2025

Open Calls – Results

6G-XR Project

SUMMARY OF EXPERIMENTS AND IMPLEMENTATIONS

Results Achieved by 3rd Parties involved in 6G SNS Projects through the mechanism of Cascading Funding – Open Calls

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6G-XR PROJECT

6G eXperimental research infRastructure to enable next-generation XR services

OVERVIEW

6G-XR project "6G eXperimental Research infrastructure to enable next-generation XR services" is a Horizon Europe-funded initiative under the umbrella of the Smart Networks & Services Joint Undertaking (SNS JU). Its core ambition is to strengthen European leadership in 6G technologies by enabling the next generation of immersive XR (Extended Reality) services — including virtual reality, augmented reality and mixed-reality — by building an experimental, multi-site research infrastructure (RI) that supports "beyond 5G" and future 6G use-cases.

More specifically, 6G-XR aims to develop enablers for networking and computing, radio access technologies beyond 5G, XR service enablers (including federation, trial-management, abstraction tools), and an energy-measurement framework supporting sustainable operation of immersive services. It will validate multi-access edge computing (MEC) scenarios, their integration into a cloud-continuum, and immersive, demanding applications such as real-time holography and digital twins.

Use-Cases and Research Infrastructures

6G-XR project has identified three different application areas that would benefit from the large-scale deployment of B5G/6G networks:

- Real-Time Holographic Communications
- Collaborative 3D Digital Twin-like Environment
- Energy Measurement Framework for Energy Sustainability

around which five internal Use Cases have been developed: UC1, UC2, UC3 under Real-Time Holographic Communications, UC4 under Collaborative 3D Digital Twin-like Environment and UC5 under Energy Measurement Framework for Energy Sustainability.

The infrastructures are divided between the North and South Node. Within the South Node, the following Use Cases have been internally developed, leveraging the advanced network capabilities of the infrastructures of 5TONIC (Madrid) and i2CAT (Barcelona) testbeds.

Real-Time Holographic Communications

Three of the internal 6G-XR Use Cases (UC) revolve around real time holographic communications, by incorporating novel XR, network and cloud continuum enablers to enhance their performance and interoperability.

- UC1: Resolution Adaptation or Quality on Demand - Detect network congestion or Quality of Service (QoS) dropped to trigger network-assisted Rate Adaption recommendation or request Quality on Demand (QoD)
- UC2: Routing to the Best Edge - Discover, select and make use of the most appropriate Edge resources to run XR processing or communication functions, based on specific criteria and goals
- UC3: Control Plane Optimizations - Integrate holographic communications to the network control plane

Under the North node other internal Use Cases have been developed leveraging the advanced capabilities of the VTT 5GTN, UOULU 5GTN testbeds located in Oulu (Finland).

Collaborative 3D Digital Twin-like Environment

Infrastructure: UOULU 5GTN

Remote collaboration enhances societal and team productivity/efficiency. Real collaboration around of a common asset, machine, manufacturing place or environment is enabled thanks to a collaborative 3D DT environment. Key outcome is extracted due to the capabilities of bridge regional disparities and provide equal opportunities regardless of the geographical location. Traditional example of gaps covered is the disparity between industrial and rural locations.

- UC4: Collaborative 3D Digital Twin-like Environment - Enable real-time collaboration and control of physical assets in virtual reality

Energy Measurement Framework for Energy Sustainability

- UC5: Energy Measurement Framework for Energy Sustainability - Measure and optimise end-to-end energy consumption in mobile networks

Infrastructures: VTT 5GTN, UOULU 5GTN

The 6G-XR project aims to deploy an extensive energy measurement framework for the test sites as well as to introduce the required intelligence and functionality into the network components so that the energy consumption data can be utilized to optimize the end-to-end energy consumption and use of local renewable energy for variety of different XR related applications.

Open Calls: Rationale and Structure

To achieve its objectives and to open up the infrastructure to broader innovation, 6G-XR implements a series of three cascading Open Calls (OCs) to attract third-party innovators (SMEs, industry, research organisations). The reason for these OCs is threefold:

- To enable external teams to leverage the RI and enablers developed by 6G-XR, thereby extending the impact of the project beyond the core consortium.
- To validate and trial novel XR services, components and architectures in realistic research/testbed environments aligned with the 6G era.
- To foster vertical replicability, i.e., uptake by industry verticals, cross-sector innovation and faster deployment of immersive XR services.

Three Open Calls Key information

- **6G-XR-OC1: Platform & Network Enablers**: Focused on providing access to the core RI, network and platform enablers developed by the project.
- **6G-XR-OC2: Stream B Enablers**: Builds on OC1, offering further access and support for enabler development under the Stream B Enablers thematises.
- **6G-XR-OC3: Vertical Replicability Enablers**: Targeted at innovators who want to deploy, replicate and validate XR use-cases in verticals (e.g., industry, media, mobility) using the 6G-XR infrastructure. Access to advanced testbeds and enablers, with focus on real-world demonstrators.

The budget allocated for this cascading funding is approximately €1.8 million, and around 30 proposals are projected to be selected over the 2023–2025 timeframe.

Open Call	Project duration	Max funding (€)	No of projects	Total funding (€)
6G-XR-OC1	6 months	60.000	8	480.000 €
6G-XR-OC2	6 months	60.000	10	600.000 €
6G-XR-OC3	6 months	60.000	12	720.000 €

6G-XR Intended Impacts of the Open Calls

Through these open calls the project intends to:

- Stimulate innovative XR-services and applications using next-generation connectivity and compute infrastructure.
- Provide third-party actors with access to high-end research/testbed infrastructure which would be otherwise difficult to access, lowering the barrier to experimentation and validation.
- Foster a broad ecosystem of XR service providers, network enabler developers, vertical domain actors and research institutions in Europe, thereby strengthening European competitiveness in 6G/XR.
- Enable the integration of vertical use-cases (industry manufacturing, media, mobility, digital twin domains) to test and validate 6G-XR enablers and infrastructure in real-life-relevant settings.
- Collect valuable data and feedback around key performance indicators (KPIs) and key value indicators (KVIs) for XR-services over 6G-capable networks (e.g., latency, throughput, energy consumption, reliability) which will feed into standardisation and future network deployments.
- Promote energy-efficient deployment and operation of immersive XR services, aligning with sustainability goals within the 6G framework (via the Energy Measurement Framework use-case).

PRESENTATION OF OPEN CALLS PROJECTS

6G-SLICE

OC Project Title	6G-SLICE: Enabling end-to-end O-RAN slicing in 6G-XR
Beneficiary(s)/Country	Allbesmart LDA, Portugal
Project Description	A network slice is a logical network comprising a set of network functions supporting the communication services for a particular use case deployed on a common physical infrastructure. In this context, the main objective of this experiment is to implement and validate end-to-end network slicing configurations for 6G-XR scenarios, leveraging the O-RAN architecture. This will be achieved by enhancing the Oulu University open-source OpenAirInterface (OAI) testbed.
Vertical	Networking and computing enablers
Testbed	UOulu 5GTN
Results & Impact	**Results:** The OAI-based 5G lab platform at the University of Oulu was enhanced to fully comply with the O-RAN architecture, integrating a Near-RT RIC and developing xApps for near-real-time monitoring and slice configuration to ensure SLA compliance. A web-based dashboard was created to simplify RAN slicing management, offering predefined configurations and intuitive control for 6G-XR experimenters. Validation was achieved through a joint demonstration with Allbesmart, Kaiotek, and Finwe at EuCNC & 6G Summit 2024, showcasing a "Co-creative Cyber Studio" use case. This demo connected remote VR/AR participants in a digital twin environment over a sliced 5G O-RAN network, demonstrating RAN sharing between VR and IoT applications. The slice management xApp dynamically controlled MAC scheduling and SLA enforcement, enabling differentiated throughput for eMBB and URLLC slices and validating real-time resource orchestration in multi-slice scenarios. **Impact:** The 6G-XR OC1 project accelerated the development of Allbesmart's OAIBOX product line, resulting in a new OAIBOX O-RAN test solution featuring automated RAN slicing. The project outcomes matured the technology to commercial readiness, enabling proof-of-concept trials with partners and new customers. For exploitation, Allbesmart will leverage its global distributor network to promote advanced O-RAN capabilities integrated into its OAIBOX 5G solution. Its strategic partnership with NI (National Instruments) further extends its reach in the test and measurement market, strengthening Europe's position in beyond-5G network innovation and accelerating the adoption of intelligent, programmable O-RAN systems worldwide.

BANQ

OC Project Title	BANQ: Bringing Automated Network QoS Monitoring Capabilities for Research Infrastructures
Beneficiary(s)/Country	Kaitotek / Finland
Project Description	The project focuses on automating network quality measurements with a passive, real-time Quality of Service (QoS) solution. This enhances network quality, situational awareness, and security. Real-time measurement and monitoring allow for immediate resolution of performance issues, improving user experience and providing valuable data for researchers. Data analysis further enables proactive traffic monitoring, anomaly detection, and real-time threat identification.
Vertical	Networking and Computing Enablers, Sustainability Enablers
Testbed	OULU 5GTN & VTT 5GTN
Implementation timeframe	February – July 2024
Results & Impact	The BANQ project successfully implemented and validated four key experimental developments within the 6G-XR framework: - Automated QoS Monitoring: A new experimental feature was developed to enable fully automated QoS measurements controlled centrally through the Qosium Storage REST API. This significantly enhances the measurement capabilities of the North Node research infrastructure. During implementation, an additional unplanned improvement was made to GTP decapsulation, further refining network monitoring performance. - Centralized Flow Monitoring: Qosium's flow monitoring capabilities were extended to allow tracking of multiple simultaneous measurement flows, providing a strong foundation for advanced cybersecurity monitoring. This represents an important step toward integrating performance and security insights in real time. - Alerting and Reporting Engine: A completely new alerting engine was introduced, capable of real-time visualization and flexible extensions for both QoS and flow-based alerts. This feature lays the groundwork for future ticket-based or automated event systems, improving responsiveness to performance and security anomalies. - Enhanced Historical Analysis and Reporting: A new reporting view in Qosium Storage now enables automatic generation of high-level performance summaries, replacing the previous single heatmap visualization. This provides more accessible and actionable insights for research and industrial use. Extensive unit and integration testing was carried out both at Kaitotek's facilities and in the University of Oulu research infrastructure, validating the new capabilities in realistic 5G-Advanced and XR environments. While full system integration with the North Node will continue post-project, all implemented components are operational and ready for deployment. Finally, the BANQ experiment contributed to a joint 6G-XR demonstration at EuCNC 2024, showcasing multiple open call projects in an integrated setup. The demo received highly positive feedback and was the basis for a joint research publication submitted to IEEE GLOBECOM 2024.

ExCalibAR

OC Project Title	ExCalibAR : User-friendly intrinsic and extrinsic calibration for multilight-field-cameras for Augmented, Virtual, and Extended Reality
Beneficiary(s)/Country	Karlsruhe University of Applied Sciences / Germany
Project Description	The ExCalibAR project implements a comprehensive, easy-to-use pipeline for intrinsic and extrinsic calibration of setups with multiple light field cameras by utilizing Structure from Motion (SfM). The proposed method allows non-expert users to get reliable and swift calibrations by following an easy-to-understand process without requiring precise calibration targets. In contrast, calibrating light field cameras and other multi-camera setups following state-ofthe-art methods can be daunting for laypeople as it relies on multiple steps with many pitfalls and requires accurate calibration targets for which the exact geometry must be known.
Vertical	XR Enablers, RAN Enablers
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	February – July 2024
Results & Impact	**Results:** The ExCalibAR project successfully developed and validated a self-calibration pipeline for light field cameras that operates without the need for calibration targets. Extensive experiments were performed using multiple camera setups with focal lengths of 12.5 mm, 16 mm, and 35 mm, and results were compared to a state-of-the-art reference calibration method. The deviation between ExCalibAR and the reference results was below 1% for nearly all parameters, confirming both high accuracy and reproducibility. A second validation used arbitrary light field camera sequences from a public dataset (Zeller et al., 2018), achieving accurate intrinsic calibration even without any structured calibration scene. This demonstrates that ExCalibAR performs robustly in real-world, unstructured environments. At project completion, the full ExCalibAR pipeline is operational and ready for extrinsic calibration once the 6G-XR volumetric setup becomes available. Final calibration results will be shared via the open-source GitHub repository based on 6G-XR Capturer data. **Impact:** ExCalibAR directly supports the 6G-XR objective of Advancing Heterogeneous XR Capture Systems, providing a user-friendly, open-source self-calibration pipeline for multi-camera light field systems. The software will be released under the GNU GPLv3 license for public access and reuse by all project partners. To maximize reusability, the system was designed for easy adaptation to different sensor types, including RGB-D and stereo camera setups, by modifying only the camera model and optimization metric. The project has already attracted interest from 6G-XR partners seeking to apply the pipeline to new sensor modalities, reinforcing its potential to become a standard tool for multi-sensor XR calibration within future 6G research and development efforts.

FALADIN

OC Project Title	FALADIN: FAb LAb DIgital TwiN
Beneficiary(s)/Country	FINWE / Finland
Project Description	FALADIN project innovated in the field of co-creation process by developing a digital twin platform for FabLabs. The result is an online web service that facilitates seamless collaboration between users and FabLab operators, streamlining 3D model review and 3D printing process.
Vertical	XR Enablers
Testbed	UOulu 5GTN
Implementation timeframe	February – July 2024
Results & Impact	**Results:** To ensure inclusivity and accessibility, the developed solution was built entirely on open and freely available technologies. The core web platform — supporting user authentication, model uploads, review scheduling, and textual discussions — was implemented using Node.js and SQLite for the backend and React.js for the frontend. For the XR component, WebXR and the open-source Babylon.js framework were adopted instead of Unity to avoid licensing costs, support all major XR headsets from a single codebase, and eliminate app store delays. Real-time communication features, including voice, low-latency video streaming, screen sharing, and synchronized multi-user interactions via avatars and shared objects, were implemented using the OpenVidu system based on WebRTC protocols. A 3D printer was integrated through OctoPrint running on a Raspberry Pi, enabling seamless physical prototyping.Testing was conducted with Meta Quest 2, Meta Quest 3, and Apple Vision Pro headsets. The solution was integrated with two other 6G-XR projects, where the user (on Apple Vision Pro) and the FabLab operator (on Meta Quest 3) were connected through sliced 5G links in the 5GTN test network. For final validation, the integrated three-project setup was demonstrated at the EuCNC & 6G Summit 2024 in Antwerp, Belgium. **Impact:** The project successfully met and exceeded its objectives, demonstrating a cutting-edge multi-user digital twin environment that combines XR headsets, avatars, and hand-tracking for intuitive real-time collaboration and object manipulation. This use case serves as an ideal testbed for advanced mobile networks, given its stringent low-latency and high-bandwidth requirements driven by synchronized 3D interactions and multiple high-quality audio/video streams. A major milestone was the successful integration with two other 6G-XR projects and the live demonstration at EuCNC & 6G Summit 2024, just four months after project kick-off. The public showcase highlighted the potential of XR-enabled collaboration over sliced 5G networks and was met with strong positive feedback from visitors and industry stakeholders. The digital twin concept has since been presented to local FabLabs, generating significant interest for its applications in 3D printing education and operator training. By enabling safe, immersive, and cost-effective learning environments, the solution supports both industrial and educational adoption.

METAPHOR

OC Project Title	METAPHOR
Benefiaciary(s)/Country	Brainstorm Multimedia / Spain
Project Description	METAPHOR allows to seamlessly extend the eXtended Reality (XR) enablers from 6G-XR by integrating its resulting holographic communication platforms with InfinitySet, Brainstorm's main virtual production engine. This integration allows InfinitySet to determine optimal viewpoints and settings from a volumetric rendered scene by 6G-XR components (e.g., including multiple remote 3D holograms and other content sources) to be interfaced with an interactive virtual scenario to provide new interactive and compelling experiences to large audiences. The resulting integration enables hyper-realistic real-time dialogues between remotely captured 3D participants and presenters from broadcast settings, seamlessly integrated within shared virtual environments in an adaptive, affordable and scalable manner.
Vertical	RAN enablers
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	February – July 2024
Results & Impact	**Results:** The METAPHOR project successfully demonstrated the integration of remote participants into live broadcast environments using the HoloMIT platform, in collaboration with i2CAT and Brainstorm. The validation took place in a real broadcast production setup, showcasing three modes of actor integration within a virtual scene. Local Actor with Chroma Key – An actor captured via iPad against a green background was composited in real time using Brainstorm's InfinitySet, with a live preview monitor providing immediate visual feedback. Remote Volumetric Actor – A second actor joined through the HoloMIT client using RGB-D or light-field cameras enabling high-quality audio-visual interaction.Lightweight 2D Avatar Setup – A third participant used only a standard webcam, represented by a 2D head and simple avatar body, demonstrating accessibility without advanced hardware. The system architecture combined Unity and InfinitySet via NDI, ensuring seamless synchronization between virtual elements. InfinitySet managed camera tracking and scene composition, while Unity rendered specific scene components, such as interactive objects. The final demonstration achieved high-quality and low-latency for multiple participants (local, remote, and lightweight) within a single interactive virtual production environment, validating the METAPHOR concept. **Impact:** METAPHOR offers unprecedented benefits across a wide range of sectors, including education, entertainment, and broadcasting. By leveraging SoA interactive and immersive XR technologies, combined with advanced distributed 6G research infrastructures, METAPHOR enables new forms of real-time collaboration, creative production, and experiential learning. This integration also paves the way for scalable, network-aware XR applications that can transform both industrial workflows and end-user experiences**.**

MST

OC Project Title	MST: Magos Surgical Training
Beneficiary(s)/Country	Quanta & Qualia - Greece
Project Description	MST demonstrate the development of a VR collaborative medical training application based on the Magos Platform. It enables 2 surgical trainees in the healthcare industry to remotely interact using their fingers in near real-time, thanks to 6G technology. So, it provides a lifelike experience, enabling users to interact with their virtual environment as if it were the real world. This realism in finger interaction is crucial for developing the dexterity required for complex surgical tasks.
Vertical	Networking and Computing, Enablers XR Enablers
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	February – July 2024
Results & Impact	**Results:** The MST project developed and validated a multiplayer VR medical training application enhanced by Magos haptic gloves, enabling realistic, collaborative surgical simulations. The system follows a peer-to-peer (P2P) Unity Netcode architecture that ensures low-latency, synchronized interactions. The Magos Player Netcode streams real-time data from hand and head tracking, allowing multiple users to train simultaneously with high accuracy and realism. The application streams detailed finger-joint and headset data, maintaining smooth, synchronized animations across participants. Key challenges—mainly in multiplayer synchronization, data streaming, and firewall restrictions—were resolved through optimized Unity network configurations and connectivity tuning. A total of ten Magos glove sets were produced. Overall, MST delivered a validated, networked VR training prototype combining haptics, realism, and multi-user interaction, providing a strong foundation for future 6G-XR healthcare applications. **Impact**: The MST project addresses a major global health crisis, the lack of access to affordable surgical care, affecting nearly 5 billion people. The MST project accelerates the transition toward medical Virtual Reality (VR) training, offering an innovative hardware and software platform that enables hyper-realistic, collaborative surgical practice through natural hand and finger interactions using Magos haptic gloves. By digitizing touch sensation, MST enables certifiable, cost-effective, and portable surgical training, reducing reliance on expensive simulators and real operating rooms. The platform enhances time efficiency, accessibility, and training repeatability, while providing data-driven performance assessment. These capabilities improve medical skill acquisition, reduce setup time, and democratize access to high-quality training worldwide. Socially, MST promotes equal training opportunities and directly contributes to two EU priorities: protecting citizens and freedom and strengthening Europe's leadership in VR and XR technologies. Within 6G-XR, MST contributes by delivering six sets of Magos gloves to i2CAT for testing, deploying a high-demand VR surgical application, and enabling research into network optimization, physics, and holographic rendering.

OpenCAMARA

OC Project Title	OpenCAMARA: Open source solution to integrate CAMARA QoD API to 5G stack
Beneficiary(s)/Country	Neutroon Technologies / Spain
Project Description	In the concept of Open Gateway, OpenCAMARA implemented CAMARA Quality on Demand (QoD) APIs over Open5GS as the 5G core. AMBR, priority tagging, 5QI and slicing are 4 means to prioritize data flows, hence offering different levels of QoS. Dealing with different features for dedicating necessary network resources to obtain desired KPI is not easy for non-expert persons. This project aims to facilitate this process by employing CAMARA QoD API as a standard way to enforce desired QoS configuration to the 5G stack elements.
Vertical	Networking and Computing Enablers, XR Enablers, RAN Enablers
Testbed	I2CAT (formerly 5GBarcelona)
Implementation timeframe	February – July 2024
Results & Impact	**Results:** The OpenCAMARA project provided two series of validation and technical results. • Validation and performance results while applying Camara QoD APIs. It is worth mentioning that even though we have proposed in the proposal to validate the OpenCAMARA with Amarisoft as 5G RAN, we decided during the project to expand the experience by validating the OpenCAMARA with Node-H as well. • Technical and comparison results of the performance when employing external UPF for Open5GS. Testing was initially carried out in Neutroon's Lab using the Nomad5G testbed, then deployed at 5GBarcelona (i2cat) for final validation.Key outcomes included:Successful AMBR and 5QI enforcement, confirming OpenCAMARA's ability to dynamically control UE throughput and prioritize traffic according to QoS profiles.Verification that Amarisoft effectively handled AMBR-based QoS, while Node-H enabled full 5QI-based prioritization, demonstrating flexibility across RAN vendors.Validation of OpenCAMARA with multiple UPFs (Embedded Open5GS, external Open5GS, eUPF, and UPF-VPP). Results showed that UPF-VPP achieved the lowest RTT and highest downlink throughput, while Open5GS UPFs performed best in uplink communications. **Impact:** OpenCAMARA implementation has been deployed at the 5GBarcelona testbed in i2CAT site, which is part of the 6G-XR south node, and will become available to experimenters applying to future 6G-XR open calls. It will be up to the 6GXR consortium and the trial site owner to study whether to open source the developed CAMARA implementation, which can benefit the research community at large because Open5GS is a very commonly used tool in research environments. With OpenCAMARA, use cases running in the 6G-XR trial site can dynamically adjust their network resource requirement. This results in saving time and resources toward a sustainable network.

REQUIEM

OC Project Title	REQUIEM: Research on QUIC client mobility
Beneficiary(s)/Country	HUN-REN Tamogatott Kutatocsoportok Irodaja- Hungary
Project Description	In this project, REQUIEM designed and implemented QUIC-based real-time media transmission suitable for the 6G-XR Remote Renderer. Standardized QUIC can migrate client connections between networks such as WiFi and cellular without breaking connections. It was developed automated measurement tools to quantify the effects of different protocol settings, which was used to evaluate the currently unknown effects of client mobility on the quality of real-time media in a Mininet based testbed and on the 6G-XR South Node. The solution has been integrated into the 6G-XR Remote Renderer. REQUIEM released code as open-source and published the key findings. The improved Remote Renderer enables inherent end-to-end security, fate sharing in control and data planes, reduced connection establishment times, improved Quality of Experience (QoE), etc. Our contributions enable novel XR applications involving client mobility.
Vertical	Networking and Computing, Enablers XR Enablers
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	February – July 2024
Results & Impact	**Results:** The project developed novel media streaming methods for the 6G-XR architecture, focusing on media transmission over QUIC: • Raw media transport stream over QUIC, integrated via new GStreamer elements. • Media-over-QUIC support for the 6G-XR Remote Renderer. An automated measurement tool was developed to assess both network performance (latency, migration behavior) and video quality (using VQMTK and iqa metrics) across virtual and real testbeds. The evaluation covered multiple migration strategies: • Planned migration—where clients switch paths proactively—delivered better video quality. • Involuntary migration performance improved when using shorter keep-alive intervals. Additional tests showed that QUIC stream mode achieved higher video quality but increased latency, while datagram mode was preferable under bandwidth constraints. The complete QUIC-based streaming system was successfully deployed and validated in the 6G-XR South Node Kubernetes cluster (5GBarcelona), confirming consistency between virtual and real testbed results. **Impact:** Firstly, REQUIEM contributions are beneficial for the 6G-XR project as an enabler for XR applications involving client mobility thanks to seamless client migration of the QUIC protocol. QUIC also enables enhanced end-to-end security, reduced connection establishment times, etc. Moreover, REQUIEM contributed to6G-XR open-source repositories creating multiple patches most of which have been merged and we opened issues resulting in new features and fixes from the developers.

5G-slAIce

OC Project Title	5G-slAIce: 5G network SLicing enhancement using AI teChniquEs
Beneficiary(s)/Country	GRADIANT - Galician Research and Development Center in Advanced Telecommunications - Spain
Project Description	The objective of 5G-slAIce is to develop an AI/ML-based system that dynamically manages the resources of the different slices of a 5G network core deployed in a Cloud-Native environment. The AI/ML block will consist of two types of ML algorithms: an incremental learning based algorithm, which will be responsible for predicting the number of users of each type of slice in the future; and the reinforcement learning based algorithm, which will be responsible for prescribing actions on the resources of the different slices and the 5G network core based on the current state of the network and the prediction of the IL algorithm, trying to anticipate possible situations of oversaturation or underutilization. The work carried out will provide a solution that anticipates certain undesirable situations by dynamically managing the resources of the different slices, thus facilitating progress towards the implementation of 6G mobile networks.
Vertical	AI/ML algorithm for efficient resource optimization in the 5G slicing techniques
Testbed	UOulu 5GTN
Implementation timeframe	SEP 2024 – MAR 2025
Results & Impact	**Results:** The project has produced multiple results. Firstly, in relation to the preparation of the AI/ML algorithms, we have developed the necessary tools to generate datasets with the metrics of this project (which can be extended to acquire others) using a simulator of user connections of different slices. Secondly, the AI/ML models themselves have been developed: the CL model and the RL model. These models produce the expected results for various evaluation metrics, forming the basis for resource management actions. Finally, an action controller for cloud infrastructure has been developed to implement these actions on Kubernetes, the de facto standard for cloud-native orchestration. For more details on the technical results achieved, please refer to the attached deliverable. **Impact:** The main outcomes are an automatic and dynamic resource controller in a 5GC with different slices using two specific ML techniques, and a simulator of connections to a 5G network with the possibility of creating datasets with metrics related to the 5GC and the infrastructure in which it is deployed. The potential lies in further improving the connections simulator to support a larger configuration of the environment and, on the other hand, in increasing the capabilities of the AI/ML block in several aspects: (i) predicting more variables by using the continuous learning algorithm; (ii) increasing the performance of the models. It can be commercialised as an additional module of a 5G network core deployment in the cloud.

REMIX

OC Project Title	6G REMIX: 6G Real-time Energy Monitoring for XR
beneficiary(s)/Country	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. - Germany
Project Description	6G REMIX aims to analyze the energy consumption of 5G networks by monitoring and visualizing real-time data. Determining energy consumption through measurements of the individual components along the streaming chain and collecting and analyzing existing operating data on power consumption are essential prerequisites for modeling an end-to-end video streaming service. To achieve this goal, 6G REMIX focuses on enhancing the 6G-XR nodes, particularly the South Node (5GBarcelona), by developing tools and procedures for collecting and measuring energy consumption throughout the streaming chain, as well as recording and evaluating existing operating data.
Vertical	Energy: (Residential/industry) energy management and provisioning
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	Oct 2024 - Mar 2025
Results & Impact	**Results:** Main findings and outcomes: • The gNodeB and the Edge are the most energy-intensive components. It is necessary to focus on optimizing the power usage of these components for improved energy efficiency. • The impact of the video bitrate on the UE power is minimal. We do not recommend reducing the video bitrate to save energy because of unnecessary deductions in video quality. • Edge component shows a significant power consumption increase (by 71%) when remote rendering is activated. We suggest developing and implementing strategies to limit remote rendering usage or optimize its efficiency. • Switching from 100 MHz to 40 MHz bandwidth does not significantly reduce energy consumption. It is not necessary to reduce the bandwidth to save energy. **Impact:** Potential for further developments and commercialization: • The insights gained from real-time energy monitoring can lead to the development of advanced energy management systems for 6G networks. These systems could optimize power usage dynamically, offering solutions to network operators aiming to reduce operational costs and environmental impact. • The project's analysis of energy consumption across different streaming scenarios can inform the development of adaptive streaming techniques. These technologies can adjust video quality based on network conditions and energy availability, enhancing user experience while minimizing energy use.

AI4EE

OC Project Title	AI4EE: A holistic approach for energy efficiency driven by AI-based deep understanding of the process stability
beneficiary(s)/Country	Nissatech - Serbia
Project Description	Based on a previous work on the energy optimization in the industry domain, we proposed an innovative approach for analyzing optimization potential in the 5G Test network infrastructure, applied on 6G-XR north node. The result is an energy analysis framework, which uses AI for a deep understanding of the energy consumption and discovering optimization potential, achieving E2E energy efficiency and self-sustainability in next generation mobile networks. The approach is validated with the energy consumption data collected from the existing energy measurement infrastructure, consisting of accurate power meters for continuous measurement of the power consumption at different network elements. The conclusion from the validation is that the tool can identify anomalies in the monitored network infrastructure's energy consumption data accurately.
Vertical	Energy measurement
Testbed	VTT 5GTN
Implementation timeframe	Sep 2024 – Mar 2025
Results & Impact	**Results:** Main result is an energy analysis tool AI4EE, which uses AI for a deep understanding of the energy consumption and discovering optimization potential, achieving E2E energy efficiency and self-sustainability in next generation mobile networks. AI4EE tool is an extension of the D2Port framework with the new methods for data analysis, which are developed as a specialization for the energy measurement provide in the 6G-XR north node. The methods are results of intensive discussions between Nissatech and energy experts and mentors from 6G-XR north node. Main goal was to detect and understand situations where some deviations in the energy consumption have occurred and validate if these situations are caused by some anomalies in energy management system. The work is based on the data collected from the energy management system installed in the 6G-XR north node. Main conclusion is that the tool can identify anomalies in the monitored network infrastructure's energy consumption data accurately. Both high load / overload and maintenance / fault situations are highlighted in the produced graphs at the expected time windows. **Impact:** Proposed energy management system (AI4EE) is based on the D2Port framework (d2port.rs), which offers set of services (data collection, observation, analysis, visualization) for the development of advanced data-driven systems. As a part of the impact creation, D2Port will be extended with new developed data analysis methods (anomaly detection) in order to offer new services for the energy market. The approach for the deployment is very general/universal and can be applied in any similar infrastructure.

DYNAMICOM

OC Project Title	DYNAMICON: Dynamic Service Migration Optimization in Unified Network Continuum
beneficiary(s)/Country	E-lighthouse Network Solutions SL – Spain
Project Description	The DYNAMICON project focuses on advancing the orchestration of dynamic service migration and load balancing across the Device/Edge/Cloud continuum. This innovative venture leverages the Edge Computing Optimization Tool (ECOT) to enhance the 5TONIC MEC Orchestrator's capability in managing edge resources for efficient service distribution. It aims to refine network resource utilization and quality of service (QoS) by developing algorithms for computational load balancing, application migration, and network slice selection. Key to DYNAMICON's strategy is its integration with the 5TONIC testbed's existing infrastructure, which allows for real-time, slice-aware service management. DYNAMICON not only aims to enhance the 5TONIC framework's service management but also seeks to explore its application in multi-site environments. The project's success helps to redefine network and service management operations, supporting a variety of high-stakes real-time applications aligned with the 6G-XR goals.
Vertical	5G/6G Network Orchestration
Testbed	5GTONIC
Implementation timeframe	Oct 2024- Mar 2025
Results & Impact	**Results:** The DYNAMICON project achieved significant technical advancements by integrating the ECOT into the 6G-XR South Node infrastructure, validating its core functionalities: load balancing, and predictive migration. The validation process was executed in two phases: • Integration Tests: ECOT was successfully integrated with both the 5GC NEF and MEC orchestrator APIs, confirming its ability to collect the needed data properly. • Execution Tests: Demonstrated ECOT's ability to identify congestion patterns, simulate migration strategies, and recommend actions to the MEC orchestrator related to load balancing and migration operations. **Impact:** DYNAMICON has directly contributed to advancing the orchestration capabilities of the 6GXR South Node by introducing ECOT, a novel optimization tool for real-time service migration and load balancing. By integrating ECOT with the 5TONIC infrastructure, the project demonstrated a practical approach to enhancing resource utilization, ensuring service continuity, and maintaining QoS across distributed edge nodes. The experiment validated the use case showcasing how ECOT can make intelligent decisions based on real-time and predictive analysis. These contributions extend the flexibility and responsiveness of the 6G-XR architecture, particularly for the South node.

EMSEOS

OC Project Title	EMSEOS: Energy Monitoring System for Energy-Efficiency Optimization and Sustainability of Multimedia VNFs
Beneficiary(s)/Country	IKERLAN - Spain
Project Description	The increasing energy demand of computing edge nodes and cloud services needs the development of energy-aware systems to enhance efficiency, reliability, and cost-effectiveness without degrading performance. The EMSEOS experiment addresses this challenge by implementing an energy monitoring system capable of estimating CPU and GPU power consumption for virtualized network functions (VNFs). Deployed within the 6G-XR project's infrastructure, this system leverages Kubernetes for seamless integration and Prometheus for persistent metric storage and analysis.
Vertical	Energy: energy management and provisioning
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	SEP 2024 – MAR 2025
Results & Impact	**Results:** The system was validated through a series of 15-minute tests, with results averaged over a 3-minute window to ensure consistency and remove initial or final fluctuations Initial tests used a synthetic CPU/GPU stress workload, confirming that energy consumption increased sharply under full load. Subsequent experiments employed a Remote Renderer VNF with varying configurations (resolution, framerate, bitrate, and mode) to analyze how these factors affect power usage. Results showed that energy consumption scales with rendering complexity, with the highest usage observed in the most demanding configuration (T4.1 – stereo 4K, 10 fps, 30 Mbps). These tests demonstrated the system's ability to accurately capture consumption fluctuations across different VNF setups, successfully meeting the experiment's objective. **Impact:** The EMSEOS experiment extends the 6G-XR project's capabilities by integrating a real-time energy monitoring system into its computing infrastructure. EMSEOS results contribute to the broader research community by demonstrating a scalable methodology for power-aware resource management in cloud and edge environments. The collected energy metrics can serve as a foundation for future optimization strategies, helping operators and developers improve energy efficiency without compromising performance. This aligns with the growing need for sustainable computing in next-generation networks, where energy-aware orchestration will play a key role in balancing performance, cost, and environmental impact.

ENORMOUS

OC Project Title	ENORMOUS - ENergy Optimization in multimedia tRansMission and 5G netwOrks Unified System
Beneficiary(s)/Country	University of Malaga - Spain
Project Description	ENORMOUS responds to the need for energy efficiency raised in the 6G-XR OC2 initiative, specifically addressing the monitoring and prediction of the energy consumption of the different network elements within virtualized network functions during data transmission. It has developed advanced tools for real-time monitoring and measurement of energy consumption, as well as investigating AI/ML-based techniques for predicting consumption based on the network state. The aim is to enable the dynamic optimization of network resources and configuration parameters to reduce energy consumption. The techniques have been tested on the VTT infrastructure in Oulu provided by the 6G-XR consortium. The results generated are expected to provide important contributions to both operators and the scientific community, facilitating the transition towards more sustainable, resilient and efficient networks, aligned with global sustainability goals and the IMT-2030 framework.
Vertical	Energy: (Residential/industry) energy management and provisioning
Testbed	VTT 5GTN
Implementation timeframe	Sep 2024- Mar 2025
Results & Impact	**Results:** The ENORMOUS project developed an effective solution for monitoring and predicting energy consumption in the Central Unit (CU) and Distributed Unit (DU) within the Open5GS environment. The system combines real-time data collection, feature engineering, and supervised AI/ML models (such as LSTM, linear trees, and MAPIE) to estimate short-term energy usage. Validated through deployment in the Open5GS testbed under multimedia traffic conditions, the tool enables dynamic network adjustments that reduce energy consumption while maintaining Quality of Service (QoS). A continuous optimization feedback loop allows the models to refine predictions and improve performance over time, supporting more sustainable network operations. **Impact:** The project's outcomes, validated monitoring tools and AI/ML prediction models, provide practical mechanisms for energy-efficient network management applicable to operators, researchers, and standardization bodies. From an industrial perspective, the results allow telecom operators to optimize resource utilization, reducing operational costs while maintaining service quality. From an academic viewpoint, the methodologies and findings advance research in AI-driven network management and energy-aware system design. Furthermore, it promotes open collaboration by sharing datasets and models publicly, encouraging benchmarking, reuse, and innovation across the broader scientific and industrial communities. These contributions accelerate progress toward sustainable and efficient 6G technologies.

StreamAnalyzerFor5GSlicing

OC Project Title	StreamAnalyzerFor5GSlicing: Integration and enhancements of Lamda Networks' NWDAF implementation to 6G-XR for providing AI/ML capabilities for slicing
beneficiary(s)/Country	Lamda Networks - Greece
Project Description	This project addressed ML/AI challenge in the sub area AI/ML algorithm for efficient resource optimization in the 5G slicing techniques, focusing on two key objectives:(i) developing a centralized AI-based load balancer that meets UEs' bandwidth requirements, and(ii) implementing a distributed reinforcement learning scheduler to optimize 5GTN RI resource utilization under congestion in Cumucore slices.The resulting open-source codebase constitutes a valuable asset for the 6G-XR project and a significant contribution to the SNS Stream B "System Architecture" initiative.
Vertical	AI/ML for slicing
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	Sep 2024- Mar 2025
Results & Impact	**Results:** The AI-based centralized use case demonstrated that the admission control agent effectively restricted UE access when more than seven active UEs were connected, as it learned that additional UEs could not achieve the target bandwidth of 5 Mbps. The model also showed a preference for Slice 2 (UPF250) in specific scenarios, optimizing performance based on its training experience.For the AI-based decentralized use case, the deep reinforcement learning (DRL) UE scheduler successfully learned to optimize slice assignment decisions. The agent minimized both waiting time and slice usage time by prioritizing smaller UE requests and assigning them dynamically to the appropriate network slice (Slice 1 or 2). The results confirm that the agents learned effective scheduling policies that balance load and maximize overall system efficiency within the 5GTN testbed. **Impact:** StreamAnalyzerFor5GSlicing yielded promising results serving as the basis for a realistic business plan. The implementation is currently integrated and operational within the 5GTN production network and is available to support other researchers and experimenters throughout the duration of the 6G-XR project. Additionally, the open-source codebase developed during the project constitutes an asset for Stream B "System Architecture" of the SNS program.

TRUSTNET

OC Project Title	TrustNet - Trust Management Framework for 6G Networks
Benefiaciary(s)/Country	WINGS ICT Solutions S.A. - Greece
Project Description	TrustNet aims to tackle the challenges of ensuring end-to-end trust and reliability in 6G networks, within the compute continuum, which extends computing capabilities from centralised cloud to distributed edge infrastructures, as well as up to end-user devices. This project focuses on the development and validation of a Trust Management Framework (TMF) that quantifies and manages trust. The project aims to enhance trust quantification, optimise data paths, and ensure secure, reliable communication across multi-domain 6G ecosystems, with a particular focus on XR applications. Ultimately, TrustNet contributes to the creation of secure, trustworthy environments for future 6G networks, supporting dynamic, multi-stakeholder service provisioning.
Vertical	Security and trust mechanisms
Testbed	5GTONIC
Implementation timeframe	SEP 2024 – MAR 2025
Results & Impact	**Results:** TrustNet enabled the collection of a diverse set of trust quantification-relevant performance metrics and the evaluation of two available 5TONIC edge domains, leveraging the collected datasets. The 5TONIC-TMF integration (including extended API configurations, related to the exposure of performance KPIs, dynamic traffic load modelling, etc.) was successfully tested, while interesting preliminary results were collected. The potential for further development and commercialization of the TrustNet project lies in its ability to provide a scalable and robust Trust Management Framework (TMF) for dynamic, multi-domain 6G networks and XR applications. The TMF's capability to quantify and optimise trust in real-time can be applied to various industries, including telecommunications, smart cities, and autonomous systems. It offers significant value for service providers, application developers, and infrastructure managers who need to ensure reliable, trust-aware communication across complex networks. Further development could focus on enhancing the framework for specific use cases, such as secure edge computing or resource optimisation. The commercialization potential includes licensing the technology or offering tailored solutions for enterprise applications across a wide range of sectors. **Impact:** TrustNet, leveraging the 5TONIC infrastructure, significantly contributes to the broader community by offering real-world trust quantification experimentation outcomes as well as a novel methodology for evaluating trust at both the device and edge domain levels, addressing a key gap in current technology. This approach enables communication service providers, cloud providers, and application developers to assess the trustworthiness, reliability, and security of their networks and infrastructures, while also providing valuable insights for third-party application developers and 6G stakeholders.