalable, cost-effective, high-bandwidth, and low latency packet-optical fronthaul and midhaul for 6G networks.

OVERVIEW

Future 6G applications will demand higher data rates, ultra-low latency, greater flexibility, improved energy efficiency, and AI-enabled resource management. PROTEUS-6G addresses these needs with a novel optical transport network design.

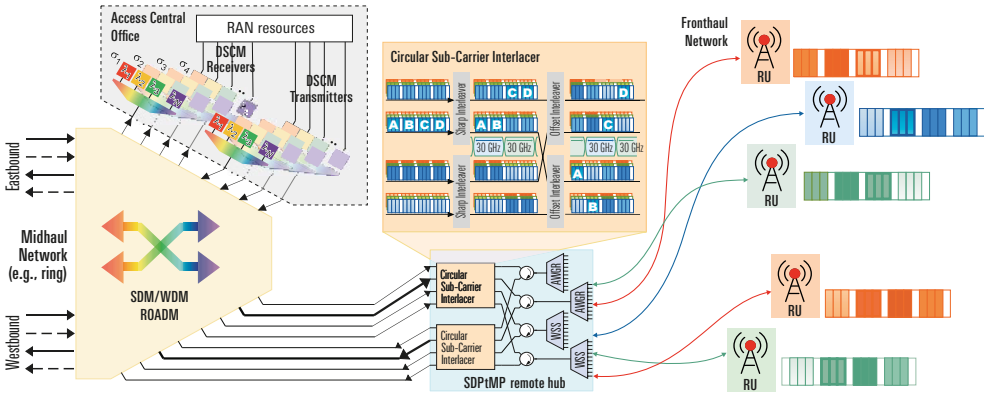
Its architecture connects each cell site via fibre-connected to a central distribution point, allocating capacity at the subcarrier level based on real-time demand. Traffic can be dynamically reassigned across signal paths, to improve efficiency and reduce energy use.

Adapting data-centre traffic management to access and mobile networks, PROTEUS-6G uses lossless photonic integrated circuit (PIC)-based techniques for subcarriers allocation and supports disaggregated topologies with multiple feeds while maintaining lossless operation.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

PROTEUS-6G deploys an optical interconnectivity architecture for dynamic traffic, linking each cell site via fibre to a central hub. Capacity is allocated at the subcarrier level and traffic dynamically reassigned to optimise efficiency and reduce energy use.

Adapting datacenter traffic management to access and mobile networks. It uses lossless PIC-based techniques for subcarrier distribution and supports disaggregated topologies with multiple network feeds, while maintaining lossless operation.



PROTEUS-6G Front/Mid-haul Node Architecture for routing flexibly subcarriers to cell sites via low loss photonic filter.

INNOVATIONS

A key innovation of PROTEUS-6G is the development of energy-efficient optical transmitters and receivers that process signals directly in the optical domain, avoiding complex and power-hungry electronic processing. This approach significantly increases both capacity and energy efficiency.

By using orthogonal polarisation states of light in a standard single-mode fibre, a single optical channel can carry two independent data streams, effectively doubling capacity. This enables data rates of up to 800 Gb/s per channel and over 6 Tb/s per fibre when multiple channels are combined. Advanced receivers correct for distortion and delay, ensuring reliable performance at these very high data rates.

USE CASES/ TRIALS/ APPLICATIONS

The PROTEUS-6G solution is designed to support future 6G services demanding ultra-high throughput, flexible bandwidth allocation, and low latency. It can be applied across access, front- and mid-haul networks, enabling efficient handling of dynamic mobile traffic by using a reconfigurable low-loss optical filter.

RESULTS/ IMPACT

PROTEUS-6G has developed the PICs and the assemblies for the sub-systems of the transmitter, receiver and the optical filter. A first component analysis is published at the Journal of Optical Communication and Networking about the operation of the optical filter.

PROTEUS-6G also introduces a unified control system that integrates packet and optical management within a single framework. At this framework, algorithms implemented at the 5G-LENA about the implementation of the Flexible Functional Splits can be integrated enabling real dynamic routing based on the traffic of the wireless side.

By combining advanced hardware, optimised optical routing, and integrated control, PROTEUS-6G provides a flexible, reconfigurable, and energy-efficient transport foundation for future 6G networks.

Programmable Reconfigurable Optical Transport for Efficiently offering Unconstrained Services in 6G

PROTEUS 6G

Coordinated by Ioannis Tomkos, University of Patras

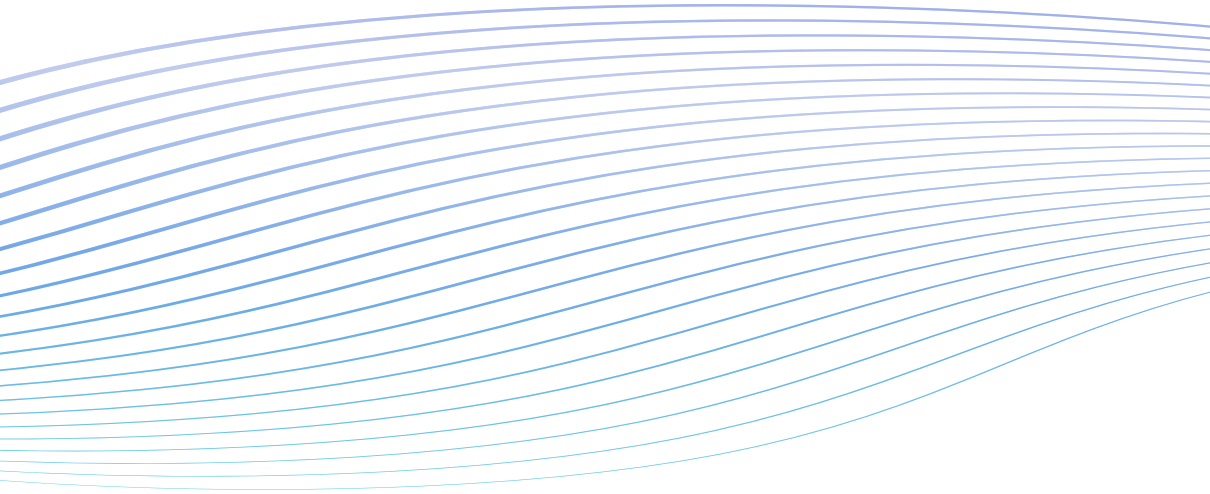
January 2023 – December 2026

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Verticals: Communication Infrastructure Technologies and Devices

Partners: University of Patras, CNIT, CTTC, Fraunhofer HHI, Hebrew university of Jerusalem, LionIX International, Opsys Technologies, PICadvanced, Telefonica ID, Ubitech, Coriant R&D, Universidad Carlos III de Madrid, ETH Zurich, Polariton Technologies.



Stream B4

RELIABLE SERVICES AND SMART SECURITY

The projects have been selected in such a way as to ensure a secure transition to 6G that prioritises user data protection and privacy, reliability, trust and resilience.

ELASTIC

ELASTIC targets enhancing security and efficiency in 6G network management.

OVERVIEW

Future 6G services will operate across a highly distributed edge-cloud continuum, spanning constrained IoT devices, industrial edge nodes, private infrastructures, and public clouds. Ensuring secure, portable, trustworthy, and efficient execution across such heterogeneous environments is a major challenge identified by the SNS JU.

The ELASTIC project addresses this challenge by introducing a novel orchestration and execution framework that allows workloads to run seamlessly on-premise, at the edge, or in the cloud without compromising security, confidentiality, or performance. By combining WebAssembly, extended Berkeley Packet Filter (eBPF), and confidential computing, ELASTIC enables lightweight, isolated, and privacy-preserving execution, architecture-agnostic serverless orchestration, and secure IoT and edge services aligned with European 6G priorities.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

ELASTIC adopts a modular architecture for secure and resource-efficient orchestration of 6G services across the cloud-edge continuum. It is structured around five functional blocks covering orchestration, isolation and confidentiality, communication, monitoring and detection, and trust and access control. During its first reporting period, ELASTIC consolidated this architecture into a project-wide reference framework, mapped over 25 interoperable components to demonstrator needs, and delivered initial implementations and prototypes. Secure execution is enabled through WebAssembly and Trusted Execution Environments (TEEs) with remote attestation-based trust enforcement, while eBPF supports accelerated communication and continuous observability.

INNOVATIONS

Even in its first half, ELASTIC has delivered significant innovations advancing secure, efficient, and portable service orchestration across the 6G cloud–edge continuum. The project enables lightweight, portable execution with WebAssembly and enhanced observability via eBPF, while introducing confidential computing to support trusted execution across heterogeneous infrastructures. Platform-agnostic hardware abstraction layers allow WebAssembly workloads to run unmodified within TEEs, supported by multi-platform and cross-TEE attestation for distributed and serverless applications.

ELASTIC also implements cloud-to-far-edge serverless orchestration, supports the deployment of WebAssembly services from cloud environments down to real-time operating system (RTOS)-based IoT devices and provides cyber-physical WebAssembly and standardised WASI interfaces. Remote direct memory access (RDMA) enables low-latency microservice interconnection suitable for real-time services. In parallel, ELASTIC deploys AI-based intrusion detection integrated with eBPF on edge nodes, validates its approach on WebAssembly-capable IoT devices, and contributes to W3C standardisation, establishing a strong technical foundation for secure 6G service execution.

USE CASES/ TRIALS/ APPLICATIONS

ELASTIC validates its approach through two real-world demonstrators, focusing on concrete operational scenarios rather than isolated technology evaluations.

Demonstrator 1 – Smart Connected Factory of the Future. ELASTIC showcases a secure IoT Data Fabric across three independent industrial scenarios deployed over distributed factory infrastructures. **Predictive Maintenance** processes sensor data at the edge to detect anomalies in real time, reducing downtime while protecting machine data and intellectual property. **Cross-Factory Data Sharing** enables collaboration across manufacturing sites via federated learning, allowing model exchange without exposing raw industrial data and preserving data sovereignty. **Real-Time Robot Control** executes control logic close to robots, ensuring the ultra-low latency and deterministic behaviour required for safety-critical automation. Across all scenarios, services are dynamically orchestrated across the edge-cloud continuum, data-in-use is protected within TEEs, execution integrity is verified through remote attestation, and security policies are consistently enforced.

Demonstrator 2 – Privacy-Preserving Cloud Migration. ELASTIC validates the secure migration of sensitive enterprise IT service, the **Badge Request Tool (BRT)**, from on-premise infrastructure to the public cloud. Managing personal and security-critical identity data, the BRT runs inside TEEs to protect data during processing, with remote attestation verifying cloud trust and policy-based orchestration ensuring compliance and auditability. This demonstrator confirms that security-critical services can migrate to cloud and edge environments without compromising confidentiality, control, or regulatory compliance.

RESULTS/ IMPACT

ELASTIC has delivered significant scientific, technical, and industrial results, demonstrating the feasibility of secure, portable, and confidential service execution across edge, cloud, and 6G infrastructures. The project defined a consolidated reference architecture, identified 26 components, and implemented initial versions of 14 prototypes. Over 40 functional and non-functional requirements and key performance indicators were derived from demonstrator needs, enabling measurable validation.

ELASTIC confirmed that future services can run anywhere - on - premise, at the edge, or in the cloud - without compromising security, confidentiality, or performance. Early minimum viable products for two industrial demonstrators validated the deployability of WebAssembly, eBPF, and confidential computing technologies in real environments. Beyond technical achievements, the project contributed to major open-source ecosystems and standardisation activities (including W3C/WASI, ETSI, and 3GPP), strengthened ties with the European 6G community, and prioritised five key exploitable results for industrial uptake. These outcomes position ELASTIC as a concrete enabler of trustworthy, efficient, and interoperable 6G services.

Efficient, portabLe And Secure orchesTration for reliable servICes

elastic

Coordinated by Sotiris Ioannidis, Technical University of Crete

March 2024 – February 2027

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Partners: Technical University of Crete, Ericsson Finland and Sweden, Telefonica I+D, Thales SIX and DIS, IMEC Ultraviolet, Aalto University, Lunds University, Abstract Machines, Zendrix Lab, Polytechnic University of Turin.

iTRUST6G

Revolutionising 6G security with a zero-trust architecture, employing AI/ML for dynamic threat management, and improving trust through innovative identity models and advanced security policies.

OVERVIEW

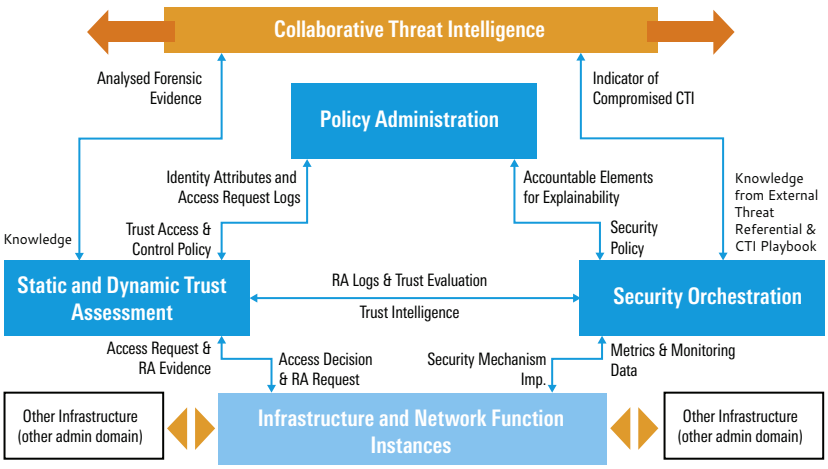
iTrust6G pioneers a zero-trust (ZT) architecture for 6G, using AI/ML to enhance trust, mitigate threats, enforce security policies, and track assets. The project streamlines trust establishment, optimises security procedures, and reduces network overhead through continuous threat monitoring, programmable security, and intent-based end-to-end security orchestration. Novel trust algorithms address service design, stakeholder identity, and software supply chain security, complemented by an identity management model that exploits cyberthreat intelligence to strengthen trust and improve 6G service decisions.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The iTrust6G architecture comprises five layers, supporting zero-trust (ZT):

- **Collaborative Threat Intelligence Layer**: Shares threat insights, coordinates trust evaluation and supports remediation with CTI playbooks.
- **Policy Administration Layer**: Manages tenant-specific, intent-based policies and interfaces with trust and orchestration layers.
- **Static & Dynamic Trust Layer**: Assesses asset posture, guides ZT access decisions, and connects with CTI, policy, and orchestration layers.
- **Security Orchestration Layer**: Automates AI-driven threat responses, generates remediation playbooks, and integrates tenant-specific security tools.
- **Infrastructure Layer**: Unifies heterogeneous 6G environments, reduces complexity and enables multi-tenant collaboration.

iTRUST6G architecture



INNOVATIONS

As network complexity grows, so does security risks, requiring new approaches to protection. iTrust6G introduces a paradigm shift towards trust-centric, adaptive, collaborative and intelligent security. The project enables secure management of diverse resources, criteria, and data source to trust evaluation, supported by a policy framework that enforces operator security compliance and address threats at both design and run time. Core building blocks include federated machine learning, AI-driven threat detection, intent-based security, and continuous real-time trust inference.

Together, these capabilities ensure intelligent and secure service orchestration in dynamic 6G environments, positioning iTrust6G to redefine trust and security in hyper-connected, multi-stakeholder digital ecosystems.

USE CASES/ SCENARIOS

iTrust6G integrates design, implementation, and testbed validation across telecom and cybersecurity verticals, testing its architecture through three complementary use cases:

UC1: Dynamic Security Orchestration and Trust Establishment – Demonstrates intent-based security in multi-stakeholder 6G environments, including automated isolation of compromised components and secure onboarding of new stakeholders.

UC2: Operational Security and Trust Re-evaluation – Maintains trust under attack, validating AI-driven threat detection, collaborative threat intelligence (CTI), forensic analysis and recovery via service isolation, and redeployment.

UC3: Programmable Security as a Service – Shows policy-driven security orchestration in multi-tenant settings, including automated mitigation, adaptive trust evaluation, enriched threat intelligence, and proactive risk reduction using external CTI playbooks.

RESULTS/ IMPACT

iTrust6G has established a solid foundation for secure and trustworthy 6G networks though the following results:

- Consolidated project use cases, requirements and architecture;
- Collaborative Threat Intelligence (CTI): Cross-domain threat sharing based on STIX 2.1, enabling proactive trust evaluation and federated ML-based threat classification via an integrated CTI platform;
- Policy Administration layer: Design and implementation of intent policy management, including an Intent Processor translating high-level goals into enforceable rules, supported by a tamper-evident accounting ledger;
- iTrust6G Trust Model: Lifecycle assessment combining conformity checks (e.g., secure boot, signed firmware, software bills of materials), dynamic trust scoring, and forensic feedback, through an AI Trust Evaluator (AITE) and Transparent Evidence Repository (TER);
- Security Orchestration: Implementation of CTI automation playbooks, a secure service orchestrator, and a security capability model, enabling AI-driven, risk aware automated remediation;
- Infrastructure Layer: Integration of programmable security mechanisms and remote attestation directly into network functions for pervasive enforcement and integrity verification;
- Standardisation impact: 97 contributions submitted to 3GPP, ETSI, IEFT, and GSMA during 2025.

Intelligent Trust and Security Orchestration for 6G Distributed Cloud Environments

Coordinated by Mir Ghoraishi, Gigasys Solutions

January 2024 – June 2026

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Partners: Gigasys Solutions, i2CAT, Telefonica, Lenovo, National Technical University of Athens, Politécnico de Torino, PDMFC, Adrestia, Universidad Carlos III de Madrid.

NATWORK

NATWORK aims to establish and implement the first economically feasible, energy-efficient, and effective bio-inspired, AI-driven cybersecurity and resilience framework specifically designed for 6G networks.

OVERVIEW

NATWORK aims to establish and deploy the first economically viable, energy efficient, bio-inspired AI-based 6G cybersecurity and resilience framework for intelligent networking and services. Taking a holistic, cross-sector approach, it addresses diverse requirements and challenges in real-world business environments. NATWORK is part of the Reliable Services and Smart Security SNS JU program focusing on 6G cybersecurity use cases.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The NATWORK consortium develops bio-inspired approaches for key performance indicators (KPIs) management and 6G network security, drawing an analogy between a 6G network and a complex biological system. In this design, the immune system learns from past incidents, predicts potential threats and adapts security protocols dynamically. NATWORK's architecture mirrors biological immunity in layers. The first layer uses AI-based proactive mechanisms to dynamically reduce the attack surface. The second employs adaptive artificial intelligence/machine learning (AI/ML) models to classify threats, initiate mitigation, and learn from prior events. The final architecture integrates multiple components and services.

Key components and technologies are:

- **Decentralised Orchestration**: Energy efficient and attack resilient orchestration, security-by-design services, dynamic user association, and resource allocation in heterogeneous networks;
- **Energy Efficient AI Services for RAN (physical layer)**: AI-enabled reconfigurable intelligent surface (RIS) configuration, ML-based multiple input multiple output (MIMO), AI-powered anti-jamming, and AI-enhanced physical key generation in sub-THz;
- **Edge/Core Cloud**: Security monitoring, security-performance balancing, programming protocol independent packet processors (P4)-based network analytics, security as a service (SeCaaS) software, security based slice management, AI-enabled intrusion detection, behavioral analysis, and moving-target defense (MTD), distributed federated learning across the continuum.

INNOVATIONS

NATWORK NATWORK has developed, and continues to enhance, a suite of innovative tools including:

1. Dynamic MTD framework for end-to-end security;
2. AI-native 6G architecture with cross-layer, decentralised secure federated learning;
3. Composer for secure-by-design 6G cloud-native slices;

4. Platform-agnostic, sustainable SE-CaaS covering all types;
5. Advanced AI-driven decentralised orchestration and management services.
6. Deep software runtime monitoring for denial of service (DoS) attack detection.
7. AI-powered anti-jamming and RIS Defense module.
8. Decentralised node (self) attestation and trust regulation.

USE CASES/ TRIALS/ APPLICATIONS

The consortium has identified four Use Cases (UCs) to demonstrate the NATWORK security framework and enable comprehensive evaluation, validation and verification.

UC1: Sustainability and reliability of 6G Slices and services. Explores energy-efficient solutions to support reliable connectivity and high-quality services while minimising costs and environmental impact.

UC2: Anti-jamming technologies for autonomous vehicles. Detects, classifies and mitigates jamming attacks in real-time, using AI/ML , by analysing signal patterns.

UC3: IoT security. Ensures security and privacy of IoT devices and data in 6G networks through advanced threat detection and mitigation mechanisms.

UC4: Continuous security in dynamic networks. Maintains robust security across highly dynamic and heterogeneous 6G network architectures.

RESULTS/ IMPACT

Detailed user requirements have been translated into technical specifications, forming the foundation of NATWORK's technological base. Use cases scenarios and requirements have been defined and the first release of NATWORK technology, along with the final architecture, has been completed. Preliminary results were obtained through experimental testbeds, supporting frameworks for final integration. Key components include secure-by-design orchestration and management, runtime payload security, cyberthreat intelligence and explainability, physical layer threat modelling, and AI-powered anti-jamming and RIS defense mechanisms.

Activities have also progressed toward the first round of NATWORK pilots, including evaluation framework and draft pilot specifications. The roadmap for commercial exploitation has been established, partners' exploitation plans elaborated, and standardisation activities initiated.

NATWORK aims to influence 6G standardisation and policy, aligning with EU regulations such as GDPR and the Cybersecurity Act. By delivering trusted, secure and regulatory-compliant technologies, the project strengthens Europe 6G ecosystem, supports digital sovereignty, and enables end-to-end security, privacy and resilience in multi-stakeholder, host-neutral infrastructures. AI-based security, lifecycle trust management and secure-by-design services reduce systemic risks, enhance interoperability and accelerate deployment of innovative 6G services aligned with EU policies and industrial needs.

Net-Zero self-adaptive activation of distributed self-resilient augmented services

NAT WORK

Coordinated by
Antonios Lalas and Anastasios Drosou, CERTH/ITI

January 2024 – December 2026

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Partners: CERTH, Gradiant, Tages, CNIT, ISRD, Eötvös Loránd university, Montimage, IMEC, NEC Laboratories Europe, Nova, P-NET, Zurich university of Applied Science, university of Zurich, university of Essex, university of Applied Sciences and Arts of Western Switzerland.

ROBUST-6G

ROBUST-6G aims to address the new concerns posed by the dynamic nature of forthcoming 6G services and networks in the future cyber-physical continuum by developing data-driven, AI/ML-based security solutions.

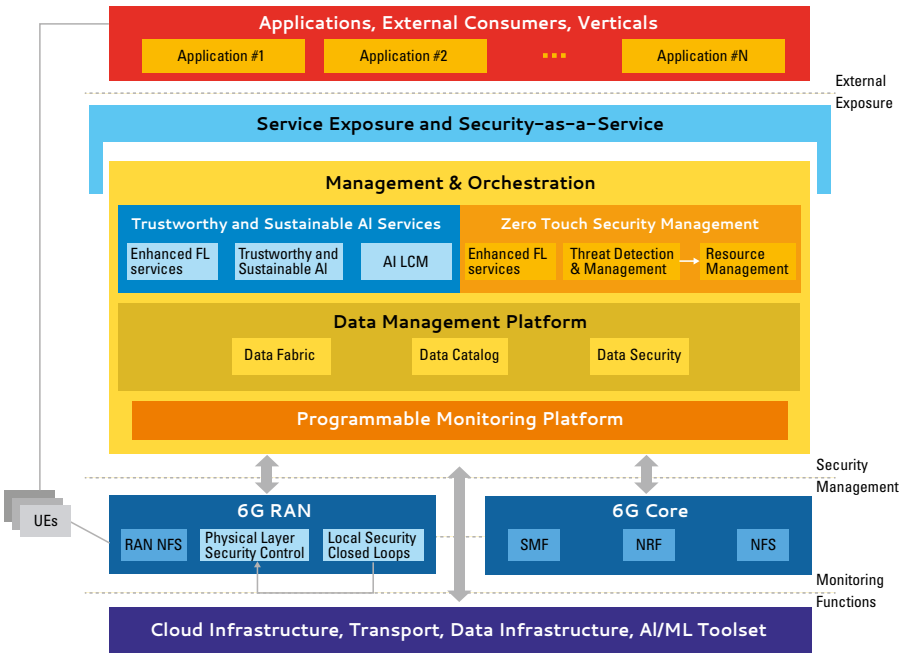
OVERVIEW

ROBUST-6G addresses G security challenges with AI/ML-based solutions, enhancing robustness, privacy and security transparency in distributed intelligence. The project promotes sustainable AI optimising computation and energy use without compromising performance. It enables zero-touch security and resource management across stakeholders, while pioneering AI/ML- techniques to counter physical layer (PHY) attacks and developing security schemes suited to 6G's low-latency, low-energy and low-complexity requirements.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The ROBUST-6G architecture provides autonomous, end-to-end 6G security through a modular, AI-native, closed-loop design. Continuous network monitoring observes the feeds a secure Data Management Platform, while zero-touch security management orchestrates detection and mitigation Federated, explainable AI enables threat prediction, physical-layer loops protect the air interface and an exposure framework allows trusted integration with verticals and applications.

ROBUST-6G architecture



INNOVATIONS

ROBUST-6G has introduced key security innovations for 6G:

1. **Federated learning-based on intrusion detection systems(IDS)**: preserving IDS network traffic and IoT data while securing privacy;
2. **Data Fabric**: Collection, processing, storage, and exposure of security data;
3. **Data Governance**: Enables data cataloging and access authorisation;
4. **Network-Security-as-a-Service (NetSecaaS)**: Exposes security capabilities to third-party applications;
5. **Physical Layer (PHY) Authentication Module**: Develops low-latency authentication and key agreement (AKA) solutions, including false base station detection;
6. **Spiking Neural Networks simulator**: Simulates spiking neural networks using PyTorch optimisers;
7. **Robust IDS framework**: Enhances IDS to detect/respond to PHY attacks;
8. **Signal Identification as Attack Detection**: Uses signal processing for cyber-attack detection;
9. **Privacy-preserving Federated Learning (FL)**: Prevents data leakage and poisoning attacks;
10. **Robust AI/ML against adversarial attacks**: Defends AI models from evasion and poisoning;
11. **Architecture and Signaling for Network Security**: Automates security services like trustworthy AI and PHY security.

USE CASES/ TRIALS/ APPLICATIONS

ROBUST-6G innovations will be validated through three use-case scenarios. The first focuses on evaluating the trustworthiness of AI models in distributed 6G environments, combining federated learning with robustness, explainability, sustainability, fairness, and physical-layer security to enable resilient and privacy-preserving AI. The second targets automatic threat detection and mitigation in 6G-enabled IoT at the extreme edge, leveraging AI-driven closed-loop security and zero-touch orchestration for proactive, self-adaptive protection. The third demonstrates security capability exposure via NetSecaaS, using the GSMA Open Gateway to allow applications and enterprises to seamlessly integrate ROBUST-6G security functions into 6G networks.

RESULTS/ IMPACT

ROBUST-6G has developed an integrated security framework to address the limitations of current mobile networks in the face of6G's scale, autonomy, and intelligence. Unlike 5G, 6G introduces on extreme densification, AI-native control, sensing-communication convergence, and autonomous agents, creating new attack surfaces that static or purely cryptographic mechanisms cannot secure. To address this, the project developed a closed-loop 6G security architecture combining physical-layer, cross-layer, and AI-driven security functions with zero-touch orchestration.

The project introduced novel mechanisms for physical-layer authentication, jamming and distributed denial of service (DDoS) detection, trust establishment, and privacy preservation, exploiting 6G enablers such as high-resolution radio features, sensing, and distributed intelligence. The project also delivered secure, privacy-preserving, and trustworthy AI capabilities by developing robust AI methods resilient to adversarial and evolving threats, and enabling privacy-preserving learning in both standalone and collaborative scenarios. AI/ML-based detectors were validated to identify known and previously unseen attacks using radio, network, and semantic features, including frequency-domain analysis, RF fingerprinting, and federated learning.

Sustainability and transparency were ensured through energy-efficient AI-driven security operations and the application of explainable AI for effective threat detection, prediction, and mitigation.

Smart, Automated And Reliable Security Service Platform For 6G

ROBUST-6G

Coordinated by Ramin Fuladi, Ericsson Turkey

January 2024 – June 2026

Website: https://robust-6g.eu/

LinkedIn: www.linkedin.com/company/robust-6g/

Partners: Ericsson Turkey, Telefonica, university of Murcia, Chalmers university, university College Dublin, university of Padova, Nextworks, ENSEA, Linkoping university, Eurecom, Thales, Gohm Elektronics, Axon Logic.

SAFE-6G

SAFE-6G pioneers a holistic research approach, situating a native trustworthiness framework atop the open and distributed USN/NSN-based 6G core, leveraging (X)AI/ML techniques to coordinate user-centric safety, security, privacy, resilience, and reliability functions, strategically optimising the Level of Trust (LoT).

OVERVIEW

The SAFE-6G project aims to create a trust-driven, user-centric 6G ecosystem using cognitive frameworks, AI/ML techniques and distributed architectures. Its objectives include defining trustworthiness requirements for a user-centric, zero-touch 6G framework, deploying distributed AI/ML across the edge-cloud continuum, developing cognitive coordination frameworks and MLOps tools for trust management and AI/ML optimisation, designing AI-assisted functions for safety, security, privacy, resilience and reliability with a zero-trust approach, adopting cloud-native paradigms for compatibility with 5G/6G networks and edge-cloud systems, like aeriOS MetaOS, validating the framework via Metaverse pilots, and promoting results through dissemination, standardisation and stakeholder engagement.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The SAFE-6G reference architecture offers a holistic, user-centric architectural blueprint for enabling native trustworthiness in distributed 6G networks across the edge–cloud continuum. In SAFE-6G, trustworthiness is treated as a native system property and explicitly defined along five dimensions -Safety, Security, Privacy, Resilience, and Reliability-, going beyond the traditional security focused perspective of mobile networks.

User interaction with the framework is facilitated through an LLM-based conversational chatbot interface, which interprets high-level user intents expressed in natural language and serves as the primary entry point to the trustworthiness management process.

At the core of the SAFE-6G architecture lies the Cognitive Coordinator, which interprets high-level user intents and contextual information and translates them into coordinated trustworthiness actions across the system. These actions are enforced through AI-assisted Trust Functions (TFs), which monitor, decide and adapt within its respective trust dimension and are deployed as composable applications. The architecture spans the edge–cloud continuum, and is supported by integrated MLOps and data operations (DataOps) capabilities for AI lifecycle management, while Explainable AI, differential privacy, and Digital Twin components ensure transparency, compliance, and continuous validation.

In SAFE-6G, TFs are user-centric, AI-assisted components enforcing trust via Safety, Security, Privacy, Resilience and Reliability. Each TF follows a layered architecture: a Local AI Agent for real-time decision-making, Vertical Applications (vApps) at the service level, and Network Applications (nApps) at the network plane. TFs receive the required Level of Trustworthiness from the Cognitive Coordinator, derived from user intent and continuously monitor inputs from the network, edge–cloud continuum, and applications. Using this multi-plane awareness, TFs take adaptive, coordinated actions to maintain a trustworthy system.

SAFE-6G

Smart and Adaptive Framework for Enhancing Trust in 6G Networks

Coordinated by
Javier Garcia Rodrigo, Telefónica ID

January 2024 – December 2026

Website: https://safe-6g.eu/

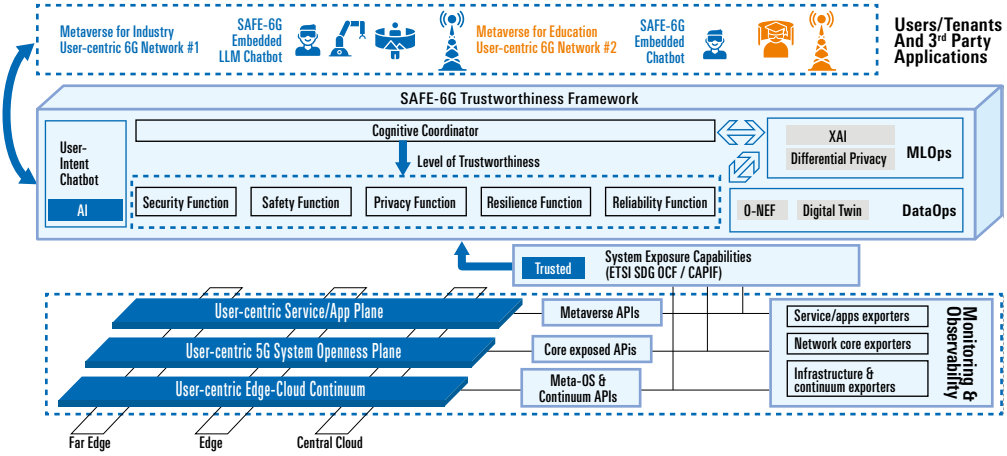
X: @SAFE6G

LinkedIn: www.linkedin.com/company/safe-6g/

Facebook: www.facebook.com/safe6g

Verticals: Industry, Education and Training

Partners: Telefonica ID, National Center for Scientific Research "Demokritos", Thales Six GTS France; Inqbit Innovations, Atos Spain, University of West Attica, SPACE Hellas, Infolysis, eBOS, Polytechnical University of Valencia, 8Bells, CUMUCORE, Immersion.



SAFE-6G Reference Architecture

INNOVATIONS

SAFE-6G introduces user-centric innovations in next-generation network architectures, placing user intent, cognitive coordination and e2e trustworthiness at the core of 5G/6G systems. Key advancements include programmable/distributed 5G/6G infrastructure with flexible resource management across the edge–cloud continuum; AI-native network intelligence and orchestration, combining a LLM-based chatbot for user intent extraction, an AI-enabled CoCo for trustworthiness, MLOps and explainable artificial intelligence (XAI) capabilities and localised AI intelligence embedded in trust functions; open and interoperable service exposure via CAPIF, providing controlled, standardised access to network capabilities; metaverse and extended reality (XR)-enabled applications leveraging digital twins, immersive training and XR for realistic, user-centric industrial and service experiences.

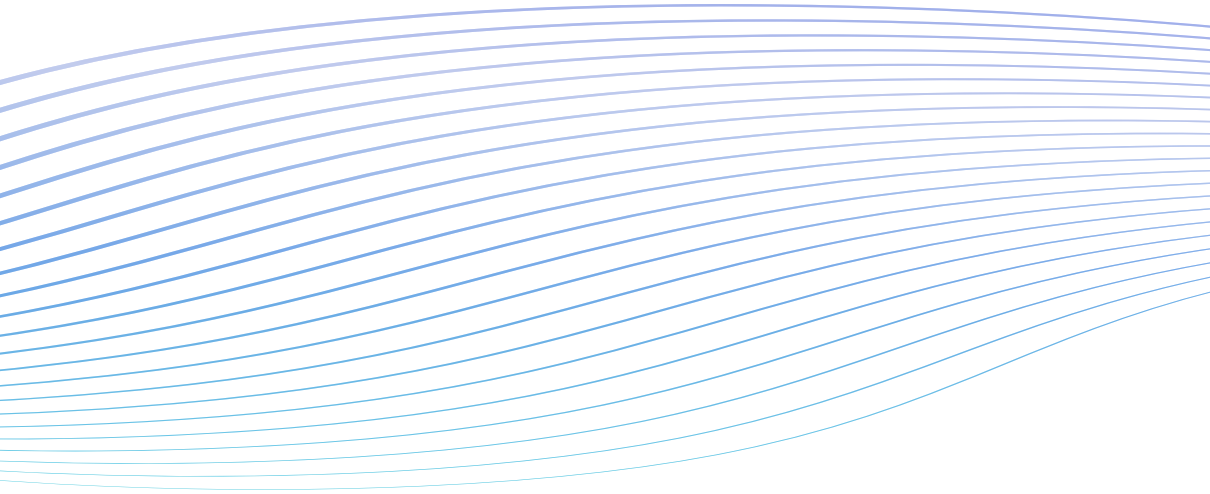
USE CASES/ TRIALS/ APPLICATIONS

Two metaverse UCs are foreseen at the SAFE-6G testbed, which interconnects experimental B5G and cloud infrastructures across Athens/Greece, Egaleo/Greece and Valencia/Spain, enabling realistic cross-site validation. UC1 focuses on a Digital Twin (DT) of an industrial production line, enhancing trustworthiness through secure, resilient access in XR. This setup allows real-time updates and secure modifications of production processes. UC2 explores hybrid education in XR+AI, improving hands-on learning through seamless collaboration, while ensuring strong personal data protection.

RESULTS

SAFE-6G introduces a user-centric, e2e cognitive trustworthiness framework designed to enhance trust in 6G networks. Unlike 5G, which primarily focuses on security, SAFE-6G integrates safety, security, privacy, resilience and reliability across the edge-cloud continuum, redefining trust in a holistic manner.

SAFE-6G has already achieved a functional prototype, validating the feasibility of user-intent-driven orchestration and AI-based trust functions in both open-sourced and commercial B5G systems.



Stream B5

MICROELECTRONICS-BASED SOLUTIONS FOR 6G NETWORKS

Call 2 B5 projects will contribute to the strong push towards the advancement of European microelectronics in providing solutions for next-generation communication networks and devices at various levels of the device data processing chain, from baseband and mixed-signal processing to RF and antenna systems covering frequencies from sub-6 GHz to THz.

6G-REFERENCE

6G-REFERENCE targets transceiver hardware innovations enabling 6G densely distributed systems exploiting Distributed MIMO (D-MIMO).

OVERVIEW

6G-REFERENCE investigates integrated circuit (IC) and antenna hardware for centimetre-wave (cm-wave) integrated communication and sensing, enabling multi-users through a cell-free network of distributed radio units (RUs). In this context, distributed multiple input multiple output (MIMO) plays a central role in extending coverage, improving reliability, increasing data rates, mitigating interference and enhancing power efficiency.

In dense deployment scenarios, fibre connectivity to RUs cannot always be assumed. As a result, highcapacity wireless backhaul and precise overtheair synchronisation become critical hardware enablers. Achieving fully coherent distributed MIMO represents a key long-term objective, requiring major advances in synchronisation accuracy. In parallel, integrated sensing and communication (ISAC) is recognised as a fundamental building block of future 6G systems.

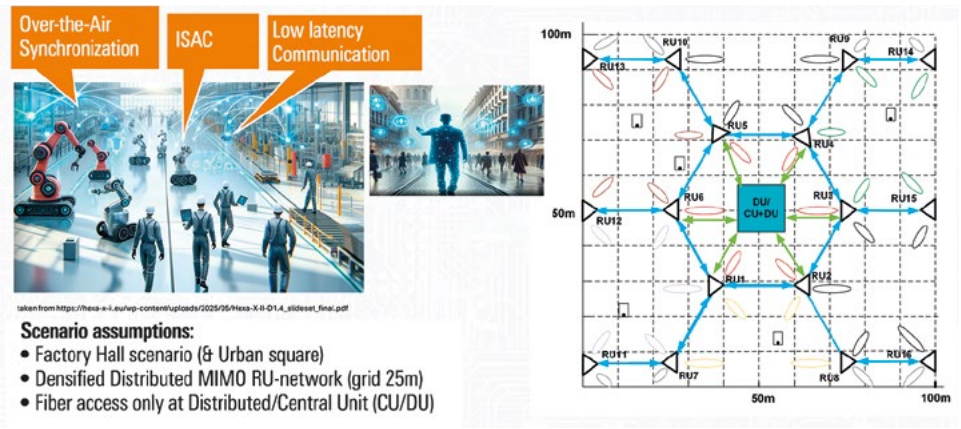
CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

Key use scenarios and an example deployment grid is illustrated assuming that only one central RU has fibre access, while all other RUs communicate wirelessly.

A dense hexagonal grid of RUs with 25 m spacing is proposed, with hardware research focusing on RU platforms and five key project objectives:

1. Cooperative transmission to user terminals by clusters of distributed RUs, supported by efficient over-the-air (OTA) fronthaul data distribution;
2. Accurate over-the-air synchronisation (OAS) of distributed RUs;
3. Accurate sensing and localisation using the same RU hardware platform;
4. Frequency and spatial selectivity to enable coexistence with other services in the FR3 bands;
5. Economic and environmental sustainability achieved through low power, cost effective hardware solutions.

6G-REFERENCE scenarios



INNOVATIONS

The project focuses on developing advanced hardware and RF solutions to enable high-performance distributed MIMO networks, integrating communication, synchronisation, and sensing functionalities:

1. **In-band Full-duplex transceiver ICs and antenna arrays** to enhance data capacity between distributed MIMO RUs, reduce latency for communication and synchronisation and minimise self-interference supporting monostatic radar;
2. **Novel synchronisation solutions** to achieve accurate frequency and time synchronisation, enable fast and continuous synchronisation;
3. **Novel RF and antenna components** including time modulated arrays (TMA) to reduce power, complexity and cost, frequency modulated arrays (FMA) to increase positioning accuracy, supporting for reconfigurable intelligent surface (RIS) solutions to enable beam re-direction, antenna arrays, including environmental sensors, filtering cm-wave antennas.

USE CASES/ TRIALS/ APPLICATIONS

The focus is on IC and antenna hardware enablers that support low latency full duplex communication, high precision synchronisation and accurate sensing and localisation. Demonstrators are designed to validate the basic feasibility of these hardware solutions and to characterise the limits of achievable performance.

RESULTS/ IMPACT

To guide the development of a distributed MIMO system for communication, sensing, and timing synchronisation, key specifications and performance analyses were established:

System specifications for operation at 14.8-15.35GHz:

- Communication Key Performance Indicator (KPI)s: 480 Mbps per user, 43 Mbps/m^2, 0.1–1 ms latency
- Sensing KPIs: resolution <0.5 m and 0.5 m/s, 0.1 s refresh time
- Synchronisation KPIs: $\Delta f/f < 2$ ppb, $\Delta\varphi < 22.5°$, $\Delta t < 100$ ns

Link budget analysis for 50–400 MHz channel bandwidth indicates sufficient margin for 4×4 antenna arrays at low-mW transmit power per element.

Ray-tracing simulations in a factory hall model the channel impulse response for both communication and synchronisation.

Antenna array and IC co-simulation suggest that a full-duplex link budget is challenging but potentially feasible.



6G haRdware Enablers For cEll fRee cohEreNt Communications & sEnsing

Coordinated by
Ignacio Llamas-Garro, CTTC
January 2021 – December 2026
Website: http://6greference.eu
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Verticals: Industry, Smart Cities
Partners: CTTC, Ericsson, University of Twente, CEA, Anteral, Australo, IMEC, polytechnical university of Zurich, Advanced Circuit Pursuit, university of Birmingham.

FirstTo6G

FirstTo6G brings together European SMEs, universities, and consultancy to create a revolutionary 6G transceiver microchip technology.

OVERVIEW

FirstTo6G unites InCirT, Sivers Wireless, and Argo Semiconductors with RWTH Aachen, Yeditepe University, and SCIPROM to develop next-generation 6G transceiver microchips. The project focuses on energy-efficient data converters with up to 16 GHz instantaneous bandwidth and integrated mmWave front-ends, delivering two complete transceiver chipsets to support 6G standardisation and trials toward global deployment by 2030.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

FirstTo6G is developing transceiver solutions for both V-band and D-band (figure). Its architecture combines advanced Fourier Domain digital-to-analog converter/analog-to-digital converter (DAC/ADC) technologies (FDDACs/ FDADCs) with new frontend designs. The V-band target is a single 22nm fully depleted silicon on insulator (FDSOI) chip integrating the full transceiver with 8 GHz instantaneous bandwidth. The D-band target is a two-chip solution: 22nm FDSOI data converters paired with a silicon-based and III–V frontend, achieving 16 GHz instantaneous bandwidth. The project addresses key 6G challenges, including bandwidth, energy efficiency, cost, and scalability.

Fig. 1: The two demonstrators to be developed in FirstTo6G



INNOVATIONS

InCirT has developed a disruptive Fourier-Domain DAC/ADC architecture that eliminates oversampling and digital filtering. This decouples performance from advanced semiconductor nodes, enabling up to **100× higher instantaneous bandwidth** and **10× greater energy efficiency** than current state-of-the-art solutions. In this project, the 8-GHz DAC/ADC exceeds existing solutions by more than **4× in coherent instantaneous bandwidth** while reducing energy consumption and cost using mature 22FDX technology. For the D-band, the **16-GHz DAC/ADC** doubles the achievable bandwidth compared to current designs.

USE CASES/ TRIALS/ APPLICATIONS

If adopted, FirstTo6G technology could accelerate 6G rollout and enable ultra-high-speed, always-on connectivity. This would support smart cities with real-time traffic and safety coordination, smart grids with dynamic energy management, and autonomous drones and robots for infrastructure monitoring. At the same time, augmented, virtual and mixed reality (AR/VR/MX) could reach new levels of realism and responsiveness, becoming everyday tools for work, learning, entertainment, and remote collaboration anywhere, anytime.

RESULTS/ IMPACT

2025 was a highly productive year for the FirstTo6G project with four tapeouts submitted in both CMOS and III-V technologies. For the **V-Band demonstrator**, a 22nm CMOS tapeout was submitted in May, integrating 6G transceiver designs from baseband to frontend from InCirT, Argo Semiconductors, and Sivers chip micrograph shown in figure 2. Measured are currently underway with the setup shown in figure 3.

For the **D-band demonstrator**, three tapeouts in SiGe were submitted (figure 4), incorporating all required building blocks. The first of these SiGe chips arrived in 2025, and RWTH and Yeditepe universities have begun characterisation.

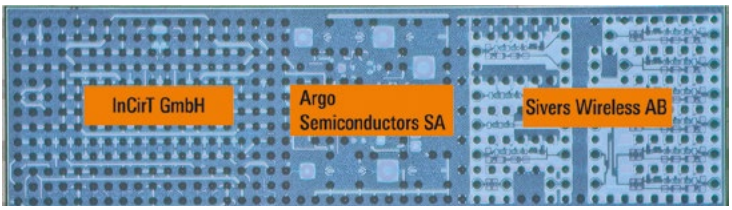


Fig. 2: Chip micrograph for the below 100GHz components. The chip is fabricated in Global Foundries 22nm FD-SOI technology.

Fourier-Domain TRx solutions enabling widespread realisation of 6G

FirstTo6G

Coordinated by
Sebastian Waters, InCirt

January 2024 – June 2027

Website: https://www.firstto6g.eu

LinkedIn: www.linkedin.com/company/firstto6g

Verticals: Automotive, Industry, PPDR, and Smart Cities

Partners: InCirT, Sivers Wireless, Argo Semiconductors, Yeditepe university, RWTH Aachen university, SCIPROM.

Fig. 3: Measurement setup for the data-converters of InCirT

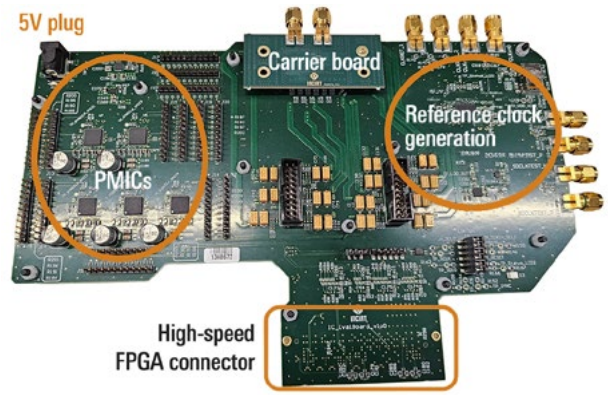
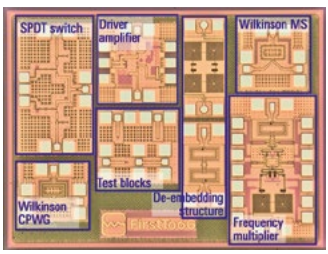
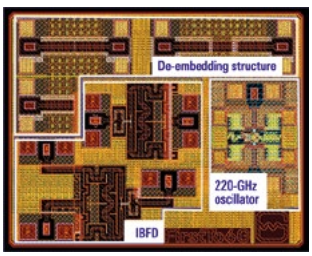
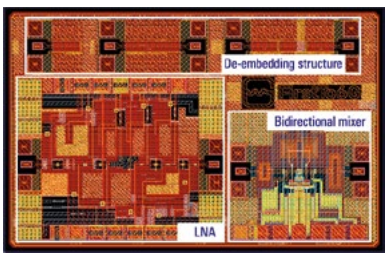


Fig. 4: Chip micrographs of the SiGe chips.







TERAGREEN

Towards Energy-Efficient High-Speed Wireless Links

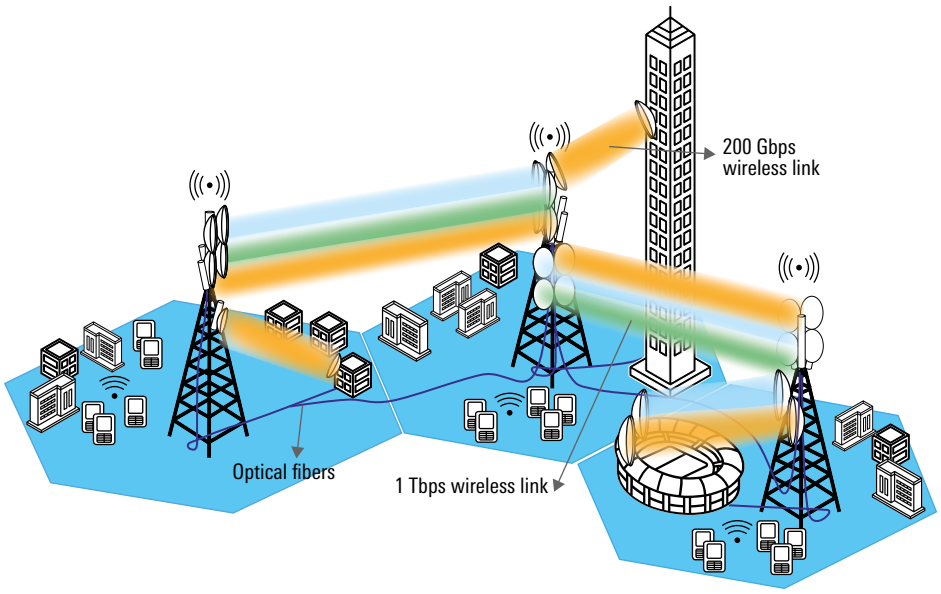
OVERVIEW

TeraGreen lays the foundations for future Tbit/sec communication systems by demonstrating energy-efficient, scalable techniques for generating, detecting and multiplexing ultra-wideband signals in the 300GHz band. The project targets high-speed, low-power wireless links for line-of-sight backhaul, fronthaul in ultra-dense small cells, and fixed wireless access in 6G networks. Two link demonstrations aim to achieve **>200Gbps** over medium-range links and provide a practical path towards **>1Tbps** capacities with unprecedented energy efficiency.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

TeraGreen brings together a multi-disciplinary team to deliver integrated THz transmitters and receivers for Tbps point-to-point links across the 252-325GHz band. Key developments include:

- **Quasi-optical multiple input multiple output (MIMO)** antennas transmitting a record number of wideband signals in parallel with unprecedented low radiated energy.
- **Low-power, wideband THz transceivers**, implemented in silicon processes, offering strong commercialisation potential.
- **Novel baseband with zero-crossing modulation**, enabling energy-efficient wideband communication using 1-bit analog-to-digital (A/D) conversion with temporal oversampling.



INNOVATIONS

Europe currently lacks full ownership of the connectivity value chain, such as smartphones. Leading in infrastructure and key service would give Europe a strategic advantage to shape future 6G networks, standards, environmental strategies, and regulations. TeraGreen contributes to this goal by ensuring that its outcomes:

- Deliver key technologies that make radio access networks (RANs) more energy-efficient, flexible and scalable than current deployments,
- Enable EU suppliers to compete globally with hardware and software solutions at the forefront of capacity, spectrum, and energy efficiency.

USE CASES/ TRIALS/ APPLICATIONS

TeraGreen focuses on four use cases:

- **UC1: Fronthaul in ultra-dense small cell networks**

  TeraGreen addresses the challenge of providing energy-efficient and high-capacity fronthaul solutions. Small cells are key for high data rates and low latency in dense urban 6G networks, but fronthaul links must handle massive data traffic. TeraGreen's THz-based links deliver ultra-high bandwidth, ensuring seamless communication while reducing energy consumption.

- **UC2: High throughput fixed wireless access**

  TeraGreen enables ultra-fast, energy-efficient internet for homes, businesses, and remote areas using THz spectrum. Multi-Gbps data rates deliver fibre-like speeds wirelessly, avoiding the cost and complexity of installing physical fibre-optic cables.

- **UC3: Live immersive Extended Reality (XR) at large-scale events**

  TeraGreen provides high-bandwidth, ultra-low latency links for real-time interaction with virtual elements. This supports immersive technologies such as augmented reality and virtual reality experiences for concerts, sports games, or conferences, regardless of audience sizes.

- **UC4: Wireless data centres.**

  TeraGreen's THz technology supports terabit-per-second links, between servers and switches surpassing current fibre and ethernet speeds. Wireless connections reduce cabling, simplify data centre design, and enable flexible, scalable server deployment without extensive rewiring or restructuring.

RESULTS/ IMPACT

The success of TeraGreen will drive significant advances in 6G network evolution, serving as a key enabler over the long-term (5-10 years post-project).

In the first two years (2024 & 2025), the project has achieved:

- Definition of the TeraGreen system architecture and Tbps backhaul use cases.
- Lab validation of 300GHz SiGe component performance, including circuits and dual-polarisation antennas.
- MIMO system specification, link budget analysis, and theoretical evaluation of MIMO link capacity.

Towards Energy-Efficient Tb/s Wireless Links

TeraGreen

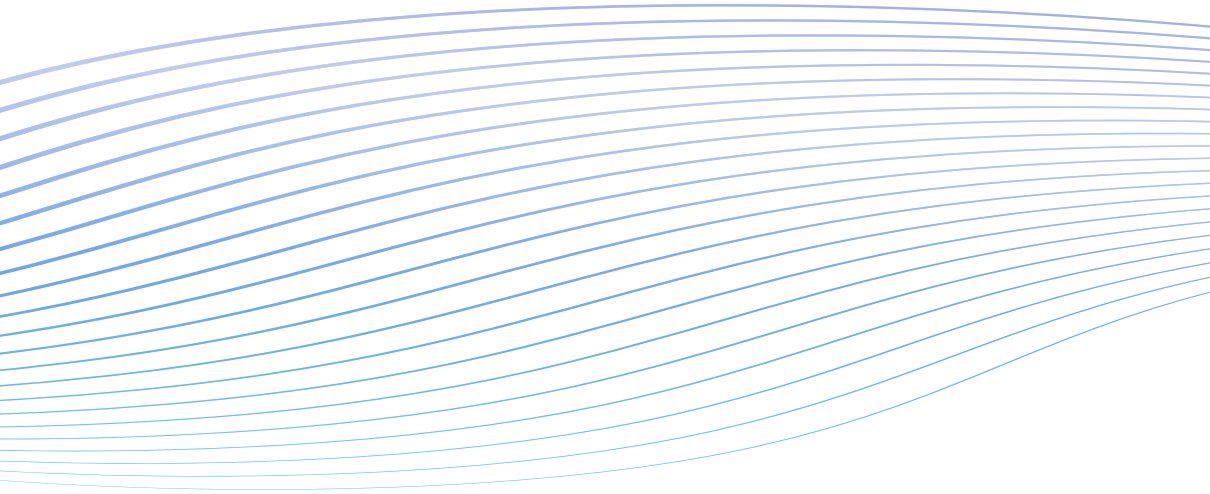
Coordinated by Marta Kluba, Delft university of technology

January 2024 – December 2027

Website: https://TeraGreen.eu

LinkedIn: www.linkedin.com/company/teragreen

Partners: Delft University of Technology, Chalmers University of Technology, Infineon Technologies, Ericsson, Dresden, University of Technology, OTE.



Stream B6

EU-US 6G R&I COOPERATION: 6G-XCEL

The aim of 6G-XCEL is to seamlessly integrate AI to enhance the capabilities of the 6G network, while also ensuring the collaboration between EU and US stakeholders is concrete and productive.

6G-XCEL

The 6G-XCEL project aims to integrate AI into the development of 6G networks, focusing on decentralised AI controls in edge network use cases.

OVERVIEW

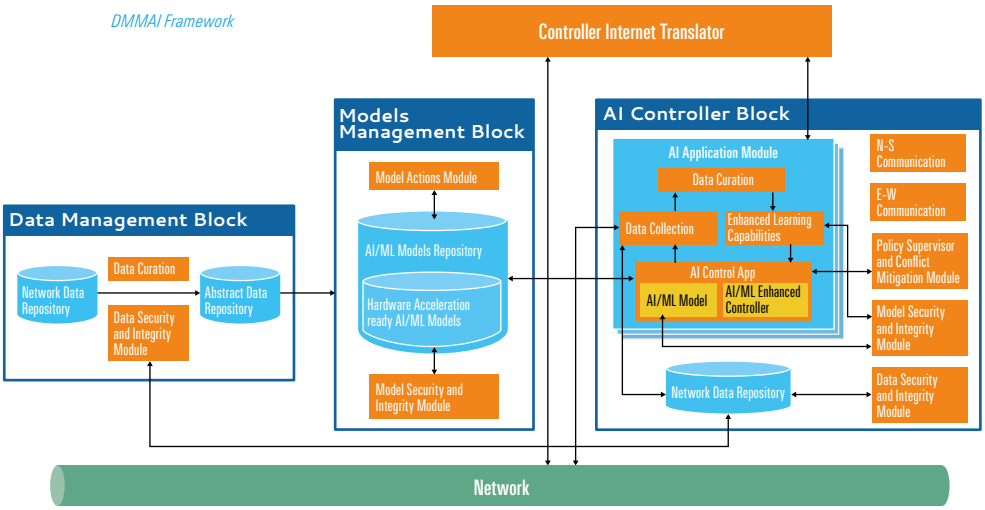
6G-XCEL explores artificial intelligence as a core capability for 6G networks, addressing limitations in scalability, coordination, and cross-domain control.

The project advances decentralised, multi-party AI mechanisms spanning radio and optical networks , extending beyond existing radio access networks (RAN)-centric control. Its decentralised multi-party, multi-network AI (DMMAI) framework ensures secure, sustainable, and interoperable AI-driven network management across heterogeneous infrastructures. 6G-XCEL also provides reference use cases, shared data and model repositories, and benchmarking tools for validation. The framework is implemented and tested on federated EU and US testbeds, ensuring reproducibility and aligns with with international standardisation to support global AI adoption in 6G.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

6G-XCEL provides a framework and tools for research and development of decentralised AI methods for network control across radio and optical domains. Building on the O-RAN architecture, it supports multi-party applications (xApps/rApps) via the RAN intelligent controller (RIC) and extends AI-driven control from the RAN to the optical network. The project benchmarks the DMMAI framework across testbeds, addressing key challenges including energy efficiency, control loop timescales, scalable large-scale data management, security and privacy in multi-party scenarios, and integration with AI orchestration platforms.

DMMAI Framework



INNOVATIONS

6G-XCEL introduces key innovations advancing AI-native 6G network design and operation. The project delivers the first holistic decentralised multi-party, multi-network AI (DMMAI) framework, enabling coordinated, AI-driven control across radio and optical networks, beyond RAN-centric approaches. A modular AI controller (AIC) architecture supports distributed, multi-vendor, multi-controller environments, allowing parallel AI algorithms to operate synchronously. The project embeds established artificial intelligence/machine learning (AI/ML) models directly into network control loops, achieving measurable performance gains without requiring new algorithms. Security-, privacy, and trust are integrated by design, including explainable AI, data integrity, and privacy-preserving governance. Energy-efficiency AI control models further enable operators to balance performance, latency, and sustainability in future 6G systems.

USE CASES/ TRIALS/ APPLICATIONS

The 6G-XCEL project explores AI-driven spectrum management and energy-efficient network operation through two key use cases.

The first focuses on AI-powered spectrum coordination across testbeds in OpenIreland, IMEC CityLab, and the US-based COSMOS, using the DMMAI framework to enable cooperation between independent networks via peer-to-peer and hierarchical AI/ML models. This establishes a "spectrum control plane" that optimises allocation, predicts traffic, and adapts to real-time conditions, including mmWave performance under varying environments, enhancing reliability in dense urban areas.

The second use case, evaluated at the university of Patras, applies AI/ML to optimise energy efficiency and enable seamless mobility between private and public networks. Using Juniper's RAN Intelligent Controller, AI tools reduce power consumption, improve resource allocation, and integrate legacy equipment via a custom translation layer, ensuring secure interoperability. Together, these use cases illustrate how AI can enable smarter, more efficient, and sustainable 6G networks.

RESULTS/ IMPACT

6G-XCEL has delivered a validated decentralised multi-party, multi-network AI (DMMAI) framework showing how AI can be natively embedded into future 6G network control across radio and optical domains. The project demonstrated that AI-driven network control can improve performance by 20–30%, enabling faster response times, higher throughput, and more reliable service delivery. By integrating existing AI/ML models into a modular AI Controller, 6G-XCEL proved the scalability and flexibility of decentralised AI without requiring new algorithms, reducing adoption barriers.

Validation across EU and US testbeds strengthens international collaboration and accelerates global standardisation of AI for 6G.

6G Trans-Continental Edge Learning

Coordinated by Dan Kilper, Trinity College Dublin

January 2024 – December 2026

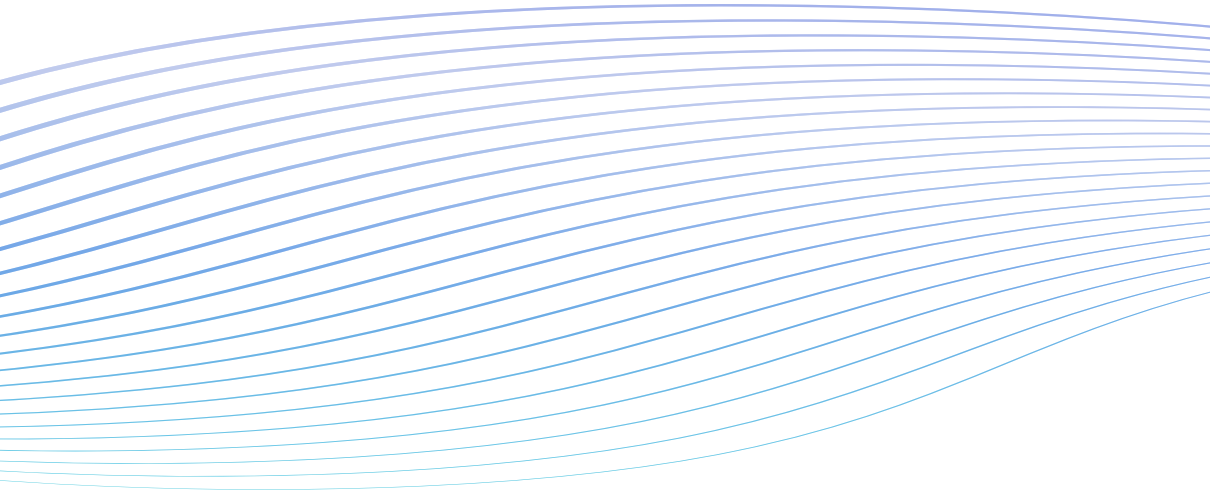
Website: www.6g-xcel.eu

X: @6GXcel

LinkedIn: www.linkedin.com/company/6g-xcel/about/

YouTube: www.youtube.com/@6G-XCELProject-tb8su

Partners: Trinity College Dublin, university of Patras, IMEC, Aalborg university, Sorbonne university, Fraunhofer HHI, IBM Ireland, Deutsche Telekom, Juniper, Dienekes.



Stream C

COMPLEMENTARY SNS JU EXPERIMENTAL PAN-EU FEDERATED INFRASTRUCTURE: SUNRISE-6G

The stream C focuses on SNS JU Enablers and PoCs with a target to further develop and consolidate Europe wide experimental infrastructure(s), in support of the various phases of the SNS JU. Federation of EU platforms is also targeted with capabilities to extend to non-SNS JU test platforms, either at national level or with third countries. SUNRISE-6G is the SNS JU Call 2 flagship project in this field.

SUNRISE-6G

SUNRISE-6G aims to develop an open, scalable approach for experimenting and deploying vertical applications within a Europe-wide 6G infrastructure network.

OVERVIEW

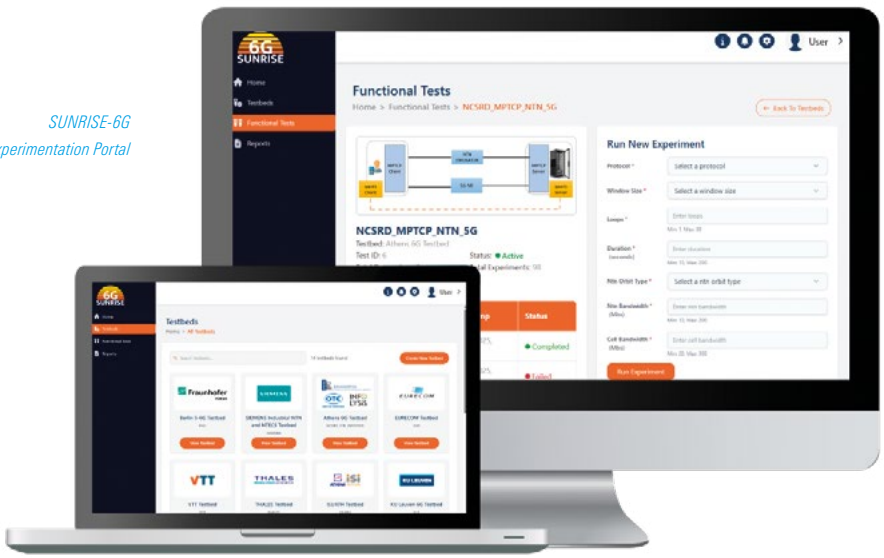
SUNRISE-6G aims to create a pan-European federated 6G experimentation facility, offering a scalable, standards-compliant infrastructure for testing-as-a-service (TaaS) and vertical application deployment, uniting 28 partners to integrate 14 existing 6G testbeds, and providing a unified environment for experimenters, vertical developers, infrastructure owners, and technology providers.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

SUNRISE6G federates heterogeneous 6G testbeds across Europe into a unified "**network of networks**". Its user-friendly platform gives researchers and experimenters access to all the tools, data, and resources needed to run experiments using the library of 6G components and onboard vertical applications.

To achieve this, SUNRISE-6G provides two key solutions:

- **Web-Based Experimentation Tenant Portal**: A structured, intuitive interface that makes experiment setup and management straightforward, even for non-experts. Its flexible framework allows users to efficiently control all aspects of their experiments with precision and confidence.
- **Open Operator Platform**: The first – and currently only – open-source implementation of the GSMA OPG (Federation) standard. It enables exposure of testbed resources and the dynamic creation of federations among testbeds.



SUNRISE-6G Experimentation Portal

INNOVATIONS

SUNRISE-6G embraces the "network of networks" vision of 6G, aiming to unify public and private infrastructures under a scalable, internet-like architecture. It will deliver a pan-European experimentation platform featuring Integrated Sensing and Communication for context-aware services, AI-driven network management, a modular end-to-end 6G architecture adaptable to diverse needs, seamless integration of non-terrestrial networks, and energy-efficient, sustainable solutions.

USE CASES/ TRIALS/ APPLICATIONS

SUNRISE-6G enables federated experimentation across diverse 6G application scenarios via its pan-European testbed ecosystem:

- **Federated Metaverse**: Cross-domain experimentation of immersive, real-time services spanning multiple testbeds and network segments.
- **Collaborative Robotic Exploration of Mining Environments**: Federated robotics and automation experiments in challenging industrial settings, integrating communication, computation, and edge AI across testbeds.
- **Non-Terrestrial Networks (NTN)**: Trials combining satellite and terrestrial infrastructures to explore inter-public land mobile network (PLMN) handover and simultaneous multi-connectivity.

In addition, SUNRISE-6G offers twelve Functional Test cases, accessible through the portal, to enable remote experimentation with the 6G Library components.

RESULTS/ IMPACT

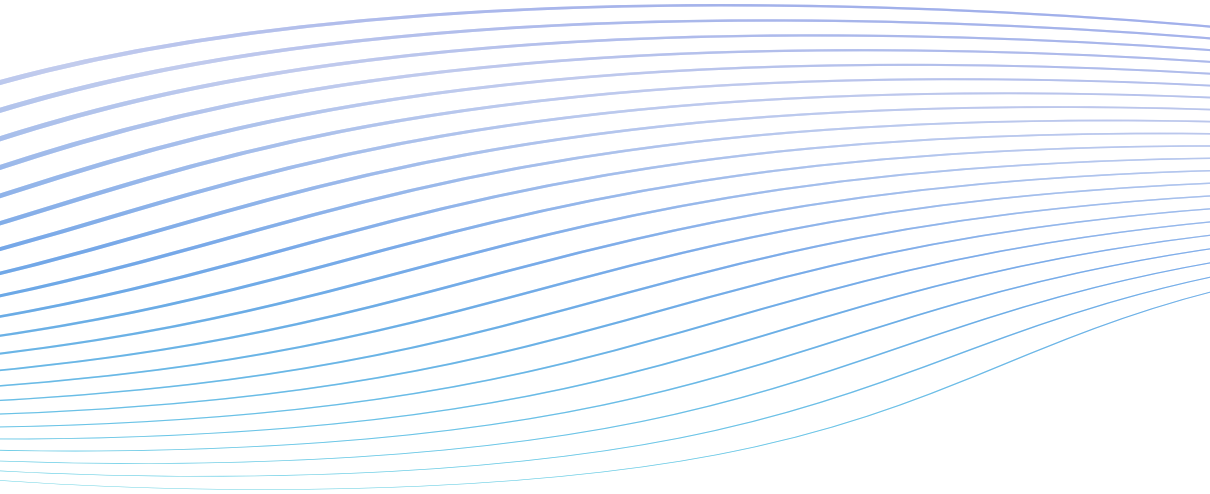
SUNRISE-6G has delivered key foundational elements of a federated 6G experimentation ecosystem:

- **Experimentation Portal**: Fully operational and accessible to the community (https://sunrise6g.eu/portal/).
- **6G Library Components**: Comprehensive library available for remote experimentation.
- **Open Operator Platform**: Framework recognised as the new ETSI OpenOP SDG.
- **Early Use Cases and Trials**: Demonstrating cross-testbed vertical application deployment and onboarding.
- **Standards Contributions**: 48 submissions across in 3GPP SA1, SA2, SA6 and ETSI MEC.

The facility addresses a major 6G research challenge: **the lack of a unified, scalable infrastructure for harmonised access to diverse 6G enablers and the absence** of open source implementations of key federation standards. By federating European testbeds through the Open Operator Platform (OpenOP) framework, and supporting AI-driven experimentation, SUNRISE-6G accelerates 6G innovation, lowers barriers for experimenters, and strengthens Europe's leadership in 6G architecture and ecosystem development.

SUstainable federation of Research Infrastructures for Scaling-up Experimentation in 6G

Coordinated by
Christos Verikoukis, ISI/ATH
January 2024 – December 2026
Website: https://sunrise6g.eu/
LinkedIn: @company/sunrise6g/
YouTube: www.youtube.com/@SUNRISE6G
Verticals: Automotive, Industry, Public Protection and Disaster Relief, Health, Energy, Smart Cities, Transport and Logistics, Media and Entertainment
Partners: ISI/ATH, Iquadrat, Siemens, Thales, IBM Ireland, Intracom, University of Oulu, National Centre for Scientific Research "Demokritos", KU Leuven, Eurecom, Fraunhofer IZM, i2CAT, Greenerwave, Infolysis, Fogus innovations and services, Sorbonne University, CNR, University of Thessaly, OTE, eBOS, NH APPART, Lulea technical University, VTT, Lenovo, Altice Labs, CNIT, IS-Wireless, Juniper Greece.



Stream D

LARGE SCALE TRIALS AND PILOTS WITH VERTICALS-FOCUSED TOPIC

The stream D targets large-scale SNS JU Trials and Pilots with Verticals, including the required infrastructure. Projects are expected to explore and demonstrate technologies and advanced applications and services for the vertical domains focusing on two priorities less covered in the previous call, namely i) Automotive and ii) Health, Smart Cities, Farming or Education.

6G-PATH

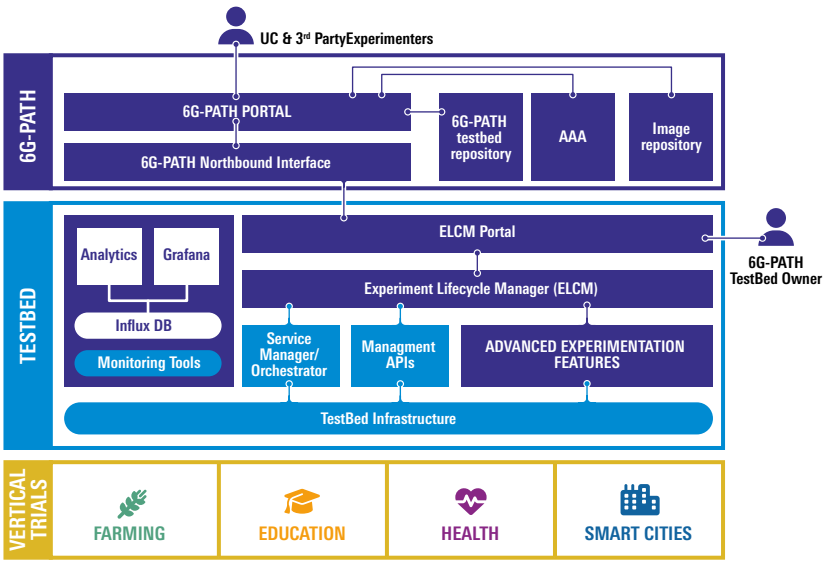
6G-PATH focuses on developing innovative infrastructures, delivering and refining an experimentation platform, expanding user communities, and shaping the future of 6G through research and standardisation efforts.

OVERVIEW

In the B5G/6G transition defining requirements and specifying demanding use cases (UCs) is crucial to set 6G challenges and validate solutions in realistic, market-oriented scenarios. 6G-PATH aims to foster the development and integration of new tools and products from EU companies while measuring relevant Key Performance Indicators (KPIs) and key value indicators (KVIs). The consortium includes nine testbeds supporting ten UCs across four key verticals: Farming, Education, Health and Smart Cities. Through funding and support for third parties (FSTP) open calls, ten additional technologies and thirty further UCs are planned for testing.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The 6G-PATH platform provides a unified environment for UC partners to configure, schedule, execute and analyse experiments, abstracting testbed operations via middleware and backend tools. Pilots and UCs define service compositions, and metrics. Northbound application programming interfaces (APIs) enable programmability, flexibility and interoperability, while the Portal allows planning, execution and monitoring through tools like the experiment Scheduler, authentication, authorisation and accounting (AAA) and the KPI/KVI Dashboard. The backend uses Southbound APIs to integrate infrastructure management, Artificial intelligence as a service (AIaaS), security as a service and monitoring, standardising operations for seamless communication across diverse testbeds and supporting scalable experimentation.



6G-Path

6G Pilots and TriAls Through Europe

Coordinated by Ioannis Chochliouros, OTE

January 2024 – December 2026

Website: https://6gpath.eu

X:@-gpath

LinkedIn: www.linkedin.com/company/6g-path

Verticals: Agriculture, Education, Health, Smart Cities

Partners: OTE, Telefonica ID and SA, Orange Romania and Foundation, Airbus DS SLC, Hewlett-Packard Italy, University of Malaga, Karlstad University, Charité – University Hospital of Berlin, University of the West of Scotland, University of Bradford, Aston University, University of Leicester, Altice Labs, Fraunhofer FOKUS, Instituto de Telecomunicaçoes, ICT-Ficial, OneSource Consultoria Informática, RedZinc Services, Odin Solutions, eBOS, Apart AE, F6S Network Ireland, MCS Data Labs, ACTA, Terraview, CloudSigma, Agencia Estatal Consejo Superior de Investigaciones Cientificas (CSIC).

INNOVATIONS

6G-PATH builds on previous 5G-PPP, H2020 and SNS JU Phase-1 projects, maturing low-technology readiness levels (TRL) developments into a state-of-the-art experimentation platform. Integrated with testbeds and evolving alongside internal and open calls UCs, it drives 6G progress through AI-driven networks, cross-domain continuum management, 6G RAN prediction, and distributed and federated learning. In addition, high precision localisation support extended reality (XR) technologies, the Internet of Senses and ultra-precision manufacturing. Selected UCs evaluate AI integration, edge-cloud computing, XR, ultra-low latency and high-bandwidth capabilities, for applications such as smart farming, immersive education, healthcare monitoring, large-scale IoT, city mobility, automated logistics and public safety.

The project enables advanced 6G network capabilities, fostering innovation across sectors with strong market relevance and impact.

USE CASES/ TRIALS/ APPLICATIONS

6G-PATH includes ten initial UCs spread across four verticals:

1. **Farming** – Water-saving techniques and smart vineyards, testing off-grid, intermittent and interconnected deployments with network slicing and different quality of service (eMBB, URLLC, eMTC) and AI-driven edge-cloud integration to optimise sustainability.
2. **Education** - XR rural schools; classroom of the future, and XR health training, leveraging edge computing, location-aware processing and AI for immersive learning and KPI/Quality of experience measurement.
3. **Health** - 3D hydrogel patches and elderly monitoring, using micro and nomadic edge nodes for ultra-low latency, secure communication and real-time precision treatments and monitoring.
4. **Smart Cities** - Connected city, automated logistics, and security coordination; integrating large-scale IoT-edge-cloud for mission-critical communications, high bandwidth streaming and URLLC and mMTC.

RESULTS/ IMPACT

Current results can be summarised as follows:

- **Execution of Large Trials and Pilots across 10 UCs in 4 Verticals**: These activities have validated the potential of B5G/6G-enabling technologies in diverse, real-world scenarios, demonstrating the performance, scalability and societal impact of advanced network capabilities. Each UC integrates advanced technological components and is validated in collaboration with vertical stakeholders and end users, enabling a comprehensive assessment of KPIs/KVIs.
- **Definition and Implementation of a Unified, Modular, and Scalable Experimentation platform**. This platform ensures flexibility, security and scalability and provides a solid foundation for executing and evaluating complex 6G experiments. It enables cross-vertical validation of emerging technologies in realistic environments and represents a significant contribution to Europe's 6G vision.
- **Implementation of a modern validation and evaluation framework**: This framework distinguishes sustainability KVIs - including social, economic and environmental dimensions and user experience KVIs for assessing perceived 6G quality of service, while KPIs are grouped into performance, security and functional indicators. 6G-PATH offers a multiplicity of innovations to help digitise economy & society, via the promotion of UCs of real market interest and with corresponding viable business models.

ENVELOPE

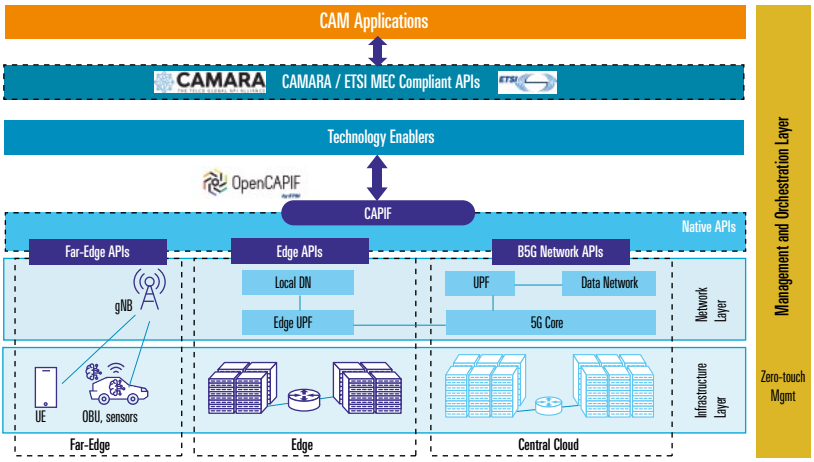
ENVELOPE aims to advance and open up a reference 5G advanced architecture and transform it into a vertical-oriented one.

OVERVIEW

The main objective of ENVELOPE is to advance and open up the reference 5G advanced architecture, transforming it into a vertical-oriented system with the necessary interfaces for connected and automated mobility (CAM) Use Cases (UCs) that i) expose network capabilities to verticals; ii) provide vertical-information to the network; iii) allow verticals to dynamically request and modify certain network aspects in an open, transparent and semi-automated way. ENVELOPE aims to deliver three large-scale Beyond 5G trial sites (TSs) in Italy, Netherlands and Greece.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The project supports B5G adoption in the CAM vertical (and beyond), by enabling seamless interaction between applications and the 5G network via LF CAMARA / ETSI MEC compliant application programming interfaces (APIs). These simplified APIs abstract the complexity of the B5G Core allowing service providers to benefit from network programmability while reducing development barriers.



ENVELOPE Architecture The northbound APIs simplify the interaction of vertical services with a series of advanced technological enablers delivered by the project. The Experimentation-as-a Service framework facilitates extensive testing.

INNOVATIONS

ENVELOPE introduces innovative support for advanced network features through APIs and technical enablers, including: **(i) Device Location/ Geofencing**: UE location in various updates, and area-based queries; **(ii) Connectivity Insights/Predictive Connectivity Data**: Performance forecasts; **(iii) Edge Cloud**: Service/host discovery, edge service orchestration, service migration (handover) and traffic influence; **(iv) 3GPP-compliant Access Traffic Steering-Switching-Splitting (ATSSS)**: Configured via ETSI MEC-015 Traffic Management APIs; **(v) Automated control loops**: Zero-touch network adjustments reducing manual intervention.

USE CASES/ TRIALS/ APPLICATIONS

ENVELOPE's innovations will be validated in three large-scale trials.

Greek Trial Site: The Athens site demonstrates data sharing for real-time situation awareness in CCAM scenarios. It validates seamless edge service migration over inter-public land mobile network handover (OTE/NCSRD), access traffic steering, switching and splitting multi-connectivity (5G/Wi-Fi), predictive quality of service (pQoS), and supporting application programming interfaces (APIs), enabling automotive applications that require programmable, reliable, and low-latency communications.

Dutch Trial Site: The Dutch site showcases digital twin-based automotive use cases supported by advanced network capabilities exposed via standardised CAMARA and new APIs. It supports reliable vehicle data collection with network-assured throughput and session stability, dynamic QoS, device localisation, and edge-enabled processing, enabling telemetry for analytics and predictive maintenance, mixed-reality vehicle testing, and tele-operated driving.

Italian Trial Site: The Italian Trial site focuses on B5G/6G system dynamism that meets varying vehicle and edge communication/computing needs. Two use cases validate system reconfiguration: (i) 3D scene reconstruction at the edge from vehicle sensor after accidents, and (ii) dynamic HD map updates performed upon detection of outdated road segments. The trial validates network exposure and programmability based on quality on demand, device location and geofencing, edge service migration, mobile edge computing (MEC) federation, and MEC handover.

Left: ISFM vehicle (GR TS); Center: gNb (NL TS); Right: vehicle equipment (IT TS)



RESULTS/ IMPACT

ENVELOPE aims to provide the community with a well-defined set of technology enablers and vertical-friendly APIs that support a more flexible interaction with the network. The project places significant focus on sharing and extensively validating these advancements both through open-source solutions and the establishment of three experimental facilities. The latter will enable extensive experimentation and technology solution validation in the context of the ENVELOPE Cooperative CAM UCs, offering valuable insights on the functionality and use of the corresponding features in realistic conditions. Building on these established facilities, the project's Open Calls will create a feature-rich experimentation environment. This allows third-parties to validate the provided solutions in various conditions or industries, and test additional technology enablers and interfaces.

Evaluation and validation of connected mobility in real open systems beyond 5GS

ENVELOPE

Coordinated by
Angelos Amditis, ICCS

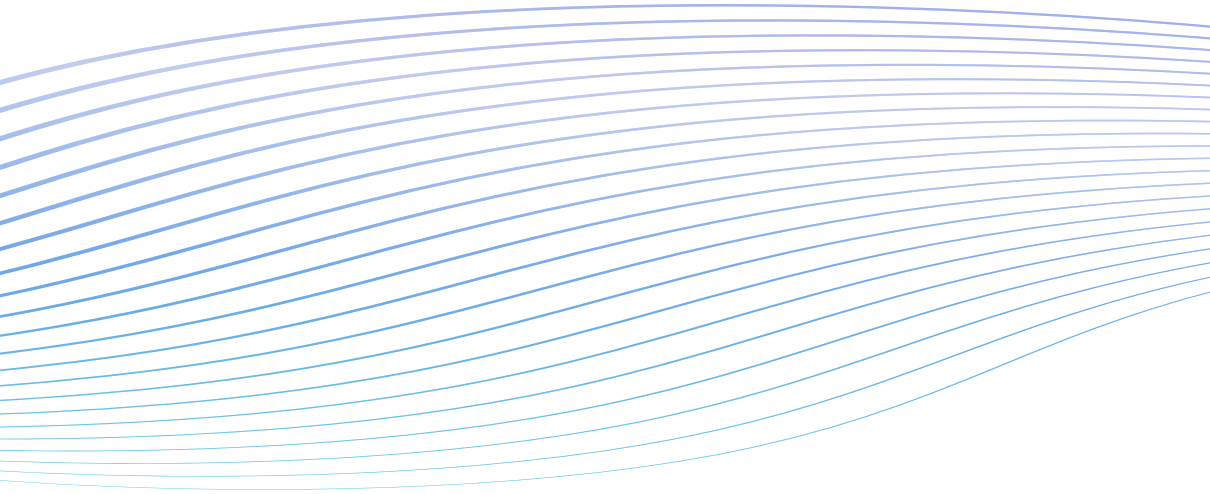
January 2024 – December 2026

Website: https://envelope-project.eu/

LinkedIn: www.linkedin.com/company/envelope-project

Verticals: Automotive: Connected car – V2X and Autonomous driving

Partners: ICCS, Commsignia, LINKS Foundation, NCSRD, Leibnitz university Hannover, TNO, Athena Research Centre, VICOMTECH, OTE, KPN and TIM, Teoresi, ISFM, Hewlett Packard Enterprise, LENOVO, Nextworks, FOGUS, Iquadrat, eBOS, InCites, ERTICO.



SNS JU SOCIETAL CHALLENGES

The three Streams of the Call 2 are complemented by the SNS JU Coordination and Support Action (CSA) 6G4Society which aims at dealing with societal challenges related to SNS JU technologies.

6G4SOCIETY

Bridging technology and societal values in 6G development.

OVERVIEW

6G4Society promotes next-generation connectivity driven by **ethical, environmental and societal and sustainability considerations**, as it seeks to deepen public understanding of 6G and the qualities of social acceptance, and **supports a European framework that embeds societal values, trust and sustainability into network design**. Through active citizen engagement and alignment with EU polices, 6G4Society aims to ensure 6G develops **inclusively, transparently, and in the public interest**.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

6G4Society reframes 6G as a value-driven system, embedding **societal, environmental, and economic impacts from the start, where Social Acceptance frameworks, citizen and vertical feedback, and sustainability considerations are integrated directly into design cycles**, rather than treated as external constraints. key value indicators (KVIs) and Key Sustainability Indicators (KSIs) complement technical KPIs, enabling evaluation of architectures and technologies, not only on throughput or latency but also on inclusivity, safety, trust, well-being, and skill development.

Public engagement and **survey results highlighted priorities** such as privacy, fairness, environmental sustainability, human-centric design, and tangible everyday benefits. **These insights guided the application of the Social Acceptance of Technology (SAT) framework and operationalisation of KVIs and KSIs**, ensuring technologies **are developed and assessed** as enablers of people- and planet-centric outcomes, making value-driven 6G **operational rather than aspirational**.

INNOVATIONS

6G4Society integrated **complementary and multidisciplinary perspectives across multiple layers of action** in the project work plan. The project **advanced knowledge and provided guidance on social and ethical aspects of 6G, focusing on** KVIs, KSIs, and on the development and a SAT framework. Empirical evidence from **citizen surveys, public engagement, expert interviews, policy discussions and literature review revealed emerging public expectations around privacy, fairness, environmental sustainability, human-centric design, and tangible benefits**.

The project highlighted the need to capture diverse social priorities, understand societal impacts, and embed values early in 6G innovation, while investigating potential risks to privacy, inclusion, and technology sovereignty. These insights informed the operationalisation of SAT, KVIs, and KSIs, as well as four policy briefs for policymakers and four operational briefs for industry.

By engaging with the SNS JU Community, standardisation discussions, and cross-project collaboration, 6G4Society explored societal acceptance and social sustainability from low-TRL stages onward. Participatory activities, public position documents, and accessible

communication materials addressed barriers of trust, legitimacy, and awareness, producing practical frameworks, methodologies, and recommendations to support transparent, ethical, and socially legitimate 6G development.

USE CASES/ TRIALS/ APPLICATIONS

Societal acceptance and social sustainability are critical for technology adoption, and 6G4Society addressed these across multiple verticals. A workshop with public protection and disaster relief stakeholders identified key values, objectives, contextual factors, and monitoring priorities, providing insights for a wide range of 6G use cases that affect citizens, communities, and public trust. Citizen surveys revealed that public priorities focus privacy, inclusion, technology sovereignty, environmental sustainability, fairness, and tangible everyday benefits. Generational differences emerged—youth emphasised equity and sustainability, while older groups prioritised reliability and practicality—but all agreed that future networks must serve society as a whole.

Through collaboration with other SNS JU projects, through mechanisms like the SNS JU Sustainability Task Force, 6G-IA working groups, and especially the Societal Needs and Value Creation (SNVC) subgroup, 6G4Society helped communicate 6G's **potential benefits, risks, and trade-offs to both market players and society**. The project also implemented its communication strategy within a dedicated **Information Package of infosheets, infographics, and an animated video, offering clear and accessible explanations grounded in societal perspectives**.

RESULTS/ IMPACT

6G4Society delivered a 6G-specific Social Acceptance of Technology (SAT) framework, structured Key Value and Sustainability Indicators (KVIs/KSIs), four policy briefs, four operational briefs, two position papers, and citizen-focused communication materials. These outputs translated societal values into operational guidance, extending beyond traditional performance metrics to address social acceptance, impact, and sustainability. All results were informed by citizen surveys, participatory workshops, expert interviews, and ongoing engagement with the SNS JU community and related 6G initiatives. Findings emphasised that trust cannot be retrofitted and that social acceptance depends on governance frameworks protecting rights, fairness, and socially aligned 6G development, embedding acceptance and sustainability as foundational dimensions rather than downstream, dimensions.

Briging Technology and Societal Values in 6G Development

6G4SOCIETY

Coordinated by Monique Calisti, Martel Innovate

January 2024 – December 2025

Website: www.6g4society.eu/

X: @6g4society

LinkedIn: www.linkedin.com/company/6g4society/

Verticals: Media and entertainment

Partners: Martel Innovate, Digital for Planet, CyberSocial Lab, Nova, Public Safety Communication Europe, eBOS.

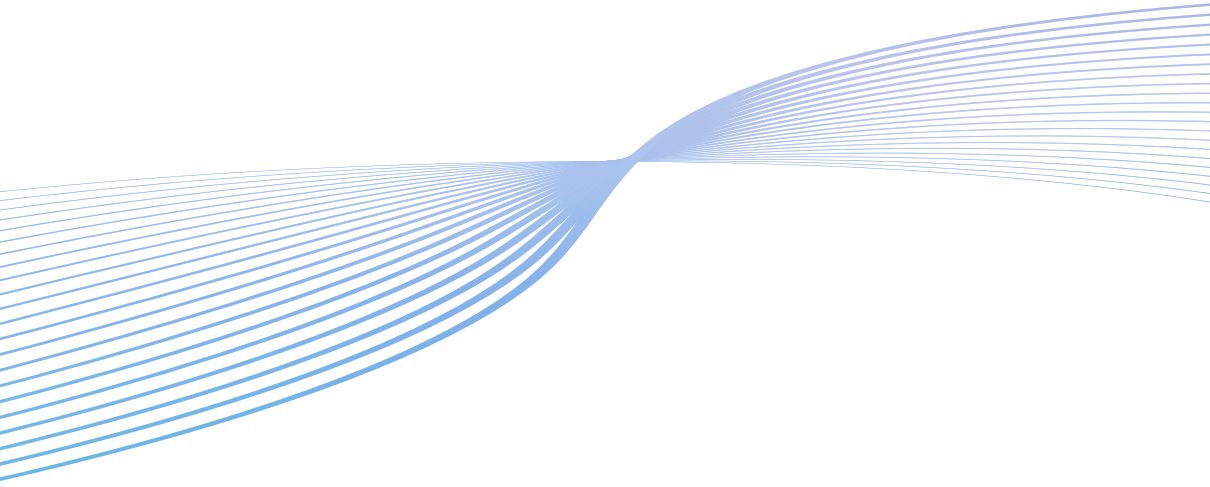
Call 3 Projects

The SNS JU Call 3 received an enthusiastic response, with requested grants totalling €863 million, more than 7 times the available funding. The 16 selected projects in Call 3 support 301 beneficiaries from 25 countries in developing and deploying next-generation network infrastructure, platforms, and services.

Stream B

WIRELESS COMMUNICATION TECHNOLOGIES

The focus of stream B is on wireless communication technologies. It is divided in eight sub-sections for a total of twelve projects.



Stream B1

SYSTEM ARCHITECTURE

FLECON-6G

Enabling Scalable, Intelligent, and Collaborative 6G Networks.

OVERVIEW

FLECON-6G develops an **Intelligent 6G Network of Networks** that enables automated, scalable service orchestration across heterogeneous infrastructures and stakeholders. The project integrates native and trustworthy AI, multi-layer network digital twins (NDT), and a collaborative, distributed architecture spanning terrestrial and non-terrestrial domains. Through intent-driven automation, advanced data transfer and edge integration, and a smart marketplace for sustainable resource sharing, FLECON-6G supports flexible multi-domain 6G services. The proposed solutions are validated through targeted proofs-of-concept across multiple vertical sectors.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The FLECON-6G project introduces a modular, distributed 6G architecture with network digital twins for real-time monitoring and efficient resource management. It integrates Native AI for zero-touch operations and intelligent service composition, with intent-based APIs enabling seamless automation for stakeholders. Key technologies include AI-as-a-service (AIaaS), digital twin-as-a-service (DTaaS), edge computing, and network slicing. Moreover, the smart marketplace improves access to resources and supports sustainable business models. These innovations create a high-performance "Network of Networks" that supports use cases in automotive, industry, healthcare, and public safety.

Flexible Open Architecture and AI-driven Enabling Technologies for a Novel 6G Connectivity Platform

FLECON-6G

Coordinated by
Christos Verikoukis, ISI/ATH

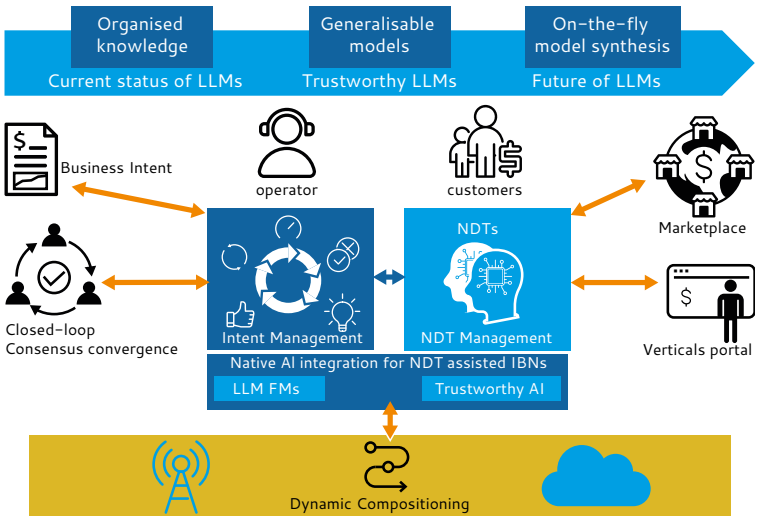
January 2025 – December 2027

Website: https://www.flecon6g.eu/

LinkedIn: www.linkedin.com/company/flecon-6g/

Verticals: Automotive, Industry, Media and Entertainment, PPDR, Health

Partners: ISI/ATH, Eurecom, CNIT, Technical University of Delft, UCLAN Cyprus, EBOS Technologies, Iquadrat, NeXtworks, Brainstorm Multimedia, E-Lighthouse Network Solutions, Real World Eastern Europe, Airbus DS, Ericsson, LENOVO, NVIDIA, Siemens, Orange Romania, OTE, Telefonica ID.



FLECON-6G high-level Vision

INNOVATIONS

The project introduces multi-layer NDTs for real-time monitoring and analytics to optimise multi-domain 6G networks. intent-based application programmable interfaces (APIs) enable scalable service orchestration and seamless resource management. The smart marketplace facilitates resource sharing through models like AIaaS and DTaaS. Native AI ensures zero-touch, self-optimising operations using trustworthy algorithms. A collaborative architecture supports multi-domain coordination, while advanced data transfer paradigms enhance efficiency with edge integration. The integration of non-terrestrial networks (NTNs) combines terrestrial and satellite systems, offering scalable connectivity for underserved areas. The user-centric design ensures accessibility and usability through responsive, inclusive interfaces.

USE CASES/ TRIALS/ APPLICATIONS

The FLECON-6G project includes four proofs-of-concept (PoCs) showcasing advanced 6G technologies:

- **PoC 1: Seamless Immersive Reality (SIR)**. SIR Combines Virtual Reality (VR), Augmented Reality (AR), and Extended Reality (XR) to create multi-sensory experiences, enhancing entertainment and education through real-time, interactive environments. Focuses on high-bandwidth, low-latency communication for seamless integration.
- **PoC 2: Machine Inspection with Autonomous Robots and VR**. Uses VR-enabled robots for efficient anomaly detection during inspections. Ensures reliable video quality in varying wireless conditions, enabling effective remote operations.
- **PoC 3: Network Digital Twin with Non-Terrestrial Networks**. Network Digital Twin with Non-Terrestrial Networks: Integrates Network Digital Twins with NTNs for real-time monitoring and control in remote areas enabling immediate configuration adjustments to ensure consistent connectivity.
- **PoC 4: Public Safety Services**. Public Safety Services: Improves emergency communication systems with low-latency, secure solutions. Addresses infrastructure limitations to ensure reliable performance in critical scenarios. Provides public safety solutions to meet high-performance demands during emergencies.

RESULTS/ IMPACT

During its first year, the FLECON-6G project has achieved initial architectural and system-level results that lay the foundation for an intelligent 6G Network of Networks. Key outcomes to date include:

- **Definition of a modular and distributed 6G reference architecture**, supporting multi-domain orchestration across heterogeneous administrative and technological environments;
- **Initial design and specification of the smart marketplace**, enabling controlled exposure, discovery, and composition of network, AI, and digital twin resources under AI-as-a-Service and Digital Twin-as-a-Service models;
- **Early integration of Native AI** concepts within the architecture to support intent-driven, automated service orchestration and scalable network management.

These initial results establish the basis for subsequent implementation and validation activities, which will be demonstrated through targeted Proofs of Concept across multiple vertical sectors.

FLECON-6G addresses key limitations of current networks in terms of automation, trustworthiness, sustainability, and interoperability. By leveraging 6G capabilities such as ultra-low latency, high reliability, and native intelligence, the project enables advanced applications including immersive media, autonomous systems, and mission-critical public safety services, contributing to the development of scalable and resilient future communication infrastructures.

UNITY-6G

Pioneering Sustainable, Scalable, Intelligent and Integrated 6G Networks.

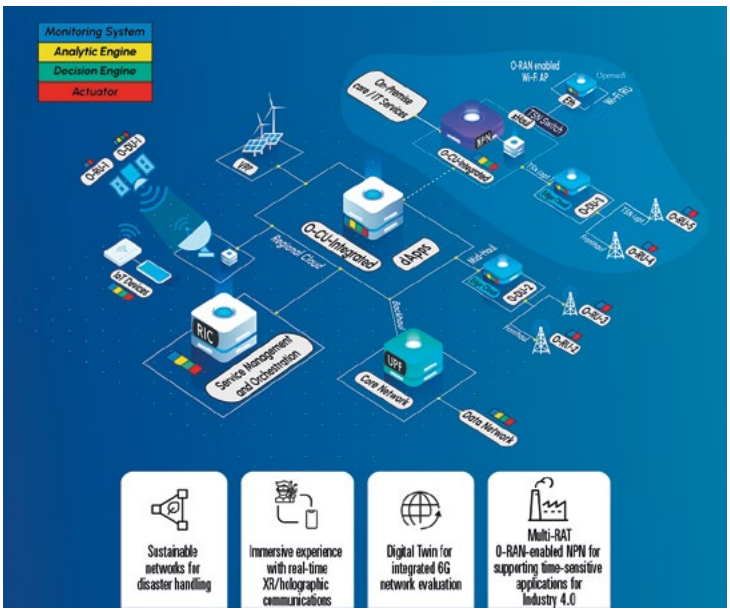
OVERVIEW

UNITY-6G project aims to transform 6G networks through innovative architectures and advanced technologies, focusing on scalability and sustainability across integrated networks including non-terrestrial and terrestrial networks (NTNs and TNs), xHaul, open radio access networks (RANs), non-public networks (NPNs), edge, core, and cloud. The project leverages AI-native architectures to automate and optimise operations, enhancing performance and reliability and uses digital twin technology for real-time simulation and adaptative management. By integrating renewable energy sources via smart grid interfaces, UNITY-6G delivers a sustainable, intelligent, and trustworthy 6G infrastructure ready to support next-generation digital applications.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The UNITY-6G architecture uses a multi-layered approach to create an integrated and intelligent 6G network. The infrastructure layer combines traditional and integrated network components with virtual power plants (VPPs) and time-sensitive networking (TSN) for efficient energy management and precise timing. The edge-cloud continuum layer enables processing and storage closer to end users, while the management layer leverages AI-driven service orchestration to optimise resources and service quality. Finally, the digital twin layer provides real-time simulation and testing enhancing predictive maintenance and operational resilience.

UNITY-6G architecture



UNified archITecture for Open RAN-enabled Distributed, Scalable and SustainabilitY enhanced 6G Networks

Coordinated by
Engin Zeydan, CTTC

January 2025 – December 2027

Website: www.unity-6g.eu

LinkedIn: www.linkedin.com/company/unity-6g/

Verticals: PPDR, Industry, Media and Entertainment, Energy

Partners: CTTC, Telefónica ID, Keysight Denmark, Orange, Nokia Solutions and Networks, Software Radio Systems, independent Power Transmission Operator of Greece, Poznan University of technology, Ceragon Networks, Hispasat, Nearby Computing, Hololight, University of Bologna, German Aerospace Center, Four Dot Infinity, IMEC, LINKS Foundation, Greek National Center for Scientific Research "Demokritos", Martel, University of Applied Sciences and Arts of Western Switzerland.

INNOVATIONS

UNITY-6G drives innovation in 6G network development, with a strong focus on sustainable, scalable, and intelligent operations. The project leverages **AI-native architectures** for dynamic resource management and predictive maintenance, improving network efficiency and reliability, particularly under dynamic and challenging conditions. UNITY-6G also develops **a service-based architecture that enables seamless interaction** across heterogeneous network domains, including non-terrestrial networks, xHaul, open RAN, and edge, core, and cloud systems. In addition, it introduces **digital twin technology** for network management, enabling real-time performance simulation and proactive adaptation to enhance resilience and service delivery, supported by common interfaces and protocols for seamless cross-domain communication. Finally, UNITY-6G integrates **renewable energy sources through smart grid interfaces**, promoting sustainable grid operations and strengthening resilience to natural disasters.

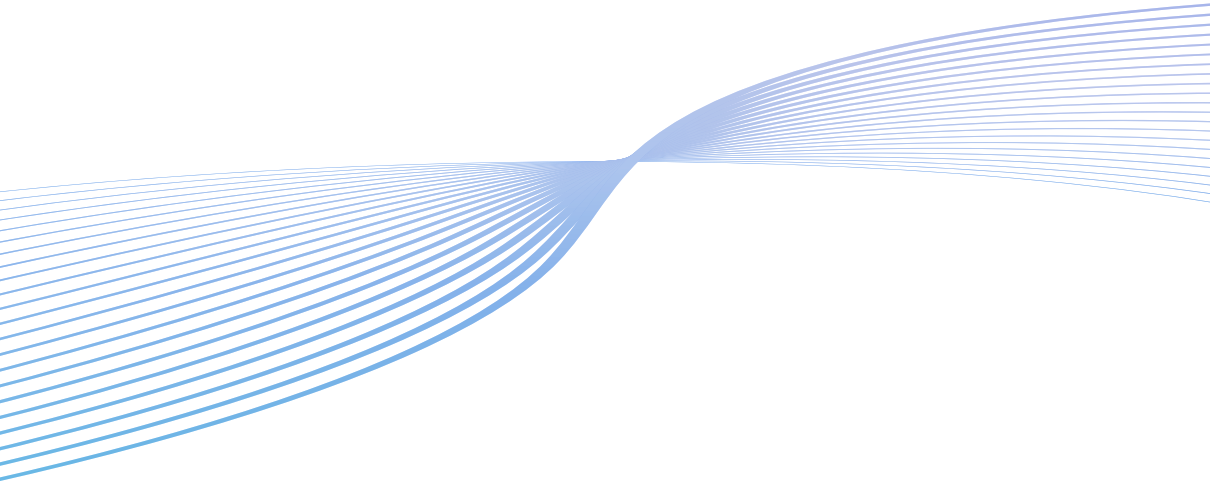
USE CASES/ TRIALS/ APPLICATIONS

UNITY-6G develops four key use cases:

- **UC1: Sustainable networks for disaster handling**. Building resilient networks that maximise alternative power sources, such as solar and wind, through coordination with local microgrids. These networks leverage a service-based architecture to ensure efficient resource utilisation and flexible service deployment.
- **UC2: Immersive experience with real-time XR/holographic communications**. Designing a semantic-aware 6G network optimised for real-time holographic communications, prioritising on minimal latency, high performance, energy efficiency, and a enhanced user experience.
- **UC3: Digital Twin for integrated 6G network evaluation**. Using digital twin technology to test and rapidly deploy novel 6G services, evaluate future scenarios, and assess the impact of configuration and function changes. This approach simplifies site deployment, enhances transport, satellite, and radio resource management, strengthens operations across the edge-cloud continuum, addresses trustworthiness and resiliency, and enables effective network orchestration and management.
- **UC4: Multi-radio access technology (RAT) O-RAN enabled NPN for supporting time-sensitive applications for Industry 4.0**. Developing a multi-RAT RAN tailored to 6G NPN architectures that integrates cellular and IEEE 802.11 technologies. This use case supports low-latency, high-reliability communication for industrial automation applications spanning end-to-end wired and wireless domains across different RATs.

RESULTS/ IMPACT

UNITY-6G envisions transformative advances in 6G networks, emphasizing sustainability, intelligence, scalability, and trustworthiness. Its key technologies include AI-native architectures that dynamically optimise network operations for higher efficiency and reliability; digital twin technology that enables real-time simulations and proactive management, enhancing resilience and adaptability; and distributed ledger technology that ensures secure, transparent resource sharing and fosters trust among network participants. Additionally, UNITY-6G integrates renewable energy sources to reduce the environmental impact of networks.



Stream B2

WIRELESS COMMUNICATION TECHNOLOGIES AND SIGNAL PROCESSING

6G-LEADER

AI-Driven and Open RAN Innovations for Next-Generation 6G Networks.

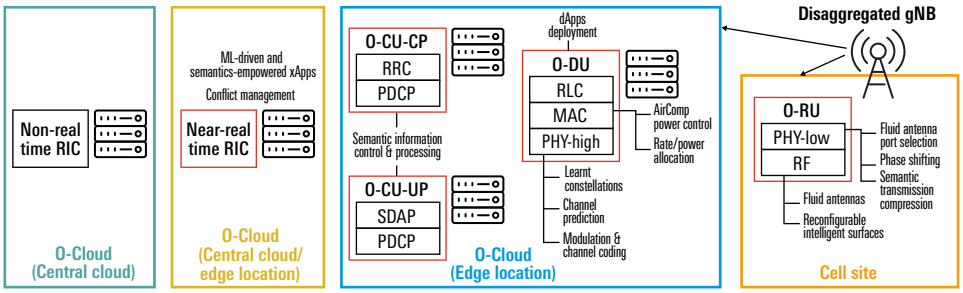
OVERVIEW

6G-LEADER is a European-led initiative focused on designing a flexible, intelligent, and sustainable radio access network (RAN). By combining AI-driven algorithms with open architectures (O-RAN), the project aims to create a 6G ecosystem that is faster, greener, and highly adaptive to diverse service requirements.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The 6G-LEADER architecture is built on the principles of openness and intelligence. At its core, an **AI-native O-RAN framework** embeds machine learning directly into the physical (PHY) and medium access control (MAC) layers. The project leverages the **FR3 spectrum (7–24 GHz)** to bridge the gap between traditional cellular bands and millimeter-wave frequencies, enhancing capacity. **Reconfigurable intelligent surfaces (RIS) and flexible arrays (FA)** dynamically shape and control the radio environment, ensuring robust connectivity even in complex urban scenarios.

High-level 6G-LEADER architecture



INNOVATIONS

6G-LEADER introduces advanced techniques to enhance network efficiency, intelligence, and sustainability:

- **Semantic & Goal-Oriented Communication** - moving beyond transmitting "raw bits", our approach prioritises data relevance, sending only the information necessary for the specific task, reducing network load.
- **AI/ML-aided Multiple Access** - novel non-orthogonal schemes that outperform current solutions, enabling more devices to connect simultaneously with higher efficiency.
- **AirComp (Over-the-Air Computation**) - a "Wireless for AI" approach where data aggregation occurs directly over the air, accelerating distributed AI training.
- **Green Signal Processing** - energy-aware designs that dynamically adjust hardware power consumption to match real-time traffic demands.

USE CASES/ TRIALS/ APPLICATIONS

6G-LEADER is validating its innovations through five distinct proofs-of-concept (PoCs):

- **PoC1**: XR and UAV seamless real-time interaction.
- **PoC2**: Enhanced Mobile Broadband Experience.
- **PoC3**: AI/ML Trainable 6G RIC Conflict Manager.
- **PoC4**: Wireless for AI based on AirComp.
- **PoC5**: AI/ML-aided enhanced multiple access.

RESULTS/ IMPACT

Now in phase 2, 6G-LEADER has already delivered significant technical contributions to the O-RAN Alliance, ETSI, and 3GPP, reinforcing European leadership in the 6G landscape. Our work demonstrates that open, modular network design, can reduce the operational footprints while supporting the next decade of digital transformation.

The project's ultimate impact spans in three dimensions: **Scientific**, through breakthroughs in AI/ML-driven RAN technologies; **Environmental**, via energy-aware hardware and network designs; and **Societal**, by ensuring cost-effective, inclusive thigh-speed connectivity across Europe.

LEArning-Driven and Evolved Radio for 6G Communication Systems

Coordinated by Mateusz Kowacki, F6S Network Ireland

January 2025 – December 2027

Website: https://6g-leader.eu/

LinkedIn: www.linkedin.com/company/6g-leader/

Verticals: Industry, PPDR, Health, Smart Cities, and Transport & Logistics.

Partners: F6S Network Ireland, university of Cyprus, Four Dot Infinity Information and Telecommunications Solutions, Aalto university, Atos Spain, Linköping university, Accelleran, university of Granada, Software Radio Systems, ICCS, Digital Catapult, Samsung Electronics, Nokia UK, CNT, Massive Beams, Universidad Carlos III de Madrid, Telefonica, polytechnical university of Catalunya.



6G-LEADER Consortium

MULTIX

The project aims to revolutionise 6G RAN design by developing a MultiX fusion perceptive 6G-RAN system (MP6R) that integrates multi-sensor, multi-band, multi-static, and multi-technology capabilities.

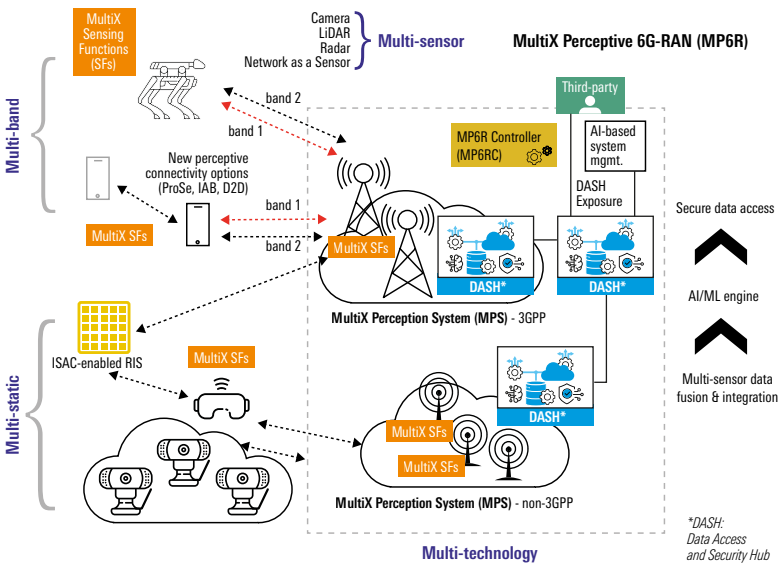
OVERVIEW

MultiX is revolutionising 6G radio access networks (RAN) through the development of the MultiX fusion perceptive 6G-RAN (MP6R). Unlike traditional communication-only networks, MultiX transforms the RAN into a high-resolution sensor capable of intelligent environmental interaction. By integrating multi-technology, multi-sensor, multi-band, and multi-static perception, the project aims to significantly enhance sensing accuracy, resolution and sub-centimeter localisation and real-time situational awareness.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The architecture centers on a distributed, service-based architecture (SBA) that separates sensing control from the data plane: **MultiX perception system (MPS)**: Embeds the measurement sensing processing function (m-SePF) at the RAN edge, enabling near-real-time processing of raw IQ samples for low-latency perception; **MP6R Controller (MP6RC)**: Dynamically coordinates heterogeneous 3GPP and non-3GPP sensing resources including Wi-Fi, Radar, and LiDAR; **Data Access and Security Hub (DASH)**: Provides a distributed framework for secure multi-modal sensor fusion, data governance, and privacy-preserving exposure to third-party applications.

MultiX vision



Advancing 6G-RAN through multi-technology, multi-sensor fusion, multi-band and multi-static perception

Coordinated by
Antonio de la Oliva, Universidad Carlos III de Madrid

January 2025 – June 2027

Website: https://multix-6g.eu/

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Mastodon: https://mastodon.social/@MultiX6GProject/

YouTube: www.youtube.com/@MultiX-6GProject

Verticals: Industry, Logistics, Health, Smart Cities

Partners: Universidad Carlos III de Madrid, Apple, BubbleRAN, CNIT, INTEL, InterDigital Europe, IHP, i2CAT; IMDEA Networks, Institute of Accelerating Systems & Applications, Catholic university of Leuven, NEC Laboratories Europe, Nextworks, OTE, Siemens, Telefonica, university of Cantabria.

INNOVATIONS

During its first year, MultiX has achieved significant technical milestones that address fundamental challenges in the 6G landscape.

- **Defined six 6G perception use cases and their associated key performance indicators (KPIs)**: Establishing a baseline for high-resolution environmental awareness.
- **Designed the first version of the MP6R reference architecture**: Extending the 3GPP SBA concepts across RAN and core domains. It integrates sensing data from both 3GPP and non-3GPP sources, including cellular user equipment (UE), Wi-Fi, radar, LiDAR, and cameras -enabling near-real-time processing and synchronisation, to meet stringent latency requirements. This work contributes to ETSI ISAC ISG and is being explored for standardisation in 3GPP and IEEE.
- **Data Access and Security Hub (DASH)**: Serves as the core component for sensing data processing, storage, governance, and secure exposure. DASH ensures that sensing information is accessible only to authorised entities, including internal network functions and third-party applications, through authentication, authorisation, and accounting mechanisms. Standardised interfaces support discovery, subscription, and controlled reporting of sensing data, enabling perception-driven services while maintaining operator control over data usage and access policies.
- **MultiX Perception System (MPS)**: Focuses on (i) perception enablers such as channel modelling, multi-band processing, waveform design; (ii) Multi-technology and multi-static sensing integration, including over-the-air synchronisation for multi-static integrated sensing and communications (ISAC) and non-coherent mono- and multi-static sensing techniques; (iii) AI-based energy efficient solutions to reduce overall consumption while maintaining or improving sensing performance. Pioneering target phase coherence measurements were conducted in the 7-24 GHz (FR3) band, a key spectrum for 6G offering a balance of propagation efficiency and bandwidth.

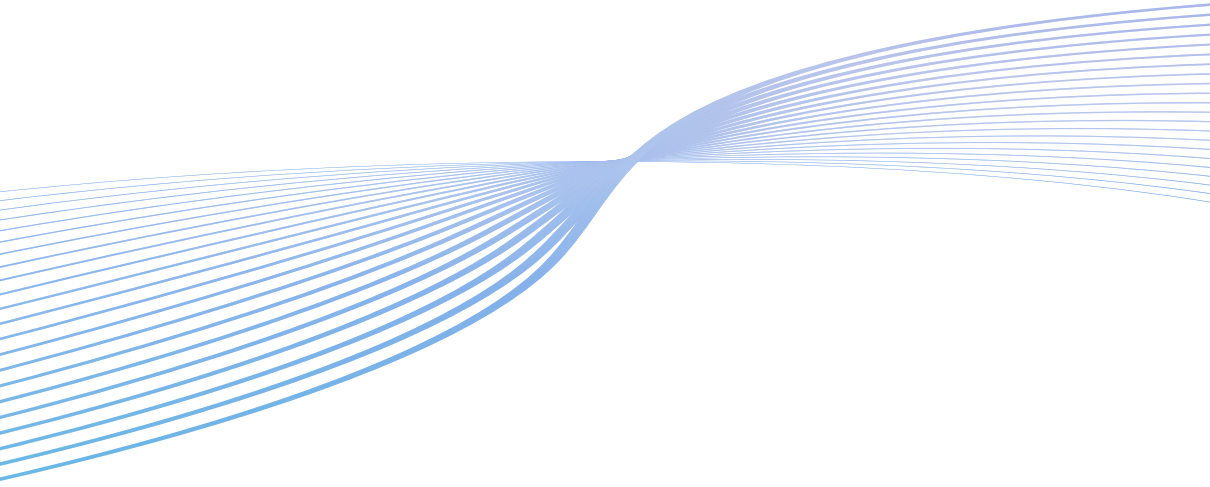
USE CASES/ TRIALS/ APPLICATIONS

Validation is progressing through two high-impact TRL 4-5 proofs-of-concept (PoCs):

- **PoC 1 Industrial Digital Twin (Madrid/Munich)**: Demonstrates robots proactively adapting their paths and network parameters (reconfigurable intelligent surfaces adjustments, radio access technology switching) using real-time ISAC environment maps to navigate moving obstacles.
- **PoC 2 Contact-free eHealth (Athens/Leuven)**: Achieved high-precision human respiration detection (>90% F1-score) and vital sign monitoring using commodity Wi-Fi and massive multiple input multiple output, showing that 6G can deliver medical-grade monitoring without wearables.

RESULTS/ IMPACT

MultiX has established itself as a leading contributor to the global 6G ecosystem. In standardisation, the project exceeded its targets with 101 technical contributions to ETSI ISG ISAC, 3GPP, and IETF, including 39 adopted items actively shaping 6G normative work. Scientific leadership is reflected in 14 journal articles and 19 conference papers in top-tier venues such as IEEE Transactions on Wireless Communications. Key outcomes have also been showcased at major industrial events including MWC2025 and ETSI ISAC workshops. The project demonstrated that sensing-aware deep reinforcement learning (DRL) can reduce RAN resource utilisation by nearly 30%. In lien with Open Science principles, the consortium has released 26 artifacts, including datasets and software, via the Zenodo MultiX Community, ensuring all results are findable, accessible, interoperable, and reusable.



Stream B3

COMMUNICATION INFRASTRUCTURE TECHNOLOGIES AND DEVICES

AMBIENT-6G

AMBIENT-6G will develop standardised enablers to integrate ambiently powered energy neutral devices into the 6G network infrastructure.

OVERVIEW

The limited autonomy of battery-powered IoT devices increases maintenance costs, adds system complexity, and compromises long-term reliability. AMBIENT-6G addresses this challenge by introducing a new class of energy-neutral ambient-IoT (AIoT) devices that harvest ambient energy or utilise radio-frequency wireless power transfer (RF-WPT), enabling operation for decades without battery replacement. A key challenge for AMBIENT-6G is to maintain acceptable quality of service while using only a fraction of the energy budget of conventional IoT devices. While current AIoT standardisation primarily focuses on passive devices relying on backscatter communications, AMBIENT-6G also explores energy neutral devices equipped with active radios, expanding the range of AIoT deployment options, use cases, and technological components.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The overall objective of AMBIENT-6G is to design, prototype, validate, and standardise both hardware and software technology components for AIoT, along with the 6G network infrastructure that connects AIoT devices to the Internet. The project focuses on the secure integration of active and passive devices within the 6G network architecture and the end-to-end cloud-edge-device continuum. Active devices will leverage novel low-power wide area network (LPWAN) protocols designed to achieve energy consumption orders of magnitude lower than current 5G LPWAN options, such as NB-IoT and LTE-M. These protocols will be lightweight, secure, and energy aware. The network will also support backscatter communications for passive devices and provide RF-WPT for remote energy recharging. Devices will be integrated into a cloud-edge-device continuum, enabling distributed and federated AI with low-power on-device inference and training, energy-aware offloading to edge and cloud resources, and over-the-air model updates.

INNOVATIONS

AMBIENT-6G introduces transformative innovations for maintenance-free IoT, organised around three key areas. The first focuses on a **holistic hardware/software device architecture**, addressing performance, cost, and materials trade-offs, and encompassing circuits for energy harvesting, storage, and management, as well as radio transceivers supporting RF-WPT, backscatter, and wireless wake-up. The second area targets a **6G LPWAN for AIoT devices**, including infrastructure enablers for backscatter and RF-WPT, alongside secure, lightweight protocols with reduced signaling overhead and energy-aware transmission scheduling. The third area explores **enablers for end-to-end intelligence**, covering predictive mechanisms for energy-awareness, distributed and on-device AI (including inference and training), and orchestrated cloud-edge-device offloading.

USE CASES/ TRIALS/ APPLICATIONS

The AMBIENT-6G project enables transformative use cases across multiple IoT verticals by leveraging AIoT devices and 6G infrastructure. Overall, the consortium identified 11 relevant AIoT use cases, grouped into three overlapping use case families:

1. Hard-to-Reach Devices

Devices embedded in materials or deployed in remote or hazardous locations, making them difficult and costly to access. Relevant use cases include smart home sensing, infrastructure health monitoring, on- or in-body medical sensing, smart agriculture, logistics tracking, predictive machine maintenance, and mobile cobots.

2. Massive-Scale Sensor Networks

Devices that are relatively accessible, but whose large-scale deployment makes maintenance extremely time consuming. Relevant use cases include electronic shelf labels, smart agriculture, asset tracking, museum guiding system, logistics tracking, predictive machine maintenance, and mobile cobots.

3. Extreme-Lifetime Applications

Devices for which battery replacement is possible, but undesirable due to factors such as ease of use, or requirements for long maintenance-free operation. Relevant use cases include smart home sensing, infrastructure health monitoring, person/item tracking, in- or on-body medical sensing, asset tracking, museum guiding system, and predictive machine maintenance.

RESULTS/ IMPACT

The project's first outcome was an AIoT device classification methodology, based on energy, hardware interfaces and functional capabilities (processing, memory, and communication), defining four modes: ultra-passive, duty-cycled barebone, duty-cycled persistent, and continuous. A life-cycle assessment methodology was also developed to evaluate devices' environmental impact. AMBIENT-6G further analysed the state of the art and published initial findings for its three innovation areas:

1. AIoT hardware design

AMBIENT-6G consolidates designs of AIoT devices leveraging energy harvesting, power management, and backscatter radio technologies into a coherent hardware map. This links capability needs, energy-neutral operation, and sustainability metrics to concrete implementation options for ultra-low-power, low-cost, and eco-friendly AIoT devices.

2. Low-power 6G network protocols

AMBIENT-6G develops methods to connect intermittently, powered and resource-constrained devices to the network. This includes low-complexity synchronisation, modulation, waveforms, network management and security approaches, along with energy-aware channel access and scheduling algorithms. The integration of backscatter and RF charging functionalities into the 6G network architecture is also explored.

3. Energy-aware on-device and edge computing

AMBIENT-6G proposes energy-aware task scheduling and offloading methods to optimise device operations - sensing, actuation, computing, and communication-based on energy predicted energy availability and consumption. These methods address both conventional applications and AI workloads.

Towards standardised 6G connectivity for ambiently-powered energy neutral IoT devices

AMBIENT-6G

Coordinated by
Jeroen Famaey, imec

January 2025 – December 2027

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Verticals: Industry, Health, Smart Cities, Transport and logistics, Smart agriculture

Partners: IMEC, Aalto university, university of Oulu, Ericsson Finland, Sequans Communications, WINGS ICT, KU Leuven, Quicksand, NXP Semiconductors Austria, Technical university of Graz, Telefonica.

NEXASPHERE

NexGen 3D networks spin harmonies across 6G, AI, and unified TN/NTN.

OVERVIEW

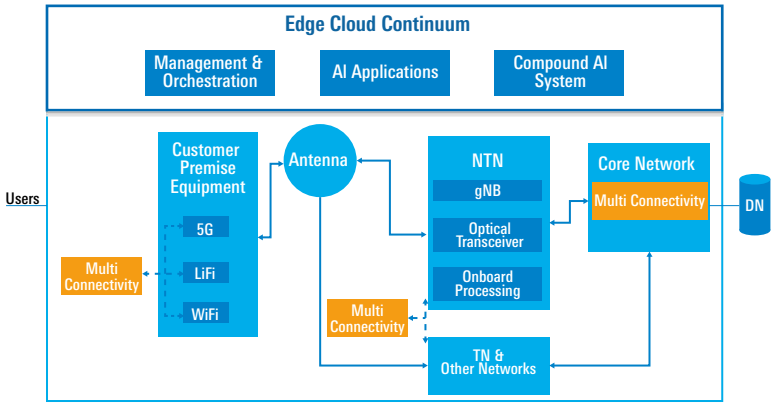
NexaSphere represents Europe's flagship effort to build a unified 3D connectivity framework seamlessly integrating terrestrial, aerial, and space-based networks to meet the mobility and communication demands of the coming decade. By developing key enabling technologies – ranging from multi-connectivity radio and optical interfaces to AI-enabled orchestration and cross-domain resource management- NexaSphere strengthens Europe's leadership in 6G-era communication systems.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The NexaSphere vision is to deliver continuous and resilient data connectivity through a 3D, multi-layer non-terrestrial network (NTN)-enabled 6G network, in which the space segment complements and extends terrestrial infrastructure coverage. The envisioned architecture is based on a **integrated space layer comprising LEO, MEO, and GEO satellite nodes** that connect users and vertical applications to the data network. End-to-end coverage is ensured through free space optical communications (FSO)-based inter-satellite links (ISL) interconnecting space assets, while high-capacity data exchange across ground and space is enabled by the joint use of RF and optical in space technologies, combined with advanced user terminal antenna designs.

This vision further introduces a new dimension of the edge-cloud continuum, extended into space to support a more flexible and mature data space paradigm aligned an anytime – anywhere - anydevice connectivity model. In this context, the space segment evolves into a smart, programmable infrastructure delivering connectivity, communication, and coverage by hosting gNB functionalities - either centralised or distributed - according to the most appropriate functional split.

NexaSphere's architecture



NexGen 3D Networks Spin Harmonies Across 6G, AI, and Unified TN/NTN



Coordinated by Babak Mafakheri, Safran Passenger Innovations

January 2025 – December 2027

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Verticals: Aviation, Automotive, Railways

Partners: Safran Passenger Innovations, German Aerospace Centre, aeroLiFi, French national conservatory of Arts and Crafts; Sotfware Radio Systems, 8Bells, HPE Italy, ROMARS, Stellantis Europe, RF Microtech, CNIT, Vienna technical university, Magister Solutions, OTE, Network Rail Infrastructure, OHB System, Hellas Sat Consortium, university of Naples Federico II.

INNOVATIONS

NexaSphere drives innovations that surpass current terrestrial/non terrestrial network (TN/NTN) integration studies. It introduces a **multi-connectivity subsystem** capable of simultaneously leveraging heterogeneous access links including 3GPP Wi-Fi, LiFi, DVB, etc.), using both 3GPP-compliant access traffic steering, switching, and splitting mechanisms and flexible non-standard policies to steer, switch and split traffic according to application requirements and network conditions. This is complemented by a **3D edge-cloud continuum**, where a management and orchestration-based orchestrator, supported by an AI-powered resource manager and a compound AI element, jointly optimises the placement, scaling and routing of workloads and network functions in a sustainable manner.

On the access side, NexaSphere integrates **hybrid RF/optical technologies combining a LiFi subsystem** for in-cabin or cabin-like environments with high-throughput laser links for optical feeder and inter-satellite connections, forming a tightly coupled radio-optical stack tailored to high-mobility scenarios.

The project also advances the use of **virtualised 5G Core, functional splits, disaggregated radio access networks, and edge computing** within within in TN/NTN contexts, enabling differentiated service guarantees across critical, performance-sensitive, and passenger services, all within a unified 3D architecture.

USE CASES/ TRIALS/ APPLICATIONS

NexaSphere addresses a range of mobility-driven use cases where seamless, high-capacity connectivity across terrestrial, aerial, and space networks is critical.

Aviation Use Cases

These scenarios tackle high-mobility conditions, global coverage gaps, and the increasing demand for gate-to-gate broadband and in-cabin digital experiences. The focus is on robust multi-connectivity, seamless handovers across heterogeneous links, and optimised in-cabin systems.

Automotive Use Cases

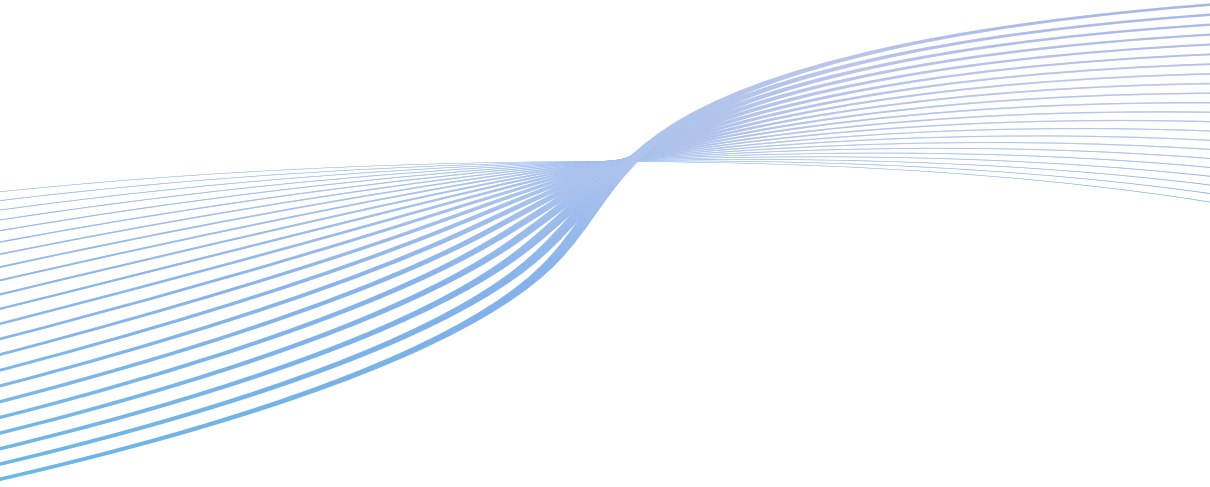
Automotive applications emphasise cooperative perception, autonomous driving, safety-critical Vehicle to anything functions, and bandwidth-intensive passenger services. They highlight the necessity of continuous coverage in both urban and rural deployments, where TN/NTN integration is essential.

Railway Use Cases

Railway scenarios focus on uninterrupted connectivity for high-speed trains, supporting train control, operational monitoring, and passenger Internet services. These use cases underscore the importance of deterministic communication performance across rural areas, tunnels, and other underserved regions.

RESULTS/ IMPACT

The planned project demonstrations across the aviation, automotive and railway sectors will highlight Europe's ability to deliver interoperable, multi-environment communication solutions with tangible societal, economic and environmental benefits. In this context, NexaSphere's distinctive contribution to the European ICT roadmap beyond 2030 lies in developing a unique AI-enabled, multi-technology 3D system architecture, designed to guide the future standardisation and deployment of 6G TN/NTN networks.



Stream B4

RELIABLE SERVICES AND SMART SECURITY

MARE

A reliable 6G services provisioning platform through the definition of a novel security plane.

OVERVIEW

MARE is developing a **Security Plane for 6G networks**, and aims to provide unified, programmable, proactive and transparent security across domains and stakeholders. The project introduces a modular architecture composed of security functions (SFs) built from atomic, reusable security primitives (known as "DOTs"), enabling dynamic composition of protection mechanisms tailored to specific threats throughout the 6G lifecycle.

Over the past year, MARE has delivered its first version of the Security Plane, including the functional design, threat modelling, proofs-of-concept (PoCs) descriptions, and the initial implementation of core primitives and workflows for threat detection and prediction.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

MARE's security plane follows a three-layer architecture, which is composed of a cybersecurity core, abstraction layer and interface layer. This architecture can be seen in the figure below.

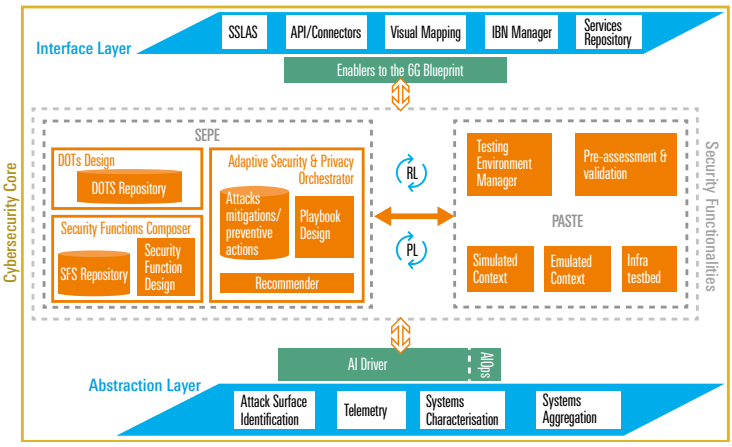
These three layers are connected through the following three major components:

- **Security & Privacy Enabler (SEPE)**: Manages the catalogue of DOTs and security functions;
- **Automatic Security Plane Orchestrator (ASPO)**: Dynamically selects and composes security functions based on the threat landscape and DOTs which compose them;
- **Pre-Assessment Test Environment (PASTE)**: Evaluates security solutions using modelling, emulation and real infrastructure.

The project provides:

- A complete threat landscape analysis across five thematic areas, mapping threats to DOTs and security functions;

Mare Architecture



MARE, Programmable, Modular and Disaggregated Security Plane for 6G Ecosystems

Coordinated by Andreas Zalonis, Space Hellas

January 2025 – December 2027

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Zenodo: https://zenodo.org/communities/mare_eu_project/

Verticals: 6G Netwoks, Telecommunications & Mobile Networks, Cybersecurity, Edge Computing, AI, Data Analytics & Software Intelligence, Satellite & Non-Terrestrial Networks

Partners: Space Hellas, Telefonica ID, Atos (Eviden), Ericsson Italy, Thales Six GTS France, HP Italy, Orange France, Airbus Defense and Space, National Centre for Scientific Research "Demokritos", Braunschweig Technical University, Polytechnical University of Catalunya, CNIT, University College Dublin, national University of Ireland, Dublin networks, Four Dot Infinity, XLAB, Accelleran, 8Bells, Ubitech.

- A mature DOT model - capturing inputs, outputs, requirements, application programmable interfaces (APIs) and deployment format;
- A smart composition process, dynamically tailored to build SFs responsible for dealing with both detected and predicted incidents;
- Workflows for threat detection and threat prediction using telemetry collection, analysis and enforcement pipelines;
- A programmable microservice-based implementation, enabling DOTs to be integrated into PoCs using containerised deliveries.

INNOVATIONS

MARE introduces a fully modular and programmable security framework for 6G. Its key innovations include:

- **DOTs (atomic security primitives)** that standardise how tools, ML models, algorithms and detection components are described, delivered and composed;
- **SFs** - built dynamically by chaining DOTs through ASPO, enabling fast adaptation against new threats;
- **A unified functional and threat modelling approach**, where DOTs are mapped to threats, SFs and PoCs, enabling repeatable, verifiable security composition;
- **The PASTE environment**, which integrates simulation, emulation and real data to pre-assess Security Functions before deployment;
- **A cross-layer, multi-domain security vision**, with detection, prediction and enforcement coordinated over the network, control and management planes.

USE CASES/ TRIALS/ APPLICATIONS

MARE validates its Security Plane through 11 PoCs derived directly from the threat analysis and thematic areas. These PoCs target 6G-relevant threats and rely on 6G-enabling technologies, including distributed intelligence, intent-based control, secure exposure of network capabilities and integration with digital twin-based modelling.

Each PoC will be used to demonstrate how MARE's programmable DOTs and Security Functions can be deployed to identify threats, assess risks and apply mitigations across distributed and multi-stakeholder 6G networks.

RESULTS/ IMPACT

During the first integrated Security Plane, MARE achieved major results, including:

- A full taxonomy of threats for the 6G ecosystem across five thematic areas;
- A first catalogue of DOTs, with clear definitions of their functions, inputs/outputs, data types, interface parameters and deployment models;
- A set of Security Functions, each mapped to threats and composed from DOTs, composed through a first development of the smart composition process;
- A functional design of the Security Plane with detailed workflows for detection and prediction, including telemetry sources and processing sequences;
- Implementation of DOTs for their use by multiple PoCs;
- A pre-assessment methodology combining modelling, simulation and emulation, integrated within the PASTE environment.

These are part of the first MARE Security Plane prototype, which will demonstrate how programmable and composable security can protect 6G infrastructures.

XTRUST-6G

Extended zero-trust and intelligent security for resilient and quantum-safe 6G networks and services.

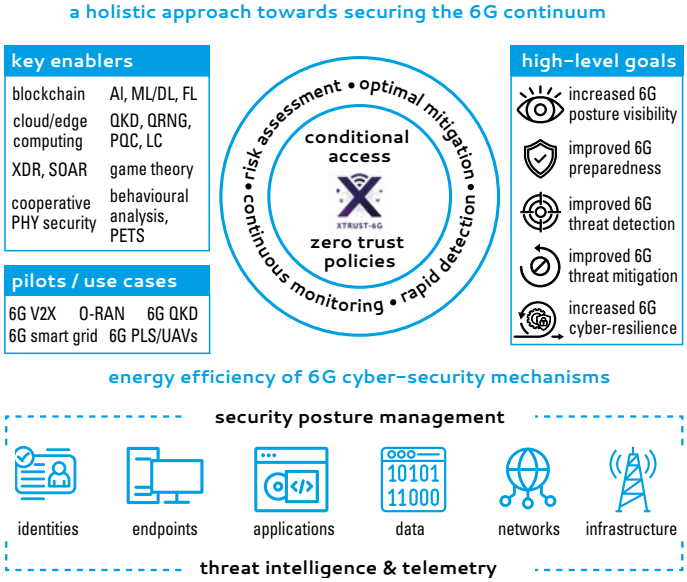
OVERVIEW

XTRUST-6G is a research and innovation project addressing the security, trust, and resilience challenges of future 6G networks. It delivers a holistic, zero-trust-based security framework tailored to highly distributed, cloud-native, and open 6G architectures, with a particular focus on open radio access networks (O-RAN) ecosystems. By combining advanced cybersecurity mechanisms, AI-driven automation, quantum-safe technologies, and energy-aware orchestration, XTRUST-6G aims to enable secure, trustworthy, and sustainable 6G connectivity under real-world operational conditions.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

XTRUST-6G follows a security-by-design and security-by-orchestration approach in which trust is never assumed and is continuously assessed across the 6G infrastructure. Its modular, cloud-native architecture aligns with O-RAN and zero-trust principles, enabling secure operation across the RAN, edge, core, and cloud. At its core, the project integrates a zero-trust policy engine, AI-driven extended detection and response (XDR) and security orchestration, automation and response (SOAR), a distributed ledger technology (DLT)-based identity and integrity plane, quantum-safe cryptographic, and energy-aware resource management. These components are orchestrated through standardised interfaces to ensure scalability, interoperability, and autonomous adaptation to evolving threats.

High level architecture



Extended Zero-Trust and Intelligent Security for Resilient and Quantum-Safe 6G Networks and Services

XTRUST-6G

Coordinated by Stefanos Vrohidis, CERTH – Greek National Center for Research & Technology Development

January 2025 – December 2027

Website: www.xtrust-6g.eu

X: https://x.com/XTRUST6G

LinkedIn: www.linkedin.com/company/nexasphere-eu/

Verticals: Automotive, Energy

Partners: CERTH, university of Portsmouth, European Dynamics, university of Peloponnese, K3Y, ADDITESS, INCITES, Hellenic Data Protection Authority, Summit TEC, university of Thessaly, university of Luxembourg, Ericsson Italy, Tallinn university of technology, Public Power, Iquadrat, Telefónica ID, Cyentific, Telekom Slovenije, Sphynx.

INNOVATIONS

XTRUST-6G introduces several key innovations beyond the state of the art: end-to-end zero-trust enforcement tailored to 6G and O-RAN environments, Dynamic, AI-driven trust and risk assessment resilient to adversarial attacks, DLT-enabled identity management, provenance tracking, and tamper-resistant logging for 6G systems, integrated supply chain security for real-time and non-real time applications (x/rApps) and virtualised network functions, Quantum-safe security through combined use of post quantum cryptography (PQC) and quantum key distribution (QKD), AI-enhanced physical layer security against intelligent jamming threats, energy-aware security orchestration, minimising operational and environmental impact.

Together, these innovations form a unified, adaptive, and future-proof security framework for 6G.

USE CASES/ TRIALS/ APPLICATIONS

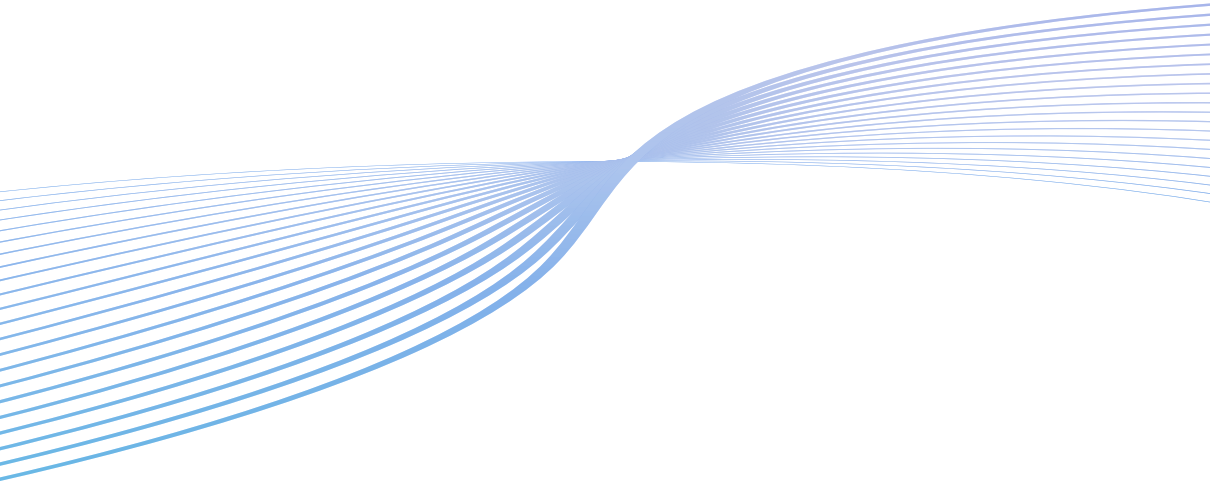
XTRUST-6G will validate its solutions through large-scale, realistic trials and pilots across the 6G ecosystem. Key use cases include: secure O-RAN deployments with trusted onboarding and lifecycle management of x/rApps, collaborative intrusion detection and response across distributed RAN, edge, and cloud environments, quantum-safe fixed wireless access and backhaul communications, resilient physical-layer communications under jamming and adversarial conditions, and energy-efficient security management in multi-tenant and multi-domain 6G infrastructures.

These trials will demonstrate the scalability, interoperability, and real-world applicability of XTRUST-6G solutions.

RESULTS/ IMPACT

XTRUST-6G will deliver validated architectures, software prototypes, and open-source components that advance the security of future 6G networks. The project contributes to scientific excellence through innovative approaches to zero trust frameworks, AI-driven cyber defence, and quantum-safe communications, while supporting standardisation and industry adoption.

Its outcomes will reduce security risks and deployment costs for operators, enable trusted third-party innovation, and reinforce Europe's digital sovereignty. By integrating energy-efficient security mechanisms, XTRUST-6G also aligns with the European's sustainability and green transition goals, ensuring that future 6G infrastructures are not only secure, but also trustworthy and environmentally responsible.



Stream B5

INTERNATIONAL COLLABORATIONS
EU-JP, 6G-MIRAI

Stream B6

INTERNATIONAL COLLABORATION
EU-ROK, 6GARROW

6G-MIRAI

6G Machine Intelligence based Radio Access Infrastructure

OVERVIEW

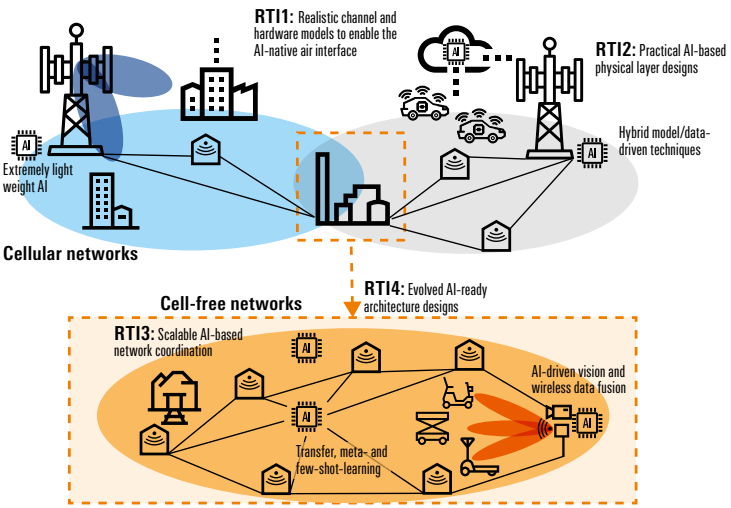
6G-MIRAI (Machine Intelligence based Radio Access Infrastructure) addresses the gap between the theoretical promise of artificial intelligence/machine learning (AI/ML) for 6G and the practical constraints of real-world wireless systems. The project brings together European academia and industry with Japan's HARMONY partners to develop future-proof 6G physical-layer and radio access networks (RAN) solutions, with a strong focus on user-centric cell-free massive multiple input multiple output (MIMO), enabled by robust and reliable AI/ML methods.

The project is organised around four core objectives:

1. **Reliable and robust AI/ML Foundations**: Identify practical and theoretical limitations of distributed MIMO systems to improve offline AI/ML design, focusing on low-physical (PHY) building blocks critical for cell-free MIMO.
2. **AI-Native RAN Design**: Define functional placements, data requirements, and design architectures, functional splits, protocols, and data acquisition to enable deployable cell-free networks.
3. **Unified Benchmarking Platform**: Establish a joint European-Japan framework for data management, testing, benchmarking, and validation of AI-enabled techniques and protocols.
4. **Standardisation Alignment**: Build on early 3GPP to integrate realistic data – based on generative channel models or measurements -- into AI/ML training, evaluation, and testing, supporting future standardisation efforts.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

To achieve these objectives, the project builds on a set of research and technology items (RTI) illustrated in the figure.



INNOVATIONS

The project's innovations focus on futureproofing 6G physical layer technologies and open RAN architectures, with a strong emphasis on AI/ML enabled multiantenna solutions such as usercentric cellfree massive MIMO. It develops AI-native functions grounded in solid fundamental theory and practical requirements, aligned with current 3GPP standards for 6G RAN.

USE CASES/ TRIALS/ APPLICATIONS

As a key use case, 6G-MIRAI addresses critical multi-node connectivity challenges across three network deployment scenarios: **wide-area distributed MIMO networks**, **multi-carrier distributed MIMO**, and **multi-carrier cell-free networks**. The project develops a unified next-generation framework that extends and integrates existing existing multi transmission reception point (TRP) multi downlink control information (DCI) and non-collocated carrier aggregation, enabling seamless connectivity across multiple network controllers while preserving a single protocol stack on user devices.

In parallel, the project advances **generative AI models** that synthetise realistic, context-aware channel state information (CSI) – for example, conditioned on user location — to enrich training datasets for AI-native radio models. These data-driven approaches capture complex, analytically intractable impairments and, through differentiable modelling, enable end-to-end optimisation and task-specific fine-tuning. This reduces reliance on costly measurement campaigns and supports advanced RAN optimisation and AI-for-PHY evaluation in challenging 6G propagation environments. Finally, 6G-MIRAI develops the **theoretical foundations and AI-based solutions for CSI acquisition and joint power control**, beamforming, and scheduling, explicitly addressing practical constraints such as phase estimation errors in distributed MIMO systems.

RESULTS/ IMPACT

Spatial CSI prediction using AI/ML: AI/ML techniques can predict CSI across all antenna ports from a reduced number of antenna port measurements, significantly lowering transmission overhead. In urban macro scenarios with 256 antenna ports, this approach achieved an average downlink overhead reduction of around 5%. These results have been presented to the 3GPP Rel20 6G study item, and they will inform the selection of use cases for further 6G studies.

Transformer-based power prediction: Transformer models with linear attention predict uplink and downlink power levels using only access-point and user coordinates. Pilot constraints are embedded directly in the model architecture, inherently avoiding pilot contamination, while maintaining linear complexity in the number of users.

Power control algorithms for distributed MIMO: Simple algorithms have been developed to solve power control problems previously unresolved in the distributed MIMO literature, enabling new AI-based approaches to power control.

6G Machine Intelligence based Radio Access Infrastructure

6G-Mirai

Coordinated by Tobias Ley, Ericsson Research

April 2025–March 2028

Website: https://6g-mirai-harmony.eu/

BlueSky: https://bsky.app/profile/6g-mirai-harmony.bsky.social

LinkedIn: www.linkedin.com/company/6g-mirai-harmony/

Verticals: Telecoms

Partners: Ericsson, Fraunhofer HHI, Apple, CNIT, university of Pisa, KU Leuven, IS-Wireless, Telefonica, Sequans.

6GARROW

Unlocking new levels of efficiency, flexibility, and performance with AI-native Radio Access Networks and integrated device-network approaches.

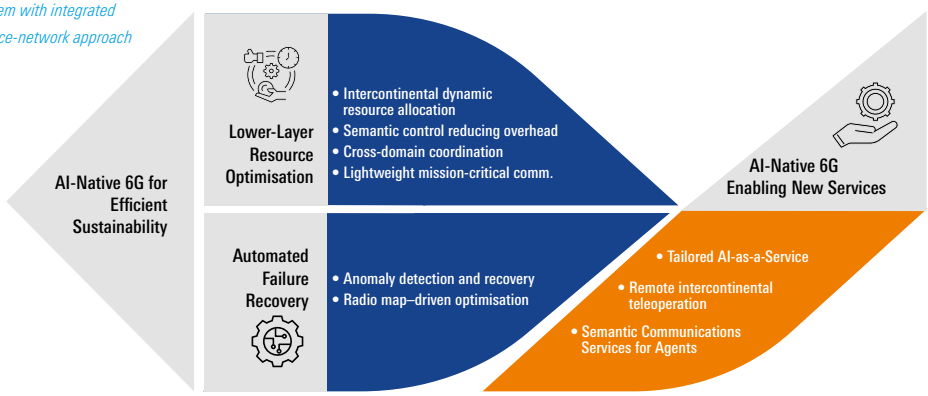
OVERVIEW

The 6GARROW project is an Europe-Republic of Korea (ROK) collaboration focused on advancing AI-native 6G mobile networks through innovations in radio access networks (RAN) and integrated device-network interactions. It brings together three research centers, four academic institutions, four industrial partners, and one business school, covering the full spectrum of relevant areas, from architecture and AI algorithms to experimentation and innovation.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The 6GARROW architecture is designed to embed intelligence across all layers, enabling data-driven, adaptive, and goal-oriented network operation. It leverages advanced AI/ML techniques, including distributed learning and semantic information processing, to optimise network performance, energy efficiency, and user experience. The system architecture supports flexible service exposure and closed-loop automation through analytics-driven control functions across 6G devices, RAN, and core network (CN) components. Key enabling technologies include **AI-assisted resource management and semantic communications**, complemented by standardised interfaces and protocols. Together, these elements facilitate seamless integration of AI and semantic communications across different network domains paving the way for truly 6G-ready deployments.

6GARROW AI-native 6G system with integrated device-network approach



INNOVATIONS

Innovation in the 6GARROW project is driven by a structured **innovation program** designed to maximise technical impact and foster effective collaboration across the consortium. The program combines **bottom-up identification** of partner-driven innovation items with **top-down alignment** to the project's strategic objectives. Partner-specific innovations are grouped into a coherent set of cross-cutting **innovation areas**, mapped to the technical Work Packages, enabling synergies across architecture design, AI-native network control, semantic communications, and energy-efficient operation. This approach ensures that innovation outcomes

directly support the project's goals, while facilitating their maturation towards **proof-of-concept validation, exploitation, and contributions to pre-standardisation and standardisation activities**.

USE CASES / APPLICATIONS

The 6GARROW use cases shown in the figure demonstrate how future 6G networks can become more intelligent, autonomous, and efficient by embedding AI directly into the RAN and devices. **These use cases address a wide set of stakeholders**. Industrial operators and service providers benefit from reduced operating costs, and the ability to offer tailored services, such as AI-as-a-Service. Businesses building AI-powered agents - from logistics robots to consumer applications -, gain access to communication systems that understand the meaning of the data exchanged rather than simply transporting bits. End users ultimately enjoy improved reliability, faster response times, and more sustainable networks with lower energy consumption.

TRIALS

Current testbeds and experimentation platforms typically integrate AI/ML functionalities either locally within isolated signal processing modules or as add-ons on top of the networking stack. This often result in stand-alone models without end-to-end, online optimisation capabilities. Going beyond the current state of the art, 6GARROW will design and validate an integrated experimentation framework to demonstrate key architectural innovations and AI-native solutions across devices, RAN, and core network (CN) domains. A **proof-of-concept will be developed to showcase an AI-enhanced network** in which intelligence is natively embedded and coordinated across all layers, enabling advanced orchestration of network functions such as fronthaul/backhaul management, authentication, and user management. The platform will also provide open interfaces to support customer-driven application development and facilitate the integration and testing of novel 6G functionalities in realistic experimental environments.

RESULTS/ IMPACT

The 6GARROW project is expected to deliver significant scientific, technological, and societal impact by developing novel architectures, algorithms, and mechanisms that enable data-driven, energy-efficient, and goal-oriented network operations across next generation mobile devices, RAN and CN components. Through planned large-scale experimentation and joint EU-ROK PoC implementations, 6GARROW will validate its innovations in realistic environments, accelerating their maturity and adoption.

The project's results 6GARROW will also contribute to international pre-standardisation and standardisation activities, influencing technical specifications in ongoing 3GPP Study Items and Work Items in Releases 19 and 20. In parallel, extensive dissemination, open collaboration, and exploitation planning will ensure that outcomes support Europe's technological leadership of, foster innovation ecosystems and create long-term value for industry, academia, and society.

6G AI-native integrated RAN-Core networks

6GARROW

Coordinated by Emilio Calvanese Strinati, CEA Leti & Seong-Lyun Kim, Yonsei University

January 2025 – December 2027

Website: https://6garrow.com/

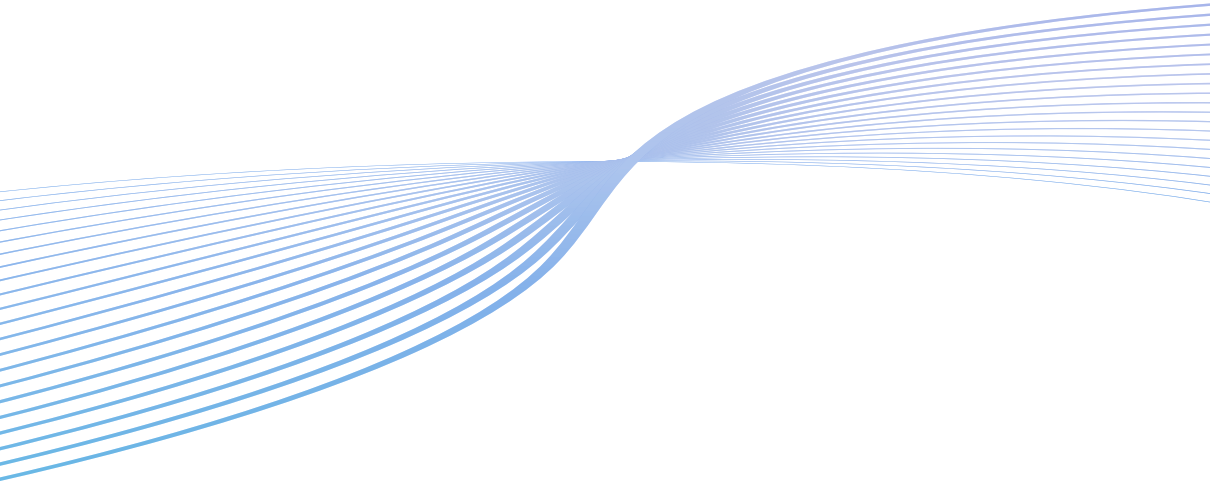
X: https://x.com/6GARROW

LinkedIn: www.linkedin.com/company/6garrow/

Youtube: www.youtube.com/@6GARROW

Verticals: Automotive, Industry, Media and entertainment, PPDR, Health, Energy,Smart Cities, Transport and logistics

Partners: CEA, Fraunhofer HHI, Aalto university, university of Oulu, Intel Germany, HPE Germany, Grenoble school of management, Orange France, Yonsei university, Korea University Research And Business Foundation, ETRI, LG Electronics.



Stream B7

SUSTAINABILITY LIGHTHOUSE, SUSTAIN-6G

Stream B8

RELIABLE AI FOR 6G COMMUNICATIONS SYSTEMS AND SERVICES, 6G-DALI

SUSTAIN-6G

European Sustainability Lighthouse Project – The holistic perspective on Sustainable 6G and 6G for Sustainable Applications.

OVERVIEW

SUSTAIN-6G is Europe's lighthouse project for embedding holistic sustainability across economic, environmental, and social pillars in 6G systems. It develops and evaluates concepts for efficient, resilient, secure and low-carbon digital services across **health, agriculture, and energy smart grids**. The project promotes lifecycle-aware network design and circular economy principles including energy-efficient architectures, AI-enabled optimisation, low-impact components, and a sustainability management plane for end-to-end 6G operations.

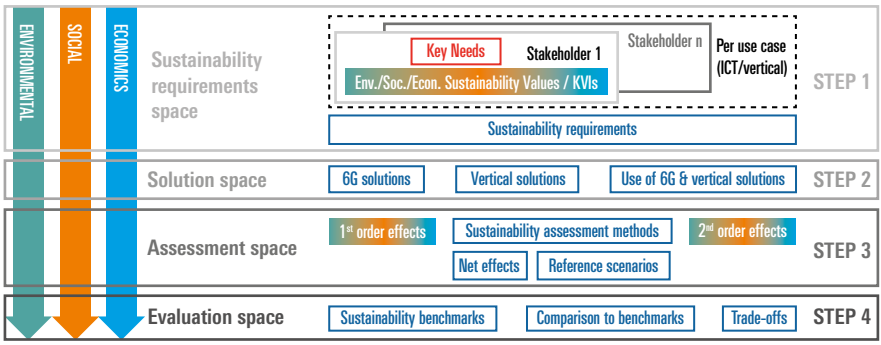
SUSTAIN-6G establishes a key performance indicator/key value indicator (KPI)/(KVI) framework to support value-driven, accountable decisions aligned with global policies such as the United Nations (UN) Sustainable Development Goals (SDGs), validated through proofs-of-concept (PoCs). Insights are distilled into best practice, strategic guidelines, roadmaps, and business models for a sustainable digital future.

CONCEPT/ INNOVATIONS/

In 2025, SUSTAIN-6G developed a draft **methodology to define sustainability requirements** by translating stakeholder needs into sustainability values and KVIs for mobile network operation and three vertical sectors (Step 1 in figure). These KVIs guide concrete requirements for the design, deployment, operation, and end-of-life of sustainable 6G ecosystems.

A draft methodology for sustainability assessment (Step 3) was also created, highlighting opportunities to align with existing reporting standards and leveraging 6G technologies for automated monitoring. The overarching aim is to integrate diverse assessment tools into coherent, comprehensive evaluations of 6G sustainability.

SUSTAIN-6G delivered a **comprehensive catalogue of sustainable ICT enablers and innovations** ("Sustainable 6G") with deliverables D2.1 and D3.1 covering all network segments—devices, radio access network (RAN), edge, transport, core, and cloud. **Initial assessments** focused on key enablers such as RAN energy modelling



SUSTAIN-6G steps to define sustainability requirements, map them to the solution space (technologies & use cases), create assessment methodology, and evaluate / benchmark effects

and optimisation, distributed multiple input multiple output (MIMO), all-optical networking, AI-native sustainable networks, joint communication-computation optimisation. These evaluations examined **first-order effects** for energy consumption, resource use, privacy, and cost efficiency.

Gap analysis identified areas requiring deeper investigation, and design trade-offs between performance and sustainability. Work in 2026 work refine technological designs, define sustainability metrics, and improve enabling qualitative assessments PoC activities.

USE CASES

SUSTAIN-6G studied use cases in **health, agriculture, and energy smart grids** refining their ICT requirements, to advance sustainability for connectivity needs ("6G for sustainability").

Assessments revealed that most gaps arise not caused from current ICT performance but from deployment limitations e.g., insufficient coverage or missing 3GPP features. In some cases, 6G could reduce costs or environmental impact, though full life cycle assessment is required to justify new deployment. The 2026 work will intensify these evaluations alongside ICT enablers and PoC activities.

RESULTS

A key achievement in 2025 was defining the **end-to-end sustainability validation platform and its associated measurement methodology** (Deliverable 5.1). **Ten vertical sector PoCs** and **seven core ICT PoCs** (e.g., Green RAN, all-optical networks, sustainable AI) were specified with measurable KPIs, validation scenarios, and test benchmarks. Eleven project testbeds were detailed with capabilities to measure sustainability metrics across all technical layers (from physical layer to cloud orchestration).

A consolidated set of metrics ensures **systematic, consistent, traceable assessment** linking project performance indicators (e.g., energy consumption per bit, CO_2 avoidance) to the UN SDGs and the three sustainability pillars.

Key 2025 achievements included initial standardisation efforts and broad dissemination. Contributions were made to 3GPP SA1 6G studies. The project reached a wide audience via newsletters, website and social channels, conferences presence (e.g., EuCNC booth and workshops, Berlin 6G Summit), webinars, and scientific publications (e.g., IEEE ComMag and Springer book chapters).

SUSTainability Advanced and Innovative Networking with 6G

SUSTAIN 6G

Coordinated by
Christoph Schmelz, Nokia Solutions and Networks

January 2025 – June 2027

Website: https://sustain-6g.eu

LinkedIn: www.linkedin.com/company/sustain-6g/

Youtube: https://www.youtube.com/@SUSTAIN-6GProject

Zenodo: https://zenodo.org/communities/101191936/

Verticals: Telecommunication, Health, Agriculture, Energy

Partners: B-COM, CEA, Cybersocial Lab, Deutsche Telekom, Ericsson, EDF, Eurescom, John Deere, KU Leuven, MDCREATE, Nokia France and Germany, Orange France, university of Oulu, P-NET, Polytechnical university of Turin, Argotec Solutions and telecoms, Qualtek, Real Wireless, Siemens Germany and Austria, Telecom Italia, Universidad Carlos III de Madrid, WINGS-ICT.

6G-DALI

User-friendly e2e AI framework for DataOps and MLOps in 6G.

OVERVIEW

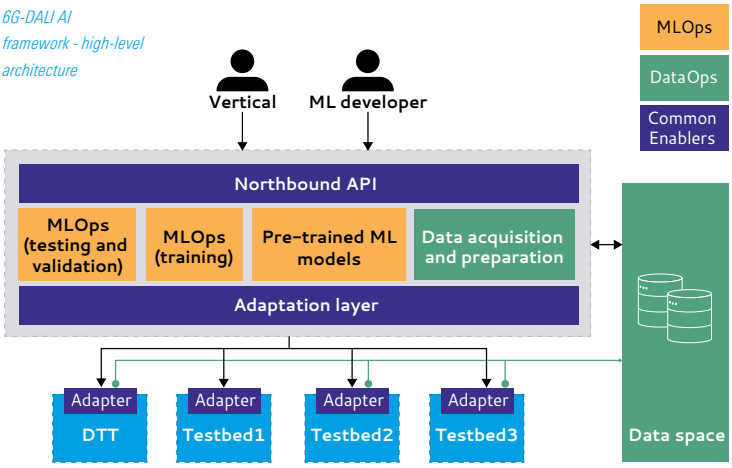
6G-DALI develops an AI framework that connects 6G data with vertical industries, ML developers, and experimenters. It leverages 6G testbeds from the SNS JU phase 2 SUNRISE-6G project, bringing together expertise in 6G systems, AI/machine learning operations (MLOps), and data operations (DataOps). This multidisciplinary collaboration supports the development of an efficient, trustworthy AI/ML experimentation framework. The project's objectives are to:

- Deliver an end-to-end AI framework,
- Integrate Gaia-X and Extract Load Transform (ELT) capabilities;
- Advance MLOps functionalities;
- Enable seamless integration with 6G testbeds;
- Develop a digital twin (DT) testbed;
- Ensure ethical compliance;
- Support dissemination and standardisation activities.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The 6G-DALI architecture, as depicted in the figure, defines an AI framework supporting: (i) AI experimentation via MLOps and (ii) data analytics via DataOps. It automates workflows, linking ML developers improving 6G with vertical users optimising services. It connects to 6G testbeds (radio access —RAN —, core networks—CN—, edge/cloud), where some sites offer digital twins. The framework establishes the first 6G Dataspace, enabling secure data sharing among ML developers, operators, and vendors using international data space (IDS) and Gaia-X to drive 6G data economies.

6G-DALI AI framework - high-level architecture



6G DAta and ML operations automation via an end-to-end AI framework

Coordinated by
Christos Verikoukis, ISI/ATH

January 2025 – December 2027

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LinkedIn: www.linkedin.com/company/6g-dali/

Partners: ISI/ATH, Intracom, IBM, VIAVI, EURECOM, Catholic University Leuven, IQuadrat, Spark Works, CyberEthics Lab, Nextworks, OTE, Technical University of Delft.

INNOVATIONS

6G-DALI drives innovation across key areas:

1. **Design and implement the first 6G data space** hosting 6G data sets, dataservices, and ML models with enhanced data discovery and governance.
2. **Collaborative MLOps & Reinforcement Learning (RLOps) –** Orchestrates ML pipelines via a unified framework.
3. **Trustworthy AI** – Detects ML model drift and improves unseen scenario accuracy by 20%.
4. **Explainable RL** – Uses LLMs for a 2× improvement in RL explainability.
5. **Digital twin** – Builds the first DT for RAN and CN.
6. **Knowledge transfer automation** – Simplifies integration and maximises insights.
7. **Federated learning** – Ensures 6G privacy and efficiency with network data analytics Function (NWDAF) operations.
8. **Large language model (LLM)-enabled AI & high parameter optimisation (HPO)** – First European AI experimentation and data generation platform for 6G-as-a-Service.

USE CASES/ TRIALS/ APPLICATIONS

This section summarises the proofs-of-concept (PoCs) validating 6G-DALI's enablers: DataOps (PoC 1) and MLOps (PoC 2), along with their experimentation platforms.

- **PoC 1: Data management & experiment on demand**

  Showcases the 6G-DALI AI framework's ability to fulfill user data requests via the 6G data space.

Objectives:

i. Integrate the AI framework with 6G data space and Gaia-X for trust and service cataloging.

ii. Use LLMs to translate user requests into datasets and experiments.

iii. Implement an extract load transform (ELT) pipeline for data cleaning, augmentation, and storage.

- **PoC 2: AI as a Service (AIaaS) for CDN apps via cross-testbed Decentralised MLOps**

  Validates 6G-DALI's AI framework, including decentralised MLOps, meta-orchestration, and AI services. It assesses cooperative ML model management and demonstrates applicability in a content delivery network (CDN) use case.

- **PoC 3: Digital Twins for large and medium-scale 6G experiments**

  Addresses the lack of representative datasets for RAN and CN. It enables large-scale experiments using Digital Twins, aiming to:

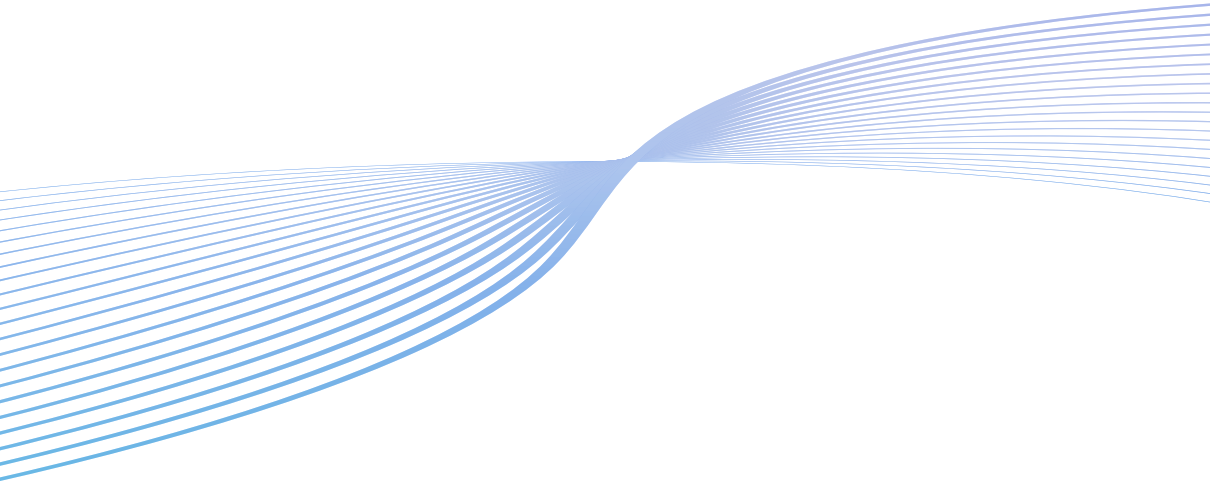
i. Generate and integrate datasets into the 6G data space via 6G-DALI ELT.

ii. Implement RLOps for testing and validating trained RL agents.

RESULTS/ IMPACT

The project has successfully completed a detailed analysis of both functional and non-functional requirements for the framework, ensuring a comprehensive understanding of the system's needs. Key societal values have been identified alongside their corresponding key value indicators, providing measurable criteria to guide development. A techno-economic analysis of creating a 6G data space has been conducted, highlighting potential exploitation opportunities for 6G-DALI.

Additionally, the initial high-level architecture has been designed, establishing a solid foundation for future implementation. The primary architectural building blocks have also been defined, clarifying the responsibilities of each component and their interactions within the system.Initial definition of the primary architectural building blocks, clarifying component responsibilities and interactions.



Stream C

SNS JU MICROELECTRONICS LIGHTHOUSE, X-TREME 6G

The goal of Stream C is to provide a foundational open microelectronics platform in Europe and to validate some 6G candidate technologies.

X-TREME 6G

X Transceivers & RF front-ends made in Europe's Microelectronics light house to Enable new 6G use cases.

OVERVIEW

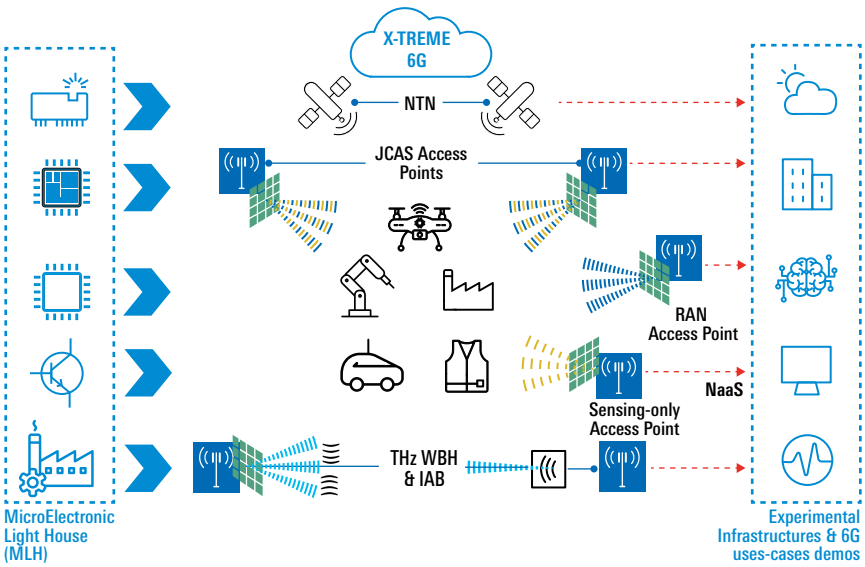
As Europe continues to navigate its 5G deployment, 6G represents a landscape of endless possibilities. X-TREME 6G aims to harness those opportunities, contributing to a network-centric, open, democratised 6G ecosystem that reduces reliance on hyperscalers, while empowering European industry.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

X-TREME 6G leverages a unique industry-led consortium to deliver **a foundational open microelectronics platform** in Europe, aiming to develop disruptive next generation chiplets and chipsets for 6G use cases. The project seeks to harness the full potential of best-in-class Silicon bipolar complementary metal-oxide semiconductor (BiCMOS), indium phosphide (InP) and heterogeneous 3D integration for high capacity radio access technologies, including sub-terahertz wireless backhauling, joint communication and sensing (JCAS), non-terrestrial networks (NTN) and network as a sensor (NaS).

As part of the SNS JU "Microelectronics LightHouse" initiative, X-TREME 6G aims to establish a sustainable open platform throughout the SNS JU program and beyond, supporting 6G verticals across Europe.

X-TREME 6G Vision: Unleash the full potential of Microelectronic chips and chiplets for truly innovative 6G platforms and use-cases



INNOVATIONS

The first year focused primarily on microelectronics, achieving key innovations in high frequency process availability. These include **pre-industrial availability of silicium-Germanium (SiGe) heterojunction bipolar transistor (HBTs)** with a maximum oscillation frequency (Fmax) of 500GHz, **prototype availability of InP HBT** with a Fmax of 600GHz and **wideband SiGe amplifiers** operating in the 200GHz-300GHz range.

Building on these foundational advances, the second year will shift focus toward telecom innovations, targeting 6G applications and system-level integration of these high-frequency components. These efforts will enable high-capacity, ultra-fast radio access technologies and prepare the platform for industrial development.

USE CASES/ TRIALS/ APPLICATIONS

The project targets several key 6G application domains, including wireless X-haul - providing high-capacity links for backhaul and fronthaul in dense network deployments, JCAS - enabling networks to simultaneously transmit data and sense the environment for enhanced situational awareness, NTN - integrating satellites, high-altitude platforms, and drones to extend coverage beyond terrestrial networks, network as a sensor (NaS) - leveraging the network itself to collect real-time environmental and operational data, Private 6G Networks - deploying dedicated infrastructures for industrial, enterprise, or critical-use cases with high reliability and low latency.

RESULTS/ IMPACT

The project is expected to generate significant impact. It will validate and demonstrate 6G candidate microelectronics technologies and systems as part of a representative end-to-end 6G architecture. It will build on the results and momentum of the 5GPPP ICT-42 COREnect coordination and support action project.

Key 6G hardware solutions, technologies, components, and architectures will be tested across various frequency bands to demonstrate their performance.

The project will integrate Chips JU developments and validate the feasibility of "better-than-5G/5G-Advanced" key performance indicators, including capacity, ubiquity, speed, latency, reliability, user density, location accuracy, energy efficiency, security, service creation time, and network management capital expenditures and operational expenditures.

The project has delivered significant advancements in microelectronics and radio systems. These include the fabrication of SiGe HBT BiCMOS55x and InP HBT processes, enabling high-performance transistors for 6G applications. Novel radio systems and components have been developed in the THz bands, along with new radio interfaces such as line-of-sight MIMO (LoS-MIMO) and in-band full-duplex (IBFD). In addition, efficient models have been designed for hardware implementation in baseband applications, supporting high-speed, low-latency signal processing for next-generation networks.

X Transceivers & RF front-ends made in Europe's Microelectronics light house to Enable new 6G use cases

X-TREME 6G

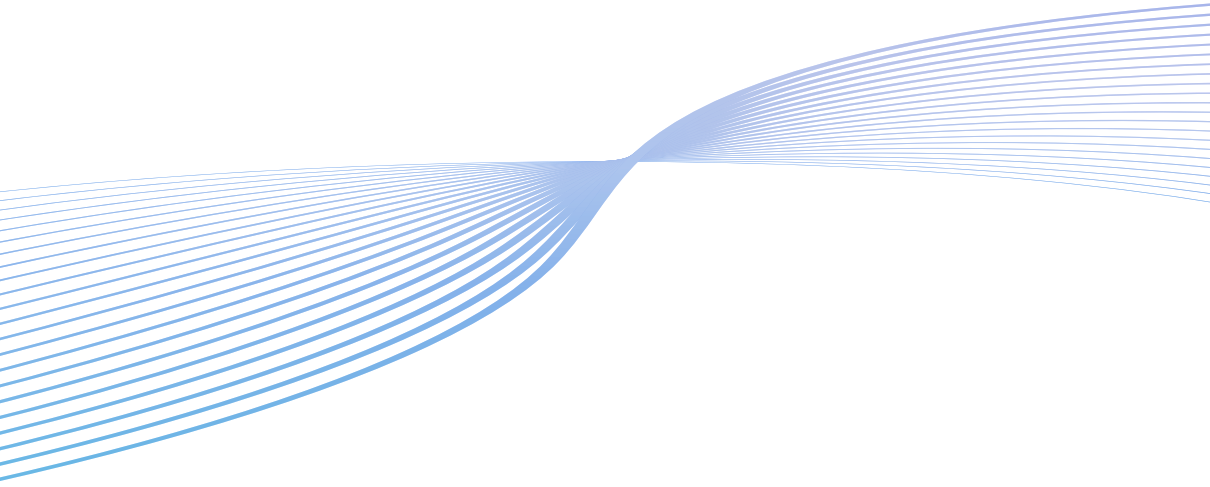
Coordinated by Didier Belot, STMicroelectronics
January 2025 – June 2028

Website: https://x-treme6g.eu/

LinkedIn: www.linkedin.com/company/x-treme-6g/

Verticals: Automotive, Industry, PPDR, Energy, Smart Cities, Transport and logistics

Partners: ST Microelectronics, Fraunhofer IZM, III-V LAB, Nokia Solutions and Networks Italy, Nokia Networks France, Karlsruhe Insitute of Technology, univesrsity of Bordeaux, French national research centre (CNRS), Denmark technical university, CEA, AMIRES, IMST, Politecnico di Milano, university of Patras, P-NET, Orange Poland, ETU Zurich, Argus Space.



Stream D

SNS JU LARGE SCALE TRIALS AND PILOTS WITH VERTICALS (IA)

Stream D targets large-scale SNS JU Trials and Pilots with Verticals, including the required infrastructure. This third call is to explore sustainability in these new 6G verticals.

6G-VERSUS

6G-VERSUS showcases the significant sustainability benefits of 6G technology through targeted vertical pilots and trials.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

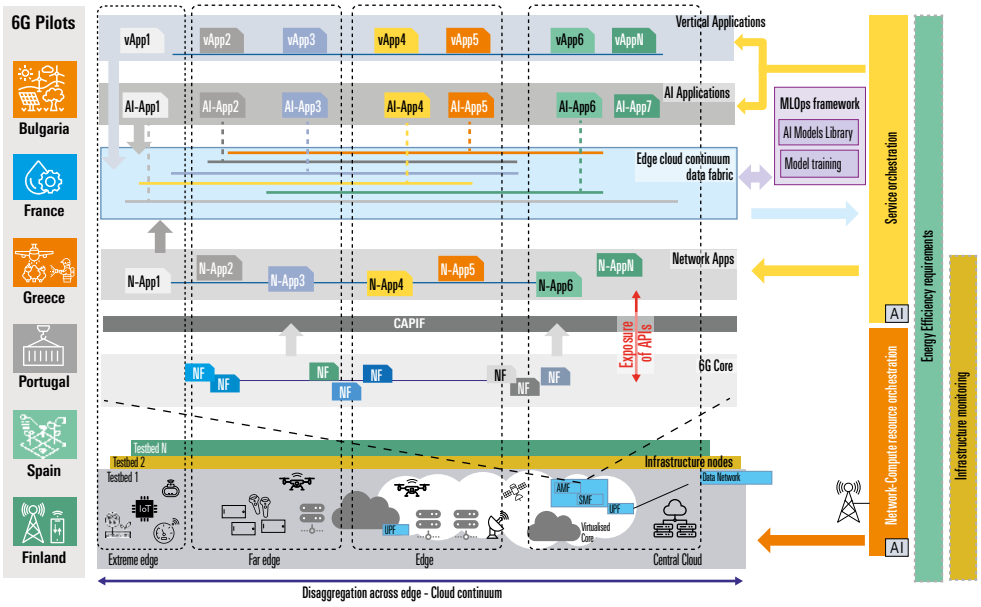
6G-VERSUS defines a **standards-aligned reference architecture**, layered (figure), and modular reference architecture that each pilot adapts locally, maintaining coherence across diverse testbeds, verticals and deployment conditions. The architecture allows verticals to specify objectives, such as latency, resilience, or energy efficiency, while exposing interfaces and control points to monitor and reconfigure network and compute resources.

Central to the design is the "6G Application triplet" comprising:

- **Vertical Application (V-App)** hosts service logic;
- **Network Application (N-App)** enables programmable interaction with the network;
- **AI Application (AI-App)** provides analytics to adapt the V-App and/or N-App.

The triplet is supported by cross-cutting **Data Fabric** and machine learning operations (**MLOps**) framework across the edge–cloud continuum for telemetry collection, data harmonisation, and model lifecycle management. Orchestration and monitoring are enhanced via common application programming interface framework (CAPIF) and related functions such as network exposure functions (NEF) and network data analytics function (NWDAF), with energy efficiency integrated across all layers.

6G-VERSUS triad architecture



INNOVATIONS

6G-VERSUS transform use cases into intelligent 6G applications through the **App triplet**, enabling efficient, sustainable and adaptative service delivery. The project leverages in AI-driven innovations, to dynamically manage 6G-resources, including network slicing for real-time allocation, autonomous optimisation for self-healing and predictive maintenance, and cybersecurity enhancements. Sustainability is embedded via energy-efficient networks, renewable energy integration, and AI-assisted power management.

Building on prior initiatives, the six clusters in Bulgaria, Finland, France, Greece, Portugal, and Spain are upgrading experimental 5G networks with state-of-the-art radio access network and core technologies, exposed application programmable interfaces, cloud and edge infrastructures, user and connected devices, transport networks, energy efficiency mechanisms, and other advanced features such as non-terrestrial (NTN) or integrated sensing and communication (ISAC). A cross-cluster artificial intelligence and machine learning (AI/ML) framework supports coordinated, intelligent experimentation, ensuring reliable and sustainable operation across all sites.

USE CASES/ TRIALS/ APPLICATIONS

6G-VERSUS structured around six complementary 6G pilots addressing sustainability challenges. Entering its first trial phase in early 2026, all clusters will conduct on-site trials to showcase scenarios to stakeholders, and assess 6G's environmental, societal and economic impact.

The methodology follows three steps:

1. **Transforming existing use cases and services into 6G applications;**
2. **deploying and validating them on the experimentation platforms** with energy efficiency mechanisms;
3. **measuring their sustainable impact.**

Trials are conducted on large-scale testbeds across the six clusters: Bulgaria deploys **AI-assisted monitoring of distributed renewable energy**; Finland demonstrates a **self-sustainable 5G base station**; France tests **data-driven water and waste management**; Greece validates **collaborative robotics for Search and Rescue operations**, Portugal pilots **sustainable, safe and resilient port operations**; and Spain trials **immersive telepresence for remote field operations**.

Together, these first trials provide early, measurable evidence of 6G-enabled sustainability benefits.

RESULTS/ IMPACT

6G-VERSUS demonstrates the feasibility, viability and sustainability of 6G vertical applications, providing new insights into the capabilities of 6G technology for divers sectors. Engagement with stakeholders raises awareness of the environmental and business benefits of 6G, fostering broader adoption and investment in sustainable 6G infrastructure. The knowledge and insights generated will also inform standardisation and policy-making, helping to shape the deployment of future 6G policies.

6G-VERSUS

6G vertical applications for sustainability

Coordinated by Sanna Tuomela, university of Oulu

January 2025 – December 2027

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X: https://x.com/6G_VERSUS/

Facebook: https://www.facebook.com/6gversus

Youtube: https://www.youtube.com/@6G-VERSUS

Verticals: PPDR, agriculture, logistics, energy, transport and logistics

Partners: University of Oulu, Keysight Technologies, OneSource, 8Bells, InCites, Polytechnical university of Valencia, university of Bradford, Envolve, Centre for Social Studies, National Centre for Scientific Research "Demokritos", OTE, ICCS, Infolysis, Rescue Team of Attica, university of Malaga, Telefonica ID, CSIC, CETAQUA, Hidralia, Nokia Spain, Eurecom, GreenCitizen, Thales, A1 Bulgaria, Entra Energy, university of Cyprus, Software Company, Instituto de Telecomunicacoes, Altice Labs, Aveiro Port, JSIO – IOT Hassle free, Institute Pedro Nunes, ISTID, Hewlett-Packard Italy, Kingston university London.

AMAZING-6G

Evaluation and validation of B5G/6G sustainability and performance via large-scale trials in the vertical domains of Health, Public Safety, Energy, Transport.

OVERVIEW

AMAZING-6G explores Beyond 5G (B5G) and 6G networks through large-scale trials, that assess performance, sustainability, and real-world applicability. These trials validate key technologies while revealing new use cases across sectors such as healthcare, public safety, energy, and transport. The project places strong emphasis on sustainability across environmental, social, and economic dimensions, leveraging value-driven methodologies to refine both technical specifications and business models. By fostering close collaboration between industry, researchers, and policymakers, AMAZING-6G supports innovation, standardisation, and scalability. The project demonstrates the European's added value in developing intelligent, sustainable, and secure 6G networks, aligned with core design principles including resilience, trust, and inclusion and highlights the transformative potential of 6G for applications such as IoT, artificial intelligence, extended reality (XR), and smart cities.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The overall technical scope of the architecture is structured around three strata that provide **(i) vertical support enablers** (AI/ML and IoT), **(ii) compute continuum enablers** and **(iii) networking enablers**. Together, these enablers support verticals services by allowing them, through AMAZING-6G, to access both the compute and networking continua. This enables full flexibility in service deployment and management - from vertical-owned far-edge compute nodes to edge and cloud infrastructures – as well as fully customised, vertical-specific network slices. In addition, verticals benefit from advanced functionalities and toolsets designed to support AI and IoT-enabled services. AMAZING-6G technology enablers are split into four categories:

- **Communication enablers**, covering radio, transport and core network capabilities.
- **Compute-as-a-Service enablers**, spanning the full compute continuum.
- **Application and AI enablers**, including network exposure Application Programming Interfaces (APIs) and AI-driven application services.
- **IoT and localisation enablers**, encompassing IoT platforms, devices and localisation technologies.

INNOVATIONS

AMAZING-6G advances B5G/6G innovation across multiple sectors by enhancing connectivity, intelligence, and sustainability. In **healthcare**, AI-enabled ultrasound imaging combined with wearable sensing supports continuous patient monitoring and enhanced post-operative care. **Public safety** UCs rely on rapid private network deployment, end-to-end network slicing, and autonomous drone cooperation to enhance situational awareness in mission-critical scenarios. In the **energy** domain, the project applies AI-driven optimisation of renewable resources and user behaviour modelling to improve efficiency and sustainability. **Transport** innovations include real-time digital twins, seamless mission-critical connectivity, and network slicing for next-generation railway signalling. AI-powered, zero-touch network and

service management further enables dynamic orchestration of teleoperation services and automated mobility. By integrating advanced edge computing, large-scale IoT integration, and sustainability-by-design principles, AMAZING-6G supports a systemic transformation of key industries, strengthening efficiency, resilience, and inclusiveness in future B5G/6G networks.

USE CASES/ TRIALS/ APPLICATIONS

During its first year in 2025, AMAZING-6G defined a comprehensive portfolio of use cases across health, public safety, energy, and transport, demonstrating how B5G/6G technologies can enhance connectivity, intelligence, and sustainability in critical sectors. They will be validated through large-scale trials and pilot deployments by 2027.

In **health**, continuous wearable ultrasound monitoring enables real-time assessment of cardiac function, reducing hospital visits, improving clinical outcomes, and lowering healthcare costs. AI-driven data analysis enhances diagnostic accuracy and supports both prehospital and perioperative care.

Public safety use cases leverage ubiquitous B5G/6G connectivity, private networks, and network slicing to support public protection and disaster relief (PPDR) operations. These capabilities enable seamless interoperability for mission-critical services, including augmented/extended reality-enabled control centres, search-and-rescue missions in extreme environments, and mobile emergency response units, improving situational awareness, first responder safety, and disaster management efficiency.

In **energy**, use cases focus on optimising renewable energy production and infrastructure maintenance, including autonomous offshore wind turbine inspections, edge-cloud intelligence for solar monitoring, and real-time energy consumption analysis within renewable energy communities (RECs). These solutions reduce carbon emissions, improving grid efficiency, and enabling AI-driven forecasting and coordination of distributed energy resources.

Transport applications target safer, more efficient, and sustainable mobility and logistics. Use cases cover protection of vulnerable road users, enhanced railway signalling with B5G/6G connectivity, and reliable teleoperation of autonomous vehicles. Port operations benefit from improved logistics coordination and operational management, enabling smoother goods flows and reduced environmental impact.

RESULTS/ IMPACT

AMAZING-6G delivers significant scientific and technological impact by addressing key trade-offs in health, public safety, energy, and transport—verticals where B5G/6G adoption remains limited. In year one, the main technical deliverable flow began with an analysis of use cases, requirements and initial system architecture (D2.1). This led to an initial proposal for technology enablers (D3.1), where we identified the technology enablers in terms of communication, computing, management and AI, IoT and localisation. From these enablers, concrete research and deployment targets towards the trials will derive. An achievement to be highlighted among the dissemination activities, is the reception by the project of the Best Booth Poster Award at EuCNC 2025, a premier event for telecommunications research, bringing together leading experts and projects from around the globe. Through large-scale experimentation and upgraded, interoperable testbeds, AMAZING-6G strengthens Europe's capacity to design, validate, and deploy next-generation communication infrastructures.



Amazing Large-Scale Trials and Pilots for Verticals in 6G

Coordinated by
Andreas Georgakopoulos, Panagiotis Demestichas, WINGS ICT.

January 2025 – December 2027

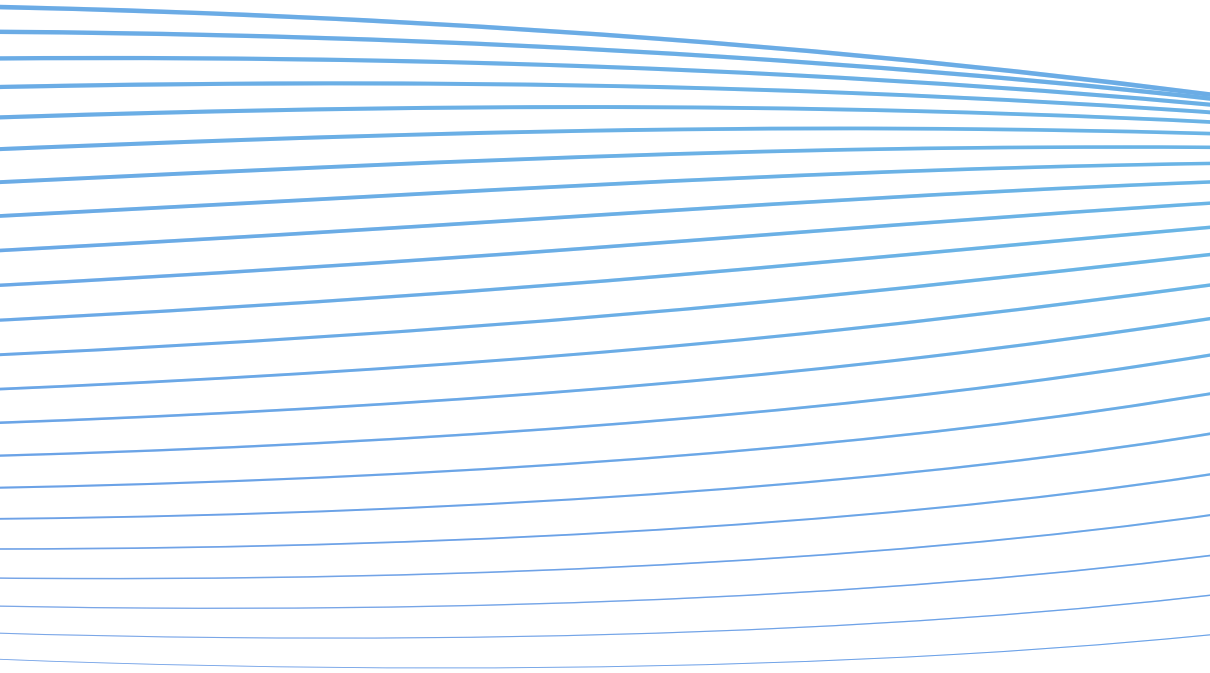
Website: https://amazing6g.eu/

X: https://x.com/Amazing6G

LinkedIn: www.linkedin.com/company/amazing-6g/

Verticals: Automotive, PPDR, Health, Energy, Smart Cities, Transport and Logistics

Partners: WINGS ICT, University of Patras, Centre for Research and Technology Hellas, Port of Thessaloniki, PNet, Telecom Italia, Nextworks, LINKS, City of Turin, Hewlett Packard Italy, Bellantenna, TNO, Oslo University Hospital, VTT, Finnish Meteorological Institute, Aurora Power Trains, IMEC, IS-Wireless, Orange, SIMTEL, Custom Soft Solutions, STS, University of Technology Chemnitz, Smart Rail Connectivity Campus, University of Surrey, Universidad Carlos III de Madrid, CAPGEMINI Portugal, Acromove Europe, Telefonica ID, OQ Technology.



CSA: SNS CO-OP

SNS CO-OP

Supporting and coordinating the activities of the European SNS JU.

PRIME OBJECTIVES

The SNS CO-OP prime objective is to support and coordinate the activities of the SNS JU community and its Work Programmes, building on the first phase activities, to integrate the second phase activities and prepare for subsequent phases. SNS CO-OP also orchestrates and organises strategic activities to maintain a dialogue in the wider European 6G community, in collaboration with the 6G-IA.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

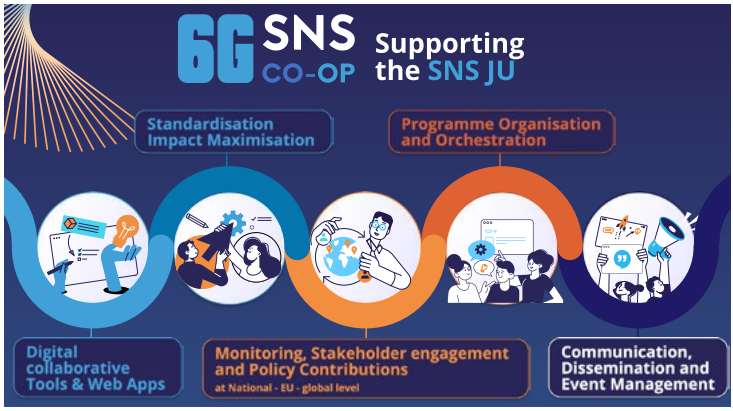
The SNS CO-OP project provides programme coordination services and support, shared information spaces and increased stakeholder involvement by building on the strengths and assets of the platforms and communities established through the SNS OPS and SNS ICE work. During the first year of the SNS CO-OP project (2025), the project has taken over all SNS JU support activities from SNS OPS and SNS ICE and, in addition, took over the EuCNC support for the event in 2025 and 2026, building on the 6GStart EuCNC support. The project is divided into 6 core streams of work.

RESULTS/ IMPACT

In its first year, SNS CO-OP has advanced work across all six core activity streams and achieved all planned results, even exceeding target KPIs.

The first stream, **strategic perspectives**, includes the SNS CO-OP monitoring and analysis framework activities. Two versions of questionnaires were revised, issued to SNS JU projects, and the responses evaluated. Projects from Calls 1 and 2 show strong research momentum, with a high volume of publications, contributions to standardisation, open-source engagement, lab validations, and early trial activities. Call 3 projects highlight ambitious plans in key technical domains. SNS CO-OP also conducted a **6G landscape and trends analysis**, examining research and innovation activities of other regions and stakeholders. These insights provide a valuable perspective on global 6G visions and are highly useful for SNS JU helping benchmark the European and SNS approach against other stakeholders.

The second stream, **stakeholder engagement**, began with the development of an **SNS JU stakeholder identification and involvement strategy** to foster a dynamic and resilient community. Activities are tailored to the needs of specific stakeholder groups, including global stakeholders, peer JUs, national initiatives, vertical and complementary domains, small and medium enterprises (SMEs) and digital innovation hubs (DIHs). In the first year, SNS CO-OP engaged with all these groups, attending major global events to promote the work and vision of SNS JU, organising meetings with national initiatives, and holding events with vertical and complementary domains.



In the third stream SNS CO-OP supports **SNS JU programme organisation and orchestration**. This work ensures the smooth functioning of the main SNS JU initiative bodies; Steering and Technology boards, facilitating efficient collaboration among SNS JU projects. With the addition of Call 3 projects these Boards expanded to 79 project members, requiring significant effort for organising activities. SNS CO-OP also manages the **SNS Collaboration Agreement** among SNS JU projects, supports the SNS JU and 6G-IA Working Groups (WGs), facilitated the creation of the new Sustainability WG, introduced a streamlined quarterly reporting methodology, managed terms of reference updates, and supported extensive cross-project publications, including 15 White Papers.

The fourth stream, **Dissemination and Communications**, has focused on promoting the SNS JU and coordinating communications across its projects. All activities align with the SNS JU communications policy and plan. Major events including MWC25, EuCNC25 and Techritory were supported. **The SNS JU Journal 2025** was prepared and published while news items were shared on SNS JU social media channels X, LinkedIn or Mastodon. All dissemination and communication activities were conducted in close cooperation with the SNS JU Office.

The fifth stream, **EuCNC & 6G Summit**, successfully organised and ran the event 2025 in Poznan, which was a major success, setting new records with **288 papers submitted** and **1,049 registered attendees**. This edition also achieved a high level of exhibitor participat ion, with **59 booths featuring live demonstrations**. In the second half of 2025 this stream advanced preparations for the next EuCNC & 6G Summit 2026 in June 2026 in Malaga..

The sixth stream, **events, logistics & support infrastructure**, focuses on providing full organisational and technical support. In the first year, SNS CO-OP delivered full organisational support for 21 events and actively contributed as speaker to 20 additional events, at both on European and global level. SNS CO-OP also ensured the continuity and evolution of the SNS JU's digital infrastructure and collaboration services. Key achievements include the operation and further development of the SNS JU website which attracted **93,159 visits in 2025**, the highest since its launch. Various collaborative tools were provided to SNS JU participants, including a BSCW document repository with over **20,000 documents stored, a brokerage service, and the SNS JU mail list server** which distributed 1.9 million emails with a total traffic of over 406 GB.

SNS JU Collaborative Operations and Output Optimisation

6G SNS CO-OP

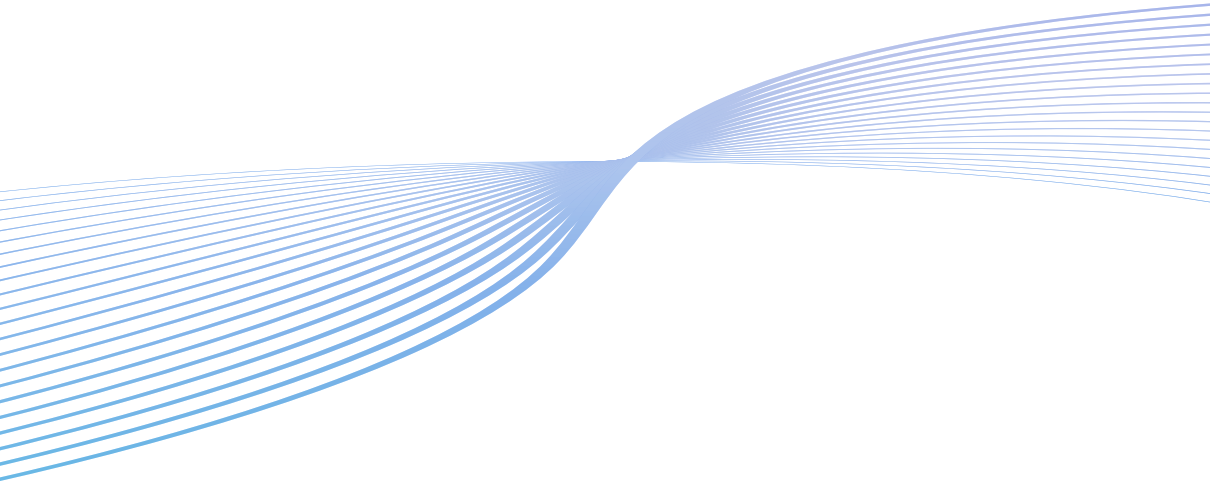
Coordinated by
Uwe Herzog, Eurescom

January 2025 – March 2027

Website: https://smart-networks.europa.eu/call-3-stream-csa/#SNS-CO-OP

LinkedIn: www.linkedin.com/company/sns-coop/

Partners: Eurescom, 6G-IA, Nokia Solutions and networks, Ericsson, Telenor, Telecom Italia, IDATE, Nokia Networks France, Southeast Technological university, Australo, TRUST-IT, Instituto de Telecomunicacoes, TNO, CTTC, Electronic Communications Office of Latvia, INOV, Universities of Oulu, Poznan and Malaga, Telefonica ID, Thales.



HORIZON-ER-JU-2024-01

is a call under the Europe's Rail Joint Undertaking aimed at accelerating the digital transformation of the European rail sector. It includes a dedicated SNS-Europe's Rail synergy topic focused on testing and validating next-generation railway communication systems based on advanced 5G technologies and future 6G developments. By bridging railway innovation and SNS research, the call supports the deployment of secure, reliable, and interoperable connectivity solutions for the future European rail network.

FP2-MORANE 2

Testing and Validating the Future Railway Mobile Communication System (FRMCS)

OVERVIEW

The FP2-MORANE-2 project is focused on testing and validating the Future Railway Mobile Communication System (FRMCS) specifications through tests and demonstrations in laboratories and real railway operational environments (field testbeds).

The first step is to develop a complete set of test cases, and a set of test plans for each laboratory and field activity.

Testing will then be carried out in three different laboratories in France, Germany and Hungary, where FRMCS functionalities and other system related tests will be performed.

The final step is five different field tests in four countries (Sweden, Netherlands, Germany and Spain), one of the testbeds being a high-speed line.

Co-funded by EU-RAIL and SNS JU, the project is focused on the definition and execution of end-to-end test scenarios that will assess the performance and maturity of the FRMCS specifications.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

One major step of the FP2-MORANE-2 project has been the development of the test specifications V1, containing a global set of test cases to validate the system and functional requirements of the FRMCS Specifications Version 2.2.

These tests are to be performed in laboratory and field testbeds using critical applications such as voice, railway emergency call, and also European train control system (ETCS), automatic train operation (ATO) and train management and control system (TCMS).

FRMCS is based on 3GPP Mission Critical 5G Standalone standards.

The relevant technologies include dispatcher systems and equipment; onboard and trackside monitoring equipment, ETCS and ATO simulators, including public key infrastructure and key management system; on-board FRMCS equipment, track side gateway; and cab radio (voice application system), including human-machine interface (HMI) and coordinating function.

All this will be captured in the test architecture, which will include the elements mentioned above in greater detail, interconnected so that every end-to-end test can identify the equipment and interfaces it requires.

FP2-Morane 2

Coordinated by Jean-Michel Evanghelou, UIC – International Union of Railways

January 2025 – September 2027

Website: www.fp2morane2.eu/

Verticals: Transport and logistics

Partners: European Rail Supply Industry Association (UNIFE), International Union of Railways (UIC), Administrador de Infraestructuras Ferroviarias, BaneDanmark (ADIF), Bane NorDeutsche Bahn, Infrabel, Network Rail, ProRail, Schweizerische Bundesbahnen (SBB),Trafikverket, Väylävirasto, Alstom, Construcciones y Auxiliar de Ferrocarriles (CAF), Ericsson, Eviden, Frequentis, Funkwerk, Hitachi Rail GTS, Kontron, Nokia, RideOnTrack, SiemensTeltronic, Viavi Solutions, KPN, Telia.

INNOVATIONS

The project validates the FRMCS specifications for the operational deployment of FRMCS across Europe as the successor to GSM-R, with the two systems initially operating together in coexistence mode.

Because GSM-R will require gradual replacement, the innovation lies in developing a future-proof, high-capacity communication system that enables a next level railway digitalisation.

The technology will deliver enhanced safety and control, advanced digital operations such as automated train operations (ATO) and predictive maintenance. Most importantly, the technology is central to creating a unified, harmonised system so trains can move across European borders in a completely interoperable manner.

USE CASES/ TRIALS/ APPLICATIONS

FP2-MORANE-2 aims to integrate FRMCS and application prototypes in three main labs hosted by Ericsson, Nokia, and Kontron, providing 5G standalone (SA) cores, Railway Mobile Radio-band radios, mission-critical servers, dispatcher systems, cab radios, GSM-R where needed, and trackside/ onboard simulators (European train control system, automatic train operation, train movement control system).

These labs will support remote partner access, end-to-end integration of onboard and trackside components, preparation of remote connections to external networks and railway test fields, and execution of the defined test plans.

Once this is complete, field tests to validate the FRMCS v2.2 specifications will take place under real operational conditions. The results and experience gained from these trials will then be used as key inputs for the development of the FRMCS v3 specifications. To achieve this objective, participants have focused on preparing their respective test tracks and rolling stock, to carry out the field tests during 2027.

RESULTS/ IMPACT

FP2-MORANE-2 will validate the FRMCS specifications. The final V3 Specifications will be included in the 2028 Control-Command and Signalling Technical Specifications for Interoperability (CCS TSI), marking the starting point for the first FRMCS national pilots.

This system will not only replace GSM-R, ensuring the continuity of European Railway Traffic Management System (ERTMS), but will also enable railway digitalisation, by supporting automatic train control, train performance applications, and more, thereby improving overall rail system performance.



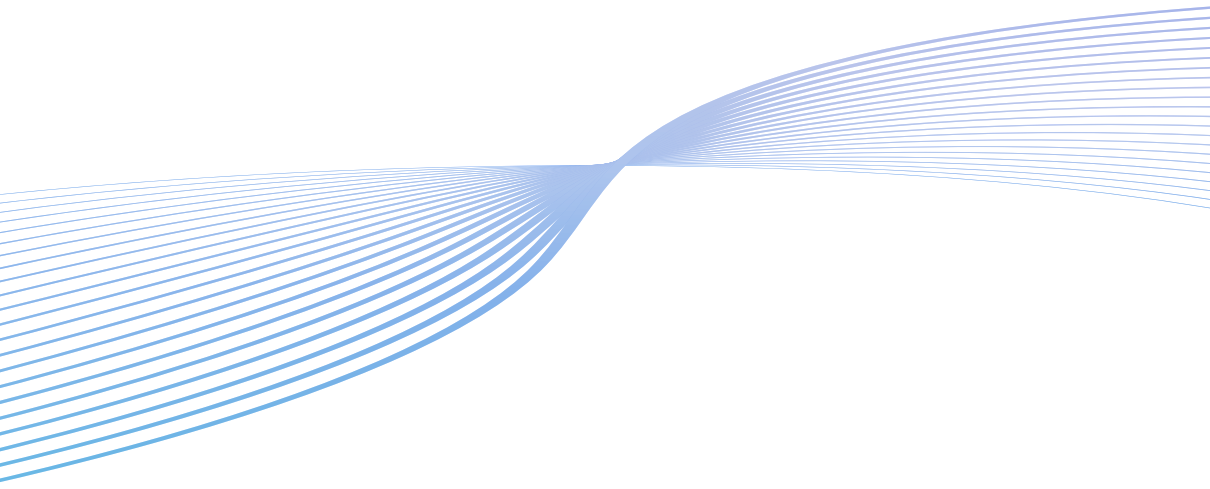
Calls 4/5 Projects

The 20 new projects, launching in 2026 across three streams, are backed by €116 million from the SNS JU to advance European 6G research and innovation. They will deliver foundational 6G research, proofs-of-concept, and large-scale 5G and early 6G trials across sectors including healthcare, mobility, space, media, and advanced manufacturing, accelerating the path to future 6G deployment.

Stream B

Stream B covers research into revolutionary and evolutionary technology advancements in preparation for 6G, including developments in IoT, devices and software. This Stream targets both low-medium TRLs leveraging WP 2024 with the objective of delivering innovative solutions towards real-life networks in a short to medium-term period and also low TRL targeting forthcoming 6G / disruptive technologies in a long-term period.

The Stream contains the topics dedicated to wireless communication and signal processing, communication infrastructure technologies and devices, and reliable services and smart security.



Stream B01-01

ADVANCED ARCHITECTURES SYSTEMS AND TECHNOLOGIES

Stream B01-01 focuses on the transformation of 6G architectures towards AI-native, autonomous and service-oriented networks. Through complementary approaches covering AI orchestration, agentic systems, serverless computing, semantic networking and simplified architectures, the five projects contribute to the foundations of future intelligent, adaptive and sustainable 6G infrastructures.

6G-OPTICON

Embedding Orchestration Intelligence into 6G

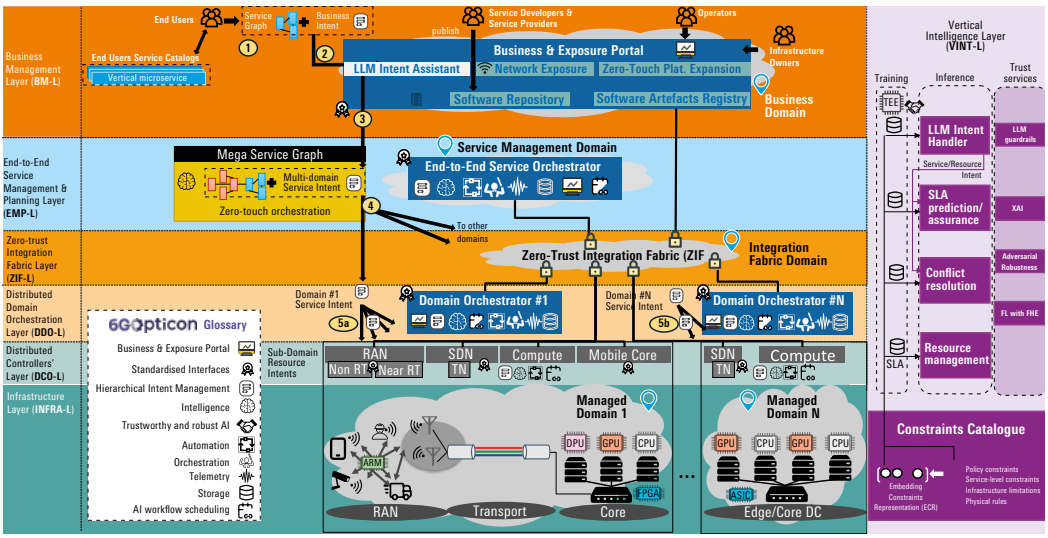
OVERVIEW

Modern orchestration initially developed in centralised cloud environments is now extending across the cloud-to-edge continuum. The 6G-OPTICON is a pioneering initiative developing an AI-native orchestration framework for intelligent planning, optimisation and autonomous management of heterogeneous end-to-end 6G infrastructures. Rather than treating AI as an external optimisation engine, the project embeds constraint-native deep learning directly into orchestration, enabling algorithms that inherently respect operational constraints while adapting to dynamic network conditions.

The project envisions an open, modular orchestration ecosystem unifying open radio access network (O-RAN), transport, mobile core, cloud and edge infrastructures into a single programmable environment. It integrates secure-by-design AI, trusted execution environments, explainable AI and energy-aware deployment strategies to enable trustworthy and sustainable 6G network operations.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

6G-OPTICON builds on previous SNS JU projects, including ACROSS, and introduces a distributed seven-layer architecture for AI-native 6G orchestration, as shown in the figure. The infrastructure layer (INFRA-L) comprises heterogeneous radio, transport, core, cloud and edge resources, with the distributed controllers (DCO-L) and domain orchestration (DDO-L) layers providing their management and local orchestration. The end-to-end management & planning layer (EMP-L) enables multi-domain service orchestration, and the business management layer (BM-L) provides Large Language Models



The 6G-OPTICON Reference Architecture:An AI-Native, Zero-Trust, and Intent-Driven Framework

(LLM)-based intent management, network exposure and zero-touch platform expansion. In addition, the Zero-Trust Integration Fabric (ZIF-L) ensures secure multi-domain connectivity, while the Vertical Intelligence Layer (VINT-L) delivers AI training, inference, service level agreement (SLA) prediction, conflict resolution and resource optimisation, supported by TEEs, XAI, homomorphic encryption (HE), federated learning (FL/FHE) and LLM guardrails to ensure trustworthy AI operation.

ENVISIONED INNOVATIONS

6G-OPTICON introduces complementary innovations that **redefine intelligent 6G network orchestration**. It pioneers in constraint-native deep learning, embedding latency, energy, security and service constraints directly into AI models to improve robustness and operational efficiency. The project also implements **secure-by-design AI pipelines**, integrating trusted execution, privacy-preserving AI and Explainable AI to ensure trustworthy decision-making. Furthermore, it enables **event-driven autonomous orchestration**, allowing AI-driven responses to infrastructure events across multiple domains. These innovations are validated through a test-case-driven methodology, using geographically distributed testbeds to measure performance against key 6G Key Performance Indicators (KPIs) and Key Value Indicators (KVIs) before deployment in realistic scenarios.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

The 6G-OPTICON architecture is validated through **multiple representative proofs-of-concept (PoCs)** that demonstrate AI-native orchestration across heterogeneous 6G environments. These validate end-to-end service deployment, dynamic resource optimisation, automated service adaptation and multi-domain coordination, while ensuring secure, explainable and energy-efficient operation. Through iterative experimentation on geographically distributed testbeds, the project evaluates intelligent orchestration across O-RAN, transport, core and cloud domains, measuring performance against representative 6G KPIs and KVIs.

ENVISIONED RESULTS AND IMPACT

By project completion, 6G-OPTICON will deliver an open, interoperable orchestration framework supporting secure, sustainable and AI-driven management of future 6G infrastructures. The expected outcomes include:

- **Standards-aligned open interfaces** enabling seamless migration from 5G to 6G,
- **AI-native, serverless multi-domain orchestration** with open service exposure for rapid innovation,
- **Constraint-aware, event-driven and zero-touch orchestration** for secure, autonomous and low-latency network management,
- **Reproducible KPI/KVI validation frameworks**, governance aligned with the AI Act and Cybersecurity Act, and
- **Replicable testbed artefacts** supporting interoperability, portability and standardisation.

Overall, 6G-OPTICON will strengthen European leadership in AI-native network management by delivering an interoperable, trustworthy and energy-efficient orchestration platform that accelerates the deployment of intelligent 6G infrastructures.

6G-OPTImisation and CONstrained Intelligence for end-to-end network operations across heterogeneous segments

6Gopticon

Coordinated by
Thanasis Charemis, UBITECH

June 2026 – May 2029

Website: https://6g-opticon.eu/

LinkedIn: www.linkedin.com/company/6g-opticon

Partners: UBITECH, Telefonica ID, Ericsson Italy, K3Y, EBOS Technologies, University of Patras, Tecnalia, Sant'Anna School of Advanced Studies, Jožef Stefan Institute.

AGENTIC6G

Autonomous Multi-Agent Intelligence for Native AI 6G Networks

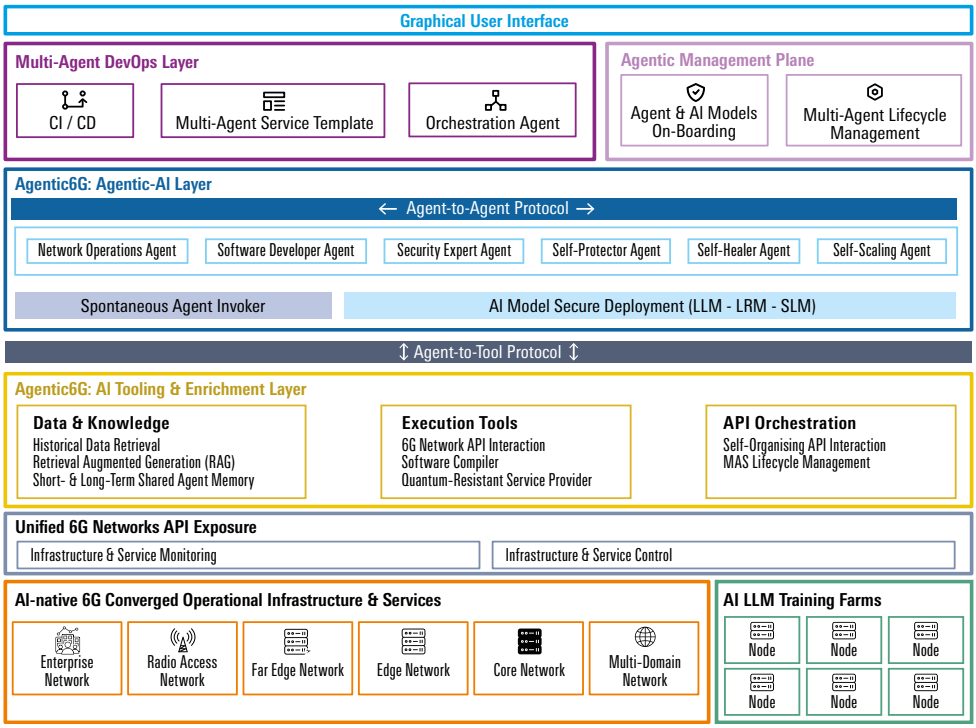
OVERVIEW

Agentic6G aims to enable AI-native 6G networks that can understand context, make real-time decisions, and continuously adapt to changing conditions with minimal human intervention. By embedding intelligence across all network layers, the project moves beyond traditional automation towards self-evolving systems that proactively optimise performance, enhance resilience, and improve resource utilisation. Agentic6G combines distributed intelligence, advanced orchestration, and secure-by-design principles to support next-generation services while reducing operational complexity and costs.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

Agentic6G introduces a distributed architecture based on a collaborative ecosystem of intelligent agents that continuously monitor network conditions, analyse data, and make autonomous decisions. Local agents provide rapid responses to dynamic events, while hierarchical control loops ensure alignment with service intents and overall system efficiency.

Built on cloud-native technologies, virtualised technologies, the architecture supports continuous learning and adaptation through AI/ML lifecycle management.



A key component is the **AI Agents Catalogue**, which enables the dynamic creation, onboarding, and orchestration of specialised agents for intent translation, network optimisation, software generation, and security analysis. Trustworthy AI is ensured through secure model onboarding, privacy-preserving data processing, and advanced security mechanisms.

As presented in the figure, distributed AI agents operate across device, edge, and core domains, coordinated through hierarchical control loops that enable autonomous decision-making, intent-driven orchestration, and end-to-end optimisation cross-domains.

ENVISIONED INNOVATIONS

Agentic6G delivers a coherent set of innovations enabling fully autonomous, AI-native 6G systems. It builds a **multi-agent architecture where distributed intelligent agents collaboratively manage network operations**, enabling scalable and adaptive decision-making across domains.

This is complemented by an **on-demand agent generation framework**, allowing new AI agents to be dynamically created, deployed, and integrated as requirements evolve.

The AgenticOps framework orchestrates of multiple large language model-based agents, ensuring flexible and scalable operation.

Intent-based tools translate high-level service requirements into network actions, enabling capabilities such as self-optimisation, self-protection, and self-healing.

A **hybrid AI-native orchestration layer** supports dynamic workflow composition and efficient knowledge sharing across agents, allowing continuous adaptation to changing conditions.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

Agentic6G validates its approach through two complementary use cases.

The first focuses on **zero-touch service assurance in multi-vendor telecom environments**. Deployed in a B5G testbed at Orange Romania, it demonstrates how intelligent agents enable autonomous monitoring, anomaly detection, and corrective actions under realistic conditions such as network failures and cyber-attacks, improving reliability and enabling proactive service assurance.

The second addresses **swarm-intelligent multi-robot interaction over private pre-6G networks**. Heterogeneous robots operate as a coordinated swarm, supported by ultra-low latency connectivity and edge-cloud intelligence with autonomous orchestration, self-healing, and resource optimisation enabling efficient operation in disaster response and industrial scenarios.

ENVISIONED RESULTS AND IMPACT

Agentic6G aims to demonstrate the benefits of AI-native 6G networking through improved efficiency, resilience, and automation. In telecom environments, it reduces operational costs while enhancing service quality and security through proactive and autonomous management.

In vertical domains, it enables advanced swarm intelligence with improved coordination, scalability, and robustness. These results underline the need for 6G capabilities such as distributed intelligence and real-time orchestration for secure, autonomous, and high-performance digital infrastructures.

Autonomous Multi(Agentic AI system for 6G networks

AGENTIC6G

Coordinated by Cristian Petrache, Orange Romania

May 2026–April 2028

Website: agentic6g.eu

Verticals: Industries, smart cities, PPDR

Partners: Orange Romania, Aston University, Ericsson Italy, Bull Spain, University of Murcia, University of Leicester, polytechnical University of Valencia, One Source, eBOS.

MAGIC-6G

Redesigning 6G network decision-making to provide application-centric support to cyber-physical systems and deliver the most important information for the task

OVERVIEW

The advent of 6G will tightly connect the human, physical and digital worlds, enabling applications such as immersive experiences, collaborative robots, and digital twins. However, these use cases place unprecedented demands on communication systems, that were designed as "bit pipes," unaware of the meaning of transmitted data.

MAGIC-6G addresses this challenge by advancing the goal-oriented communication paradigm, in which the network dynamically interprets application needs and transmits only the information required to achieve a given objective. The project extends the concept to goal-oriented networking, viewing the network and applications as a distributed system of cooperating agents. Its vision is a 6G architecture in which applications and network functions are co-designed through context-aware and intent-driven interfaces to achieve specific goals.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

At the heart of the MAGIC-6G vision lies the ability to evaluate and act upon information based on its relevance to specific objectives. While current goal-oriented solutions are often siloed and limited to point-to-point scenarios, MAGIC-6G proposes a comprehensive architecture in which applications can explicitly define their goals. This enables decisions not only on what to transmit, but also on who should transmit it and when.

The core innovation of MAGIC-6G is the introduction of two native layers into the 6G protocol architecture: the **Knowledge Layer**, which manages

Multi-Agent Goal-oriented networking for Interpretable, Secure, and sustainable 6G

MAGIC6G

Coordinated by Andrea Zanella, University of Padova

June 2026 – November 2028

Website: https://magic6g.eu/

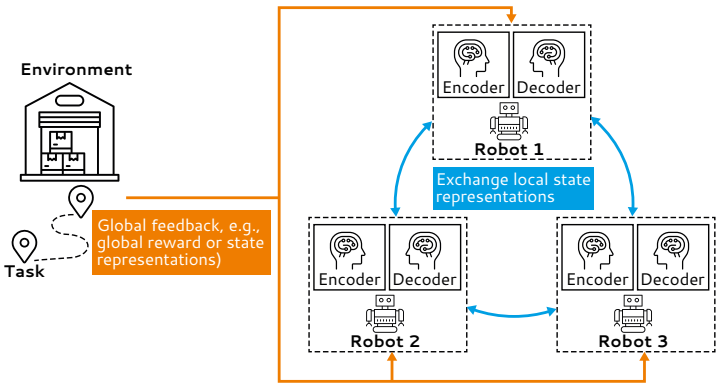
LinkedIn: www.linkedin.com/company/135194547/

Youtube: www.youtube.com/@magic-6g-eu

Verticals: Industry, media and entertainment

Partners: Linköping University, King's College London, Nokia Solutions Finland, Nokia Systems and Networks, Turkcell, WINGS ICT Solutions, Brainstorm3D.

MAGIC-6G architecture



what each network node knows and how this information is represented; and the **Agent Layer**, which is responsible for network decision-making and resource optimisation.

These layers interact directly with applications through dedicated interfaces, translating high-level intents into actionable metrics and operational constraints for the network.

ENVISIONED INNOVATIONS

This vision calls for new theoretical frameworks for goal-driven operations, including the definition of novel performance metrics and distributed optimisation methods. **Advanced AI modules** will enable optimal performance under complex goals and time-varying conditions, significantly reducing latency and communication overhead. This, in turn, supports faster and more reliable data transmission while seamlessly integrating communication, computing, and control capabilities.

Furthermore, safety, security, and sustainability are natively embedded into the architecture. **Robust safety mechanisms are required** to prevent operational failures, while strong security measures are essential to mitigate threats from malicious or compromised nodes and eavesdroppers and ensure system resilience. At the same time, the energy consumption of these techniques, particularly the execution of AI models, must be carefully balanced against performance gains to minimise the overall carbon footprint of the 6G ecosystem.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

The project encompasses three main use cases: digital twins for environmental protection, industrial autonomous mobile robots, and cooperative XR for education. While diverse, these scenarios share a common requirement: **intelligent agents (e.g. sensors, robots, and Extended Reality devices) must exchange information** to coordinate and adapt their actions in a dynamic environment under constrained communication resources.

By transmitting only the most relevant information, MAGIC-6G ensures that all network agents maintain an up to date representation of their environment. This establishes a **shared knowledge base** that AI-driven algorithms can exploit to significantly enhance system performance.

Ultimately, MAGIC-6G aims to tightly integrate these verticals with the communication network, by tailoring solutions to each application, delivering a **robust 6G proof-of-concept** with potential far beyond the initial use cases.

ENVISIONED RESULTS AND IMPACT

MAGIC-6G will have a significant impact on future 6G standards and cyber-physical systems. Industrial automation, environmental monitoring, and other real-time applications will benefit from an application-centric approach that enables network agents to exchange only the most relevant information with maximum efficiency. As 6G networks evolve beyond connectivity to integrate computing, sensing, and AI, orchestrating these resources to meet application-specific objectives while ensuring safety and security becomes essential. MAGIC-6G will deliver the core architectural modules needed to unlock these capabilities. It will also advance the AI-native vision of 6G by establishing a goal-oriented framework and intuitive interfaces that allow applications to express their requirements and performance objectives directly to the network.

PROSPERO

A Uniform, Integrated and Simplified (UIS) 6G system architecture for cost-efficient, AI-native and resilient networks

OVERVIEW

PROSPERO is designing a 6G system architecture described as uniform, integrated and simplified (UIS), bringing connectivity, intelligence and sustainability together in one framework. Today's networks are expensive to run, consume a lot of energy, and depend heavily on proprietary equipment. The project pursues three goals that matter to network operators:

- Cut the total cost of ownership (TCO) by 15–25%.
- Open new revenue streams above business-as-usual levels, with a 20+ billion EUR upside.
- Build resilience into the network from the start.

Each goal is translated into specific technical solutions, which the project tests through proof-of-concept (PoC) evaluations.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

PROSPERO is built on three architectural ideas.

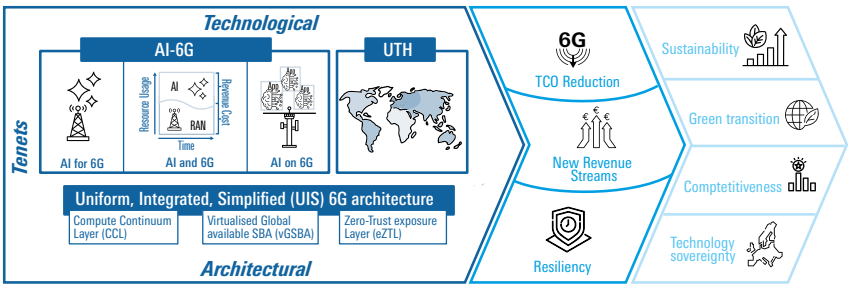
The first, the **UIS architecture**, replaces today's fragmented, siloed networks with a single infrastructure that works the same way everywhere. It relies on three building blocks:

- The virtualised global service-based architecture (vGSBA), which extends 5G service principles across every network domain.
- The compute continuum layer (CCL), which pools different types of computing hardware so operators can run network functions on general-purpose equipment.
- The evolved zero trust layer (eZTL), which keeps interactions secure and auditable.

The second idea, the **Unified Telco HyperFabric (UTH)**, lets operators, cloud providers and enterprises work together securely across borders, with flexible placement of core functions and a single global user identity.

The third, an **AI-6G framework**, builds purpose-made AI into the network instead of relying on large, energy-hungry models. It works on three levels: AI-for-6G optimises network operations, AI-and-6G shares spare computing capacity as a service, and AI-on-6G turns 6G data into new monetisable services.

PROSPERO's overview



ENVISIONED INNOVATIONS

The main innovations include a **compute continuum that runs radio access network (RAN) functions on shared, general-purpose hardware** to reduce dependence on any single vendor; **energy-aware control of radio units**, both individually and as a group; **dynamic scaling of virtualised distributed units** (vDUs); **energy-efficient programming of the user plane**; **AI/RAN multiplexing** that sells spare computing capacity as a service (AI-as-a-Service); a nomadic, multi-cloud core; **a causal-inference method** that configures the network from data rather than from costly field trials; a **programmable service-based architecture**; **flexible semantic communications for sending images** efficiently over satellite (non-terrestrial) networks; and resilience features such as a confidential computing continuum and programmable defence infrastructure.

POTENTIAL USE CASES/ TRIALS/ APPLICATIONS

PROSPERO validates its architecture through a set of evaluations and PoCs: AI-driven energy-aware radio control; dynamic 6G/AI computing multiplexing; semantic communications for non-terrestrial networks systems; running the UTH core across a combined cloud, edge and on-premises environment; a secure-by-design UTH core based on the eZTL; a causal-inference method for configuring the core; a digital twin that decides when to switch RAN carriers on and off; energy-aware programs in the user plane; and a combined RAN and core implementation. These PoCs will show the benefits for telecom operators and for the sectors that rely on dependable connectivity, including manufacturing, transport and automotive, energy, public protection and disaster relief (PPDR), health and smart cities.

ENVISIONED RESULTS AND IMPACT

PROSPERO aims at measurable results: RAN energy efficiency at least twice that of current 5G; 15–25% lower total cost of ownership while guaranteeing 99.999% reliability, and improved revenue potential.

Reaching these targets also cuts Europe's reliance on proprietary technology and supports both technological sovereignty and the green transition.

Realising this vision depends fundamentally on the transition to 6G. Earlier network generations competed mainly on speed and latency. PROSPERO argues that the real value of 6G lies in redesigning the network itself so that it is affordable to run, AI-native, sustainable and resilient. Incremental upgrades to 5G cannot lower cost, open new markets and guarantee resilience at the same time, while a 6G redesign can.

Programmable and Scalable Operation for Efficient, Resource-Aware architecture in 6G Networks

PROSPERO

Coordinated by Universidad Carlos III de Madrid (Spain)

July 2026 – June 2029

Website: sns-prospero.eu

X: x.com/sns_prospero

LinkedIn: www.linkedin.com/in/sns-prospero/

Youtube: www.youtube.com/@sns-prospero

Instagram: www.instagram.com/prospero_sns/

Verticals: Cross-vertical telecom infrastructure; enables Industry & Manufacturing, Transport & Automotive, Energy, Public Safety (PPDR), Health, and Smart Cities

Partners: Universidad Carlos III de Madrid, Telefónica ID, NEC Laboratories Europe, Fundación IMDEA Networks, Nokia Solutions and Networks, FiberCop, CanaryBit,Real Wireless,Universidade Estadual de Campinas.

SIXG

Real-Time Serverless Computing across the 6G Compute–Network Continuum

OVERVIEW

SIXG develops a real-time serverless computing framework for future 6G systems, addressing the gap between emerging 6G infrastructures and today's software platforms. While 6G enables programmable networks, pervasive edge computing, and ultra-low-latency, existing cloud-native and serverless technologies cannot meet its stringent performance requirements.

SIXG enables both real-time serverless applications across the cloud–edge continuum and integrates serverless functions directly into the 6G architecture. It combines data streaming, lightweight execution environments, programmable networking, confidential computing, and AI-driven orchestration into a unified framework for latency-critical services.

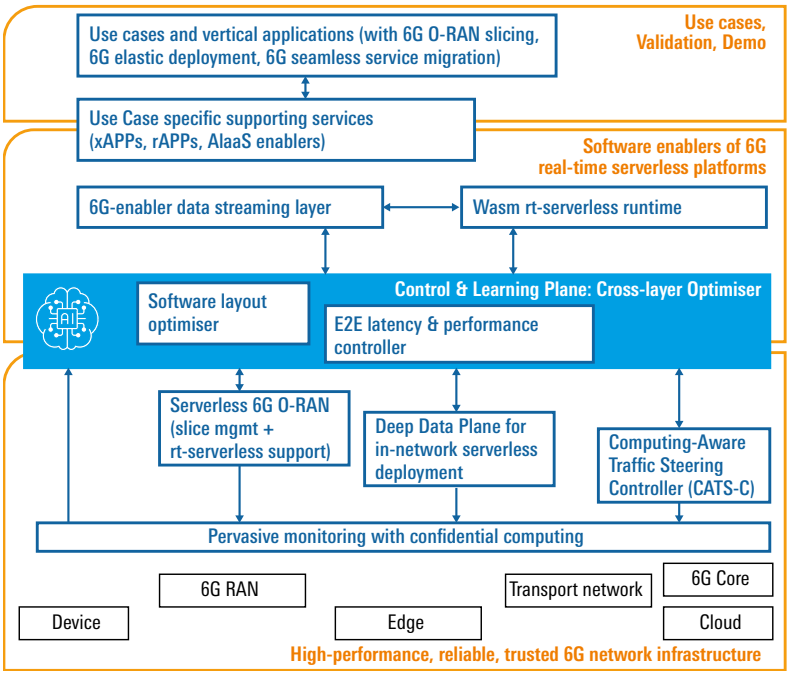
CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

SIXG adopts a cross-layer approach that jointly optimises serverless applications platforms and programmable 6G infrastructures.

Its architecture is built around four key pillars:

- Real-time streaming and state management for low-latency, stateful applications;

High-level SIXG architecture and its main technology pillars



- Instant-start web assembly runtime for lightweight execution;
- Programmable 6G infrastructure integrating open radio access network (O-RAN), programmable data planes, confidential computing, and compute-aware networking;
- an AI-driven control and learning plane enabling optimisation of placement, migration, traffic steering, and resource allocation.

A key innovation is the tight coupling of computing and networking, enabling automated compute–network co-optimisation across the 6G continuum.

ENVISIONED INNOVATIONS

SIXG advances the state of the art through stream-native serverless computing for real-time applications, near-instant WebAssembly-based serverless execution and deep data plane technologies for service migration and telemetry processing. It also introduces privacy-preserving telemetry via confidential computing, on-demand serverless network slicing in O-RAN environments, and AI-driven orchestration with compute-aware traffic steering for cross-layer optimisation. Together, these innovations support AI-native 6G architectures that tightly integrate communication, computation, and data processing.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

SIXG will validate its concepts through three proof-of-concept demonstrations:

1. **Smart manufacturing** with AI-driven serverless streaming pipelines for industrial analytics and decision support;
2. **Connected mobility using dynamic 6G** O-RAN slicing for advanced driver assistance systems applications;
3. **Seamless service migration** across distributed edge infrastructures for both stateful and stateless services.

While demonstrated in manufacturing and mobility, the developed technologies are applicable to broader verticals, such as extended reality, healthcare, smart cities, and digital twins, all requiring ultra-low-latency, native AI processing, and high reliability enabled by 6G architecture.

ENVISIONED RESULTS AND IMPACT

SIXG will establish the foundations of real-time serverless computing for 6G ecosystems through integrated software components, experimental platforms, proof-of-concept demonstrations, open-source outputs, and standardisation activities.

The project will enable new beyond-5G services, improve security and trust through privacy-preserving orchestration and confidential computing, improve resource efficiency via AI-driven compute-network optimisation and reduce energy consumption through on-demand service deployment. It will also strengthen European leadership in 6G through coordinated scientific, industrial, open-source, and standardisation contributions.

A key feature of SIXG is the joint exploitation approach bridging networking and computing communities through integrated serverless compute–network orchestration.

SIXG

Serverless Infrastructure for neXt-Generation 6G Networks

Coordinated by Balazs Sonkoly, HUN-REN TKI Tamogatott Kutatocsoportok Irodaja

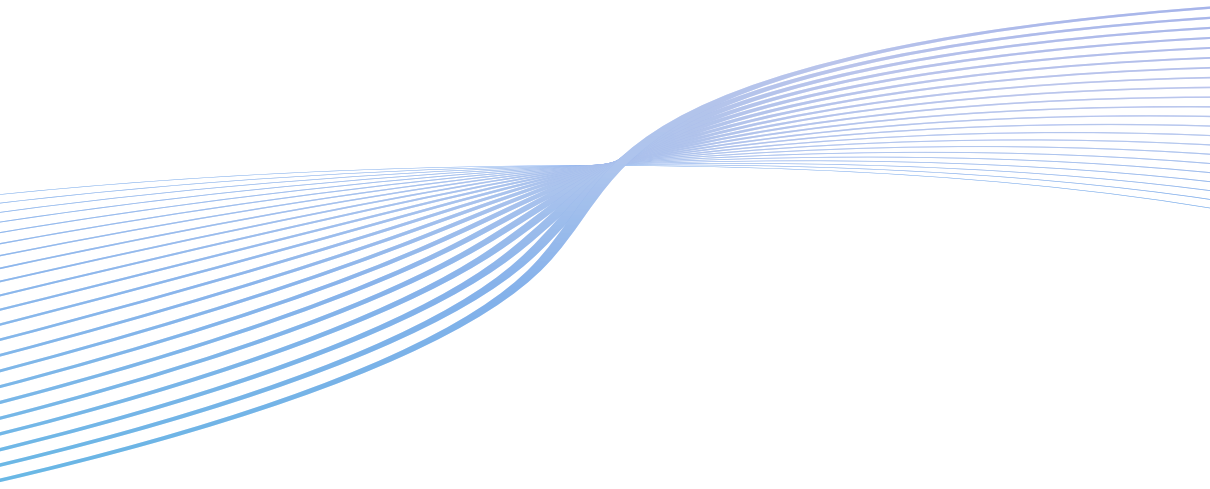
June 2026 – May 2029

Website: www.sixg-project.eu

LinkedIn: www.linkedin.com/company/sixg-project

Verticals: Industry, Automotive, Smart Cities

Partners: HUN-REN TKI, CNIT, University Rovira i Virgili, Dell Ireland and Spain, Telefónica ID, ISRD, HiveIntel.



Stream B01-02

ADVANCED IOT AND DEVICE TECHNOLOGIES

Stream B01-02 focuses on the next generation of IoT and device technologies required for 6G. By addressing heterogeneous connectivity, energy efficiency, resilience and autonomous operation, OPTIMUS-6G, IoT-ZERO and PIONEERS-6G aim to enable scalable and trustworthy IoT ecosystems across industrial, healthcare and critical environments. Their combined results will contribute to the emergence of intelligent, sustainable and globally connected IoT infrastructures beyond 5G.

IoT-ZERO

Secure Event-Driven TN–NTN Connectivity and Sensing for Near-Zero-Energy IoT

OVERVIEW

IoT-ZERO aims to transform the Internet of Things (IoT) from battery-powered, always-on devices into near-zero-energy, event-driven systems capable of decades-long, maintenance-free operation. The project combines energy harvesting, intelligent sensing, secure communications, and seamless terrestrial (TN) and non-terrestrial networks (NTN) connectivity.

Its key innovations include an energy-aware 6G architecture with digital-twins and intelligent energy management, adaptive asynchronous communications using ambient backscatter and lightweight physical-layer security (PLS) and neuromorphic, event-driven sensing that activates hardware only when needed. These technologies will be integrated and validated through a flagship proof-of-concept (PoC) for near-zero-energy asset tracking across hybrid TN–NTN environment.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

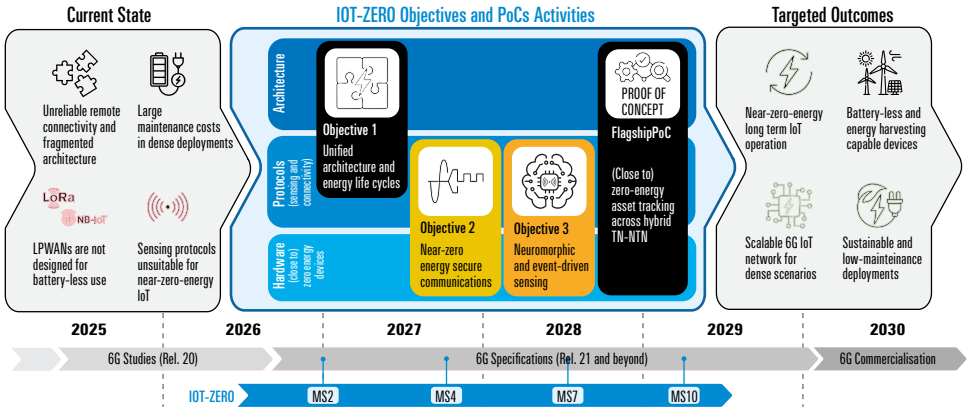
The figure illustrates IoT-ZERO's vision of transforming conventional battery-powered IoT into near-zero-energy systems. Instead of fixed sampling, synchronous communications, and energy-intensive security, IoT-ZERO adopts event-driven sensing, ambient backscatter communications, and lightweight physical-layer security. At the network level, an IoT Observer and an energy brokerage layer optimise device operation and energy allocation. Together, these innovations enable maintenance-free IoT deployments with lifetimes measured in decades and support future 6G standardisation.

ENVISIONED INNOVATIONS

IoT-ZERO will deliver innovations that go beyond today's low-power IoT technologies by:

- A unified energy-aware architecture that treats energy as a managed network resource rather than a hardware constraint;

Transition enabled by IoT-ZERO



- Event-driven communication protocols that minimise signalling and enable efficient operation with intermittent power;
- Ambient backscatter communications extending battery-less connectivity from short-range scenarios to future terrestrial and non-terrestrial 6G networks;
- Neuromorphic sensing and embedded AI for intelligent processing with ultra low power consumption;
- Lightweight physical-layer security providing authentication and key generation without energy-intensive cryptography;
- Passive positioning techniques that determine device location without continuous network attachment or power-hungry satellite navigation receivers.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

While its technologies are applicable across many sectors, IoT-ZERO will demonstrate them through a flagship asset tracking use case. Battery-less tags equipped with energy harvesting and event-driven sensing will monitor valuable assets across Terrestrial (TN) and Non-Terrestrial (NTN) networks. Devices will remain in an ultra-low-power state, waking only when relevant events are detected, with seamless connectivity switching to NTN terrestrial coverage is unavailable.

Beyond asset tracking, the developed technologies will support future 6G applications, such as maintenance-free smart city sensing, industrial monitoring and predictive maintenance, and precision agriculture and environmental monitoring.

ENVISIONED RESULTS AND IMPACT

The ambitious goals of IoT-ZERO require capabilities beyond current mobile networks. Future 6G systems are expected to natively integrate TN and NTN, support for ultra-energy-efficient devices, enable intelligent network management, and scale connectivity to billions of IoT devices.

6G will make networks energy-aware, dynamically adapting communication resources to harvested energy, intermittent device activity, and event-driven traffic. By combining these capabilities with near-zero-energy devices, IoT-ZERO will help reduce battery waste, lower operational costs, extend device lifetime, and enable more sustainable digital services across Europe.

Secure Event-Driven TN-NTN Connectivity and Sensing for Near-Zero-Energy IoT

IoT-ZERO

Coordinated by Andrea Ortiz, Technische Universität Wien

June 2026 – May 2029

Website: www.iot-zero.eu

LinkedIn: www.linkedin.com/in/iot-zero-horizon-europe-sns-ju-project-669863419/

Verticals:
Industry: Factory and process automation, in-factory tracking, agriculture and farming technologies, logistics

Transport and logistics: Rail, maritime, aviation, efficient mobility, Mobility-as-a-Service

Partners: TU Wien, IMDEA Networks, Lasting Software, LMT, Qascom, Sensoneo, Slovak University of Technology in Bratislava (STU), TU Delft, Thales SIX and CDI.

OPTIMUS-6G

OPTIMUS-6G envisions a transformative approach to next-generation 6G networks, focusing on the convergence of multi-band communications, AI-driven network optimisation, and digital twin-assisted planning for unlicensed spectrum operations

OVERVIEW

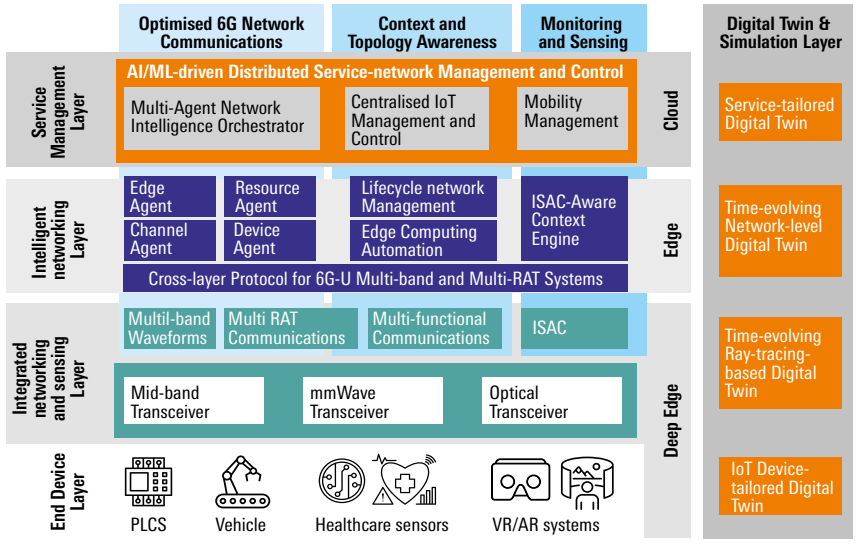
OPTIMUS-6G will develop a multi-domain architectural framework for intelligent IoT communications and sensing in unlicensed 6G bands (6G-U). It will design innovative multi-band, multi-radio access technology mechanisms to optimise heterogeneous IoT operations across radio and optical access networks, spanning the IoT-edge-cloud continuum.

A digital twin (DT)-enabled framework will support modelling, optimisation, and validation in representative deployment scenarios, enabling accurate performance assessment and faster innovation. By combining radio and optical communications, cross-layer protocols, AI-driven orchestration, and integrated sensing and communication (ISAC), OPTIMUS-6G will deliver reliable, high-capacity, low-latency and energy-efficient connectivity in unlicensed spectrum.

The approach will be validated through three use cases in smart manufacturing, precision healthcare, and immersive campus networks, demonstrating scalable, resilient, and long-term IoT deployments.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The high-level architectural framework of OPTIMUS-6G is illustrated in the figure below comprises five interconnected layers. **The End Device Layer**, includes heterogeneous IoT devices such as industrial controllers,



Envisioned OPTIMUS-6G Architectural Framework

wearables, connected vehicles, and VR systems. It is supported by **the Integrated Communication and Sensing Layer**, combining multi-band RF and optical technologies in unlicensed spectrum. **The Intelligent Networking Layer** enables adaptive, context-aware operation via AI-driven agents and cross-layer protocols, while **the Service Management Layer** provides end-to-end orchestration across the edge-cloud continuum. At the top, the **Digital Twin and Simulation Layer** supports real-time monitoring, optimisation and validation. Together, these layers form a modular, scalable and interoperable framework for 6G-enabled IoT applications.

ENVISIONED INNOVATIONS

To realise its vision, OPTIMUS-6G will deliver the following key innovations:

- Multi-band, multi-RAT communications enabling intelligent operation across unlicensed 6G spectrum bands.
- Advanced radio and optical transceivers supporting high-data-rate connectivity.
- ISAC providing sensing capabilities and localisation capabilities for 6G-enabled IoT systems.
- Hardware-agnostic cross-layer protocols for seamless multi-band and multi-RAT 6G-U operation.
- AI/ML-driven distributed service and network management across the IoT-edge cloud continuum.
- Context-aware and topology-aware generative AI models for IoT application and service management.
- A digital twin-assisted framework for network monitoring, planning, and optimisation.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

To validate the performance of the OPTIMUS-6G architecture, three representative use cases have been defined:

- **Use Case 1** – Smart factory automation and robotics: This use case investigates the use of radio technologies in unlicensed mid-band spectrum to enable ultra-reliable, low-latency, and resilient connectivity for Industry 5.0 manufacturing environments.
- **Use Case 2** - Precision healthcare and safe human navigation: This use case validate 6G communications in unlicensed mmWave bands using wearable IoT devices enabling secure, low-latency, and massive connectivity for monitoring, positioning, and sensing applications.
- **Use Case 3** - Immersive Campus Networks and Virtual Reality: This use case evaluates ultra-high-speed and reliable connectivity enabled by unlicensed 6G optical communications to support immersive IoT and extended reality applications in campus environments.

ENVISIONED RESULTS AND IMPACT

OPTIMUS-6G will enable ultra-low-energy IoT devices using low-power multi-band transceivers, energy-aware protocols, AI-driven orchestration, and edge computing to extend device lifetime without performance loss. It will ensure reliable operation in unlicensed 6G bands via multi-band/ multi-RAT architectures, radio frequency/visible light communication integration, content-centric protocols, and adaptive AI management. Finally, it will deliver advanced IoT devices with native ISAC capabilities, spectrum-aware deterministic operation, and DT-assisted optimisation, exceeding legacy 5G in flexibility and efficiency.

Optimised 6G-enabled IoT networks for unlicensed operations in the computing continuum

6G OPTIMUS

Coordinated by Nikolaos Petroulakis, Foundation for Research and Technology – Hellas (FORTH)

July 2026 – June 2029

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LinkedIn: www.linkedin.com/company/optimus-6g

Verticals:
Industry: Factory and process automation, in-factory tracking, agriculture and farming technologies, logistics

Media and entertainment: Broadcast services (B2C, B2B2C), education

Health: Smart health, pharmaceuticals, medical emergency management, hospital administration, telemedicine

Partners: FORTH, Intracom Telecom, Siemens, IMEC, LIST, InnoCube, Hyperion, ARTEMIS R&I.

PIONEERS-6G

6G-ready, end-to-end framework enabling energy-efficient, resilient, and secure IoT services across challenging environments

OVERVIEW

The Internet of Things (IoT) is rapidly expanding into environments where connectivity is difficult, energy resources are limited, and service reliability is critical. Future IoT applications will thus require capabilities that current 5G networks cannot fully deliver.

PIONEERS-6G addresses this challenge by developing the Omni-IoT platform, a new 6G-ready framework designed for IoT services in challenging environments (namely, industrial, underground, underwater, and global settings). The project aims to create an ecosystem where IoT devices can operate efficiently, securely, and continuously across these diverse environments. By combining innovations in user equipment (UE), radio access network (RAN), and core network (CN) domains, PIONEERS-6G will enable IoT services that are more energy-efficient, resilient, and secure than those supported by current 5G systems. The corresponding improvements will be quantified through tailored key performance indicators and key value indicators (KPIs/KVIs). PIONEERS-6G brings together expertise from academia and industry to demonstrate how 6G can support Europe's vision of a sustainable and trustworthy digital society.

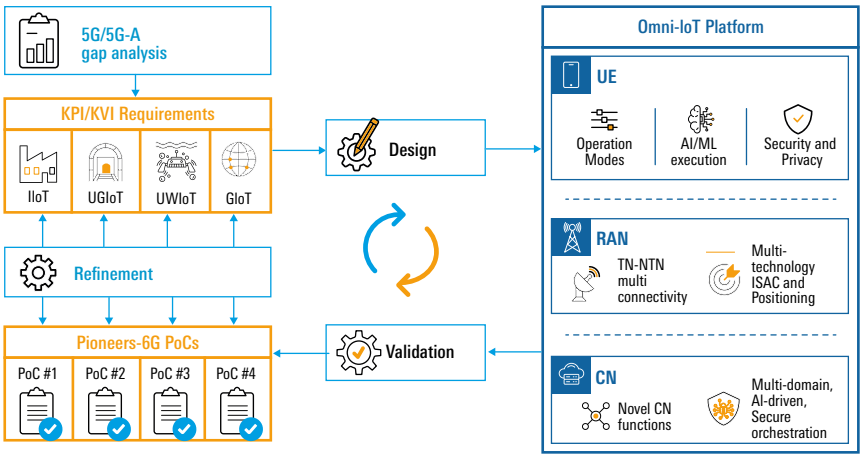
CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

At the heart of PIONEERS-6G lies Omni-IoT, an end-to-end platform integrating solutions for three complementary technological pillars:

- **Smart, energy-efficient, and secure UEs**;
- **Advanced RAN connectivity, sensing, and positioning capabilities**;
- **AI-native, secure, and cross-domain core network (CN) orchestration**.

Omni-IoT moves beyond traditional mobile network design approaches, placing IoT requirements at the centre of 6G architectural and technological developments.

PIONEERS-6G Methodological Approach.



ENVISIONED INNOVATION

PIONEERS-6G will explore several innovations that will shape future 6G-IoT systems:

- **AI-native and secure UE operations** for improved energy efficiency, connectivity, and on-device Artificial Intelligence/Machine Learning (AI/ML) execution;
- **Integration of terrestrial networks (TNs) and non-terrestrial networks (NTNs)** for increased service availability;
- **Multi-technology sensing and positioning** for enhanced communication and environmental awareness;
- **Novel CN functions** for global, cross-operator, and cross-domain interoperability;
- **AI-driven orchestration** for autonomous operations including anomaly detection, security enforcement, and regulatory compliance.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

As shown in the figure, PIONEERS-6G will be carried out using an application-driven, KPI/KVI-informed methodology, where the technical work is guided by the requirements of representative and challenging IoT scenarios, ensuring that the research outcomes lead to measurable KPI/KVI improvements.

The project will particularly validate its innovations through four use cases representing the diversity of future 6G-IoT services:

- **Industrial IoT (IIoT)** – PIONEERS-6G will demonstrate how energy-efficient devices, resilient connectivity, and accurate sensing/positioning can support safe and autonomous industrial operations while reducing operational costs;
- **Underground IoT (UGIoT)** – PIONEERS-6G will investigate how 6G technologies can provide reliable connectivity, environmental sensing, and worker protection in areas where conventional wireless systems often struggle to operate;
- **Underwater IoT (UWIoT)** – PIONEERS-6G will explore how IoT services can be extended to the underwater environments efficiently and reliably;
- **Global IoT (GIoT)** – PIONEERS-6G will demonstrate mechanisms for global UE connectivity, service continuity, and automated orchestration, enabling truly global and seamless deployments.

ENVISIONED RESULTS AND IMPACT

By combining communication, sensing, AI, security, and orchestration within a unified framework, 6G can deliver tailored IoT solutions that bridge the gaps left in 5G, transforming IoT services from a collection of connected devices into intelligent and globally integrated deployments.

PIONEERS-6G will contribute to this vision by demonstrating how 6G technologies can unlock efficient, resilient, and secure IoT services. The project is expected to deliver tangible KPI/KVI improvements compared to 5G systems, in terms of device energy consumption, service availability, sensing/positioning accuracy, security, and autonomy.

Beyond technical achievements, PIONEERS-6G will contribute to broader European priorities. Improved energy efficiency can reduce the environmental footprint of large-scale IoT deployments. Enhanced resilience and security can strengthen critical infrastructures. New approaches to global connectivity can facilitate digital sovereignty and support European competitiveness in diverse IoT markets.

Platform and Device Innovations for Energy-Efficient, Resilient, and Secure 6G-IoT Systems

Coordinated by Giuseppe Caso, Karlstad University (KAU)

May 2026 – April 2029

Website: www.pioneers-6g.eu

X: https://x.com/Pioneers6G

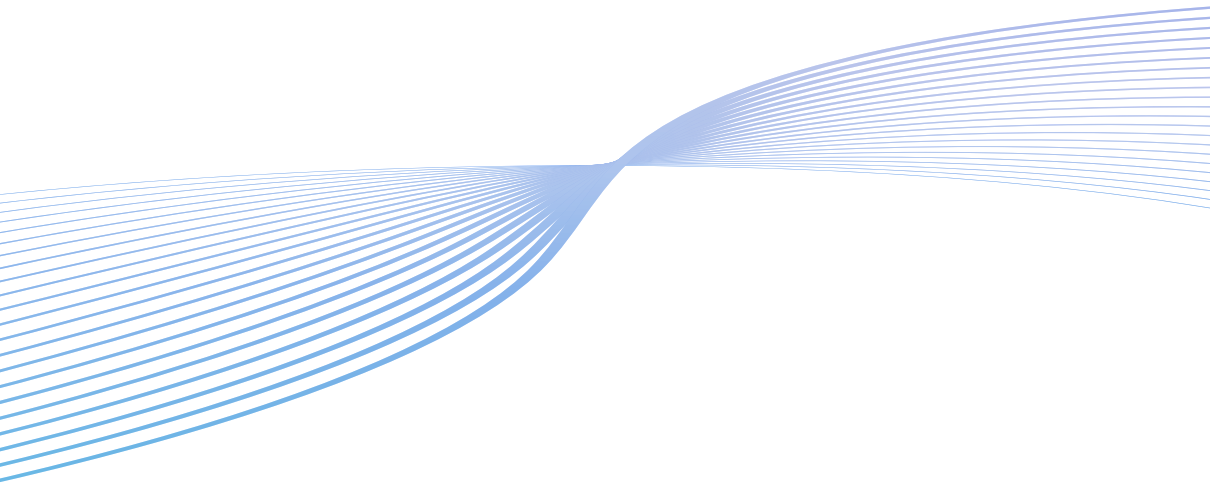
LinkedIn: www.linkedin.com/company/pioneers-6g/

Youtube: youtube.com/@PIONEERS-6G

Instagram: www.instagram.com/pioneers6g

Verticals: Industry, Transport and logistics

Partners: Karlstad University, Telefonica ID, NEC Laboratories Europe, CNIT, Universidad Carlos III de Madrid, Rinicom, Mulini, Envolve Entrepreneurship.



Stream B02

WIRELESS COMMUNICATION TECHNOLOGIES AND SIGNAL PROCESSING

Stream B-02 explores the next generation of wireless communication technologies for 6G. Through complementary research on advanced radio systems, AI-native signal processing, multidimensional communications and quantum-enabled technologies, projects aim to improve spectrum efficiency, energy performance and network intelligence, providing key building blocks for future high-capacity and resilient 6G networks.

MULTIPLY-6G

Boosting energy efficiency, capacity, and sensing with multidimensional waveform processing for 6G

OVERVIEW

Future 6G networks must deliver extremely high energy efficiency, ultra-high data rates, near-zero latency, ubiquitous connectivity, and high-resolution sensing features across diverse devices and environments. Achieving this requires a fundamental redesign of physical- and medium access control (MAC)-layer technologies.

Today, waveform design and multiple antenna technologies (MIMO) have largely been studied in isolation. This siloed approach fails to leverage the latent potential of multi-dimensional integration across time, frequency, delay-Doppler, and spatial domains. MULTIPLY-6G's mission is to jointly address waveform design and MIMO evolution within a single, integrated framework which will unlock multiplicative gains in energy efficiency, spectral efficiency, communication capacity, and bring millimetre-level sensing resolution, ensuring backward compatibility with existing 3GPP technologies.

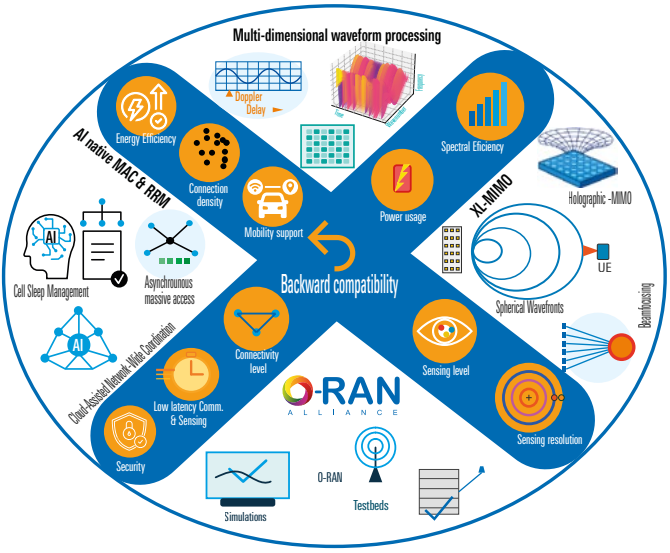
CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

Multiplicative gains are achieved through the co-design of multidimensional waveforms, near-field estimation, multi-beam focusing, AI-native MAC and radio resource management (RRM), fully aligned with Open RAN (O-RAN) control loops.

A key innovation is a joint code-angle random access scheme leveraging extra-large MIMO (XL-MIMO) spatial diversity to separate preambles in both code and angle domains, enabling grant-free access independent of the number of idle devices and significantly improving scalability.

MULTIPLY-6G: turning physics into multiplicative performance

By co-designing multi-dimensional waveforms, near-field estimation, multi-beam focusing, and AI-native MAC/RRM, standards-aligned with O-RAN, MULTIPLY-6G delivers multiplicative gains in the KPIs such as capacity, latency, energy efficiency, sensing precision, and security. Each arm of the multiplication symbol (×) represents the KPIs addressed by MULTIPLY-6G, while the sectors between arms illustrate the project tasks that deliver these gains. The centre represents Backward Compatibility, ensuring all innovations remain anchored in OFDM, aligned with NR numerologies, and ready for O-RAN deployment.



The framework further integrates advanced XL-MIMO techniques including continuous aperture MIMO (CAP-MIMO) with new waveform designs in the FR3 band to support integrated sensing and communication. This will allow 6G to achieve seamless integration of sensing, beam focusing, physical-layer security, and sustainable network operation within a unified architecture.

Overall, MULTIPLY-6G delivers gains in capacity, latency, energy efficiency, sensing accuracy, and security, while ensuring backward compatibility with orthogonal frequency division multiplexing (OFDM), new radio (NR) numerologies, and O-RAN-based deployments.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

MULTIPLY-6G defines a set of initial use cases that highlight the limitations of current 5G NR and the benefits of multidimensional waveform processing combined with uplink-centric near-field integrated sensing and communications (ISAC) and multi-beam focusing.

The targeted scenarios include urban air mobility, immersive XR, autonomous intersections, Industry 4.0, rural terrestrial and non-terrestrial networks, and disaster resilience – covering key high impact societal and industrial domains.

ENVISIONED INNOVATIONS

To achieve these objectives, MULTIPLY-6G will deliver the following key innovations: **Multi-dimensional waveform processing in the delay-Doppler-wavenumber domain**, supported by AI-based waveform optimisation; **O-RAN-compliant holographic MIMO surfaces** into a cell-free MIMO architecture; **Advanced channel modelling for holographic MIMO** in the wavenumber-delay Doppler domain; **Near-field-aware atomic norm minimisation methods and optimisation solvers** for nonlinear phase coupling; **Wideband XL-MIMO solutions** based on hierarchical spherical-wave codebooks for scalable, low-complexity real-time operation; **Delay-Doppler-beamspace-optimised cyclix prefix (CP)-OFDM waveforms** for integrated sensing and communication (ISAC), compatible with existing Wi-Fi and 5G NR infrastructure; **Deep reinforcement learning and multi-agent AI approaches** with Lyapunov-based validation for AI-driven radio resources management (RRM) techniques, waveform optimisation, and interference management.

ENVISIONED RESULTS AND IMPACT

MULTIPLY 6G will deliver a modular, measurement-driven simulation toolbox for accurate 6G validation, along with open-source, reusable modules to accelerate prototyping and foster collaboration. It also provides open, validated ISAC testbeds and datasets to support reproducibility and standardisation, reinforcing Europe's leadership in 6G sensing.

In the short term, the project is expected to significantly improve sensing resolution, latency, spectral and energy efficiency, and security. In the long-term, it aims to strengthen Europe's role in shaping 6G standards through open science and validated testbeds, while supporting massive connectivity and secure access for industrial and public networks and enhancing digital infrastructure autonomy.

Multidimensional wave and space – level optimisation for Energy efficient communications and sensing – 6G

MULTIPLY 6G

Coordinated by Arman Farhang, Trinity College Dublin

June 2026 – May 2029

Website: https://multiply-6g.eu/

LinkedIn: www.linkedin.com/company/multiply-6g/

Youtube: www.youtube.com/@multiply6g

Verticals: Automotive, Industry, Health, Smart Cities, Transport, media.

Partners: Trinity College Dublin, Istanbul Medipol Üniversitesi, Technische Universität Berlin, The American College of Greece Research Center, KTH, Universidad Carlos III de Madrid, Aalborg University, Queen's University Belfast, Vodafone Intelligent Solutions, Massive Beams, Interdigital, Software Radio Systems, F6S Networks, Ericsson.

SHARC

Deliver secure, energy-efficient, and high-performance 6G networks via intelligent workload orchestration across diverse computing platforms.

OVERVIEW

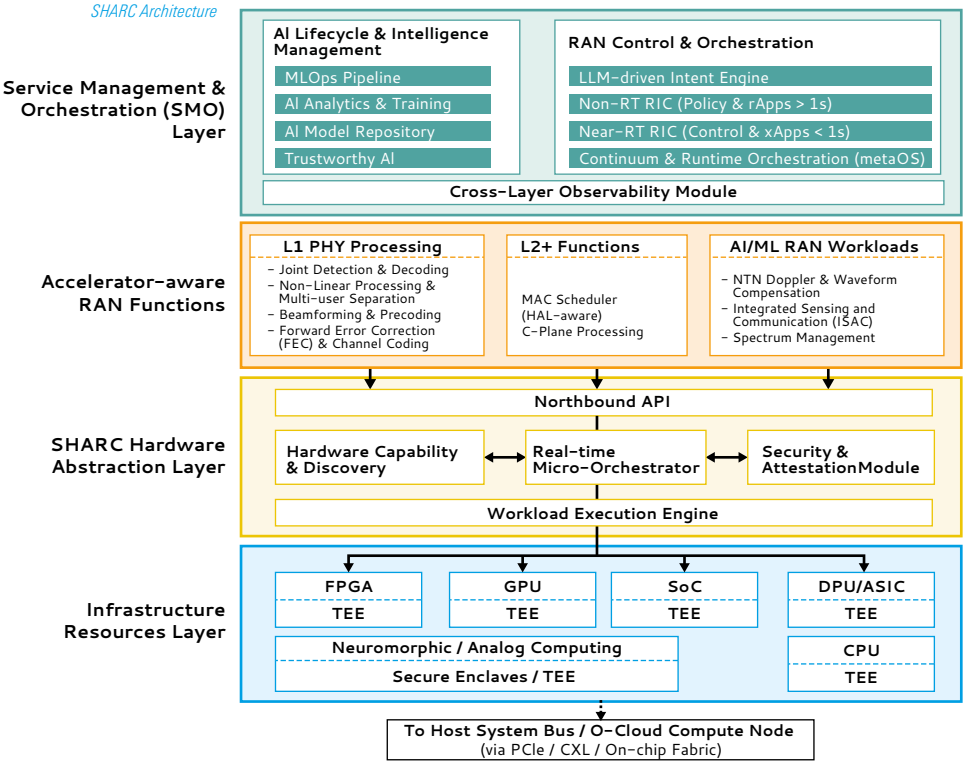
SHARC is pioneering the next generation of sustainable and intelligent 6G networks by enabling a multi-tenant, hardware-accelerated radio access networks (RAN) that dynamically orchestrates workloads across heterogeneous computing platforms, including central processing and graphics processing units (CPU/GPU), field programmable gate arrays (FGPA), and emerging neuromorphic/analogue accelerators), while ensuring trust, security, and energy efficiency. By moving beyond static, vendor-specific hardware acceleration, SHARC establishes a policy-driven framework that optimises network performance, energy efficiency, and cost across diverse computing resources.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The SHARC architecture operates as a closed-loop system that translates operator intents into real-time, hardware-accelerated actions. It is organised into four logical layers:

1. **Service management & orchestration (SMO) layer**: The intelligent control plane, integrating a telecom-grade machine learning operations (MLOps) pipeline and an

SHARC Architecture



LLM-driven Intent engine for policy generation and enforcement;

2. **Accelerator-aware RAN functions layer**: Hosts RAN software workloads (L1 Physical Layer, L2+, AI/ML tasks) designed for transparent offloading of compute-intensive functions;
3. **SHARC hardware abstraction layer (i-HAL)**: An intelligent micro-orchestrator that bridges RAN software and physical infrastructure, making real-time scheduling decisions based on telemetry, latency, and energy constraints;
4. **Infrastructure resources layer**: The physical compute fabric, composed of disaggregated heterogeneous accelerators equipped with trusted execution environments (TEEs) for secure multi-tenant execution.

ENVISIONED INNOVATIONS

SHARC introduces a set of key innovations that redefine how 6G RAN systems are orchestrated, secured, and accelerated across heterogeneous compute environments. **Dynamic Micro-Orchestration**: Replace static, vendor locked execution with i-HAL, dynamically scheduling optimal workload variants across heterogeneous hardware based on real-time network state; **Telecom-Grade MLOps**: Establishes a unified AI pipeline tailored for the strict latency, distributed nature, and hardware-aware constraints of 6G RAN, addressing the limitations of IT-centric tooling; **Emerging compute platforms**: Enables-co-design of RAN workloads for ultra-efficient execution on analogue and neuromorphic computing substrates; **Hardware-Rooted Trust Fabric**: Integrates attestation, physical unclonable functions (PUFs), and TEEs across heterogeneous accelerators to secure the expanded attack surface of disaggregated networks; **Non-Linear multiple input multiple output Processing**: Introduces advanced non-linear signal processing to significantly improve spectral efficiency while reducing the number of required base station antennas compared to traditional linear methods.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

SHARC will validate its architecture across five diverse European use cases (UCs) spanning terrestrial, non-terrestrial, and edge-cloud deployments:

UC1: Demonstrate the non-linear processing framework, delivering significant gains in throughput, and spectral and energy efficiency;

UC2: Evaluate regenerative 6G Non-Terrestrial Network (NTN) payload architectures using a modular, accelerator-enabled next-generation node B for low earth orbit, medium earth orbit and geostationary earth orbit scenarios;

UC3: Accelerator-aware execution of RAN functions within the RAN intelligent controller, transparently offloading L1/L2 workloads via i-HAL;

UC4: Orchestrates 6G RAN workloads across the cloud-edge continuum using AI-native management and LLM-driven intent translation;

UC5: Integrates neuromorphic AI accelerators with software defined radios for ultra-fast, energy-efficient embedded RAN processing.

ENVISIONED RESULTS AND IMPACT

Next generation 6G workloads will surpass the limits of general-purpose CPUs. Continuing with 5G paradigms risks unsustainable energy and operational costs, requiring natively integrated intelligence and hardware acceleration.

SHARC addresses this by dynamically matching tasks to the most suitable accelerators, significantly reducing energy consumption compared to CPU-only baselines. By decoupling software from static hardware lifecycles through open interfaces, SHARC enables substantial reductions in RAN Total Cost of Ownership aligned with Open RAN principles. Ultimately, the project strengthens European digital sovereignty and contributes foundational input to 3GPP and O-RAN Alliance standards.

Multi-Tenant, Disaggregated 6G RAN Over a Secure Hardware-Accelerated Compute Continuum

SHARC

Coordinated by
Victoria Katsarou, Space Hellas

September 2026–August 2029

Partners: Space Hellas, Telefonica, Advanced Computing , Universitat Politecnica de Catalunya, Accelleran, Software Radio Systems, National Center for Scientific Research "Demokritos", Institute of Communication and Computer Systems, VTT, University of Surrey, Plaixus Limited, Four Dot Infinity, Gigasys Solutions, Fraunhofer.

QUEST-6G

Shaping next-generation 6G networks through AI, XL-MIMO, and quantum-enhanced optimisation

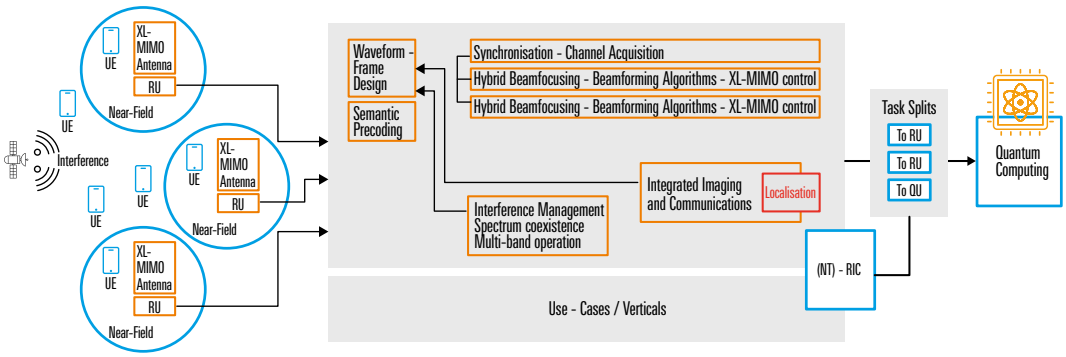
OVERVIEW

QUEST-6G aims to develop a transformative 6G radio access network (RAN) architecture that integrates advanced wireless communications, sensing, artificial intelligence, and quantum technologies into a unified framework.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

QUEST-6G adopts a layered end-to-end architecture spanning the full wireless communication stack. The **Channel Layer** focuses on FR3 propagation measurements and integrated sensing and communication (ISAC)-compatible channel characterisation. The **Array Layer** introduces extra-large multiple-input multiple-output (XL-MIMO) systems with more than 512 antenna elements, while the physical **(PHY) Layer** develops new waveforms and advanced channel estimation and tracking techniques. Above this, the **Scheduler/ Media Access Control (MAC) Layer** integrates AI-assisted resource allocation, while the **Application Layer** supports advanced services including extended reality (XR), telepresence, healthcare, and industrial automation. A dedicated **Quantum Layer** introduces quantum optimisation and quantum machine learning (QML) techniques to enhance network control, resource allocation, and operational efficiency.

The project combines a broad set of enabling technologies, including XL-MIMO, cell-free distributed MIMO, FR3 communications, beamforming and beamfocusing integrated circuits (BFICs), near-field communications, ISAC, wireless power transfer, physical-layer security, reconfigurable intelligent surfaces (RIS), AI/ML and generative AI, and quantum optimisation techniques.



System architecture for near-field XL-MIMO with hybrid beamforming, semantic precoding, interference management, and ISAC

ENVISIONED INNOVATIONS

A key innovation of QUEST-6G is **hybrid Near-Field/Far-Field (NF/FF) operation**, enabling simultaneous support of users located in both propagation regimes through advanced beamforming and beamfocusing techniques. A major differentiator is the incorporation of **quantum-enhanced optimisation** and **Quantum Machine Learning** techniques for channel prediction, beam selection, user scheduling, and anomaly detection.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

The flagship demonstration focuses on **full-body pose estimation using FR2/FR3 cell-free MIMO systems**, combining radio frequency (RF) sensing, AI inference, XR interaction, and edge computing. This use case showcases the convergence of communication and sensing in future 6G networks and highlights the project's ability to support advanced human-centric services.

QUEST-6G technologies will be validated across multiple sectors, including **Immersive XR and Telepresence, Healthcare and Rehabilitation, Elderly Care, Industry 5.0** as well as **Mission-Critical Services**. Validation activities are structured in three phases. Proof-of-concept (PoC)-0 focuses on validating extra-large-arrays, and beamforming algorithms. PoC-1 provides an end-to-end demonstration using Orange Romania testbeds and PoC-2 delivers a large-scale demonstration at IMEC facilities, integrating all project solutions.

ENVISIONED RESULTS AND IMPACT

QUEST-6G is expected to deliver fabricated XL-MIMO and reconfigurable antenna arrays, more than 100 beamforming chips, novel FR3 channel models, hybrid NF/FF beamforming solutions, a quantum optimisation layer, QML-based networking algorithms, and open-source datasets and software tools. The project defines ambitious key performance indicators, including a twofold increase in spectral efficiency, XR latency below 40 ms, a 90% reduction in outage probability, and support for more than 16 concurrent beams.

QUEST-6G advances fundamental research in FR3 channel modelling, XL-MIMO systems, near-field wireless communications, and quantum-enabled networking while enabling new commercial opportunities for telecommunications vendors, operators, and SMEs through innovative antenna and semi-conductor technologies. It also delivers societal benefits by enabling privacy-preserving sensing, remote healthcare, safer workplaces, and more immersive digital experiences, thereby supporting digital inclusion and improved quality of life. In addition, it promotes more sustainable 6G deployment through improved energy efficiency, better spectrum utilisation, and reduced infrastructure redundancy, contributing to greener communication networks.

Finally, QUEST-6G is expected to contribute to international standardisation activities in organisations such as **3GPP, ETSI, O-RAN Alliance, IEEE, and ITU-R**.

Integrating QUantum AI and rEconfigurable intelligent SysTems in 6G networks

QUEST-6G

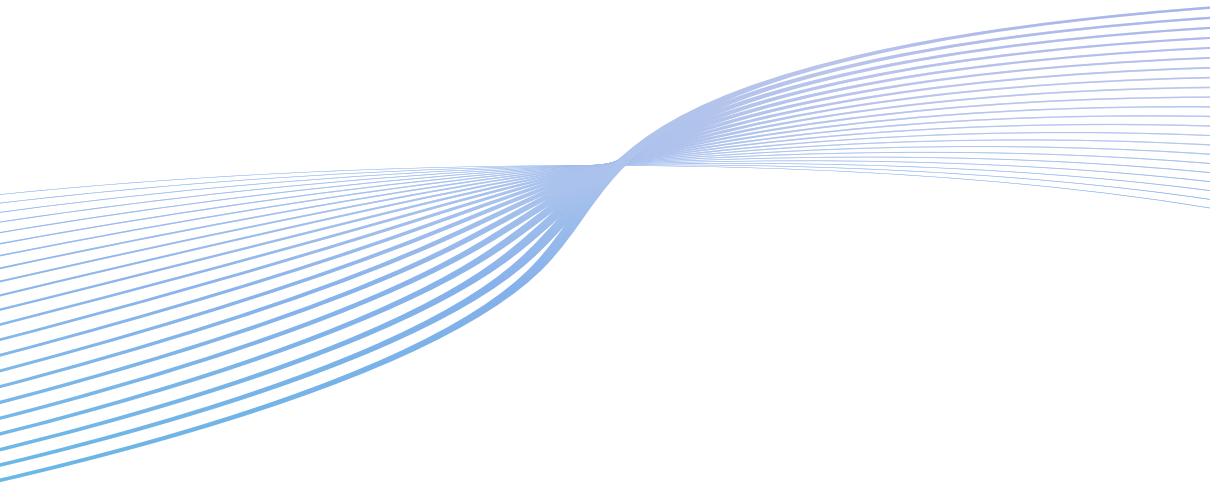
Coordinated by
Ioannis Patsouras, WINGS ICT SOLUTIONS

September 2026 – August 2029

Website: https://quest6g.eu/

Verticals: Media and Entertainment, Health, PPDR, Industry

Partners: WINGS-ICT, University of Piraeus Research Center, IMST, University of Cyprus, Orange Romania, Nokia UK, IMEC, KTH, Massive Beams, Akronic, Instituto de Telecomunicacoes, Keysight Belgium and Finland.



Stream B03-01

6G NTN-TN UNIFICATION/INTEGRATION

6G-NTN² NEXUS

6G-NTN² Nexus focuses on integrating terrestrial and non-terrestrial networks to enable seamless, resilient and ubiquitous 6G connectivity through intelligent orchestration and interoperable architectures.

Stream B03-02

HIGHER SPEED OPTICAL ACCESS NETWORKS AND FUTURE END-TO-END PACKET OPTICAL NETWORK ARCHITECTURE IN 6G

6G-CATS

6G-CATS focuses on advanced optical network architectures for 6G, enabling high-capacity, flexible and energy-efficient connectivity through intelligent and adaptive optical infrastructures.

6G-NTN^2 NEXUS

Towards a unified TN-NTN architecture for ubiquitous 6G connectivity

OVERVIEW

The 6G-NTN^2 NEXUS (6G-NTN^2) project researches, designs, evaluates, and demonstrates advanced technologies for the seamless integration of terrestrial networks (TN) and non-terrestrial networks (NTN). As ubiquitous connectivity beyond 2030 will require the convergence of ground and space networks, 6G is being envisioned to natively support a unified TN/NTN architecture. 6G-NTN^2 will identify key 6G-NTN requirements, define a baseline architecture, and pave the way for technically and economically sustainable in future standards.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The 6G-NTN^2 end-to-end architecture is a unified framework built around a harmonised 6G radio (6GR) air interface. It integrates geostationary and non-geostationary orbits (GSO/NGSO), and aerial segments like high-altitude platform stations (HAPS) and drones. Based on network virtualisation and optimised functional splits, it enables seamless multi-layer deployment and multi-vendor interoperability, and end-to-end network slicing between traditional mobile network operators (MNOs) and satellite network operators (SNOs).

ENVISIONED INNOVATIONS

6G-NTN^2 advances key innovations across the radio, network, and management layers:

- **Harmonised radio access technology** (RAT) Enablers: A unified air interface for terrestrial and multi-orbital non terrestrial environments;
- **Global navigation satellite systems-independent positioning, navigation, and timing (GNSS PNT)**: Hybrid positioning techniques that remove the dependence on GNSS;
- **Integrated sensing and communication (ISAC)**: Native sensing functionalities embedded in communication signals;
- **Distributed beamforming & reconfigurable routing**: Dynamic routing for efficient operation across protocols in multi-layered satellite constellations.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

Application scenarios are refined from previous European roadmaps and ongoing 3GPP SA1 studies, addressing real-world vertical market needs. The project focuses on two main communication pathways:

- **Direct-to-Device (D2D)**: Operating below 7.125 GHz to enable service continuity, smartphone satellite connectivity, and internet of things (IoT) services as well as public protection disaster relief (PPDR) operations;
- **Satellite Broadband**: Operating above 10 GHz (Ku/Ka-bands) to deliver high-speed connectivity to moving or fixed platforms across sectors such as automotive, maritime, aviation, rail, agriculture, and media.

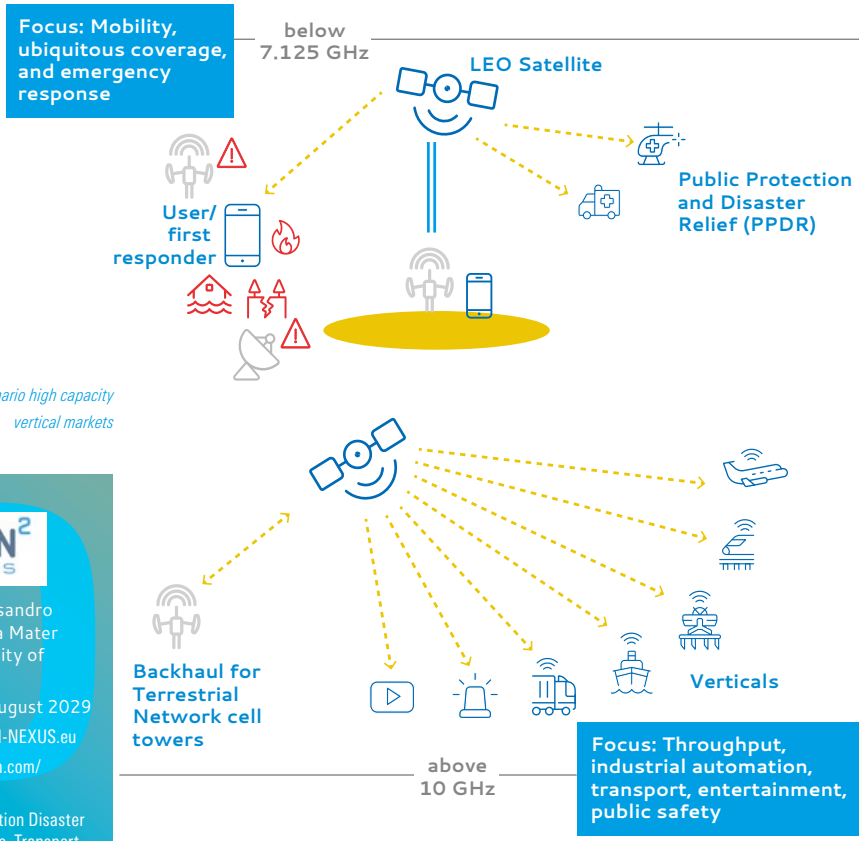
Validation is driven by **three focused, in-lab proofs-of-concept (PoCs)**:

- **PoC 1 (Harmonised Sub-7 GHz Radio Access)**: Evaluate user equipment (UE) and base stations with enhanced physical layer/ medium

access control layer (PHY/MAC) for delay/Doppler compensation, as well as GNSS-independent uplink synchronisation. Key metrics include attach success, throughput, and spectral efficiency for remote connectivity and public protection and disaster relief (PPDR) applications;

- **PoC 2 (Harmonised NTN/TN PNT & Communications Above 10 GHz)**: Validates Ku/Ka-band NGSO links using software-defined radio (SDR) platforms, assessing position accuracy, time-to-first-fix (TTFF) in GNSS-independent scenarios, and multi-satellite downlink throughput;
- **PoC 3 (Reconfiguration & Orchestration of Integrated TN-NTN)**: Uses a federation application programming interface (API) to interconnect MNO and SNO management systems, evaluating traffic rerouting, reconfiguration time, system adaptability, and tenant policy support during network disruptions.

Scenario: D2D and Public Safety



Scenario high capacity vertical markets

6GNTN² NEXUS

Coordinated by Alessandro Vanelli-Coralli, Alma Mater Studiorum – University of Bologna

September 2026 – August 2029

Website: www.6G-NTN-NEXUS.eu

LinkedIn: www.linkedin.com/company/6g-ntn/

Verticals: Public Protection Disaster Relief (PPDR), Automotive, Transport (Aeronautics, Railways, Maritime), Utilities, Agriculture, Media and Entertainment

Partners: University of Bologna, Airbus Defence and Space (France and Germany), Thales Alenia Space France, i2cat, CTTC, Martel, Ericsson, Qualcomm, Eutelsat, Hispasat, SES TechCom, Deutsche Telekom, Telefónica Innovación Digital, Orange, Telecom Italia, Politecnico di Torino, Thales SIX, Keysight Technologies, DLR, University of Luxembourg, Aalyria Technologies, Celeste Technologies, Atika Venture, Mediatek, ETRI.

ENVISIONED RESULTS AND IMPACT

6G-NTN² will deliver a validated framework demonstrating that future 6G standards can meet the satellite requirements of International Mobile Telecommunications (IMT-2030). By contributing its architecture, routing schemes, and interface specifications to key standardisation bodies such as 3GPP, the project will help shape future global standards and provide the technological foundations for European initiatives, including the IRIS² secure satellite constellation.

6G-CATS

AI-Powered 6G Networks: Secure, Energy-Efficient and High-Speed End-to-End Communication supporting Sensing and Mobility

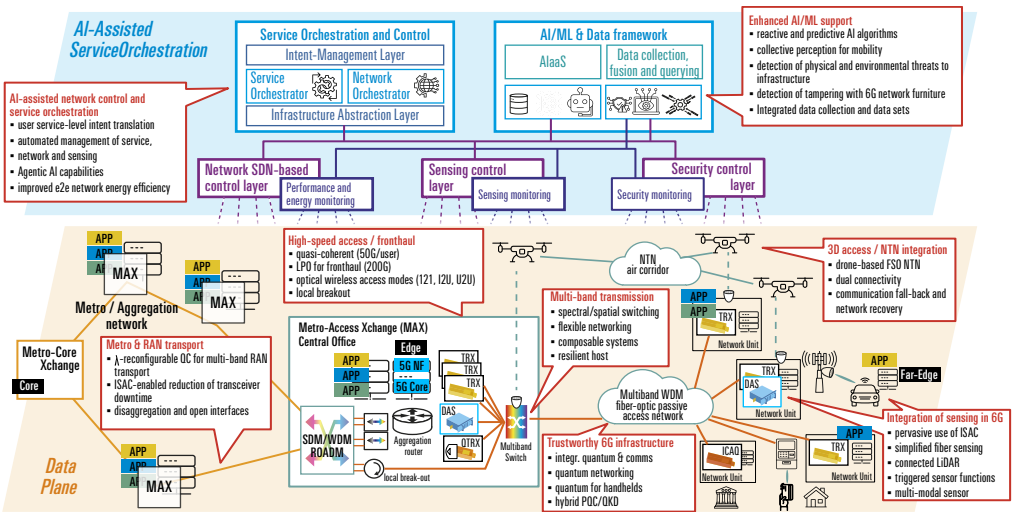
OVERVIEW

6G-CATS will demonstrate an AI-powered, disaggregated and secure 6G optical infrastructure capable of supporting a wide range of end-user applications in a sustainable way. It combines high-speed optical access and metro technologies with real-time intelligence, end-to-end resiliency and native security. The project builds on digital signal processing (DSP)-free quasi-coherent technology for unshared 50 Gb/s passive optical network (PON) and metro dense wavelength division multiplexing (DWDM) transmission, supported by 200 Gb/s linear pluggable optics (LPO) at the fronthaul. Optical multi-band switching enables flexible networking and composable networking, while an extension to the non-terrestrial networks (NTN) domain is achieved through drone-based free-space optics enabling fibre-grade dual-connectivity.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

6G-CATS will demonstrate an AI-powered, disaggregated and secure 6G optical infrastructure supporting a wide range of applications (including sensing and mobility) in a sustainable manner.

It combines high-speed optical access and metro networks with real-time **intelligence**, end-to-end resiliency, and native security. **Flexibility** is enabled through a fibre-wireless data plane extended by drone-based NTN support and multi-domain orchestration for efficient resource use. **Resiliency** is enhanced via integrated sensing–driven threat detection and predictive maintenance, complemented by a quantum-resilient architecture and intent-aware orchestration of end-to-end quantum channels within a multi-layer security



framework. **Sustainability** is ensured through energy-optimised component design while delivering beyond-state-of-the-art performance.

ENVISIONED INNOVATIONS

6G-CATS will:

1. **design a new sustainable, scalable and AI-driven network architecture** for high-impact use-cases (UCs);
2. **enable high-speed, energy-efficient integrated photonic and wireless** infrastructure for 6G ;
3. **develop multi-modal optical sensing** to enhance resiliency, security and mobility;
4. **develop an end-to-end, quantum-resilient and AI-enhanced security framework**;
5. **design an AI-assisted control plane and orchestration plane**;
6. **validate innovations** through proof-of-concept demonstrators and end-to-end testing in a federated Stream-C experimentation platform, supporting interoperability, performance, resilience and trustworthiness;
7. **maximise impact** towards a secure, sustainable, AI-powered 6G architecture integrating sensing and mobility.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

Enhanced AI/ML support will be integrated for three high-impact use-cases:

1. **Connected mobility** enabling safe transport of people and goods, while optimising traffic and supporting micro-mobility;
2. **Service continuity and automatic disaster recovery** demonstrated through TN/NTN integration, physical-layer and environmental threat detection (e.g. water infiltration) and predictive maintenance, and;
3. **6G-ready security stacks** leveraging quantum-resilient control of high-value assets and residential access with intent-based service translation, as well as detection of physical-layer tampering. 6G-CATS will validate these innovations in a Stream-C experimentation platform.

ENVISIONED RESULTS AND IMPACT

The three 6G-CATS UCs will deliver innovative results enabling intelligent 6G solutions, enhancing citizens' security and supporting AI enabled data processing. They aim to align 6G, AI, security and the ICT Industry.

- **Connected Mobility (UC1)** will demonstrate real-time sensing and connectivity using vehicle-mounted light detection and ranging (LiDAR) and camera with fixed distributed acoustic sensing (DAS) technology, combined with AI processing at the network edge in mobility scenarios, targeting tight integration between integrated sensing and communication (ISAC) integration and the edge-cloud continuum.
- **Network Resiliency and Service Continuity (UC2)** will validate automated disaster recovery through the TN/NTN integration, early threat detection and predictive maintenance through AI-driven analytics, and distributed sensing (fibre and LiDAR-based infrastructure inspection), with self-healing capabilities, through dynamic resource allocation, aiming at ubiquitous coverage.
- **Secure Communication and Automation (UC3)** will implement a hybrid quantum key distribution/ post-quantum cryptography (QKD/ PQC) cryptographic stack to industrial and residential environments, complemented by AI-based detection of tampering attempts across the 6G network, ensuring secure end-to-end service delivery.

6G Cats

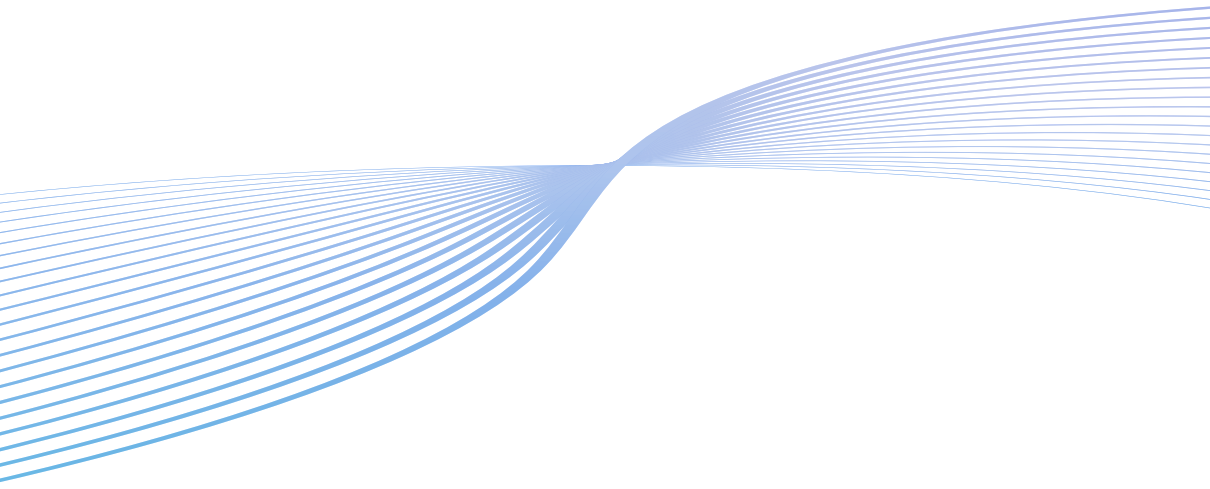
Coordinated by
Ioannis Chochliouros, OTE

September 2026 – August 2029

Website: www.6g-cats.eu

Verticals: Automotive, Industry, PPDR, energy, smart cities, transport and logistics

Partners: OTE, Universitat Politecnica de Catalunya, CTTC, Austrian Institute of Technology, Bifrost Communications, Ericsson Italy, NVIDIA Greece, Beamagine, National and Kapodistrian University of Athens, National Centre for Scientific Research "Demokritos", Internet Institute Communications Solutions, Febus Optics, Nextworks Infolysis, X-NET Services.



Stream B04-01

SMART SECURITY / SECURITY SERVICES
PAISES-6G

PAISES-6G addresses smart security for 6G, combining AI-driven protection, advanced cryptography and resilient security services to enable trusted and reliable future networks.

Stream B04-02

RELIABLE SERVICES OPERATION
SHIELD-6G

SHIELD-6G addresses reliable 6G service operation through intelligent automation, adaptive orchestration and resilient mechanisms to ensure trustworthy and efficient service delivery.

PAISES-6G

Building Secure, Trustworthy, and privacy-preserving 6G networks through AI-driven Cybersecurity, Quantum-Safe Encryption and federated Intelligence.

OVERVIEW

6G will transform digital connectivity by enabling billions of intelligent, interconnected devices through ultra-low latency, pervasive AI, and the integration of sensing capabilities into the physical environment. However, this evolution also creates an unprecedented attack surface. Open software-defined architectures, AI-driven automation, joint communication and sensing capabilities, and emerging quantum computing threats introduce complex security and privacy challenges that existing solutions cannot adequately address.

6G will connect everything. PAISES-6G aims to ensure these connections remain secure and trustworthy. The project develops and validates AI-powered security and privacy-preserving technologies for 6G, addressing secure AI deployment across federated networks, real-time protection against both conventional and quantum-enabled threats, and privacy risks from emerging sensing capabilities.

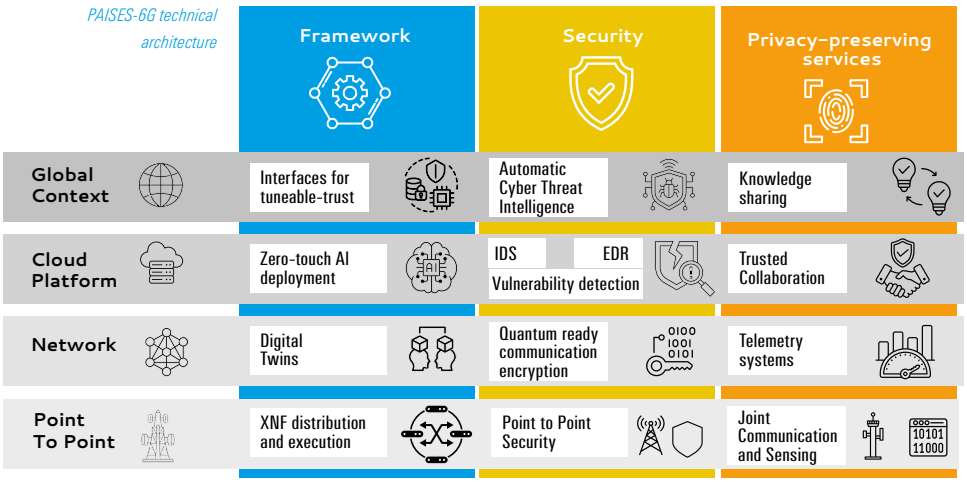
All solutions will be validated across distributed European testbeds and contribute to the work of standardisation bodies such as 3GPP and ETSI, helping embed security and privacy principles into the foundations of the future 6G ecosystem.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The architecture is organised around three mutually reinforcing pillars, as depicted in the figure.

The Framework pillar introduces cloud-native network digital twins (NDTs), enabling operators to test and optimise security configurations without affecting live systems. It also includes zero-touch AI deployment for the secure distribution of AI models across federated domains, supported by open application programming interfaces with configurable trust levels.

PAISES-6G technical architecture



The **Security pillar** covers the full network stack, from the radio layer upwards. It combines signal obfuscation to reduce eavesdropping risks, quantum key distribution (QKD) for quantum key exchange, and AI-driven real-time anomaly detection. Generative AI produces cyber threat intelligence (CTI) for proactive defence, while security-as-a-service (SECaaS) protects AI models through remote attestation and runtime integrity checks.

The **Privacy-Preserving Services pillar** enables advanced AI while safeguarding sensitive data. Federated learning with differential privacy supports use cases such as industrial internet of things (IoT) and smart health, allowing training without data leaving its source. It also addresses privacy risks linked to joint communication and sensing (JCAS), helping prevent user tracking

A cross-cutting **ethical governance framework** ensures all solutions align with fundamental rights, European values, and regulatory requirements from the outset, rather than as an afterthought.

ENVISIONED INNOVATIONS

PAISES-6G develops 14 innovative solutions targeting technology readiness level (TRL) 5, including a QKD framework immune to quantum computing threats, autonomous AI agents that continuously scan infrastructure for vulnerabilities, federated learning operations that enable AI training on sensitive data without it ever leaving its source, and generative AI-powered CTI that turns raw threat data into actionable defence strategies.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

From smart factories to quantum-secure network slices, PAISES-6G validates its solutions through three proofs-of-concept (PoCs) demonstrated across distributed testbeds.

- **Industrial IoT**: Smart factories generate vast amounts of sensitive operational data that cannot be shared without creating security and competitive risks. PAISES-6G applies federated learning to enable AI-driven optimisation without exposing sensitive data, while dynamically managing identities and access controls based on sensitivity levels.
- **Global Security**: The project develops intrusion detection systems from the network to the application level. It combines global CTI information from heterogeneous sources with vulnerability detection and mitigation capabilities to transform raw data into actionable defence recommendations.
- **Network Dynamics**: Deep learning models are used to predict and preempt traffic anomalies before they impact service quality. A QKD network, managed by a software-defined networking controller, provisions cryptographic keys across real network slices. In parallel, physical-layer signal obfuscation techniques are validated in realistic radio environments.

ENVISIONED RESULTS AND IMPACT

PAISES-6G targets impact across three dimensions:

- **Technical**: PAISES-6G will deliver 14 innovative solutions, validated through three integrated PoCs across distributed testbeds. All key exploitable results will reach TRL 5;
- **Scientific and standardisation**: The project will produce more than 40 peer-reviewed publications, and over 20 contributions to international standards bodies including 3GPP, ETSI, and IETF, through partners actively engaged in these fora;
- **Economic and societal**: PAISES-6G will enable new revenue streams based on trusted AI services and quantum-safe connectivity. By embedding security and privacy into 6G networks from the outset, the project will strengthen data protections for citizens and enhance trust in the resilience of the critical infrastructure on which the next decade will depend.

Privacy-Aware AI-Enhanced Security Services for 6G

Coordinated by Pablo Serrano, Universidad Carlos III de Madrid (UC3M), Spain

June 2026–May 2029

Website: https://paises-6g.eu

LinkedIn: www.linkedin.com/company/paises-6g/

Verticals: Smart Cities, Industry, Energy, Transport and logistics, PPDR, Health

Partners: Universidad Carlos III de Madrid, Telefonica ID, Foundation IMDEA, Ikerlan, TIM, Immanence, Nextworks, CNIT, QTI, NEC Laboratories Europe, Tages, Real Wireless, Net AI Tech, eBOS Technologies, ISRD, Kyiv Aviation Institute, Realworld Eastern Europe.

SHIELD-6G

AI-Native Cyber Threat Intelligence for Trustworthy and Resilient 6G Networks

OVERVIEW

SHIELD-6G develops an AI-native, privacy-preserving, and energy-efficient security framework for trustworthy and resilient 6G networks. At its core is an advanced cyber threat intelligence (CTI) platform that collects, enriches, and shares actionable threat intelligence across radio access network, edge, core, cloud, and vertical domains. The platform supports zero-touch security orchestration, dynamic trust management, cyber deception, AI-driven threat detection, digital-twin validation, and continuous compliance monitoring. By integrating these capabilities, SHIELD-6G enables autonomous, evidence-based protection of future 6G services.

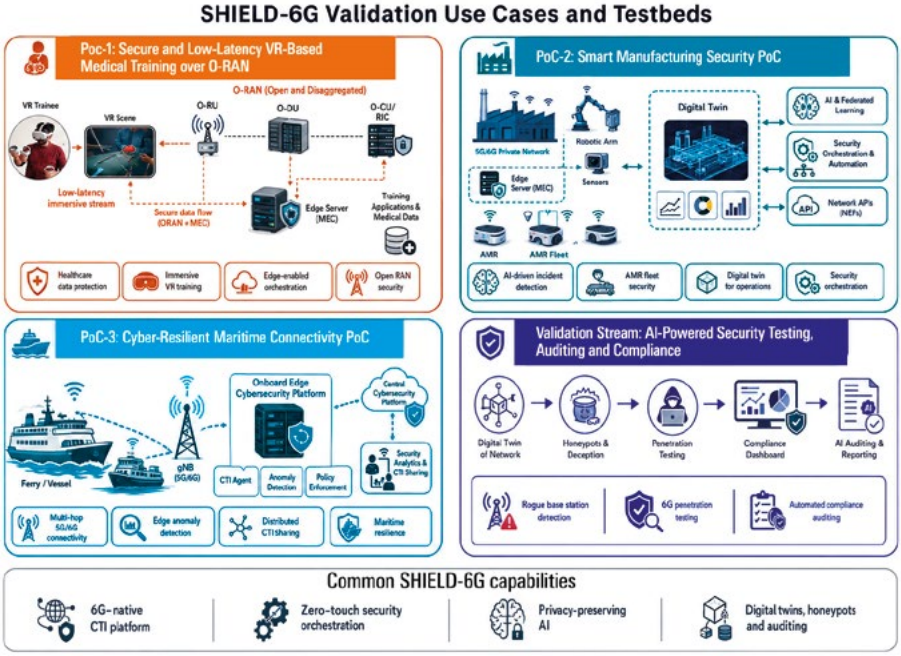
CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

SHIELD-6G follows a **modular, service-bus-based architecture** that securely connects cloud, edge, and extreme-edge environments across 6G stakeholders, enabling security as a native operational capability. It integrates key functional blocks for data ingestion, AI-driven analytics, zero-touch orchestration, automated response, and continuous security assurance. **A dedicated 6G-native CTI platform** aggregates heterogeneous sources (Security information and event management, endpoint detection and response, open-source intelligence, honeypots, digital twins) and enriches them into standardised, 6G-aware threat intelligence using privacy-preserving techniques. This intelligence is securely shared, analysed, and visualised to support prediction, correlation, and decision-making. It feeds autonomous security actions, compliance monitoring, and digital-twin-based validation. Large language model-based reporting provides human-readable explanations and audit-ready evidence for operators, verticals, and regulators.

ENVISIONED INNOVATIONS

SHIELD-6G advances the state of the art by integrating cyber threat intelligence, artificial intelligence-based analytics, privacy-preserving data exchange, automated security orchestration, and continuous assurance into a unified security framework for sixth-generation networks. It introduces a **6G-native cyber threat intelligence platform** that correlates threats across radio access networks, edge, core, cloud, application, and vertical domains using 6G-aware context. It relies on interoperable threat intelligence formats aligned with structured threat information expression, trusted automated exchange of intelligence (TAXII), malware information sharing platform, open TAXII, and collaborative automated course of action operations. **Privacy-preserving analytics** are enabled through federated learning, differential privacy, secure multiparty computation, homomorphic encryption, and controlled data provenance. The framework includes explainable and robust artificial intelligence for detection, prediction, and resistance to adversarial attacks, with energy-efficient processing. **Dynamic trust** and risk management aligns stakeholder policies with service-level enforcement across distributed environments. **Zero-touch orchestration** translates intelligence into automated containment, reconfiguration, and self-healing actions. **Digital twins and honeypots** support continuous security testing, while automated compliance and audit reporting ensure transparency and regulatory alignment.

SHIELD-6G PoC Test Cases



ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

SHIELD-6G will validate its technical enablers through complementary use cases, proofs-of-concept (PoCs), and cross-cutting test cases.

- PoC-1 will demonstrate how SHIELD-6G can secure **immersive medical training services** over a 6G-ready open radio access network (RAN) infrastructure. The validation will combine edge-enabled orchestration, real-time telemetry analysis, and policy-based security controls to protect sensitive session data while maintaining low-latency virtual reality performance.
- PoC-2 will focus on **smart manufacturing**, where autonomous mobile robots, digital twins, and distributed data-fabric mechanisms must operate securely in complex industrial environments. SHIELD-6G will validate AI-driven detection, cyber deception, secure orchestration, and adaptive mitigation for security-sensitive manufacturing incidents.
- PoC-3 will validate **cyber-resilient maritime connectivity**, where shipboard edge nodes and an onshore cybersecurity platform coordinate threat intelligence, anomaly detection, and model updates across multi-hop 5G/6G communications. This use case is designed to support secure and continuous operation even in remote or partially disconnected maritime environments.

ENVISIONED RESULTS AND IMPACT

SHIELD-6G delivers a modular, interoperable security framework for secure and resilient 6G services. It provides a 6G-native cyber threat intelligence platform, AI-driven threat detection, privacy-preserving intelligence sharing, dynamic trust and risk management, and zero-touch orchestration with automated response. It also includes digital twin and honeypot-based testing, continuous AI auditing, and compliance evidence generation. The project improves detection, response speed, automation, and privacy across distributed 6G environments. It will be validated in key sectors and supports European standardisation through contributions to 3GPP, ETSI, ITU, and O-RAN.

SHIELD-6G

Scalable, Hybrid, and Intelligent End-to-End Defense for 6G Networks

Coordinated by Madhusanka Liyanage, University College Dublin

June 2026 – May 2029

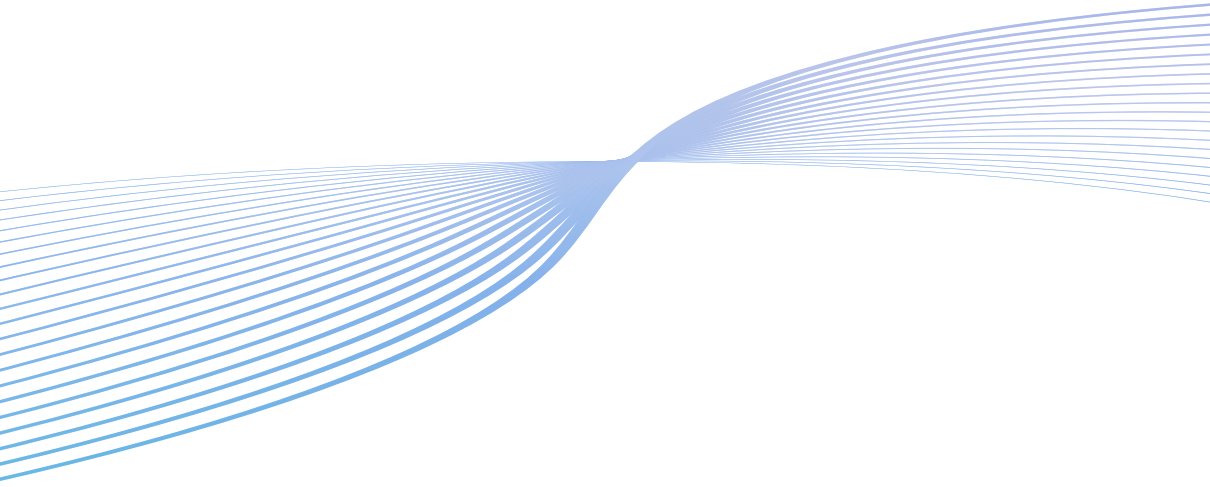
X: https://x.com/shield6g

LinkedIn: www.linkedin.com/company/shield-6g

Youtube: www.youtube.com/@SHIELD-6G

Verticals: Health, industry, transport and logistics

Partners: University College Dublin, University of Murcia, Ericsson Turkey and Finland, WINGS-ICT, VTT, Nextworks, TNO, CTTC, MBP Network Technology, Telefonica ID, Nokia Finland, LMT, Montimage, Viavi, Thales, Thales Six GTS, Cumucore, Lotus AI.



Stream C

6G TELCO CLOUD AND SERVICE PROVISION ENABLERS

Stream C of HORIZON-JU-SNS-2025-01 funds experimental infrastructure for 6G research and innovation. It focuses on telco cloud platforms, large-scale testbeds, and federated experimentation environments. The goal is to provide shared facilities that enable other SNS projects to test and validate new technologies.

SOVEREIGN-6G will develop Europe's first hybrid, multi-technology 6G Telco Cloud, bringing together IT and network infrastructures into a unified, automated platform. The project will also deliver an AI-powered service platform, advanced edge capabilities, and a pan-European testbed to help transform communication service providers into next-generation digital service providers.

SOVEREIGN-6G

Building a Sovereign, AI-native 6G Cloud Ecosystem

OVERVIEW

The 6G telco cloud is emerging as a hybrid environment where communication, computing, and acceleration resources are provided by hyperscalers, federations, and private infrastructure providers.

To manage this complexity, communication service providers (CSPs) are adopting cloud-native, Git-based architectures with automated continuous integration and continuous delivery (CI/CD), replacing rigid platform-as-a-service (PaaS) models. Standardisation efforts by the ETSI, the 3GPP, and GSMA Open Gateway aim to unify information technology (IT) and networking technology (NT) into a single resource continuum. SOVEREIGN-6G contributes by developing a real-world 6G telco cloud in Europe with an experimentation platform for validating service orchestration across compute, network, and acceleration resources. This enables CSPs to operate both cloud-native network functions (CNFs) and digital services on edge infrastructure, supporting use cases such as extended reality (XR), smart factories with strict service level agreement (SLA) and sovereignty requirements, and generative artificial intelligence (GenAI) workloads.

SOVEREIGN-6G is structured around three pillars supporting the transition from communication service providers to digital service providers:

- **Pillar 1, Delivering a new Unified Service Platform**: A next-generation business support system (BSS) and digital service aggregator enabling automated brokering and a single point of access to telco cloud services across multi-stakeholder ecosystems, removing the need for multiple platform integrations;
- **Pillar 2, IT–OT–NT Convergence**: Integration of information technology (IT), operational technology (OT), and networking technology (NT) into a unified telco cloud continuum, enhanced by AI-driven orchestration, network digital twins (NDT), and automated resource brokering for end-to-end SLA assurance;
- **Pillar 3, Native AI Edge**: AI-native edge capabilities for distributed inference, sovereign edge AI workloads, and multi-modal sensing for physical environment awareness.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

The use cases demonstrate key SOVEREIGN-6G innovations across distributed intelligence, cloud continuum orchestration, and AI-native telco infrastructures:

- **CNF Disaggregation and Collaborative Robotics**: Demonstrates 6G Core resilience for autonomous robotic inspection and real-time maintenance in collaborative environments;
- **Telco Cloud Continuum for Smart Manufacturing**: Enables cross-domain automation, SLA assurance, and AI/network-as-a-service orchestration across federated infrastructures;
- **Inference Cloud and Distributed AI for Physical AI**: Provides sovereign AI-as-a-service for drones, robots, autonomous vehicles, and augmented and virtual reality applications;

Unified Service Platform Over multi-VEndor Telco Cloud InfrastRucturEs, ExposInG beyond-ConNectivity services in 6G networks

SOVEREIGN-6G

Coordinated by
Christos Verikoukis
& Theodora Tsapikouni, ISI/ATH

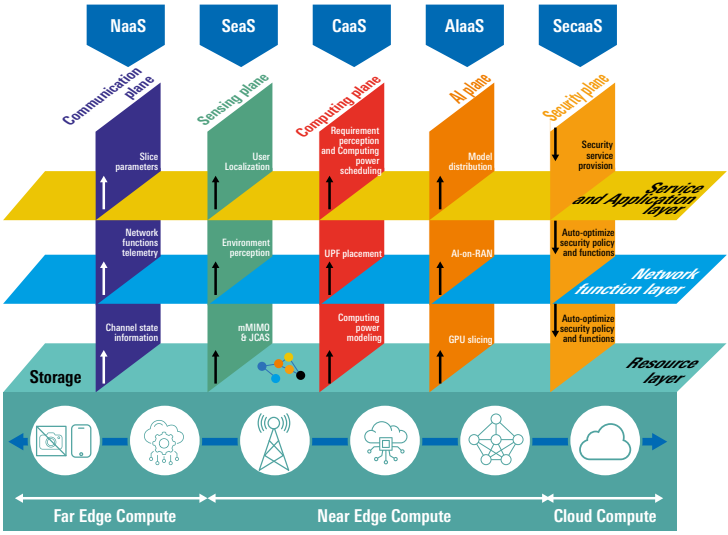
September 2026 – August 2029

Website: www.sovereign6g.eu

Verticals:
Industry: Factory and process automation, in-factory tracking, agriculture and farming technologies, logistics

Media and entertainment: Broadcast services (B2C, B2B2C), education

Partners: ISI/ATH, IQuadrat Informatica, Deutsche Telekom, Telefonica ID, BT, Altice Labs, Orange Romania, OTE, Siemens, Intracom, Ericsson Spain, NXP Semiconductors, Nvidia, Indra Soluciones Tecnologias de la Informacion, Universities of Oulu and Bristol, National Center for Scientific Research " Demokritos", Eurecom, Fraunhofer, I2Cat Foundation, ICCS, One Source, eBOS, Realworld, Nextworks, Roboverse Reply, Cumucore, Nokia.



Beyond-connectivity services exposed from the telco cloud continuum

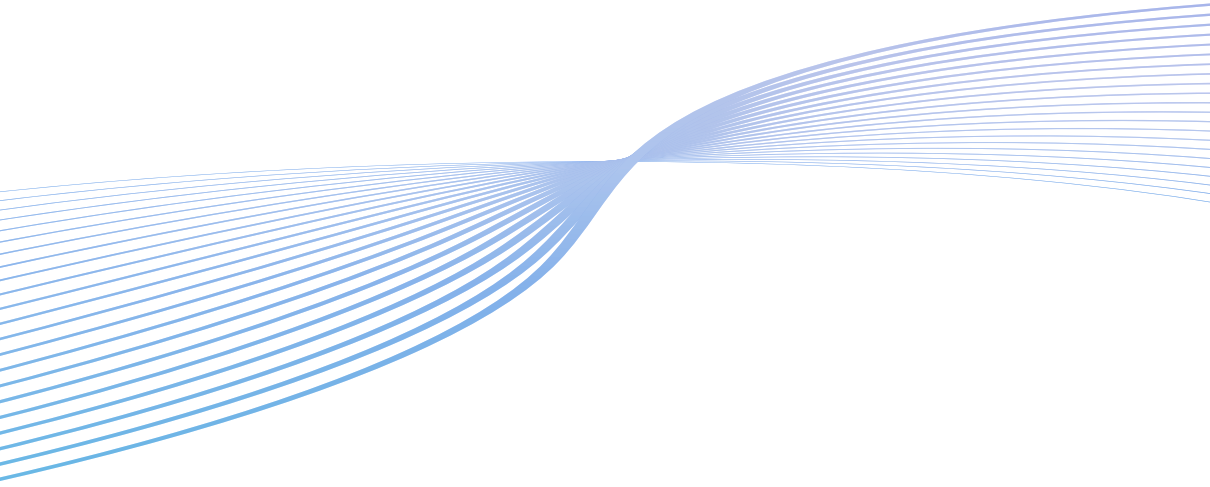
- **Multi-Modal Sensing and Generative AI via AI-Radio Access Network (RAN) at the Edge**: Supports RAN acceleration, large language model inference, and multi-modal sensing workloads;
- **Orchestration and CI/CD for Telco Workloads in Multi-Domain Sylva Clusters**: Enables closed-loop orchestration, AI-driven resilience, and secure CI/CD of CNFs and customer workloads.

ENVISIONED RESULTS AND IMPACT

SOVEREIGN-6G will deliver a 6G telco cloud experimentation infrastructure enabling validation of breakthrough technologies across interconnected EU test sites.

It will use an open-source Unified Service Platform for the aggregation, bundling, and instantiation of advanced digital services. The project will also enable automated intent fulfilment and service delivery through GenAI and NDT-assisted abstraction of communication application programme Interface (API) frameworks. It will also establish an AI-native edge infrastructure supporting inference workloads across radio access network and application domains, including full artificial intelligence model lifecycle management. Finally, it will deliver a unified orchestration continuum integrating IT, NT, OT, and native edge AI, with end-to-end SLA assurance.

These capabilities will strengthen Europe's digital sovereignty by reducing reliance on non-European platforms and enabling trusted, controllable infrastructure. They will accelerate industrial adoption of 6G through real-world, multi-domain experimentation and foster a competitive European ecosystem for advanced digital services, supporting new business models and more efficient, sustainable, and resilient communication infrastructures.



Stream D

SNS TRIALS AND PILOTS WITH VERTICALS

Stream D focuses on trials and pilots with vertical industries to test advanced 5G/6G technologies in real or near-real environments and validate performance, business models, and socio-economic impact using end-to-end systems.

6G-CARE

6G-enabled Connected and Autonomous Response for eHealth

OVERVIEW

6G-CARE will demonstrate and validate advanced 6G-enabled healthcare solutions that transform healthcare delivery and emergency response through next-generation connectivity capabilities into clinical environments. The project will engage healthcare stakeholders in a co-creation process to identify user needs, and ensure that 6G technologies address real clinical challenges.

Through end-to-end testing and large-scale trials across six pilot sites, 6G-CARE will adapt, integrate, and validate a portfolio of 6G enablers for healthcare applications, advancing them towards Technology Readiness Level 7 (TRL 7). The project will also contribute to 6G standardisation and regulatory alignment while assessing sustainable business models to accelerate the adoption of 6G solutions in healthcare.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

6G-CARE will develop an integrated framework to combine and validate advanced 6G enablers for healthcare applications, transforming fragmented solutions into a coherent, modular, and scalable ecosystem. The architecture will provide standardised interfaces, where applicable, to ensure interoperability with healthcare systems, including fast healthcare interoperability resources (FHIR)-based solutions, the European Health Data Space (EHDS), hospital information systems, and clinical decision-support platforms.

A dedicated end-to-end testing framework will assess performance, security, reliability, and interoperability up to TRL 5 before deployment. At its core, the **6G-CARE trial-management platform will coordinate validation activities across six trial sites** through open interfaces, secure data exchange, key performance indicators/key value indicators (KPI/KVI) monitoring, and real-time analysis. Supported by a healthcare requirements framework and a technology-enablers toolbox, it will integrate digital twin capabilities, AI-assisted enabler selection, experiment orchestration, federated trial management, and evaluation tools. This architecture will ensure traceable, scalable, reusable 6G and trustworthy 6G healthcare solutions while ensuring that clinical data remains protected locally.

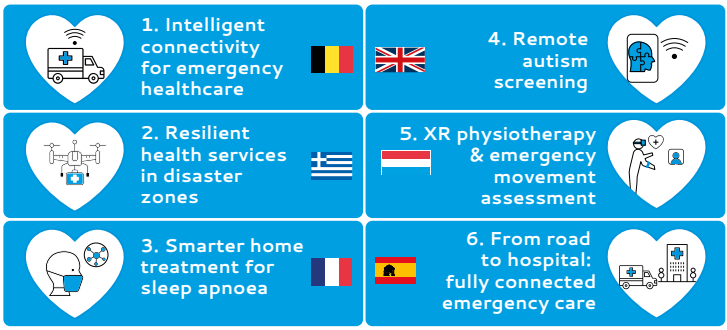
ENVISIONED INNOVATIONS

6G-CARE will advance healthcare digitalisation by combining connectivity with AI, edge intelligence, and immersive technologies to enable real-time, context-aware medical services. Key innovations include **adaptive and resilient communication for critical healthcare** and disaster scenarios, **AI-supported decision-making for personalised treatment**, and **digital biomarkers with real-time sensing** for continuous patient monitoring. The project will also introduce extended reality-based clinical interaction for remote care and rehabilitation, enabling richer physician-patient collaboration at a distance. In addition, 6G-CARE will pioneer **a federated and interoperable validation approach for healthcare enablers**, supporting reproducible experimentation across sites and accelerating their readiness for large-scale deployment and standardisation.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

6G-CARE will demonstrate the impact of 6G technologies through **six healthcare use cases** deployed across European trial sites and co-designed with medical stakeholders. The scenarios address key challenges, such as emergency response, remote care, personalised treatment, and improved access to specialised services.

In Belgium, an **AI-powered mobile emergency unit** will support first responders through adaptive connectivity and on-site diagnostics. Greece will demonstrate resilient healthcare delivery in disaster scenarios using deployable networks, drones, and wearables. France will focus on **optimising home-based sleep apnoea treatment** through AI and digital biomarkers. The UK will enable **remote autism screening** using connected mobile hubs. Luxembourg will showcase **XR-based physiotherapy and emergency movement assessment**, while Spain will demonstrate **connected emergency care** linking ambulances and hospitals through vehicle to everything communications, live medical data exchange, and augmented reality-assisted interventions.



ENVISIONED RESULTS AND IMPACT

6G-CARE will deliver 16 reusable technology components and 5 key exploitable results, including a trial management platform, healthcare application programming interface suite, and KPI/KVI evaluation framework. These outcomes will enable scalable, interoperable 6G-enabled healthcare services validated across European trial sites and designed for post-project uptake. The project will also provide open-source modules, standardisation inputs, and replication guidelines, supporting long-term exploitation by healthcare providers, SMEs, and industry stakeholders.

6G technologies are essential to meet the stringent requirements of future healthcare systems, including ultra-low latency, high reliability, massive connectivity, and secure real-time data exchange. They enable advanced applications such as emergency coordination, remote care, and immersive rehabilitation, while improving efficiency, reducing inequalities in access to care, and supporting sustainable and trustworthy digital health services across Europe.

6G-CARE

Coordinated by Sébastien Faye, Luxembourg Institute of Science and Technology (LIST)

September 2026 – December 2029

Website: www.6g-care.eu

LinkedIn: linkedin.com/company/6g-care/

Verticals: Health

Partners: LIST, IMEC, i2CAT Foundation, Internet and Digital Innovation in Catalonia, Greek Foundation for Research and Technology, Digital Catapult, University Lumiere Lyon 2, DISP Lab, Accelleran, Neutroon Technologies, Research to Market Solution France, Traqbeat Technologies, MATSUKO, Gigasys Solutions, CANON Research Centre France, Linde Homecare, Spindox Labs, POST Luxembourg, VIAVI Solutions, 6G Health Association.

6G-HOLONET

Shaping the future of Immersive Media with AI-native 6G networks

OVERVIEW

The project develops and validates 5G-Advanced and 6G-enabled media solutions driven by real business and societal needs across multiple sectors. It identifies key use cases, defines requirements, and establishes key performance indicators (KPIs) and key value indicators (KVIs) to guide development. The objective is to co-create sustainable, high-performance, and inclusive applications that contribute to future 6G ecosystems.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The project builds on existing 5G Advanced platforms and extends them towards 6G capabilities by co-developing enabling technologies for end-to-end media applications. It introduces modular, interoperable architectures designed for scalable deployment across different vertical sectors. Sustainability is embedded from the outset, addressing both environmental impact, including energy efficiency, and social inclusion. The approach leverages advanced testing infrastructures and experimental platforms to support validation across distributed environments.

POTENTIAL INNOVATIONS

6G-HOLONET introduces key innovations at the intersection of media production and advanced networking. It enables **scalable wireless volumetric production through portable, network-enabled capture systems** for real-time 3D generation. It advances AI-native orchestration using intent-driven and predictive systems to dynamically optimise network resources. It demonstrates **cross-site immersive synchronisation, enabling shared extended reality** (XR) environments across locations. It introduces **network-native production workflows** in which media systems directly interact with the network for real-time optimisation. It also pioneers **3D Gaussian Splatting (3DGS) for high-fidelity cultural heritage digitisation** without physical relocation.

POTENTIAL USE CASES / TRIALS / APPLICATIONS

The project validates its approach through four complementary use cases (UCs) spanning immersive media production, cultural heritage, and cloud-native broadcasting:

- **UC1: Immersive live music with holographic artists** enables distributed performers to appear together as real-time volumetric holograms, with extended and augmented reality (AR/VR) fan interaction and on-stage participation via volumetric capture;
- **UC2: Interactive cultural heritage experiences** uses wireless volumetric capture and 3DGS to create immersive digital replicas of artefacts and sites, with remote XR-guided storytelling;
- **UC3: Cloud-native live media production** transforms broadcast production into a cloud-based workflow with real-time AI services including subtitles, translation, sign language, accessibility features, and audience engagement tools;
- **UC4: Distributed immersive production network** validates interoperability, scalability, orchestration, and KPIs for immersive media across multiple sites.

Together, these use cases span entertainment, cultural heritage, education, and broadcasting applications.

ENVISIONED RESULTS AND IMPACT

6G-HOLONET will establish a blueprint for distributed immersive media production by integrating advanced networking, AI, and XR. It will deliver a reusable volumetric streaming platform and scalable models for cross-border immersive experiences.

The project will generate impact across three dimensions: technological, through advanced 6G capabilities such as ultra-low latency and AI-driven orchestration; economic, through new business models for media and entertainment; and societal, through more accessible and inclusive immersive experiences.

6G networks are required because 5G systems cannot support large-scale, real-time volumetric production that demands sub-millisecond latency, high uplink capacity, and tightly synchronised multi-site communication.

6G HOLO NET

Coordinated by Alex Buchan, Digital TV Group

September 2026 – August 2029

Website: 6g-holonet.co.uk
6g-holonet.eu
6g-holonet.com

Verticals: Media and entertainment

Partners: Digital TV Group, Digital Catapult, National Technical University of Athens, University of Bristol, Nephelie Technologies, Accelleran, Netherlands Organisation for Applied Scientific Research, TWIST, Sound, LiveU, ICOM Belgium Wallonia-Brussels, Effenaar, European Fashion Heritage Association, Technical University of Crete, Greek National Opera.

GENIUS

Advancing 6G-enabled multimodal Logistics through real-world Experimentation

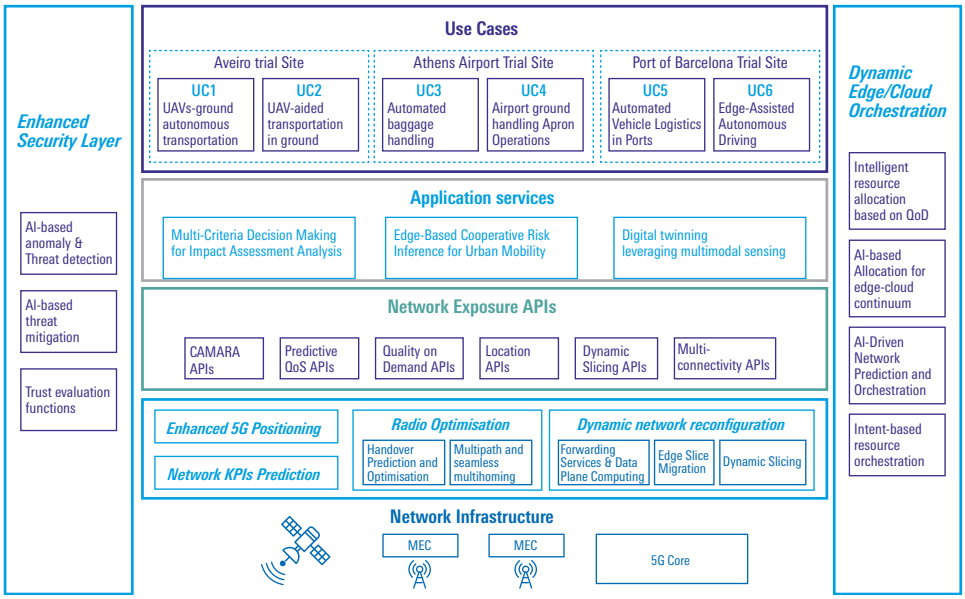
OVERVIEW

Integrating logistics, multimodal transport and automation into the 6G ecosystem will significantly improve the efficiency, sustainability, and resilience of supply chains. Ultra-reliable, low-latency communications will enable seamless coordination and real-time monitoring of goods across transport modes, while 6G-enabled digital twins and AI-driven optimisation will support dynamic routing, disruption management, and reduced operational costs and carbon emissions. In addition, massive machine-type communication will enable dense IoT sensor networks for predictive maintenance, real-time safety monitoring, and autonomous operations, strengthening Europe's competitiveness and strategic autonomy in logistics.

This project will establish real-world, business-driven testbeds across cities, ports, airports, and logistics hubs. Bringing together transport operators, municipalities, ICT providers, and research organisations, these platforms will validate high-impact 6G use cases for automated transport and logistics while generating evidence and requirements to support the evolution of future 6G standards.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The open, modular, and extensible reference architecture proposed by GENIUS is built on a set of technology enablers. It is organised into distinct horizontal and vertical layers.



ENVISIONED INNOVATIONS

The **Use Cases Layer** hosts the six automated logistics use cases. The **Application Services Layer** provides modular, intelligent enablers for advanced logistics and mobility applications, while the **Network Exposure APIs Layer** offers secure, standardised, interfaces to programmable network capabilities. The **Dynamic Edge/ Cloud Orchestration Layer** coordinates services and resources across the edge–cloud continuum and the **Dynamic Network Reconfiguration Layer** adapts network behaviour in real-time to meet ultra-reliable, low-latency requirements. The **Radio Optimisation Layer** enhances mobility and connectivity through AI- and software-defined networking (SDN)-based techniques, including proactive handover prediction. The **Network KPIs Prediction Layer** forecasts quality of service (QoS) metrics to enable proactive network management. The **Enhanced 5G Positioning Layer** delivers high-precision location services and the **Enhanced Security layer** provides adaptive, end-to-end protection through integrated detection, enforcement, and trust management.

ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

Use cases will span road, ground, air and maritime transport, including **Unmanned Aerial Vehicles (UAVs)-assisted transport of medical samples, UAV-supported ground logistics, automated airport baggage handling, smart apron ground-handling operations, automated vehicle logistics at the Port of Barcelona and edge-assisted autonomous driving within the port of Barcelona terminals.**

ENVISIONED RESULTS AND IMPACT

GENIUS strengthens European technological sovereignty and global leadership by focusing on key architectural and ecosystem-building components. It develops a modular scalable 6G architecture for 6G tailored to logistics and transportation use cases, providing a foundational building block for future EU-based innovations. Designed for scalability and interoperability, this architecture enables seamless integration across public and non-public network infrastructures and will be validated through project trials.

To reinforce Europe's leadership, GENIUS advances AI-driven capabilities, including QoS prediction, dynamic resource orchestration, and location- and mobility-aware service placement, supporting full network automation. In addition, the project releases an open-source toolset and organises community onboarding activities to ensure broad reuse of its results. This approach enables SMEs, academia, and other projects to build on its innovations, strengthening the European supply chain and fostering economic growth.

6G connEcted eNvironments for logIstics and mUltimodal tranSportation

GENIUS

Coordinated by Susana Sargento, Instituto de Telecomunicacoes

July 2026 – June 2029

Website: https://sns-genius.eu

Youtube: www.youtube.com/@GENIUS_EUP

X: https://x.com/GENIUS_EUP

LinkedIn: https://www.linkedin.com/company/genius-euproject/

Verticals: Automotive, smart cities, Transport and logistics

Partners: Instituto Telecomunicações, CapGemini Engineering, Altice Labs, Beyond Vision, I2Cat, Barcelona (BCN) Port Innovation, Seevia, Orange Spain, WINGS-ICT, Athens International Airport, Goldair Handling, IMEC, eBOS, SRS, Aveiro municipality.

PRIME-6G

Sensing, AI and deterministic 6G for the smart factory

OVERVIEW

PRIME-6G is an initiative coordinated by the Universidad Carlos III de Madrid that develops key 6G technologies for advanced manufacturing. It targets "batch-size-one" production, where highly flexible factories must autonomously reconfigure in real-time. PRIME-6G will design and validate a cloud-edge continuum platform enabling efficient service provisioning in smart factories.

CONCEPT/ ARCHITECTURE/ TECHNOLOGIES

The PRIME-6G architecture is designed around a smart factory environment where fixed and mobile robots perform manufacturing tasks using heterogeneous connectivity, combining 5G non-public networks and Wi-Fi access points in both sub-6GHz and mmWave bands.

- **Edge-Cloud Continuum**: The factory floor is connected to a hierarchy of computing resources, from extreme-edge nodes to core cloud platforms, enabling virtualised robotic control (vRC) to migrate dynamically across the network according to service requirements.
- **Deterministic Networking**: To ensure reliable operation of critical automation processes, the project integrates time-sensitive networking (TSN) and deterministic networking (DetNet) across wired and wireless domains.
- **Integrated Sensing and Communications (ISAC)**: PRIME-6G leverages existing wireless infrastructure as a "sensing platform" to detect motion and environmental structures without relying solely on cameras, providing a holistic view of the plant floor.

ENVISIONED INNOVATIONS

The project focuses on four primary innovation areas, aimed at advancing technologies from technology readiness level (TRL) 4 to TRL 7:

- **AI-driven Network & Compute Optimisation**: Introducing a multi-agent AI-native framework for decentralised, autonomous decision-making and an attention-enhanced graph neural network digital twin to optimise robot control placement;
- **E2E Deterministic Connectivity**: Development of a DetNet-based multi-domain data plane using extended Berkeley packet filter/ eXpress data path (eBPF/XDP) to ensure consistent latency and reliability across hybrid networks;
- **Multi-modal Sensor Fusion with ISAC**: Creating dynamic, operational digital twins by fusing radio frequency-based sensing with light detection and ranging (LiDAR), cameras, and robot telemetry to improve situational awareness in dusty or low-light conditions;
- **Cobotic Control Placement**: Delivering an intent-based orchestration framework for the telco edge cloud, enabling virtualised robotic control placement decisions in less than 200 ms.

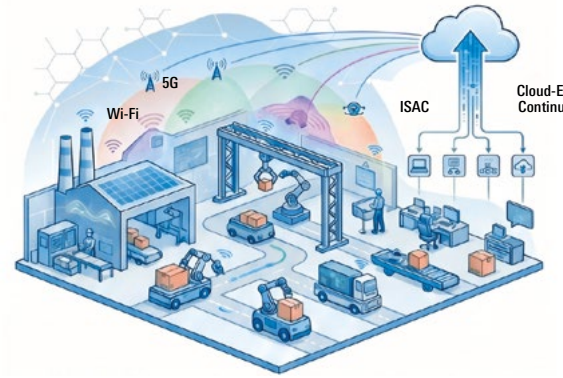
ENVISIONED USE CASES/ TRIALS/ APPLICATIONS

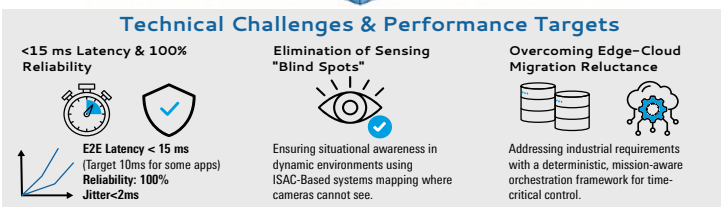
The project validates its innovations through two complementary use cases that culminate in a unified final trial:

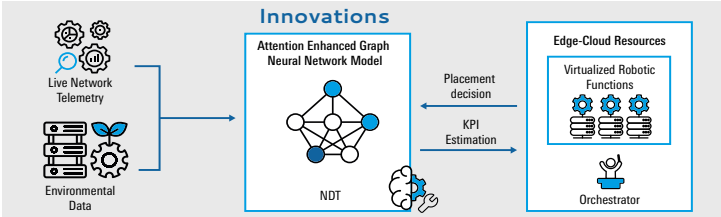
- **AURORA (Advanced Unified Robotics Operations)**: Focuses on cooperative carrying where multiple robots coordinate through sidelink to transport oversized objects. It explores decentralised fleet management and virtualised control placement;
- **SENTINEL (Sensing-Enhanced Network Twin)**: Focuses on real-time digital twin creation to enable safer human-robot coexistence by detecting "blind spots" beyond the reach of traditional sensors;
- **ARENA2036 Final Trial**: An integrated TRL 7 pilot will be conducted at the ARENA2036 facility in Stuttgart, demonstrating "Real-time Contextual Awareness for Self-Organising Logistics" in a real-world manufacturing environment.

ENVISIONED RESULTS AND IMPACT

PRIME-6G aims to deliver a mature, close-to-market solution with the following expected impacts: technical excellence through the validation of stringent KPIs, including latencies below 15 ms, jitter below 2 ms, and 100% reliability for industrial automation; economic viability through a projected 35% reduction in capital expenditures for plants using virtualised control compared to traditional hardware-heavy deployments, as well as a 20% improvement in IT infrastructure usage efficiency; sustainability and safety through optimised resource allocation and enhanced worker protection through pervasive, visionless sensing; and standardisation through concrete contributions to 3GPP Rel. 20/21, IEEE, and O-RAN to harmonise 6G industrial requirements.







Pilot for Resilient Industrial Manufacturing Environments

PRIME-6G

Coordinated by Carlos J. Bernardos (UC3M)

June 2026 – November 2028

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LinkedIn: www.linkedin.com/company/prime-6g/

Verticals: Industry

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Appendices

Steering and Technology Boards, SNS JU Working Groups

The SNS Initiative Steering Board (SB) and Technology Board (TB) act as the main governance bodies for coordination of activities between projects and drive project alignment on roadmap and technological levels.

STEERING BOARD	TECHNOLOGY BOARD
Mikael Fallgren, Ericsson **Anastasius Gavras, Eurescom**	**Kostas Trichias, 6G-IA**

SNS JU Working Groups (SNS JU WGs) are cross-project collaborations where the activities of multiple SNS JU projects are discussed by the representative project participants to converge and create positive synergies. The results of these discussions are published regularly as white papers.

WORKING GROUPS	CHAIR CO-CHAIR
6G Architecture	Ömer Bulakci, Nokia Xi Li, NEC Lab
Reliable Software Networks	Luis Contreras, Telefonica ID Dimitris Tsolkas, Fogus Innovations and Services
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Hardware Technologies	Luis Manuel Pessoa, INESC TEC Alexios Birbas, University of Patras
Sustainability	Christoph Schmelz, Nokia

Acronyms and abbreviations

3D	Three-dimensional
5G/6G	5th/6th generation Wireless Systems
5GS	5G system
6G-IA	6G Smart Networks and Services Industry Association
ABS	Anti-lock braking system
ADAS	Advanced driver-assisted systems
AI/ AI4Edge/ AI-AI/ AIML	Artificial intelligence/AI for edge/AI-native Air interface/artificial intelligence/ machine learning
AP	Access point
API	Application programming interface
AR	Augmented reality
ASIC	Application-specific integrated circuit
B5G	Beyond 5G
BiCMOS	Bipolar complementary metal-oxide semi-conductor
B-RAN	Blockchain RAN
BS	Base station
CapEx	Capital expenditure
CoMP	Coordinated multipoint
CSAs	Coordination and Support Actions
CORENect	European Core Technologies for future connectivity systems and components
CPS	Cyber physical systems
CPU	Central processing unit
CSI	Channel state information
CU	Centralised unit
D2D	Device-to-device
DaaS	Desktop as-a-service
dDAC	Optical digital to analog convertor
DDoS	Distributed denial of service
DIDs	Decentralised identifiers
DIH	Digital innovation hub
DIMO	Distributed Intent-driven management and orchestration
DLT	Distributed ledger technology
DPD	Digital predistortion
DPU	Data processing unit
DSA	Decarbonisation service agreement
DSP	Digital signal processing
DU	Distributed unit
E2E	End-to-end
EAS	Edge application service
Edge4AI	Edge for AI
eFBB	Enhanced fibre broadband
eMBB	Enhanced mobile broadband
eWLB	Embedded wafer level ball grid array
EMF	Electromagnetic fields
ETSI	European Telecommunications Standards Institute
EU	European Union
FFBC	Full fibre broadband connection
FFC	Full fibre connection
FFGRB	Full fibre guaranteed reliable broadband
FGPA	Field programmable gate arrays
FHE	Fully komomorphic encryption
FL	Federated learning
FPGA	Field programmable gate array
GEO/ NGSO/ LEO	geostationary earth orbit/ non-geostationary earth orbit/Low earth orbit
GHG	Greenhouse gas
GHz	Gigahertz
gNB	next generation node B
GNSS	Global navigation satellite system
GPU	Graphics processing unit
GRE	Guaranteed reliable experience
GRFB	Guaranteed reliable fibre broadband
GRFFE	Guaranteed reliable full fibre Experience
HAP(S)	High altitude platform (Station)
HPC	High performance computing
ICAS/ JCAS	Integrated communication and sensing / Joint communication and sensing
ICT	Information and communication technology
IIoT	Industrial internet of things
IoT	Internet of things
ITU/ITU-R	International Telecommunication Union/ ITU Radiocommunication sector
J	Joules
KPI/KV/ KVI	Key performance indicator/ Key value/key value indicator
M&O	Management & orchestration
M2MP	Point-to-multipoint
MAC	Medium access control
MANO	Management and orchestration
MAS	Managed access system
MB	Multi band
MBoSDM	Multi band over space division multiplexing
MEC	Multi-access edge computing
MIMO	Multiple-input multiple-output
mMIMO / MU-MIMO	Massive MIMO / Multi-user MIMO
mMTC	massive machine-type communication
mmWave	Millimetre wave
MP/TCP	Transmission control protocol
MPQUIC	Quick UDP internet connections
ms	Millisecond
NBI	Northbound interface
NWDAF	Network data analytics functions
NF	Network function
NGSO	Non-geostationary
NIC	Interface card
NOS	Network operating system
NTN	Non-terrestrial networks
O/E/O	Optical to electrical to optical
OFTS	Orthogonal time frequency space
OMC	Orchestration, management and control
ON	Optical node
Open RAN	Open radio access network
OpEx	Operating expense
OXC	Optical cross connect
P2MP	Point-to-multiPoint
P2P	point-to-point
PA	Power amplifyer
PHY	Physical layer
PIC	Photonic integrated circuit
PMF	Plastic microwave fibre / polarisaton maintaining fibre
PoC	Proof-of-concept
PON	Passive optical networks
PoT	Proof of transit
PQC	Post-quantum cartography

QKD	Quantum key distribution
QO	Quasi-optical
QoE	Quality of experience
R&D	Research and development
R&I	Research and innovation
RAN	Radio access network
rApps	Robotic applications
Rel.	Release
RF	Radio frequency
RIS	Reconfigurable intelligent surfaces
RRM	Radio resource management
RSU	Radio-side unit
RT RIC	Real-time RAN intelligent controller
RTO	Radio transmission operator
RU / O-RU / C-U	Radio unit / open radio unit / centralised unit
SatCom	Satellite communication
SB	Steering board
SBA	Service-based architecture
S-BVTs	sliceable bandwidth variable transceiver
SCoDIHNet	Smart connectivity digital innovation hub network
SDM	Space division multiplexing
SDN	Software defined network
SDO	Standard development organisation
SME	Small and medium-sized enterprise
SMPC	Secure multi-party computation
SNS/ SNS JU	Smart Networks and Services/SNS Joint Undertaking
SPT4AI	Secure, private and trustworthy AI
SRS	Soud reference signal
TB	Technology board
TEE	Trusted execution environment
THz	Terahertz
TN/NTN	Terrestrial network/ non-terrestrial network
TRL	Technology readiness level
UAV	Unmanned aerial vehicle
UC	Use case
UI	User Interface
UN	United Nations
UP	User plane
UPF	User plane function
URLLC	Low-latency communications
V2V	Vehicle-to-vehicle
VC	verifiable credentials
VIM	Virtual infrastructure manager
VNF/NF	Virtual network function/ network function
VR	Virtual reality
vRAN	Virtualised RAN
WBSS / WSS	Wave band selective switch / Wavelength switch
xAI	Explainable artificial intelligence
xApps	Cross applications
XR	Extended reality
ZKP	Zero knowledge proof
ZSM	Zero-touch network and service management

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