Alliance for AI, IoT and Edge Continuum Innovation

IoT and Edge Computing EU Funded Projects Landscape

Release 4.0

AIOTI WG Standardisation

29 September 2025

Executive Summary

The main objective of this deliverable is to provide the landscape of EU funded projects focusing on IoT and edge computing, which can be used to:

1) leverage on existing IoT and edge computing research and innovation activities in Europe, and
2) provide input to IoT and edge computing standardisation gap analysis activities.

The Release 2.0 of this report, compared to Release 1.0, includes:

- a list of additional ongoing projects focusing on IoT and Edge computing that are funded by the EU.
- project descriptions of projects that were labelled as ongoing in Release 1 and were in the meantime completed, are moved to the respective sections with completed projects.
- updated figures of projects landscape in relation to Standardisation Organisations and Initiatives.

The Release 3.0 of this report, compared to Release 2.0, includes: more IoT and/or Edge computing projects, which are:

- a list of additional ongoing projects focusing on IoT and Edge computing that are funded by the EU: DS2, ODEON, P2CODE, OASEES, OpenSwarm, TaRDIS, 5G COMPLETE, 5G INDUCE, 5GMED, 5GMETA, 5G-VICTORI, AI@EDGE, Evolved 5G, SmartEdge, DECICE, Hexa-X-II, 6G-Cloud, 6G-BRICKS, SUNRISE-6G, ExtremeXP, 6G-INTENSE, 6G-DALI, A-IQ Ready, INSTAR, CORTEX2, NextGEM, OMEGA-X, PEDvolution.
- project descriptions of projects that were labelled as ongoing in Release 1 and were in the meantime completed, are moved to the respective sections with completed projects: ASSITS-IoT, IntelliIoT, BD4NRG, OpenContinuum, Unlock-CEI.
- updated figures that used for the visualization of the IoT EU funded projects landscape.

In the Release 4.0 of this report, compared to Release 3.0, the following changes are introduced:

- the IoT and Edge computing projects funded by the EC, that are: (1) completed before 2025 and (2) were included in Release 3.0 of the report, are not anymore included in this Report, they can be retrieved in Sections 1.1 and 2.1 of the AIOTI IoT and Edge Computing EU Funded Projects Landscape, Release 3.0.
- a list of additional projects focusing on IoT and Edge computing that are funded by the European Union were added:
  - "TechUPGRADE", "Averato Park", "CoEvolution", "MODUL4R", "ERATOSTHENES", "CyberNEMO", "GREET", "ENACT (HE CL1)", "ENACT (HE CL4)"
  - project descriptions of projects that were labelled as ongoing in Release 3.0 and were in the meantime completed, are moved to the respective sections with completed projects: AI4CSM, AURORAL, ICOS, VERGE, Hexa-X-II, COMMECT, OMEGA-X.

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Introduction

The integration and synergy of IoT/IIoT and edge computing, including also the applied federated learning solutions, can be considered as a part of the paradigm shift from centralised solutions to decentralised and distributed computing architectures.

The main objective of this deliverable is to briefly present the EU funded projects focusing on IoT and edge computing, which can be used to

1) Leverage on existing IoT and edge computing research and innovation activities in Europe, and
2) Provide input to IoT and edge computing standardisation gap analysis activities.

This report provides landscape visualizations of ongoing and completed projects focusing on IoT and Edge computing that are funded by the EU. For each of these EU funded completed and ongoing projects, two groups of landscape visualisations are realised, based on (1) Technology and Marketing Dimensions and (2) vertical industry domains.

The Release 3.0 of this report, compared to Release 2.0, includes: more IoT and/or Edge computing projects, which are:

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Several of the received inputs were provided by EU funded ongoing projects, which we would like to acknowledge.

1. IoT EU funded projects landscape

This section provides information on IoT EU funded projects, which are grouped in completed and ongoing projects. The information related to each EU funded project, included in this section, has been collected using the template provided in Annex I of this report.

1.1 Completed Projects

This section provides a description of the completed IoT projects funded by the EU.

1.1.1 COMMECT: Bridging the digital divide and addressing the need of Rural Communities with Cost-effective and Environmental-Friendly Connectivity Solution

URL/Reference:

https://www.horizoneurope-commect.eu/

https://cordis.europa.eu/project/id/101060881

Abstract:

Over the last few years, the importance and need for broadband and high-speed connectivity have constantly increased.

The Covid-19 pandemic has even accelerated this process towards a more connected society. But this holds mainly true for urban communities. In Europe, a 13% lack of access persists and mainly concerns the most rural and remote areas. Those are the most challenging to address since they are the least commercially attractive. COMMECT aims at **bridging the digital divide** by providing quality, reliable, and secure access for all in rural and remote areas. The **goal of extending broadband connectivity in rural and remote areas** will be achieved by *integrating Non-Terrestrial Networks with terrestrial cellular XG networks and low-cost Internet of Things (IoT). Artificial Intelligence, Edge and Network Automation will reduce energy consumption both at the connectivity and computing level.*

A participatory approach with end-users and ICT experts working together on development challenges will be the key **to the digitalization of the sector**. To ensure the rich exchange of best-practice and technical knowledge among the actors of the agro-forest value chain, COMMECT will set up **five Living Labs across and outside Europe**, *where end-users' "pain" and (connectivity) "gains" will be largely discussed, from different perspectives.*

COMMECT aims to contribute to a balanced territorial development of the EU's rural areas and their communities by making smart agriculture and forest services accessible to all. COMMECT will facilitate that by developing a ***decision-making support tool*** *to advise on the best connectivity solution according to technical, socio-economic, and environmental considerations. This tool, incorporating collaborative business models, will be a key enabler for jobs, business, and investment in rural areas and for improving the quality of life in areas such as healthcare, education, and e-government, among others.*

Starting and (target) end time of project:

01/09/2022 – 31/08/2025

IoT and/or Edge Computing research challenges:

OBJECTIVE 1: Empower rural and remote communities and train them toward digitalization:

- COMMECT will adopt a twofold approach toward digital inclusion of rural communities: (1) easy access to fast and reliable broadband Internet (making it affordable for all and able to meet different end-user needs*)- including IoT and edge computing features*, and (2) educate rural communities and business toward the adoption of the digital technologies.

OBJECTIVE 2: Increase the competitiveness of rural communities and give them access to new services and business opportunities:

- COMMECT will design innovative, cost-effective, and energy-efficient (5G, last mile, and *edge*) connectivity solutions that can increase the attractiveness of rural and remote areas to businesses and individuals. COMMECT will enhance the communities' capability to create and innovate business models to impact remote and rural areas socially and economically in a sustainable way. New forms of entrepreneurship in agriculture and forestry, based on environmental and social values, will also be promoted.

OBJECTIVE 3: Facilitate decision-making in the selection of the most appropriate Internet connectivity:

- The choice of the most appropriate technology (*including IoT and Edge computing features*) depends on economic, geographic, and technical factors, the type and number of services required, the infrastructure already available, etc. COMMECT will validate such a concept in five Living Labs deployed in five countries with different regional, socioeconomic, and environmental conditions. *Technical and non-technical actors will closely work together in the Living Labs, exchanging their complementary knowledge (scientific and practical)*. COMMECT will develop a **DST** that advises farmers, forestry, municipalities, and decision-makers on the best connectivity solution, according to technical requirements and the foreseen socio-economic and environmental impact.

OBJECTIVE 4: Contribute to climate change mitigation and increase the resilience and sustainability of rural communities:

- Connectivity solutions *(including IoT and Edge computing feat*ures) will be designed considering criteria such as energy efficiency, climate change impact and total cost of ownership to improve their sustainability performance. The benefits of the connectivity solutions (i.e. Green ICT and ICT for Green) will also be assessed and compared to sustainability targets (European Green Deal and Fit for 55 package) for the agricultural and forestry sectors (e.g. reaching climate neutrality by 2050 in the EU). The socio-economic and environmental indicators will be included in the DST to guide the end-users towards more sustainable choices.

Specific challenges

- Empower rural and remote communities and train them toward digitalization
- Increase competitiveness of rural communities and give them access to new services and business opportunities
- Facilitate decision-making in the selection of the most appropriate Internet connectivity
- Contribute to climate change mitigation and increase resilience and sustainability of rural communities

Provide information about the expected activities on "Dissemination and Impact on Standards":

- Standardisation activities on facilitating decision-making in the selection of the most appropriate Internet connectivity in rural communities in the context of SDOs and alliances such as 3GPP, oneM2M, 5GACIA, NGMN.
- Standardisation activities on autonomous networks across hybrid networks (mainly TMForum and ETSI ZSM)
- Bringing COMMECT interoperability standardisation challenges in the context of the Alliance for IoT and Edge Computing Innovation (AIOTI), in reports such as the updated version of the report "**IoT and Edge Computing EU funded projects landscape**" and (2) bringing COMMECT insights in the joint cooperation of AIOTI with European

Telecommunications Standards Institute (ETSI) Environmental Engineering (EE) Eco Environmental Product Standards (EEPS) and ITU-T SG5 Q9 (Study Group 5 Question 9) group, in activities such as:

- future updates of) **L.1480**: "Enabling the Net Zero transition: Assessing how the use of information and communication technology solutions impact greenhouse gas emissions of other sectors"
- (updates of) **L.1410** => **L.1410rev** - "Methodology for environmental life cycle assessments of information and communication technology goods, networks and services"

- Contributions towards:
  - Third Generation Partnership Project (3GPP) Radio Access Network (RAN) Radio Layer 2 and Radio Layer 3 RRC (WP2)
  - Next Generation Mobile Networks (NGMN) Alliance Green Future Networks project
- Some examples are, see AIOTI Days 2024:
  - Towards NGMN:
    - Energy Efficiency White Paper, Phase 3: Energy Efficiency Roadmap - Green Future Networks: A roadmap to Energy Efficient Mobile Networks
  - Towards AIOTI:
    - AIOTI WG Standardisation: Landscape + Gaps
    - AIOTI WG Agriculture: 6G IA and AIOTI joint White Paper: The role of 6G in agriculture
    - AIOTI WG ICT for Co2 reduction Methodologies (ICM): Discussion on examples of LCA for carbon emissions in COMMECT use cases
  - Towards 3GPP:
    - RAN2 R2-2304155 Discussion on CHO (handover) procedure enhancements in case source/target cell is in NES (energy saving) mode
    - RAN2 R2-2308054 Discussion on the NTN – TN cell reselection enhancement
    - Joint ETSI TC EE/ ITU-T SG5: targeted contribution towards L.1480(rev) via AIOTI

Conclusions:

Target SDOs/Alliances: 3GPP Release 18 Temporary documents (Tdocs) related to the network energy savings and non-terrestrial network mobility from the COMMECT consortium are prepared for 3GPP RAN WG2 meetings: R2-2304155 and R2-2308054. The COMMECT project partners contributing to NGMN Network Energy Efficiency Phase 3B. Contribution to the AIOTI work on Co2 reduction Methodologies (ICM). Contribution to AIOTI – 6G-IA report "White Paper the role of 6G in agriculture".

- **Activities:** Webinars, conferences, public deliverables, workshops involving end-users. Sharing real-world living lab data for standardisation of energy-efficiency, connectivity, and decision-support systems. Applying current standards (e.g., ETSI and 3GPP) in the deployment of edge and IoT systems.

Timeline:

- **Year 1:** Identify relevant SDOs and ongoing standardisation work aligned with COMMECT objectives. Begin aligning use cases with existing standards (3GPP, ETSI, etc.).
- **Year 2:** Validate IoT and edge technologies in Living Labs. Share findings with standardisation bodies and begin contributing to relevant technical reports or discussions.
- **Year 3:** Provide formal feedback to SDOs based on trial data and DST outputs. Propose improvements or new elements to existing standards. Contribute to white papers, working group discussions, and public consultations.
- **End of Project:** Consolidate contributions and prepare final recommendations for relevant SDOs and alliances. Disseminate outcomes in standardisation fora and research communities.

1.1.2 OMEGA-X: Orchestrating an interoperable sovereign federated Multi-vector Energy data space built on open standards and ready for Gaia-X

URL/Reference:

https://cordis.europa.eu/project/id/101069287

https://omega-x.eu/

Abstract:

Large amounts of valuable data are available in energy systems but are often underused. For example, there is no single data platform connecting data from the generation, transmission, distribution and consumption domains in Europe's electricity sector or across the various energy vectors – electricity, gas, heat, etc. The barriers also imply the lack of proper mechanisms and policies that ensure secure, sovereign and fair data sharing. Relying on European common standards, the EU-funded OMEGA-X project aims to implement an energy data space. This includes federated infrastructure, data marketplace and service marketplace, involving data sharing between different stakeholders and demonstrating value for concrete energy use cases while guaranteeing scalability and interoperability with other data space initiatives.

Starting and (target) end time of project:

01/05/2022 – 30/04/2025

IoT and/or Edge Computing research challenges:

Orchestrating an interoperable sovereign federated Multi-vector Energy data space built on open standards and ready for Gaia-X. The aim of OMEGA-X is to implement a data space (based on European common standards), including federated infrastructure, data marketplace and service marketplace, involving data sharing between different stakeholders and demonstrating its value for real and concrete Energy use cases and needs, while guaranteeing scalability and interoperability with other data space initiatives, not just for energy but also cross-sector.

- The proposed concept and architecture heavily rely on the approaches adopted by IDSA, GAIA-X, FIWARE, BDVA/DAIRO and SGAM as major EU references regarding data spaces. It will pursue the GAIA-X label, which ensures highest standards on protection, security, transparency, openness and trust, avoids vendor lock-in and restricted to EU countries.

- Federated infrastructure for data ingestion. There are a lot of independent platforms for data ingestion/storage, open and private. The goal is to define the minimum interoperability and federation requirements needed for these platforms to adhere to the Energy Data Space and be able to share data in a trusted and secure way.

- Data Space Marketplaces. This is the common ground where data, which is already harmonized semantically, is indexed, and referenced, maintaining always the required standards of identity, trust and sovereignty. Using the data space as baseline, a

marketplace is implemented for stakeholders to share, use and monetize data and services. Data/service providers will be able to advertise their data/services, and data/service users will be able to discover multiple data sets and services.

- Advanced Energy Use Case demonstration. Using all underneath layers, four (4) use case families (Renewables, LEC, Electromobility and Flexibiilty) will showcased o prove the value of having a common data space for a particular problem identified by energy stakeholders.

OMEGA-X will develop an Energy Data Space that enables multiple actors sharing data and services while ensuring privacy, security and sovereignty. This will specifically address the current problem of low availability of data for innovative uses in the energy sector and beyond. OMEGA-X will collaborate with stakeholders to identify where energy-based service improvements and innovation are required, and how OMEGA-X could potentially be used and adopted to address these needs:

- This will guarantee that companies and organizations can share their data safely. At the same time, it will help existing market actors (including SMEs and start-ups) to have access to a variety of datasets to improve their AI models, and thus be able to upgrade existing services and/or bring innovative services that otherwise could not be developed.

- The availability of data will empower new participants and market roles such as aggregators and local energy community managers. This will facilitate the large-scale penetration of renewables in the local grid without significant investments in grid infrastructure and will also create an opportunity for new business models to emerge.

- OMEGA-X will put a prominent focus on developing and promoting inclusive and collaborative behaviours, which will lead to a multitude of societal and economic benefits, such as, an increase in energy autonomy and a reduction in CO2 emissions.

Expected activities on "Dissemination and Impact on Standards":

The project will ensure that the interoperability of the Data Space can be replicable both inside and outside the project. Inside the project, use cases will be, to the possible extent, replicated in multiple pilot sites, ensuring the re-usability of solution under different environments, regulations and involving different actors. External interoperability is also considered as core objective of the project.

This is achieved through the interoperable nature of the solution proposed, using IDSA and Gaia-X as reference, but also working with Open-Source developments, open standards, standard interfaces, APIs and semantic ontologies (SAREF, IEC CIM, IEC 61850...) for collaboration. Tasks dedicated to defining, implement and validate a common use case with the other projects is

where OMEGA-X will prove interoperability amongst the different developed data spaces creating a single European Energy Data Space. Interoperability with other existing EU funded projects will be proven also through BRIDGE.

The Data Space is set to have vertical interoperability, that is, offering open definition of protocols and standards to be used for external data ingestion platforms to become federated nodes.

The Data Space is set to have horizontal interoperability, that is, providing standardized protocols and APIs to collaborate with similar Data Spaces at EU level, including those coming from sister projects. This also includes the usage of Information Models based on standards such as IEC CIM, IEC 61850 and IEC COSEM, among others.

The Data Space will be developed using Open Source and standardized protocols and APIs, to maximize the interoperability both inside and outside the Data Space.

1.1.3 ERATOSTHENES: Secure management of IoT devices lifecycle through identities, trust and distributed ledgers

URL/Reference:

www.eratosthenes-project.eu

Abstract:

ERATOSTHENES will devises a novel distributed, automated, auditable, yet privacy-respectful, Trust and Identity Management Framework intended to dynamically and holistically manage the lifecycle of IoT devices, strengthening trust, identities, and resilience in the entire IoT ecosystem, supporting the enforcement of the NIS directive, GDPR and Cybersecurity Act. ERASTOSTHENES has leveraged breakthrough solutions: (a) the first-ever enclosure of cybersecurity features in IoT devices through deployment of Trust Agents and continuous trust evaluation within the network in a contextual and social approach; (b) decentralised identity management mechanisms to conciliate requirements of self-sovereignty and privacy preservation in a distributed/transparent trust model along with disposable identities; (c) self-encryption/decryption at device-level with a whole system automated recovery process (incl. software, crypto-key material, identities) after an attack based on a multi-layer recovery model; (d) threat-analysis models based on federated learning and edge execution to continuously monitor devices and detect attacks; (e) collaborative IoT threat intelligence sharing across ledgers to adapt detection/defense mechanism to the evolving security conditions and assist the IoT life-cycle; (f) integration of Physical Unclonable Functions in trust framework and distributed ledgers. Finally, it supports enforcement of the NIS directive with a security information sharing mechanism based on inter-ledger technologies to support exchange of trust and security information among stakeholders, enhancing collaboration, vulnerabilities disclosure, and secure management of software updates. The overall vision of ERATOSTHENES is to provide core cybersecurity features to be adopted by manufacturers as baseline certification elements in the production of devices and throughout their entire lifecycle. The solution will be validated in 3 industrial cases: Automotive, Health, Industry 4.0.

Starting and (target) end time of project:

01/10/2021 – 31/03/2025

IoT and/or Edge Computing research challenges:

- Design a **Trust Framework and a Reference Architecture** to ensure end-to-end trust and identity management in distributed IoT networks, suited for resource-restricted environments, critical and industrial applications
- Design and develop a **lightweight, distributed, and dynamic Trust Manager** to enhance the trust in large-scale distributed networks of heterogeneous IoT devices covering each layer and cross-layer of the network

- Design a **decentralised, scalable, efficient and privacy preserving IoT identity management** to conciliate the requirements of self-sovereignty and privacy preservation in a distributed, interoperable and transparent trust model, including self-encryption/decryption schemes and IoT identity recovery
- **Build the lifecycle management** and the overall governance layer of the trust network on novel Distributed Ledger Technologies and a hybrid consensus protocol.

  Implement Smart Contracts for enforcing access policies and sharing trustworthiness within the network guaranteeing their transparency, integrity, authenticity, and authority. Design of Inter-ledger Cyber-Threat Information Sharing, and automated Recovery Solutions based on a multi-layer approach
- Integrate and Validate the approach through **real-world pilots** to assess its effectiveness and organize hands-on training through realistic **cybersecurity exercises**
- Deliver knowledge via dissemination and capacity building, supporting the enforcement of the Cybersecurity Act and standardization activities and build a robust exploitation plan and market positioning

Expected activities on "Dissemination and Impact on Standards":

- **Final ERATOSTHENES Workshop:** https://eratosthenes-project.eu/eratosthenes-final-workshop-shaping-the-future-of-secure-iot-innovations-in-security-trust-identity-and-privacy/
- **Towards a Holistic Certification Approach for IoT Trust and Identity Management Framework – The ERATOSTHENES approach**: https://eratosthenes-project.eu/wp-content/uploads/ERATOSTHENES-Whitepaper-Certification-Activities.pdf
- **ConSenseIoT: A Consensus Algorithm for Secure and Scalable Blockchain in the IoT context:** https://dl.acm.org/doi/10.1145/3538969.3543811
- **A privacy-preserving attribute-based framework for IoT identity lifecycle management**: https://www.sciencedirect.com/science/article/pii/S138912862300484X?via%3Dihub
- **An inclusive Lifecycle Approach for IoT Devices Trust and Identity Management**: https://dl.acm.org/doi/10.1145/3600160.3605083
- Lifecycle Management of IoT Devices Via Digital Identities Management and Distributed Ledgers Solutions: https://graz.elsevierpure.com/en/publications/lifecycle-management-of-iot-devices-via-digital-identities-manage
- **Mr-TEE: Practical Trusted Execution of Mixed-Criticality Code:** https://dl.acm.org/doi/10.1145/3626562.3626831
- **Beyond selective disclosure: Extending distributed p-ABC implementations by commit-and-prove techniques:** https://www.sciencedirect.com/science/article/pii/S138912862400330X?via%3Dihub
- **Latency-Aware Node Selection in Federated Learning**: https://ieeexplore.ieee.org/document/10619860
- **Service Provider Accreditation: Enabling and Enforcing Privacy-by-Design in Credential-based Authentication Systems:** https://graz.elsevierpure.com/en/publications/service-provider-accreditation-enabling-and-enforcing-privacy-by-
- **BISON: Blind Identification through Stateless scOpe-specific derivation:** https://graz.elsevierpure.com/en/publications/bison-blind-identification-through-stateless-scope-specific-deriv
- **Decentralised Identity Management solution for zero-trust multi-domain Computing Continuum frameworks**: https://www.sciencedirect.com/science/article/pii/S0167739X24004291

1.1.4 Visualization of the IoT EU funded completed projects landscape

This section provides a landscape visualization of the completed IoT projects funded by the EU, which are introduced in this report.

The figures included in this section cover (1) completed IoT projects that are described in Section 1.1 of this release (Release 4.0) and (2) as well completed IoT projects that can be retrieved via Section 1.1 of AIOTI IoT and Edge Computing EU Funded Projects Landscape, Release 3.0, see as well the Introduction section of this release (Release 4.0).

Figure 1 shows the "IoT EU funded completed projects landscape (Technology and Marketing Dimensions)", where these completed projects are projected in two dimensions. The horizontal axis represents the market type, while the vertical axis represents the technology/solution/knowledge area that these completed projects cover and focus. Notably, the extremity of the left-hand side of the horizontal axis represents the customer (i.e., Business to Customer: B2C) market. The part at the extremity of the right side of this axis, on the other hand, represents the industrial internet (i.e., Business to Business: B2B) market. Also, it should be noted that the top part of the vertical axis represents the technology areas that are related to services and applications, while the bottom part of the same axis represents the technology areas that are related to connectivity.

The projection of these completed projects on these two dimensions has been accomplished based on discussions among experts participating in both AIOTI WG Standardisation and relevant completed project participants.

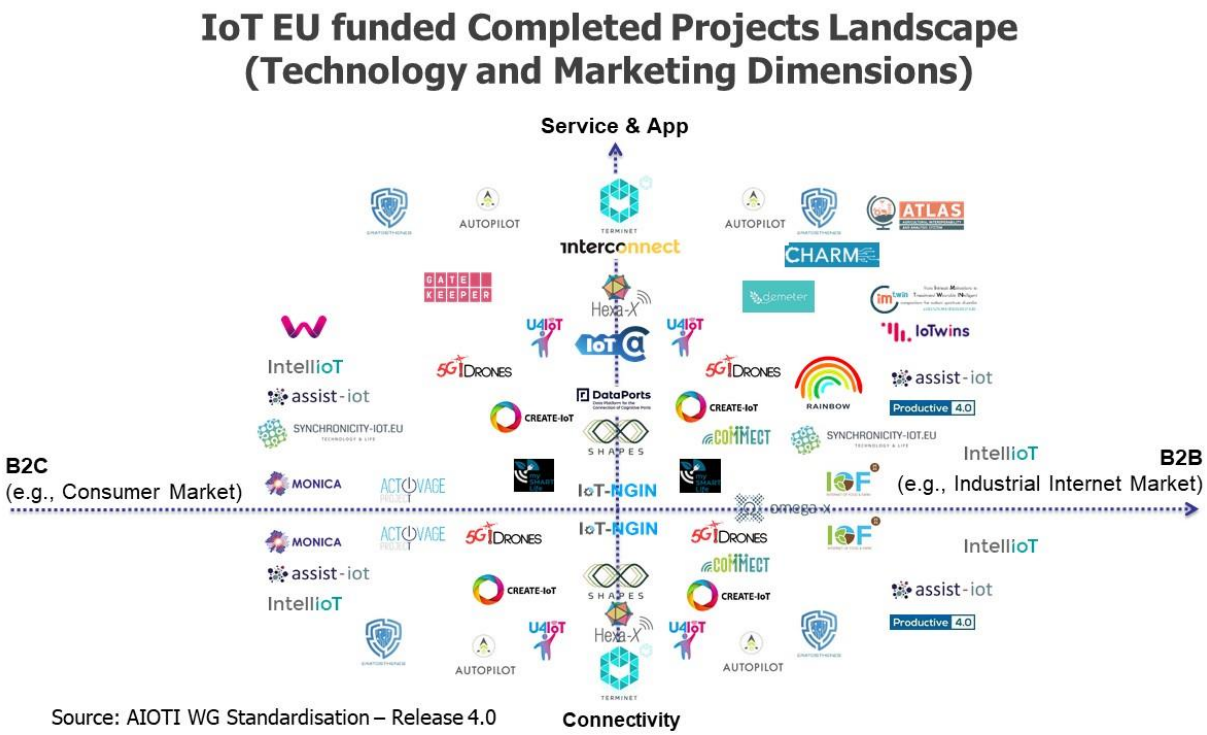


Figure 1: IoT EU funded completed projects landscape, when Technology and Marketing Dimensions are used

In addition to the IoT EU funded completed projects landscape shown in **Figure 1** a projection of these completed projects into vertical industry domains is shown in **Figure 2**.**Figure 2: IoT EU funded Completed Projects Projection on Vertical and Horizontal Domains**

Moreover, the IoT EU funded completed projects landscape projection in relation to activities in standardisation organisations and initiatives is shown in **Figure 3**. This is a graphical representation aiming at highlighting the standardisation activities (up to the day of generating this representation) of the completed projects with respect to different SDO's and standardisation

initiatives like: ETSI, AIOTI, ISO/IEC, BDVA, IEEE SA, IETF, 3GPP, ITU-T, W3C, OneM2M as well as open-source projects and standards.

Moreover, the IoT EU funded completed projects landscape projection in relation to activities in standardisation organisations and initiatives is shown in **Figure 3**.

This is a graphical representation aiming at highlighting the standardisation activities (up to the day of generating this representation) of the completed projects with respect to different SDO's and standardisation initiatives like: ETSI, AIOTI, ISO/IEC, BDVA, IEEE SA, IETF, 3GPP, ITU-T, W3C, OneM2M as well as open-source projects and standards.

The "IoT EU funded Completed Projects Landscape (Vertical and Horizontal Domains)" is a graphical representation aiming at highlighting the main activities (up to the day of generating this representation) of the completed projects with respect to the industrial domains/sectors represented as "verticals" and Telecommunication Infrastructure domain represented as "Horizontal/Telecommunication".

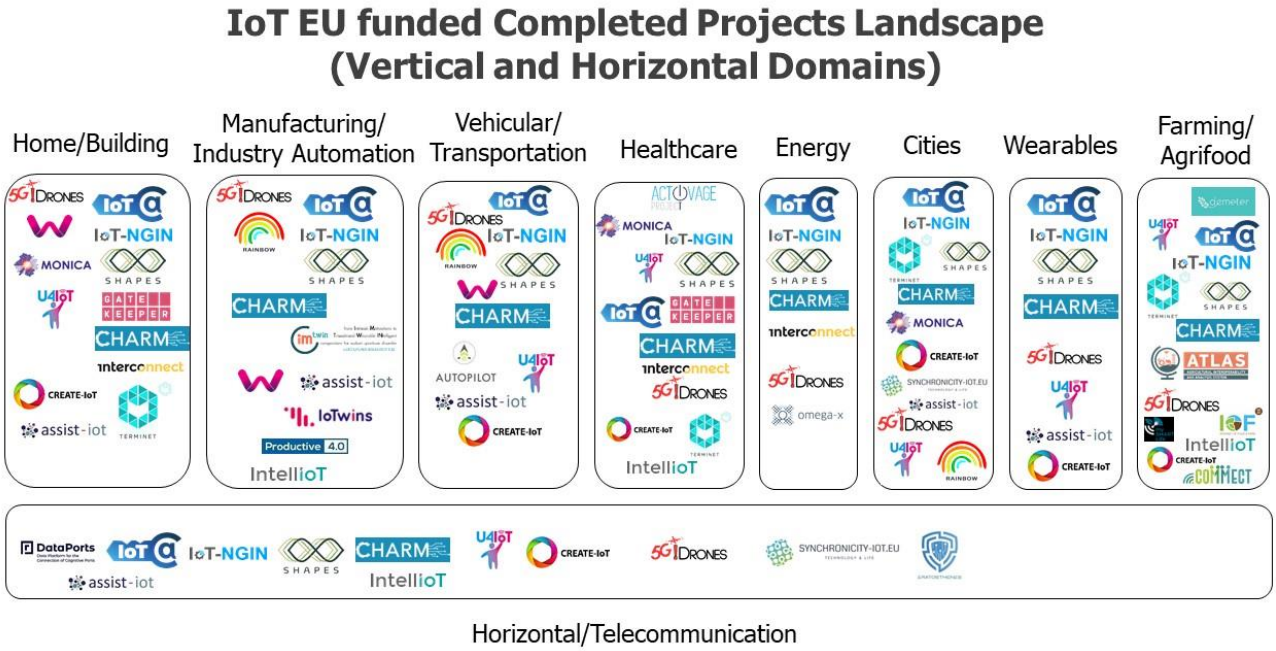
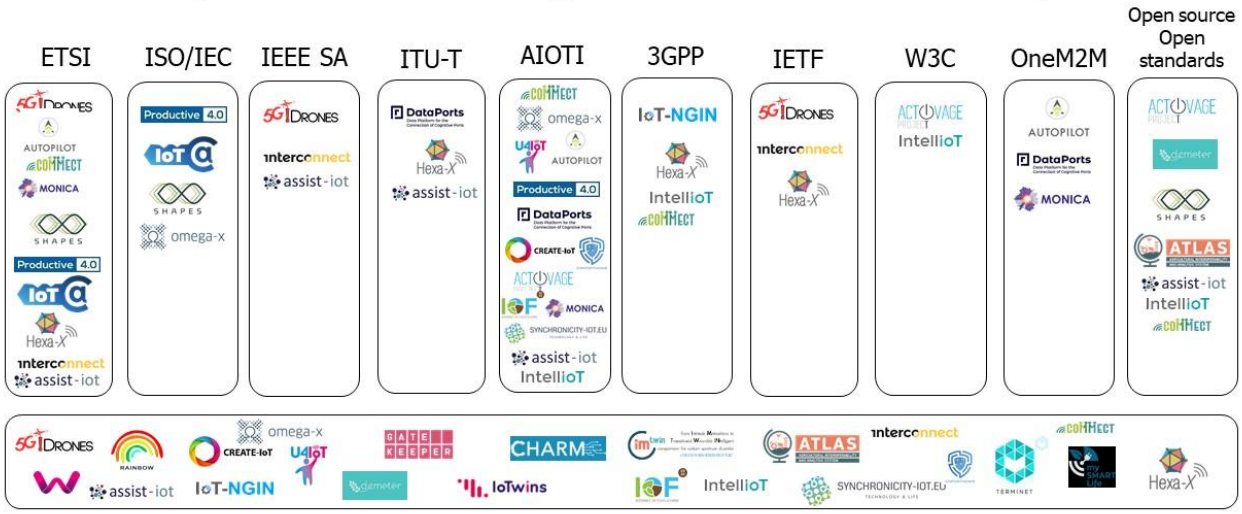


Figure 2: IoT EU funded Completed Projects Projection on Vertical and Horizontal Domains

Moreover, the IoT EU funded completed projects landscape projection in relation to activities in standardisation organisations and initiatives is shown in **Figure 3**. This is a graphical representation aiming at highlighting the standardisation activities (up to the day of generating this representation) of the completed projects with respect to different SDO's and standardisation initiatives like: ETSI, AIOTI, ISO/IEC, BDVA, IEEE SA, IETF, 3GPP, ITU-T, W3C, OneM2M as well as open-source projects and standards.



Source: AIOTI WG Standardisation – Release 4.0

Figure 3: IoT EU funded Completed Projects Projection on Standardisation Organisations and Initiatives

1.2 Ongoing Projects

This section provides a description of IoT projects funded by the EU that are still ongoing.

1.2.1 EDDIE: European Distributed Data Infrastructure for Energy

URL/Reference:

https://eddie.energy/

https://cordis.europa.eu/project/id/101069510

Abstract:

The *Clean Energy for all Europeans Package* has established the right to access energy-related data for customers and eligible parties of their choice. This can enable new data-based services which leverage energy-related data from IoT sensing devices in households, such as smart meters and home automations systems.

EDDIE aims at enabling such services by creating an open-source Data Space aligned with the work of the EU Smart Grids Task Force on the Implementing Acts on Interoperability and other European activities. This Data Space will focus on lowering the data integration costs of energy data-based services by allowing energy companies to work and compete in a common European market. In addition, an Administrative Interface for In-house Data Access (AIIDA) will be designed (which is expected to be deployed in-house thus running on edge computing resources) that has the prime goal to ensure consent-based secure and reliable access to valuable real-time data.

Starting and (target) end time of project:

01/01/2023 – 31/12/2025

IoT and/or Edge Computing research challenges:

Various challenges will be tackled within the context of EDDIE which are mostly related to achieving interoperability for accessing IoT data from smart meters and IoT sensors. Such challenges are:

- **Access to historical energy data**: At the moment, the main barrier in the way of creating services which rely on energy data is the lack of uniform procedures for accessing IoT data from households, i.e., access to smart metering information. Currently, actors are tied to acquiring data from national energy providers that use different procedures. This limits the interoperability and growth perspective of energy services. Such constraints have an industrial, economic, and social dimension on a European level and beyond.

- **Access to uniform energy data**: Even when the access to IoT data from smart meters is possible, it is still hard to exploit this data due to the variety of existing data formats (i.e., utilized syntax, structure, and file types). This becomes especially difficult when the goal is to acquire energy data (e.g., energy production and consumption patterns) from households in different counties that may use differs formats.

- **Access to real-time energy data**: Many actors also face problems when trying to access near real-time measurements of smart meters and in-house IoT sensors. This can be a problem because, typically, smart metering consumption data becomes available by the energy provider after a significant period of time, thus losing its values as real-time information.

Expected activities on "Dissemination and Impact on Standards"

The results that will be produced throughout the duration of EDDIE are expected to be submitted for publication in the proceedings of international conferences, workshops and selected high-level journals from various relevant fields including energy economics, computer science, IoT, software engineering, big data, machine learning, and AI. In addition, it is expected to participate in technical working groups such as the AIOTI WG Energy, the Digital Taskforce of the SmartEn (the European demand response association) and the Working Group 4 of the ETIP Smart Network platform.

1.2.2 NEMO: Next Generation Meta Operating System

URL/Reference:

https://meta-os.eu

https://cordis.europa.eu/project/id/101070118

Abstract:

With the rapid increase in domains of IoT and data analytics the need for more effective operations on data and human-machine interactions, management and analytics is mandatory. Based on this need, the concept of Artificial Intelligence of Things (AIoT), was introduced as an imminent solution. Based on this, the EU-funded NEMO project aims to establish itself as a pivotal player in the AIoT-edge-cloud continuum proposing the next generation of open, modular and cybersecure meta-operating systems. By exploiting existing well-established and open-source technologies and standards while introducing new concepts, methods and tools, NEMO will bring intelligence closer to the data and make AI-as-a-Service an integral part of micro-services' lifecycle management. NEMO builds on easy development, ZeroOps deployment data monetisation and new business models, engaging communities and ecosystems to enable sustainability. Through piloting activities in five diverse domains and two open call rounds, NEMO aims to be validated in a plethora of use cases to demonstrate the benefits of the work carried out within the project.

Starting and (target) end time of project:

01/09/2022 – 30/09/2025

IoT and/or Edge Computing research challenges:

Research challenges in NEMO

- Open and modular meta-Operating System (mOS)
- On-device federated MLOps and TL via CF-DRL as core part of mOS
- SLO based meta-Orchestrator
- Federated micro-services//unikernels SEE
- Micro-service sovereignty
- Intent-based migration SDK
- Cybersecurity vertical

Innovation challenges in NEMO

- Federated mNCC offering self-configured/-healing clusters
- Network Control and management IoT/5G/B5G adapters
- IoT/5G Time Sensitive Networking (TSN)

- Policies for optimal micro-services/unikernels migration
- Plugins Lifecycle Manager
- Monetization and Accountability (MOCA)
- Policy Enforcement vertical

Expected activities on "Dissemination and Impact on Standards":
NEMO partners followed the activities of standardisation bodies, which have been identified as relevant to the project developments, namely GAIA-X, AIOTI, ETSI, IETF and 3GPP standardisation. Moreover, the project monitored closely and has active links with clusters and associations in the field of IoT/Edge/Cloud Continuum, communication, software, open source, as well as domains related to the Living Labs, indicatively 5GPPP, 6G-IA, Networld Europe, NGI, DAIRO/BDVA, Eclipse IoT & Edge WG, and European Cloud Edge & IoT Continuum.

There was an initial collaboration with AIOTI and now directly with ISO/IEC (there's an alliance between the 2 bodies).

- Right now the project is directly involved within SC41 activities. The project is represented within the SC41 community by ATOS while many partners are actively contributing such as Synelixis and ASM TERMI.

How the project interacted:

- Promote research results as future standards
- In collaboration with other projects: Preliminary work item (PWI 22) already opened for providing recommendations for a taxonomy and a reference architecture for the continuum. Further interactions with other standardization committees (SCs) are also in place, e.g., for cybersecurity or AI considerations.
- Standalone: Providing a set of patterns to be promoted as standards for future development at vertical level. This is done through AG (Advisory Group) 35.

Timescales for this interaction:

Unfortunately, standardization timelines are longer than a project lifetime. Thus, there are several ongoing activities that will continue even after the end of the project.

- June 2024. Participation in the ISO/IEC plenary meeting (Helsinki) to present TF3 results and request to open a PWI.
- December 2024. PWI approved and work started to convert TF3 results in a standard-compliant document.
- March 2025. Presentation of preliminary work at DISCOVER-US series of webinars (join EU-US collaboration), including specific results from NEMO project.
- June 2025. Participation in the ISO/IEC plenary meeting (Montreal) to present PWI 22 results, as well as NEMO contributions (2 patterns) to AG 35. As a result of this, the PWI was accepted by the SC and an extension of 2 years has been approved. Patterns must be converted to smart standard format (yet to be approved).
- September 2025. Participation in the AIOTI Days as panelists of the Hourglass Model (PWI 22 and patterns will be part of the discussion)
- November 2025 (date not decided yet). Participation in the ISO/IEC plenary meeting (most probably in Berlin) to present updated patterns with the new format. Patterns will be filed and made available.
- June 2027. Presentation of PWI 22 final results ready to be promoted as a standard (including patterns).

Contributions to Standardization:

- Y. Lee. X. Liu, L.M. Contreras, "DC aware TE topology model", draft-llc-teas-dc-aware-topo-model-03 (work in progress), July 2023 (https://www.ietf.org/archive/id/draft-llc-teas-dc-aware-topo-model-03.txt)
- L.M. Contreras, X. Liu, "DC aware TE topology model", draft-llc-teas-dc-aware-topo-model-04 (work in progress), March 2025, (https://datatracker.ietf.org/doc/draft-llc-teas-dc-aware-topo-model/).
- L.M. Contreras, M. Boucadair, D. Lopez, C.J. Bernardos, "An Evolution of Cooperating Layered Architecture for SDN (CLAS) for Compute and Data Awareness", draft-contreras-coinrg-clas-evolution-01 (work in progress), July 2023 (https://www.ietf.org/archive/id/draft-contreras-coinrg-clas-evolution-01.txt).
- Luis M. Contreras, Paolo Lucente. "Interconnection Intents" (work in progress) (https://www.ietf.org/archive/id/draft-contreras-nmrg-interconnection-intents-04.txt).
- Luis M. Contreras, Paolo Lucente, Terpsichori Helen Velivassaki. "Interconnection Intents" (work in progress) (https://www.ietf.org/archive/id/draft-contreras-nmrg-interconnection-intents-05.txt).
- NEMO, as a member of the EUCloudEdgeIoT initiative, has participated through different Working Groups on Architecture Task Force 3 which has contributed with primitive work items in ISO PWI-22 Architecture considerations on IoT Edge Cloud[1]. NEMO has contributed in patterns through the Advisory Group (AG35) which contributed to IOS PW41[2].

Scientific Contributions:

- A. d. Rio, D. Jimenez and J. Serrano, "Comparative Analysis of A3C and PPO Algorithms in Reinforcement Learning: A Survey on General Environments," in IEEE Access, vol. 12, pp. 146795-146806, 2024, doi: 10.1109/ACCESS.2024.3472473.
- K. Prousalidis, S. Bourou, ,T.-H. Velivassaki, A. Voulkidis, A. Zachariadi and V. Zachariadis, "Olive Tree Segmentation from UAV Imagery," in Drones, 8(8), 408, 2024, doi: https://doi.org/10.3390/drones8080408.
- R. Martin, I. Vidal and F. Valera, "A software-defined connectivity service for multi-cluster cloud native applications," in Computer Networks, Volume 248, 2024, ISSN 1389-1286, doi: https://doi.org/10.1016/j.comnet.2024.110479.
- R. Rossini et al., "Open Source in NExt Generation Meta Operating Systems (NEMO)," 2024 9th International Conference on Smart and Sustainable Technologies (SpliTech), Bol and Split, Croatia, 2024, pp. 1-5, doi: 10.23919/SpliTech61897.2024.10612369.
- B. C. Yip Hon et al, "Challenger: Blockchain-based Massively Multiplayer Online Game Architecture," 2024.
- Z. Anastasakis, T.-H. Velivassaki,A. Voulkidis, S. Bourou, K. Psychogyios, D. Skias and T. Zahariadis, "FREDY: Federated Resilience Enhanced with Differential Privacy", in Future Internet 15, no. 9, 2023, doi: https://doi.org/10.3390/fi15090296.
- A. d. Rio, J. Serrano, D. Jimenez, L. M. Contreras, F. Alvarez, "Multisite gaming streaming optimization over virtualized 5G environment using Deep Reinforcement Learning techniques," in Computer Networks, Volume 244, 2024, ISSN 1389-1286, doi: https://doi.org/10.1016/j.comnet.2024.110334.
- M. Belesioti et al., "Putting Intelligence into Things: An Overview of Current Architectures", Springer, 2023, doi: 10.1007/978-3-031-34171-7_8.
- I. Chochliouros, et al. "NEMO: Building the Next Generation Meta Operating System," ACM, 2023, doi:10.1145/3624486.3624504.
- J. Klimt, M. Kröning, S. Lankes and A. Monti, "On the Challenge of Sound Code for Operating Systems," in proceedings of the 12th Workshop on Programming Languages and Operating Systems (PLOS '23), ACM, 2023, doi: https://doi.org/10.1145/3623759.3624554.

[1] https://www.iec.ch/dyn/www/f?p=103:38:614053953031768::::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:20486,23,126454
[2] (https://www.iec.ch/dyn/www/f?p=103:38:510268610814004::::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:20486,23,108352

- N. Eiling, M. Kröning, J. Klimt, P. Fensch, S. Lankes and A. Monti, "GPU Acceleration in Unikernels Using Cricket GPU Virtualization," in proceedings of the SC '23 Workshops of the International Conference on High Performance Computing, Network, Storage, and Analysis (SC-W '23), ACM, doi: https://doi.org/10.1145/3624062.3624236.
- A. Pham, M. Potop-Butucaru, S. Tixeuil and S. Fdida, "Data Poisoning Attacks in Gossip Learning," LIP6, Sorbonne Université, CNRS, UMR 7606, 2024.
- R. Rossini et al., "Open Source approach in two metaOS projects", in Proceedings of the 2nd International Workshop on MetaOS for the Cloud-Edge-IoT Continuum (MECC '25), Association for Computing Machinery, doi: https://doi.org/10.1145/3721889.3721930

1.2.3 DOSS: Security-by-design IoT operation with supply chain control

URL/Reference:

https://cordis.europa.eu/project/id/101120270

https://dossproject.eu/

Abstract:

The DOSS project aims to develop a secure-by-design methodology and technology for complex IoT architectures, focusing on supply chain monitoring, component testing, and architecture modeling. The project will establish a "Supply Trust Chain" to facilitate secure information exchange in the IoT supply chain. It will also include security verification of hardware and software components, define a "Device Security Passport" for third-party hardware, and test simulate IoT architectures, employ AI to model attack scenarios, and provide pre-certification for IoT architectures based on security standards and KPIs. The project will validate the procedures and technology in automotive, energy, and smart home domains and contribute to policy recommendations and standardization efforts.

Starting and (target) end time of project:

01/09/2023 – 31/08/2026

IoT and/or Edge Computing research challenges:

- Advanced security-by-design methodology for complex IoT architectures
- Establishing a "Supply Trust Chain" for secure information exchange in the IoT supply chain
- Designing a "Digital Cybersecurity Twin" to simulate IoT architectures, model attack scenarios, and enable information sharing with the supply chain
- Defining a "Device Security Passport" (DSP) as a standardized mechanism to assess and ensure the security of third-party hardware and its components used in IoT architectures
- Designing a "Component Tester" to test and assess third-party software, open-source applications, and in-house developments to ensure their security and suitability for integration into the modelled IoT architectures

Expected activities on "Dissemination and Impact on Standards":

DOSS partners are active in the following SDOs and standardization interest groups:

- AIOTI
- CEN
- DIN
- ENISA
- ETSI

- EUOS
- Global Platform
- NIST
- StandICT

The objective is to provide context-relevant recommendations for future standards and submit project results for consideration by relevant working groups. The consortium already has several contacts in the relevant SDOs and standardization interest groups as listed in 1. By actively engaging with the mentioned SDOs and standardization interest groups, the project seeks to ensure that both the Supply Trust Chain concept/technology and the DSP specifications reach a mature stage that aligns with standard requirements. In addition, collected findings can be further processed and published in SDOs. It is planned, for example, to achieve this by creating technical specifications and technical reports in ETSI technical committees, for example for the Component Tester or the Digital Cybersecurity Twin.

The work, which is oriented towards ETSI and DIN, for example, will start as early as the beginning of 2024. The DOSS project aims to start the work as early as possible to be able to complete it within the project duration and thus generate an immediate impact.

1.2.4 NEPHELE: A lightweight software stack and synergetic meta-orchestration framework for the next generation compute continuum

URL/Reference:

https://nephele-project.eu/

https://cordis.europa.eu/project/id/101070487

Abstract:

The next generation IoT and Edge Computing technologies are evolving at a rapid pace. This evolution moves in parallel with the increase in the heterogeneity of the IoT technologies. To efficiently manage hyper-distributed applications across heterogeneous infrastructure in the Cloud-to-Edge-to-IoT continuum, convergence of IoT technologies and development of synergetic orchestration mechanisms has to take place. NEPHELE aims to tackle these challenges and enable the efficient, reliable and secure end-to-end orchestration of hyper-distributed applications over programmable infrastructure across the compute continuum, considering the integration of IoT devices with the rest part of the infrastructure. NEPHELE aims to introduce two core innovations, namely: (i) an IoT and edge computing software stack for leveraging virtualization of IoT devices at the edge part of the infrastructure and supporting openness and interoperability aspects in a device-independent way; and (ii) a synergetic meta-orchestration framework for managing the coordination between cloud and edge computing orchestration platforms, through high-level scheduling supervision and definition, based on the adoption of a "system of systems" approach. A set of use cases across various vertical industries are considered, including disaster management, logistic operations in ports, energy management in smart buildings and remote healthcare services.

Starting and (target) end time of project:

01/09/2022 – 30/09/2025

IoT and/or Edge Computing research challenges:

Two main challenges are considered in NEPHELE.

The first challenge regards the need for convergence of IoT technologies based on novel architectural approaches, able to guarantee continuous and seamless openness and interoperability of the plethora of existing and emerging solutions, models and devices, while enabling analytics for their lifecycle's costs, measured in time and resources (from seconds or watts to CO2). To tackle this challenge, NEPHELE aims to develop an IoT and edge computing software stack, called as VOStack. VOStack is a multi-layer stack that covers IoT interoperability and openness aspects in two levels, namely (i) the IoT device level based on the provision of virtual counterparts of IoT devices and (ii) the level of integration of IoT functions with edge and cloud computing applications.

By supporting these two levels, we aim to achieve, on one hand, convergence of IoT technologies considering both protocol and semantic interoperability challenges, and, on the other hand, enhanced interoperability of IoT technologies with emerging edge and cloud computing specifications.

The second challenge regards the need for the provision of an integrated meta-orchestration environment for hyper-distributed applications, where a synergy between cloud and edge computing orchestration platforms takes place to optimally manage applications' end-to-end deployment and data provision over the continuum. Nowadays, multiple orchestration platforms exist, targeting orchestration needs on the cloud, the edge or the IoT part of the compute continuum. Such frameworks are not suitable per se for tackling the orchestration challenges of hyper-distributed applications, since they usually have the responsibility but not the control of the reserved resources across the continuum, nor the knowledge and authorization for proper horizontal scheduling of the various application parts. Furthermore, as applications become more distributed, the coherence of failures begins to decrease, while the distance between cause and effect increases. A meta-orchestration level is required for enabling the synergy among different orchestration systems/platforms by generalizing and modelling their orchestration modules. In NEPHELE, the meta-orchestration framework will follow a "system of systems" approach, where a set of complex systems (orchestration modules in the various parts of the continuum) are managed by a large-scale concurrent and distributed system.

Expected activities on "Dissemination and Impact on Standards":

Based on the specification of the NEPHELE VOStack, two instantiations are under development that aim to be aligned with the specifications of the W3C Web of Things (WoT) working group and the OMA LwM2M specifications respectively. Interaction with other standardization bodies is also targeted (e.g., participation at the ETSI IoT Conference 2023). Contribution to working documents of AIOTI is also highly envisaged.

In terms of implementation, the software releases are made available in the GitLab repository of Eclipse Research Labs[3]. A stable release of VOStack is envisaged by the end of October 2023, while a continuous development and integration approach is followed in NEPHELE.

Interaction with the participants of the W3C WoT working group is in progress mainly through dedicated conference calls, while participation to related events and conferences is targeted (e.g., ETSI IoT conference 2023, EclipseCon 2023). The interaction will be active during the lifetime of the NEPHELE project, while a sustainability plan will be provided for maintaining and extending this interaction upon the lifetime of the project.

[3] https://gitlab.eclipse.org/eclipse-research-labs

1.2.5 AIMS5.0: Artificial Intelligence in Manufacturing leading to Sustainability and Industry5.0

URL/Reference:

https://www.aims50.eu/

https://cordis.europa.eu/project/id/101112089

Abstract:

AIMS5.0, a collaborative Innovation Action, aims at strengthening European digital sovereignty in comprehensively sustainable production. The project and its well-balanced consortium with 53 ambitious academic and industry partners intends to boost the economy by adopting, extending and implementing AI-enabled hardware and software components and systems across the whole industrial value chain.

New technologies from IoT and based on Semantic Web ontologies, enhanced Digital Twin, ML (Machine Learning) and AI (Artificial Intelligence) will help European manufacturers to shift from Industry4.0 to Industry5.0, creating human-centric workplace conditions and a climate-friendly production. Above all, sustainability and resilience will be improved.

We will see AI enabled fabs way more productive and eco-efficient. This will go hand in hand with shorter supply chains, a better resilience, a higher sustainability and global competitiveness keeping the main production in Europe.

AIMS5.0 a collaborative Innovation Action aims at strengthening European digital sovereignty in comprehensively sustainable production, by adopting, extending and implementing AI-enabled hardware and software components and systems across the whole industrial value chain to further increase the overall efficiency.

Vulnerability of existing supply chains in crisis shows the need for shorter supply chains and for keeping production in Europe. AI enabled fabs will be given more output and higher sustainability, which makes them more competitive on a global scale.

20 use cases in 9 industrial domains will validate the project's findings in an interdisciplinary manner. A professional dissemination, communication, exploitation and standardization will ensure the highest impact possible.

Fields of Science (EU Cordis assignment): Internet of things, AI, semantic web, ontology

Starting and (target) end time of project:

01/05/2023 – 30/04/2026

IoT and/or Edge Computing research challenges:

A selection of challenges to meet (focus on IoT, Digital Twin, Edge, Edge-AI; of course, there are other challenges too):

- AI-Ready Edge Hardware ("AI at the Edge"): creation of necessary components to run the edge parts of the AIMS5.0 systems.
- Efficient system integration and communication: co-design of the edge and cloud parts of use-case demonstrators.
- Test and Validation environment (Digital Twin): a powerful test and validation environment to assess a planned system environment before performing costly installation procedures.
- Micro-service-based edge System of Systems (SoS) architectures and implementation platform **extended** for efficient integration of AI algorithms and AI hardware. Challenges addressed are related to system of systems (SoS) composability and associated tools and management support enabling efficient **integration and deployment at the edge.**

- Implementing Internet of Everything (a network of connections between people, things, data, and processes that provide general intelligence and improved cognition across the networked environment, for Industry 5.0, across domains and applications)

- Trustworthiness of IoT, Digital Twin and AI systems

Expected activities on "Dissemination and Impact on Standards":

Dissemination, exploitation and standardization are combined in a dedicated work package to increase/demonstrate the impact of AIMS5.0. It includes also the societal, ethical and environmental aspects ("Green Deal", Resilience, Sustainability). Main tasks and standardization activities are:

- Raise awareness of existing and evolving standards in the addressed areas of interest (including IoT, Edge/cloud computing, connectivity, AI at the edge, Safety, Cybersecurity, Trustworthiness, and others) and their application, including ethical and societal aspects.

- Collaborate with/participate in/join relevant standardization groups in ISO, IEC, ETSI, and ISO/IEC JTC1 SC41 (IoT and Digital Twin), SC 38 (Cloud computing and distributed platforms) and SC42 (AI) and related automotive standardization groups in ISO TC22 SC32 (road vehicles, e.g., automated driving systems, connected vehicles end-to-end safety), ISO TC22 SC31 (Extended Vehicles) and particularly Smart manufacturing standards (IEC TC65 WG 23, WG 24 and JWG 21, ISO TC184 (Industrial automation), ISO TC299 (Robotics) and IEC TC56 (Dependability) (not exhaustive). The goal is to be pre-informed on evolving standards (to become "early adopters", facilitate futureproof development) as well as transferring experiences and results from AIMS5.0 (development, use cases) to standardization. Key issues are:

  - Trustworthiness of IoT, Digital twin and AI systems
  - Safety, security, performance and dependability of components and systems (of systems).
  - Acceptance, trust & ethics for explainable industrial AI leading to human-centred sustainable manufacturing.
- Dissemination of the results among stakeholders, including standardization committees and authorities, and the industrial and scientific communities on fares, exhibitions and conferences.

- Align stakeholders and relevant groups in the semiconductor industry, industrial production, logistics, supply chain management, the automotive, aviation, machinery and other industries (e.g., food production, exo-skeleton robots to enhance human capabilities, luminaire manufacturing, consumer electronics) to support the Green-Deal initiative, initiatives towards sustainable industry 5.0, Sustainable Development Goals and a resilient society and economy.

- Collaboration between related projects particularly in the standardization area, achieve and show synergies (e.g., done in this context at the EEAI-Conference and other occasions for the cluster AI4CSM, AIMS5.0, (Edge-)A-IQ Ready and PowerizeD, all KDT/Chips JU projects of the EU Horizon Europe Programme).

Acknowledgement:

The project has been accepted for funding within the Key Digital Technologies Joint Undertaking (Chips JU), a public-private partnership in collaboration with the HORIZON Europe Framework Programme and the national Authorities from 12 involved countries under grant agreement number 101112089.

1.2.6 DS2: Data Space, Data Share 2.0

URL/Reference:

www.dataspace2.eu

Abstract:

DS2 brings together experts from various fields across Europe to ensure smooth and secure data sharing, aggregation and tracking, while respecting data owners' rights and adhering to European data regulations. Our modular software infrastructure connects different data sources, facilitating efficient cross-sector data sharing with ease.

Using the Intersector Data Space Toolkit (IDT), DS2 enables seamless communication between data sources. The IDT Toolkit consists of a Broker for fail-safe network operation and various modules for executing complex data lifecycles, including filtering and labelling, with options for both automated and human-in-the-loop processes.

In the context of AIOTI DS2 will accommodate far-edge-to-cloud, supporting the collection, processing, and the analysis of data from edged devices (IoT nodes) and their integration with cloud-based data processing and analysis systems. This concept is further enhanced through the use of data curation and data transformation technologies that reduce human intervention to a minimum. AI and Machine Learning tools will be developed to monitor data quality, that help to improve the efficiency and accuracy of data, enable data healing, and provide edge classification of data.

The project will be co-created and trialled via 3 use cases – City Scape, Green Deal, and Precision Agriculture – to demonstrate its effectiveness across sectors.

Starting and (target) end time of project:

01/01/2024 – 31/12/2026

IoT and/or Edge Computing research challenges:

IoT and Edge Computing research challenges encountered in DS2 include:

- The lack of IoT infrastructure and IoT sensors in some pilot locations,
- Diverse IoT devices and their capabilities,
- Developing an interconnected framework that allows smart devices, edge computing units, and cloud platforms to work together effortlessly
- Reducing the resources needed for services that operate throughout the IoT and edge,
- Ensuring privacy and security of data,
- Ensuring control over data.

Expected activities on "Dissemination and Impact on Standards":

- In terms of standardization activities, DS2 will interact with different standardisation bodies & policy makers such as ISO, IEEE, ETSI, DIN, CEN CENELEC, IEC, W3C, DIN, DKE.
- DS2 hopes to provide standardisation input to e.g. IEEE, ETSI, DIN, CEN CENELEC, etc. for various topics including 1 potential CEN CWA (CEN Workshop Agreement).
- Furthermore, DS2 will transfer its know-how to EC communities & networks (BDVA, IDSA, GAIA-X, FIWARE, AIoTI) outreached during the project and will investigate open-source solutions with other projects such AI4EU.

1.2.7 ODEON: federated data and intelligence Orchestration & sharing for the Digital Energy transitiON

URL/Reference:

https://odeonproject.eu/

https://cordis.europa.eu/project/id/101136128

Abstract:

Even if significant progress has been made towards the Twin Transition, the recent energy crisis revealed the EU energy system's vulnerability and dependence on external energy sources and highlighted the need for intensifying the integration of RES in electricity, transport and building (heating) sectors. To achieve on this, the energy system shall transform from a centralised/fossil-fuel-based to an energy efficient, RES-based and interdependent system, operating with a high degree of flexibility offered by distributed assets. ODEON is conceived under the principle that this can only be realized through the creation of an inclusive ecosystem of stakeholders characterized a mesh of Data, Intelligence, Service and Market flows, jointly enabling the resilient operation of the energy system under increased RES integration and distributed flexibility.

ODEON introduces a sound, reliable, scalable and openly accessible federated technological framework (i.e. ODEON Cloud-Edge Data and Intelligence Service Platform and corresponding Federated Energy Data Spaces. AI Containers, Smart Data/AIOps orchestrators) for the delivery of a wealth of services addressing the complete life-cycle of Data/AIOps and their smart spawn in federated environments and infrastructures across the continuum. It will integrate highly reliable and secure federated data management, processing, sharing and intelligence services, enabling the energy value chain actors and 3rd parties to engage in data/intelligence sharing, towards the delivery of innovative data-driven and intelligence-powered energy services in accordance to the objectives set by the Digitalisation of Energy Action Plan. ODEON results will be extensively validated in 5 large-scale demonstration sites in Greece, Spain, France, Denmark and Ireland involving all required value chain actors, diverse assets, heterogeneous grid and market contexts, and multi-variate climatic and socio-economic characteristics to support its successful replication and market uptake.

Starting and (target) end time of project:

01/01/2024 – 31/12/2027

IoT and/or Edge Computing research challenges:

- Federated Energy Data Spaces
- AI-enabled orchestration mechanisms to control both cloud computing resources and edge/IoT devices supporting automated deployments and dynamic offload of DataOps and AIOps.
- Development of standards-based open IoT Gateway to streamline IoT devices installed at the edge nodes.

Expected activities on "Dissemination and Impact on Standards":

- Project Liaison to CEN-CENELEC/ETSI
- DAIRO WG on Energy Data/Spaces (contributions and enhancements proposal to standards in terms of notation, data model, service type). The timescales are to be defined.
- BRIDGE Data Management WG (contributions and enhancements proposal to standards in terms of notation, data model, service type). The timescales are to be defined.

- GAIA-X Energy Working Group (contributions and enhancements proposal to standards in terms of notation, data model, service type). The timescales are to be defined.

ODEON intends to participate in the Energy related working groups of the before mentioned initiatives. Its participation will depend on the different action plan defined of the initiatives.

The timescale to these interactions goes from the beginning of the project (January 2024) to the end of the project (December 2027). These interactions will be aligned to the different plan's actions.

1.2.8 P2CODE - Programming Platform for Intelligent Collaborative Deployments

URL/Reference:

https://p2code-project.eu/

Abstract:

The P2CODE project aims at innovating and creating a wide-open, secure and trusted IoT-to-edge- to-cloud compute continuum that will realize the true potentials of edge intelligence.

To this aim, the P2CODE project will design and develop an open platform for the deployment and dynamic management of end-user applications, over distributed, heterogeneous and trusted IoT-Edge node infrastructures, with enhanced programmability features and tools. The platform will do so by implementing innovative design approaches and will constitute a fully-integrated infrastructure under the cloud–managed P2CODE architecture.

P2CODE will contribute to the wider scope of reinforcing Europe's position in the market of next generation smart systems (sensors and devices) integrated in an evolving Internet of Things and cyber-physical ecosystems with strong capacities at the edge.

Starting and (target) end time of project:

01/01/2023 – 31/12/2025

IoT and/or Edge Computing research challenges:

Utilities inspection - The objective of Application Area 2 is to create of a prototype digital HV substation.

Technologies/assets involved: High-frequency IoT & industrial sensors, legacy metering equipment, cameras, applications for analytics, predictive maintenance, intruder detection, smart time-scheduling of field works, blockchain, cloud support, programmability features and registration.

P2CODE aims to showcase how to provide advanced industrial services on top of critical infrastructure through a super-slice among core & edge services.

Collection of industrial data from both legacy and new IoT sensing devices

P2CODE Use Case | SMART worker assistant

The objective is to achieve effective management and improving adaptive human-machine interaction in smart factories while boosting healthy operators.

- Deployment of multiple IoT nodes serving as sensor gateways with enhanced on board processing
- Registration of operator status data (biometric, fatigue, cognitive stress)
- Multiple optimized applications over common IoT-edge
- Demonstrate real-time actions through collaborative edge-IoT nodes
- Demonstrate advanced monitoring capabilities

Expected activities on "Dissemination and Impact on Standards":

FIWARE actively collaborates on the P2CODE project, leveraging its open-source platform to maximize its impact. The Foundation's specialization in Context Information Management significantly contributes to the P2CODE platform, which focuses on secure, interoperable data exchanges and the development of a continuum from IoT to edge to cloud computing.

A cornerstone of our contribution is implementing the NGSI-LD API standard by the ETSI ISG CIM group. This standard allows for the provision, consumption, and subscription of context information in diverse scenarios involving multiple stakeholders. Context information is modelled as "digital twins" attributes that represent real-world entities, enhancing real-time data interactions and decision-making processes.

FIWARE's Data Models are not just crucial, they are transformative, ensuring interoperability across various systems and industries, and offering a unified framework for data representation and exchange. Our Smart Data Models program is not just setting a universal standard for data interoperability, it is paving the way for a future where data can be seamlessly shared and utilized across different sectors.

This project not only furthers our technical expertise but also fosters collaboration with partners, contributing to the evolution of the ETSI ISG CIM standards and expanding our influence in the context broker federation context.

1.2.9 OASEES: Open Autonomous programmable cloud appS & smart EdgE Sensors

URL/Reference:

https://oasees-project.eu/

Abstract:

The IoT, connected smart devices interacting with each other and people and collecting all kinds of data, is exploding. The massive amount of data created is processed centrally at the cloud, which helps scalability by providing on-demand access to computing resources. Centralised processing and cloud hosting bring data governance and identity management issues to the user. Similarly, existing edge device authentication solutions require a centralised entity to authenticate data. The EU-funded OASEES project aims to create an open, decentralised, intelligent, programmable edge framework for swarm architectures and applications. The framework will leverage the decentralised autonomous organisation paradigm and integrate human-in-the-loop processes for efficient decision-making.

Starting and (target) end time of project:

01/01/2023 – 31/12/2025

IoT and/or Edge Computing research challenges:

Use case **e-Health**

The outcome of this pilot will be an intelligent edge device capable of sensing, recording and analysing patients' utterances, as well as providing smart, adaptive and personalised guidance on rhythm and intonation. The system will usable both in rehabilitation centres during sessions with therapists and at home. We will adopt a privacy-by-design approach when collecting and treating patients' acoustic data.

Energy

The real-field pilot will demonstrate the capability of deploying and coordinating in a scalable yet near the real-time way the operation and management of swarms of IoT-based devices (e-vehicles), which will be coordinated and programmed through the OASEES SDK and orchestration platform.

Wind Energy

Blockchain can be used in the distribution and operation of IoT networks as a target for DAO paradigms, providing a backend for distributed data structures to securely store transactions in a decentralized manner. Smart metering is a key enabler for integrating smart energy renewable systems to existing infrastructure. In the OASEES project, novel IoT-based meters will be implemented to support on-the-fly programmability, using IoT sound transducer (microphones) applied to wind turbines

Expected activities on "Dissemination and Impact on Standards":

OASEES followed the process to become a project candidate for HSBooster service.: HSBooster service to OASEES The OASEES partners previous experience with standards:

- The participation on behalf of OTE and MonB5G EU project in ETSI ZSM PoC 7 "Zero-touch closedcontrol security management of attacks detection and mitigation" - Demonstration of closed loop automation for mitigating against DDoS attacks from MTC (Machine Type Communication) devices on 5G Core Network (CN) components.

- Project Partner - NCSR Demokritos - member of the ISG MEC.

- CTN-UNE 71/SC 14 "Tecnologías Cuánticas"

- CEN/CLC/JTC 22- Quantum Technologies

- ISO/IEC JTC1/WG 14 OASEES Priority Topics for Standardization:

Recommendation to consider the European standards organization, as CEN (the European Committee for Standardization), CENELEC (European Committee for Electrotechnical Standardization and ETSI, the European Telecommunications Standards Institute), rather than ISO (International Organization for Standardization) o Selected relevant standards: o CEN-CLC/JTC 21 - Artificial Intelligence o CEN/CLC/JTC 22 – Quantum Technologies o CEN-CLC/BTWG 6 – ICT standardization policy Intermediate, Final OASEES Version 1.0 Date 26/04/24 Page | 12 o CTN-UNE 71/SC 14 "Tecnologías cuánticas" o ISO/IEC JTC1/WG 14. o First identification by OASEES related to potential contribution to Standardization: o Quantum Computing (Tecnalia and Fraunhofer from Munich) o Cloud Accelerators / Orchestration – AI o DAO – Digital Autonomous Organization – many areas within this, the main one. HSBooster Expert

Recommendation for OASEES Regarding Potential Contribution to Standardisation In consideration of OASEES's potential contribution to standardisation, it is recommended to focus efforts on engagement with the following: ETSI ISG Working Groups (WGs):

- Topic 3: Edge Infrastructure Sharing and Monetisation. It is advised to convene a Proof of Concept (PoC) team consisting of representatives from NCSRD, IMEC, OTE, and other interested/relevant members of the consortium.

- This team should collaborate to draft and submit a proposal to the ETSI MEC ISG as an initial step towards contributing to standards development. OASEES Consortium members will monitor and/or contribute to the standardisation bodies that align most closely with its interests, while ensuring that the OASEES framework remains consistent with the standards.

The following is a description of the standardisation organisations that are relevant to the project. Proposed Standardisation Developing Organisations:

- 3GPP The 3rd Generation Partnership Project (3GPP) brings together seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC) and provides a stable environment for its members to produce the Technical Reports and Specifications that define 3GPP technologies. 3GPP includes three Technical Specification Groups (TSG), namely: Core Network & Terminals (CT), Services & Systems Aspects (SA), and Radio Access Networks (RAN). Including radio access, core network, and service capabilities, the project provides a comprehensive system description for

mobile telecommunications cellular technologies. 3GPP TSG Service and System Aspects (SA) is responsible for the overall architecture and service capabilities of systems based on 3GPP specifications.

Moreover, The OASEES partners' prior engagement with standards bodies includes:
ETSI MEC ISG membership: NCSR Demokritos is an active member of ETSI's Industry Specification Group on Multi-access Edge Computing (MEC) and co-organized ETSI MEC #40, which delivered the MEC Federation Enablement APIs (GS MEC 040) to support inter-MEC communication and multi-operator collaboration
etsi.org

Dedicated Edge-Security workshop: Within ETSI MEC #40, OASEES hosted the "Cybersecurity at the Edge" workshop (more info here: https://mecwiki.etsi.org/index.php?title=Cybersecurity_at_the_Edge), bringing together experts to define threat models and suitable security enablers for edge deployments.
In addition, OASEES integrates GAIA-X principles throughout its architecture:

- OASEES implements a portable, privacy-preserving identity-federation system for edge devices and services, fully compliant with GAIA-X federation and IDSA trust directives and specifications infrachain.com
- The OASEES SDK provides external APIs and interfaces to publish developed data assets seamlessly to EOSC and GAIA-X
- OASEES aligns its Data Products with the GAIA-X Data Product Description model and populates a federated data catalogue, enabling sovereign data discovery and access .This combined expertise in edge-security standardisation and GAIA-X federation makes OASEES a robust contributor for any next-generation network-security initiative.

1.2.10 OpenSwarm: Orchestration and Programming ENergy-aware and collaborative Swarms With AI-powered Reliable Methods

URL/Reference:

https://openswarm.eu/

Abstract:

Low-power wireless technology tends to be used today for simple monitoring applications, in which raw sensor data is reported periodically to a server for analysis. The ambition of the Horizon Europe OpenSwarm project is to trigger the next revolution in these data-driven systems by developing true collaborative and distributed smart nodes, through groundbreaking R&I in three technological pillars:

- Efficient networking and management of smart nodes
- Collaborative energy-aware Artificial Intelligence (AI)
- Energy-aware swarm programming.

The EU-funded OpenSwarm project aims to take the technology further by developing collaborative and distributed smart nodes. To do so, it will explore efficient networking and management of smart nodes, collaborative energy-aware AI and energy-aware swarm programming. The energy-aware, collaborative swarms will be demonstrated in labs equipped with two 1 000-node test beds. They will then be validated in five real-world use cases in application domains such as industrial, health, environmental and mobility.

Starting and (target) end time of project:

01/01/2023 – 30/04/2026

IoT and/or Edge Computing research challenges:

OpenSwarm is a project dealing exclusively with the internet of things (IoT). OpenSwarm will be developing the technological components to pave the way for future innovations within the IoT. Particular emphasis will be placed on smart sensors, which have the capacity to interact within dynamic, connected networks. The technology is set to revolutionise robotics and OpenSwarm will demonstrate its potential on a range of use cases, with a particular focus on swarm robotics, which involves large numbers of coordinated robot units working together on complex tasks.

OpenSwarm will begin by developing new algorithms with the capacity to reduce the time taken to transfer information between sensors within dynamic networks, aiming for near-real-time.

OpenSwarm will then harness the potential of recent innovations in embedded systems, centred around artificial intelligence for the IoT, giving them significantly higher processing capacities. Lastly, we will develop a specific compiler for programming swarms. This is something that doesn't currently exist.

OpenSwarm is seeking to develop generic solutions that can be configured and adapted for a wide range of uses, the aim being to demonstrate the robustness and effectiveness of their innovations in four sectors: the environment, occupational health and safety, mobility and smart cities.

Expected activities on "Dissemination and Impact on Standards":

A comprehensive dissemination, exploitation, and communication plan (including a diverse range of activities related to standardization, educational and outreach, open science, and startup formations) amplifies the expected impacts of OpenSwarm, achieving a step change enabling novel, future energy-aware swarms of collaborative smart nodes with wide range benefits for the environment, industries, and society.

1.2.11 TaRDIS: Trustworthy and Resilient Decentralised Intelligence for Edge Systems

URL/Reference:

https://www.project-tardis.eu/about-tardis/

Abstract:

Developing and managing distributed systems is a complex task requiring expertise across multiple domains. This complexity considerably increases in swarm systems, which are highly dynamic and heterogeneous and require decentralised solutions that adapt to highly dynamic system conditions. The project TaRDIS focuses on supporting the correct and efficient development of applications for swarms and decentralised distributed systems, by combining a novel programming paradigm with a toolbox for supporting the development and executing of applications.

TaRDIS proposes a language-independent event-driven programming paradigm that exposes, through an event-based interface, distribution abstractions and powerful decentralised machine learning primitives. The programming environment will assist in building correct systems by taking advantage of behavioural types to automatically analyse the component's interactions to ensure correctness-by-design of their applications, taking into account application invariants and the properties of the target execution environment. TaRDIS underlying distributed middleware will provide essential services, including data management and decentralised machine learning components. The middleware will hide the heterogeneity and address the dynamicity of the distributed execution environment by orchestrating and adapting the execution of different application components across devices in an autonomic and intelligent way. TaRDIS results will be integrated in a development environment, and also as standalone tools, both of which can be used for developing applications for swarm systems.

The project results will be validated in the context of four different use cases provided by high impact industrial partners that range from swarms of satellites, decentralised dynamic marketplaces, decentralised machine learning solutions for personal-assistant applications, and the distributed control process of a smart factory.

Starting and (target) end time of project:

01/01/2023 – 31/12/2025

IoT and/or Edge Computing research challenges:

- unforeseen load on the grid due to rising number of Electric Vehicles (EV**)** is a huge concern for Electric Distribution System Operators (DSOs) across Europe since they represent an unforeseen load on the grid. Grid reinforcement becomes risky as investment needs to be placed where demand naturally grows. To solve this charging problem, TaRDIS proposes multi-level smart charging, divided into three core layers: the Edge (HEMS, EV chargers); the Fog (end-users community or building level aggregator); and the Cloud (centralised controlling systems, SCADA).

- Programming abstractions for the cloud–edge continuum

  - The toolbox by defining a high-level approach towards formulating and implementing the behaviour of intelligent, heterogeneous swarm systems; it then continues to provide a set of tools that aid in applying this approach.

Expected activities on "Dissemination and Impact on Standards":

The diverse target groups TaRDIS plans to address, which have a very different level of knowledge and expectations with respect to data-centric research, require the definition and use of tailored mechanisms and tools able to properly convey the right message for each TaRDIS.

Open-source communities and standardisation bodies: Open-source communities, such as CNFC, the Linux Foundation, and Apache (Arrow, Parquet, Ranger, Atlas, Egeria). Standards Developing Organizations (SDOs), such as ETSI, 3GPP, IRTF, etc.

1.2.12 A-IQ Ready: Artificial Intelligence using Quantum measured Information for real-time distributed systems at the edge

URL/Reference:

https://www.aiqready.eu

https://cordis.europa.eu/project/id/101096658

Abstract (IoT project):

The onset of climate change and widespread geopolitical conflicts and social inequalities showcase the need for innovation and change that require a better world.

Global environmental issues, social inequality and geopolitical changes will pose numerous problems for our society in the future. To face these new challenges and deal with them, there is a need to understand and appropriately utilize new digital technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), robotics and biotechnologies.

The EU-funded project A-IQ Ready proposes cutting-edge quantum sensing, edge continuum orchestration of AI and distributed collaborative intelligence technologies to implement the vision of intelligent and autonomous Electronic and Software-Based Systems for the digital age. Intelligent quantum sensing will improve timing and accuracy of autonomous agents and reduce false alarms or misinformation by means of AI and multi-agent system concepts. Edge continuum orchestration by AI will allow decentralizing the development of applications, while ensuring an optimal use of the available resources.

The edge continuum will be equipped with innovative, multi-physical capabilities to sense the environment, distributed intelligence will enable emergent behaviour and massive collaboration of multiple agents towards a common goal.

By exploring the synergies of these cutting-edge technologies through civil safety and security, digital health, smart logistics for supply chains and propulsion use cases, A-IQ Ready will provide revolutionary means for most services and industries. These technologies and their combination will propel the transition to a Europe of Society 5.0.

Starting and (target) end time of project:

01/01/2023 – 31/12/2025

IoT and/or Edge Computing research challenges:

A-IQ Ready will utilize crucial and disruptive technologies in combination to revolutionize most services and industries by its foundational contributions. These are Edge continuum orchestration for AI systems with AI, distributed collaborative intelligence (IoT) and quantum sensing. The work is following 5 objectives:

- Increase sensing accuracy, reliability and trustworthiness in complex environments with new multi-physics (quantum) sensors.
- Provide AI methods for multi-agent autonomy in uncertain environments.
- Provide a reference open AI Edge Continuum platform integrating quantum sensors, neuromorphic (cognitive) computing and AI algorithms at the edge.
- Demonstrate the approach to build the digital society.
- Increase Europe's competitivity in developing a safe, resilient, and prosperous digital society.

Innovations to be evolving are structured into eight groups building clusters of disruptive solutions:

- Safe co-existence of automated and manual transport at industrial sites
- Search & Rescue (SAR) and emergency response for civil safety.
- Digital Health and emergency recognition (for driver and operator)
- Propulsion Health and availability in safety critical systems
- Quantum Sensor for multi-modal, multi-physical sensing at highest precision
- Hybrid Computing (Quantum Computing & High-Performance Computing)
- Cooperative Multi-Agent Systems (Decentralized AI for Emergent Industrial Solutions)
- AI, Architectures, Tools and Methodologies (for open source and cross-domain fertilization)

Expected activities on "Dissemination and Impact on Standards":

Standardization is forming a key activity in A-IQ Ready. It covers activities in the technical area as well as the important aspects of ethical design, societal/human centred aspects of the technologies and intended solutions, and also the environmental impact.

Each of the work packages following the indicated objectives and the solution clusters will on the one hand be supported by the standardization task and on the other hand motivated to

provide input to standardization groups by transferring experiences and results from development and demonstrators.

A-IQ Ready strives to support the EU Policies towards a sustainable, human centric and resilient European Society 5.0, with the goal to achieve wider societal goals beyond jobs and growth, thus supporting the vision as expressed by Ursula von der Leyen in her initial speech on a human centred, sustainable, resilient society and economy, and the Green Deal.

Partners are active in numerous standardization groups of ISO/IEC JTC1 SC41 (IoT and Digital twin), SC42 (AI), SC38 (Cloud computing, Distributed platforms and their application), JTC3 (Quantum technologies, recently founded), but also CEN/CENELEC JTC21 (AI, working for the EC AI Standardization Requests according to the AI-Act), and in many domain-specific AI and IoT standardization groups (ISO TC22 SC32 WG13, Automated Driving Systems; WG 14 Safety and AI Systems; IEC TC62, SC62D Health and REHA Robotics, including AI in medical devices; IEC TC 65 SC65A JWG21 with JTC1 SC42 JWG4 on "Functional safety and AI systems", IEC TC65 WG 23, 24 and JWG21 on Smart manufacturing and Asset Administration Shell, etc.). Impact is expected in both directions: Information flow from evolving standards to project work, and vice versa.

Acknowledgement: The project has been accepted for funding within the Chips JU Programme, a public-private partnership in collaboration with the HORIZON Europe Framework Programme and the national Authorities from 15 involved countries under grant agreement number 101096658.

1.2.13 INSTAR: Shaping international standards for advanced technologies

URL/Reference:

https://www.instarstandards.org/

https://cordis.europa.eu/project/id/101135877/

Abstract (IoT project):

INSTAR is an EU-funded project that aims to support the implementation of Europe's Digital Partnerships and the EU-US TTC by working together with Australia, Canada, Japan, Singapore, South Korea, Taiwan and the USA to drive international common standards for AI, Cybersecurity, Digital ID, Quantum, IoT, 5G, 6G and data technologies. Following the EU Standardisation strategy of February 2022 that "*Europe needs to bring the European angle of standardization at international level, rather than create EU-specific standards.*" (Commissioner Thierry Breton), **INSTAR** helps achieve this by

- **promoting EU's thought leadership for a common ICT standardization vision with strategic international partners** on key advanced technologies,
- shaping the **definition & uptake** of standards in relevant target entities,
- **delivering studies & analyses** on ICT standards,
- **monitoring international standards** in trade & cooperation agreements

INSTAR works with Task Forces built up by a number of European experts in the following areas of advanced technologies to be addressed:

- TF1 – AI: Secure, trustworthy and ethical development and use of AI systems (ML algorithms, neural networks, analytics, autonomous systems), AI Act, ETSI's Operational Coordination Group on AI (OCG AI), CEN/CENELEC, ISO/IEC, and others.
- TF2 – Cybersec-eID: Cybersecurity & electronic identification in industries like healthcare, manufacturing, financial services, energy, automotive European Cyber Resilience Act (CRA).
- TF3 – Data: Data quality, syntactic, semantic and pragmatic characteristics of data (ISO 8000-1), Standards impact on policy & regulation, investment & innovation, cross-industry scenarios.

- TF4 – IoT Edge: Cloud, Edge (near vs. far edge), IoT in smart manufacturing, precision agriculture, mobility, energy grids, smart cities, healthcare etc.
- TF5 – 5G+: Convergence of communications, sensing, sustainable services & AI, Human-centric, cognitive network of networks system.
- TF6 – Quantum: Quantum computing, communication, sensing and cryptography, as well as post-quantum cryptography techniques, Specific focus on technologies that can be integrated into European infrastructure and interoperability aspects.

Key activities include setting up Roadmaps for each area, pointing at priority areas for standardization from the European point of view (ETF – European task Forces of experts) and then aligning with the international partners (ITF – International Task Force) in a collaborative communication process.

Starting and (target) end time of project:

01/01/2024 – 30/06/2026

IoT and/or Edge Computing research challenges:

A key research aspect is not only to set up Roadmaps, identify priorities on international level, and align this with the other dedicated relevant entities in Canada, USA, Japan, Taiwan, Singapore and Australia to form a strategic alliance to shape the international standardization strategies, but also to consider the many overlaps and joint challenges for systems and systems-of-systems raised by the interconnections between various areas of AI, IoT and Edge, cybersecurity, data spaces, communications and so on. The IoT/Edge priorities' Task Force Recommendations on Standardisation Priorities in Cloud, Edge, IoT domain:

Cloud/Edge:

- (IoT) Edge computing on Unmanned Aircraft Systems
- Edge devices and sensors, especially for medical use
- Architecture consideration for IoT, Edge, Cloud
- IoT/CEI reference architecture
- Interoperability of IoT and Edge devices and protocols
- Electrical energy efficient products
- Privacy and Security framework for consumer wireless devices

IoT:

- Guidance on IoT and digital twin integrations in data spaces
- Architecture consideration for IoT, Edge, Cloud
- IoT/CEI reference architecture
- Evaluation schemes for IoT
- Electrical energy efficient products
- Privacy and Security framework for consumer wireless devices

Challenges related to IoT/Edge/Cloud are also addressed in the AI and other roadmaps.

Expected activities on "Dissemination and Impact on Standards":

Since INSTAR particularly addresses the strategic and policy view on standardization, developing roadmaps and building international connections between European Union official entities and the selected international relevant entities mentioned above, there is long term influence on standardization expected. SDOs addressed are ISO, IEC, ISO/IEC JTC1, CEN/CENELEC, ETSI, IEEE, and corresponding partner organizations outside Europe. Dissemination includes webinars, international workshops, activities at conferences and 3rd-party events, and one impact event. The targeted priorities (specific flyers), the ETFs and the roadmaps will be presented and distributed, for comments as well as support for joint standardization activities. This will generate accessible materials like reports and papers and ultimately, a standard dashboard that can provide transparency and help the community and industry to keep up to date with the latest standards in the target technologies.

Acknowledgement: INSTAR is funded by the EC in the Horizon Europe Programme, International cooperation for digital standardization, under "Digital, Industry and Space"(Grant Agrement ID: 101135877).

1.2.14 CORTEX2: Cooperative Real-Time Experiences with Extended reality (HORIZON-CL4-2021-HUMAN-01 "CORTEX2")

URL/Reference:

https://cordis.europa.eu/project/id/101070192

https://cortex2.eu/

Abstract:

Video conferencing and mixed reality are both forms of communication but based on very different technologies. Video conferencing does not provide an in-person feel to meetings and has several other drawbacks. In contrast, mixed reality has emerged as a technology that can provide a genuine feeling of presence, and better collaboration tools. The EU-funded CORTEX² project will bridge the divide between widespread video conferencing tools and innovative XR-based solutions to democratise the adoption of next-generation eXtended Reality tele-cooperation by industrial sectors and SMEs. The initiative will use and extend the widespread Rainbow teleconferencing solution from Alcatel Lucent Enterprise to allow for fully interactive XR-based cooperation. This will be demonstrated in three pilots: industrial production, business meetings, and remote training respectively.

Starting and (target) end time of project:

01/09/2022 – 30/09/2025

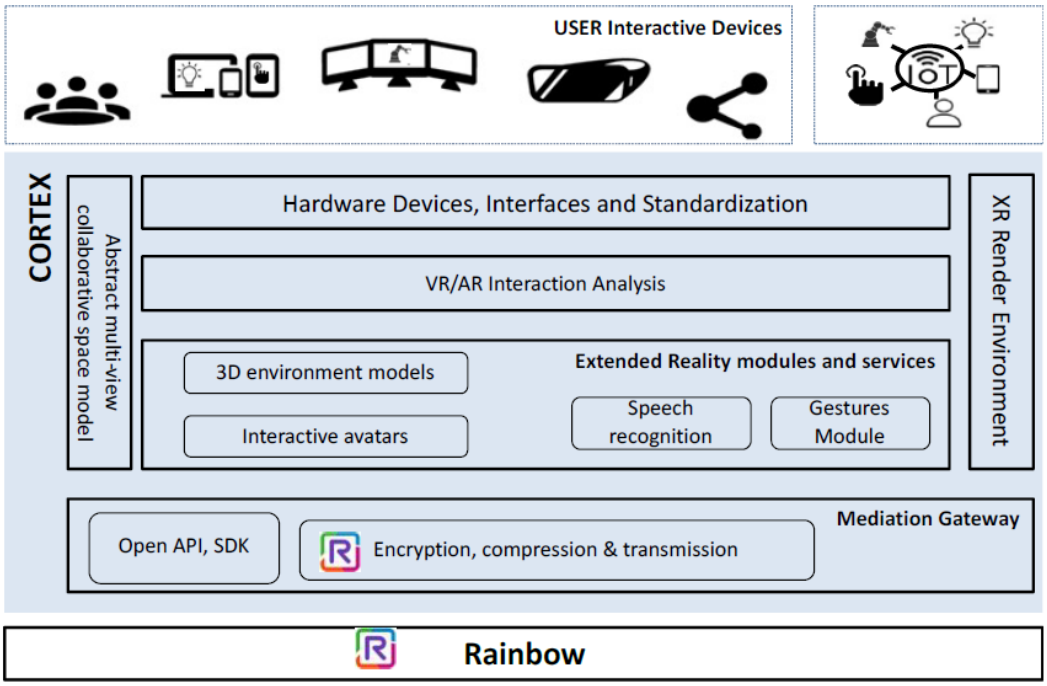
IoT and/or Edge Computing research challenges:

The mission of CORTEX² is to bridge the divide between widespread video-conferencing tools and state-of-the art XR-based solutions, democratising the uptake of next-generation eXtended Reality tele-cooperation among many industrial segments and SMEs. To this aim, our project will provide:

- Full support for AR experience as extension of videoconferencing systems when using heterogeneous services end devices through a novel Mediation Gateway platform.
- Resource-efficient teleconferencing tools through innovative transmission methods and automatic summarization of shared long documents
- User-friendly and powerful XR experiences with instant 3D reconstruction of environments and objects and simplified use of natural gestures in collaborative meetings
- Fusion of vision and audio for multi-channel semantic interpretation and enhanced tools such as dialoguing virtual conversational agents and automatic meeting summarization
- Full integration of IoT devices in XR experiences to optimize interaction with systems and processes.

- Optimal extension possibilities and wide uptake opportunity through the delivery of the core system with open APIs and the organisation of Open calls for extensions towards more technical modules and more use cases in various segments.

To ensure large adoption and fast scaling of our extended remote cooperation solution, we will use the widespread teleconferencing solution Rainbow from Alcatel Lucent Enterprise as a backbone for our innovative extended reality based tele-cooperation concept, which counts today more than 3 million users worldwide. CORTEX will extend Rainbow to allow for fully interactive XR-based cooperation and will be demonstrated in three pilots: industrial production, business meetings and remote training. Wide uptake will be guaranteed by funding of third-party projects to allow for more technical extensions, wider use-cases and deeper evaluation and assessment.



Expected activities on "Dissemination and Impact on Standards":

CORTEX² will set out a roadmap for contributing to different standardisation bodies. This activity will identify significant opportunities to push contributions into future standards, pre-normative activities and open collaborative development environments.

Standards body/forum	Planned CORTEX² contributions
WebRTC Janus	ALE contributes to code and conference of the Janus component. Janus is a core component of the overall solution as it performs the media routing and there may be dependency with the XR behaviours of augmented devices.
AIOTI	As a member of AIOTI and AIOTI WG Standardisation, ICOM will raise .awareness to the role of CORTEX2 in the integration of IoT information in XR applications
ETSI	ICOM is participant of the Experiential Networked Intelligence Industry Specification Group (ENI ISG) and will contribute in intent-based Edge Service Management for resource and energy efficiency considering a Proof of Concept (PoC) for XR services.

1.2.15 NextGEM: Next Generation Integrated Sensing and Analytical System for Monitoring and Assessing Radiofrequency Electromagnetic Field Exposure and Health (HORIZON-HLTH-2021-ENVHLTH-02 "NextGEM")

URL/Reference:

https://cordis.europa.eu/project/id/101057527

https://www.nextgem.eu/

Abstract:

Electromagnetic fields (EMFs) produced by man-made devices are all around us. Especially with the next generation of radiofrequency EMFs, further investigations regarding EMF and possible health risks are required. In this context, the EU-funded NextGEM project will generate relevant knowledge of EMF exposure in residential, public and occupational settings. The project will design a new framework for the generation of health-relevant scientific knowledge and data on new scenarios of exposure to EMF in multiple frequency bands. Its overall aim is to provide a healthy living and working environment, under safe EMF exposure conditions. The project will create the NextGEM Innovation and Knowledge Hub for EMF to provide a standardised way for European regulatory authorities to store and assess project outcomes.

Starting and (target) end time of project:

01/07/2022 – 30/06/2026

IoT and/or Edge Computing research challenges:

While emerging technologies that use radiofrequency electromagnetic fields (EMF, 100 kHz-300 GHz), particularly in telecommunications are vital for the European way of life, there is an increasing consideration of its possible adverse effects to human health and the environment, which may be potentially exacerbated by aggregation of different types of EMF signals. Some concerned citizen groups even perceive fifth generation (5G; 5G New Radio; 5G NR) of networking as a greater threat to public health compared to previous generation systems. The exposure standards issued by the International Commission for Non-Ionizing Radiation Protection (ICNIRP) and the International Committee on Electromagnetic Safety of the Institution of Electrical and Electronic Engineers (ICESIEEE), are set to prevent the occurrence of such effects. These guidelines are based on comprehensive reviews of the relevant scientific literature, providing exposure reference levels and basic restrictions for workers, and for the general population; the latter include an additional safety factor to account for vulnerable groups. Regarding occupational exposures, the European Union (EU) follows ICNIRP guidelines (directive 2013/35/EU). As for the public exposure, the EU published a Recommendation (1999/519/EC) for exposures to EMF (0 Hz to 300 GHz), with limits derived from ICNIRP 1998 guidelines. Due to non-binding nature of the recommendation, the related policies vary across European countries.

Considering all the above, adoption of new telecommunication technologies such as 5G requires extensive investigations regarding potential causal effects between EMF and health to address needs of:

- **Updated appraisal of the scientific evidence:** regarding possible links between EMF exposure level, duration. And health effects for (i) the public (ii) workers, and (iii) vulnerable groups to aid public authorities in the implementation of evidence-based policies, risk assessment and communication.

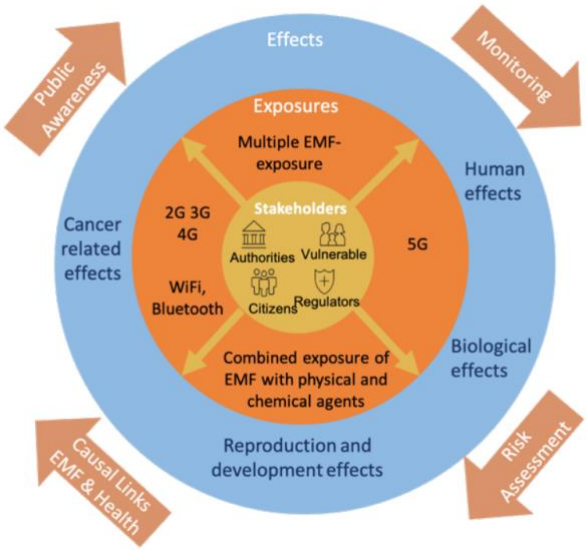
- **New quality criteria, standards, and methodologies:** (i) to assess EMF exposure and health effects and (ii) for biological investigations fulfilling the 3R standards.

- **Understanding interaction mechanisms:** between EMF and biological systems including combined exposures with other agents and with multiple signals.

Adequate scientific communication to improve awareness among authorities, employers and citizens, counteracting EMF misinformation. The NextGEM vision is to assure safety for EU citizens when employing existing and future EMF based telecommunication technologies.

This will be accomplished by generating relevant knowledge that ascertains appropriate prevention and control/actuation actions of EMF exposure in residential, public, and occupational settings.

Fulfilling the vision will provide a healthy living and working environment, under safe EMF exposure conditions, that can be trusted by people and be in line with the regulations and laws of the public authorities. For that, NextGEM will provide a framework for the generation of health-relevant scientific knowledge and data on new scenarios of exposure to EMF in multiple frequency bands and develop and validate tools for evidence-based risk assessment. NextGEM will also create the NextGEM Innovation and Knowledge Hub (NIKH) for EMF and Health offering a standardised way for European regulatory authorities and the scientific community to store and assess project outcomes and provide access to FAIR data. NextGEM is part of the European cluster on EMFs and health.



Expected activities on "Dissemination and Impact on Standards":

NextGEM's main scope is related to compliance and contribution to the development of quality criteria and standards (CEN/ISO), to updating of EU recommendations/directives and international guidelines (ICNIRP), to establish links with the WHO and other international and national organizations. Its KPIs shall be scrutinised against rationalized contributions and established links to international and national organizations, working groups and standardisation bodies (e.g. WHO, ICNIRP, ETSI, IEEE, ISO).

Conscious of the importance of producing high quality research leading to interpretable and conclusive results, NextGEM will implement quality assurance procedures during experimental work and publish them in peer review journals. These procedures will be defined within T1.4 and implemented within T8.4. The work will be carried out in collaboration with the DMP Task Force, as described in 1.2.10. SC being accredited 17025, ISO 15189 and ISO 17043, external auditors will check the organisational ISO 9001-like and ensure the quality at this level: for example, supplier evaluation and staff training. This will concern implementation of GLP-based SOPs for detailing laboratory experiments, study protocols for human studies and calibration of equipment. Moreover, selected conditions of in vitro studies will be replicated independently in another laboratory involved in the project (external verification).

Related to exposure assessment and modelling, Modelling of the environment with the aim of assessing realistic statistical exposure models (T3.1) and validation with in-situ measurements and personal exposure assessment through the development of dedicated sensors (T3.3) will be performed based on recognised methodologies for exposure assessment, in compliance with ICNIRP guidelines.

NextGEM will also contribute information that can be used as input for the standardisation processes in Technical Committees TC106X of CENELEC and IEC, especially for assessment (through measurement and/or calculation) of exposure as defined in ICNIRP 2020.

In addition, NextGEM will also contribute by generating new data and methodologies to be used for the critical review of literature on EMFs and health risk assessment through the involvement of CNR and ISS in international working groups such as WHO (The International EMF Project) and Swedish Radiation Safety Authority (Scientific Council on EMF).

1.2.16 PEDvolution: Interoperable solutions to streamline PED evolution and cross-sectoral integration (HORIZON-CL5-2023-D4-01 "PEDvolution")

URL/Reference:

https://cordis.europa.eu/project/id/101138472

https://pedvolution.eu/

Abstract:

In urban energy transitions, positive energy districts (PEDs) are constantly evolving due to environmental changes. This presents a significant challenge as PEDs must adapt to evolving social contexts, legislation, energy markets, technologies and energy prices, among others. Despite PEDs' potential, their effectiveness is hindered by this ever-changing landscape. In this context, the EU-funded PEDvolution project will integrate PEDs with social, technological, interoperability and market factors. Through seven interoperable solutions, including planning tools and social innovation strategies, PEDvolution aims to enhance PED readiness and adaptability. Real-life PEDs across Europe will serve as testing grounds, fostering replication and mainstreaming.

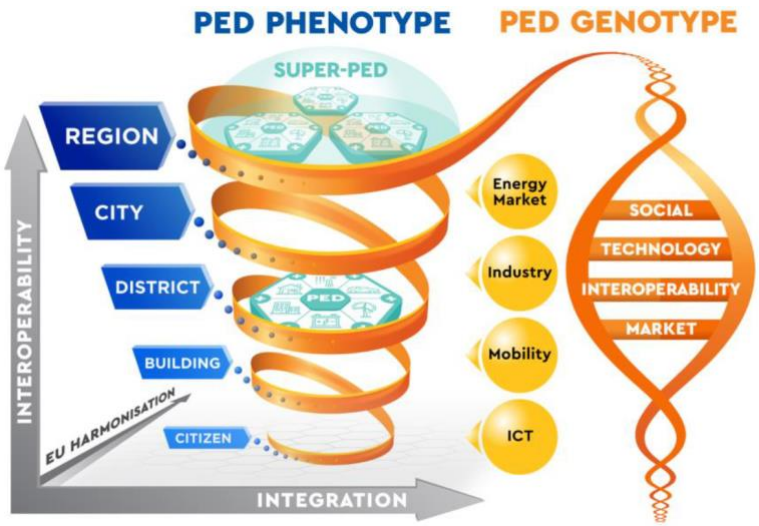
Starting and (target) end time of project:

01/01/2024 – 31/12/2026

IoT and/or Edge Computing research challenges:

The pinnacle of community driven urban energy transition is Positive Energy Districts (PED). They improve energy efficiency, integrate local renewables and excess heat more effectively and enable interaction with the energy and non-energy sectors like mobility, ICT and industry. A crucial, and often neglected complication is that PEDs are in constant evolution. This is due to ever-evolving changes in their environment: social context, legislation, energy market, increased electric vehicles, etc. As such, there is a strong analogy with the theory of evolution. Although the DNA between PEDs varies, the implementation and evolution of different PEDs is not a process of chance: the environment determines the probability of success in the urban energy transition.

The PEDvolution project paves the way for cross-sectoral integration of ever-evolving PEDs. This over a duration of three years, consisting of three consecutive phases: analyse, co-develop and demonstrate. European pioneers in PED conceptualisation, implementation and tool development will co-develop and implement seven interoperable solutions accommodating the constant evolution of PEDs: 1) PED Design and Planning Toolset, 2) PED Readiness Assessment, 3) Dynamic Decision Support Guideline for PED Development, 4) PED Energy Manager, 5) Data Exchange, Integration and Interoperability Platform, 6) PED Business Models, 7) Social Innovation tool.



These PEDvolution solutions will evaluate and improve the 'PED Readiness Level' according to the four genes of the PED genotype: social, technology, interoperability, and market. These are influenced by their interaction within the PED and its environment (PED phenotype).

Expected activities on "Dissemination and Impact on Standards":

BRIDGE will aim to overcome regulatory barriers can be highly country dependent if the right legislative frameworks are not developed at EU level. Harmonisation of requirements in the electricity markets is key for the development of robust business models. To achieve this aim, the project will provide recommendations on the regulatory barriers and potential risks of existing legislation in the commercial implementation of the PEDvolution EU-wide. We will share findings with the policy-making community at EU level, including BRIDGE, energy communities and PEDs networks, TSO and DSO associations and European Commission. Project partners are largely involved in multiple EU and international initiatives, including the three Green Deal Area 4.1 sister projects, BRIDGE, AIOTI, IEA Annex 83, JPI Urban Europe, PED-EU-NET (COST), as well as with interoperability and standardization initiatives and national/international bodies (InterConnect, FlexCommunity.eu). Early networking activities of PEDvolution will serve to take advantage from other running initiatives' results, regarding exploitation and replication potential.

Liaison with these initiatives will play an important role in the development of the PED Readiness Assessment methodology aimed to support PEDs on the energy transition, guiding them on their pathway to fulfil their goals and better adapt to a challenging environment. In phase 1 of the project, PED-RA (as well as the other PEDvolution solutions) will be co-designed. In this phase BRIDGE, AIOTI and other EU initiatives will be approached, and existing knowledge gathered. In phase 2, PED-RA will be co-developed in close cooperation with PEDvolution partners, co-developer PEDs and BRIDGE (and all entities engaged through T11.3). In phase 3, results of the testing and validation of the PED-RA in the PEDs will be presented to BRIDGE and other EU-initiatives to further improve and discuss the potential standardisation and replication of this results around Europe.

PEDvolution will support the provision of advice and evidence for EU policy making through its active involvement in the BRIDGE initiative Data Management Working Group (ICOM member of the WG), the BRIDGE Consumer and Citizen engagement WG (SIN leader of the WG) and BRIDGE Business Models WG (SIN member of the WG). Involvement in BRIDGE will also include participation to the BRIDGE annual general assembly, contributing to its annual work programme and related reports and exchange of experiences and best practices with other projects. Through different AIOTI WG (the most relevant is WG Energy) PEDvolution, and namely INLE who is AIOTI member, can contribute to: research agenda on energy, buildings; IoT vision and roadmap relating to energy efficiency in buildings; energy efficiency and integration of local renewables and local excess heat sources within the district; research initiatives and research concept continuation based on current and future energy efficiency targets; contribute to environmental/energy related policies.

1.2.17 ENACT (HE CL1) Environmental Effect on Health Care and Wellbeing and Active Interventions

URL/Reference:

- https://cordis.europa.eu/project/id/101157151
- https://enact-he.eu

Abstract:

Non-communicable diseases (NCDs) account for 80% of the disease burden as well as for many premature deaths in the EU; diminishing the citizens' quality of life, life expectancy and increasing the financial burden (from those affected to the health system). During the last 3-decade environmental stressors have been addressed through numerous studies, which have raised concerns about the detrimental effects of the environment on human health. Most evaluated environmental stressors are air temperature, particulate and gaseous air pollutants, urban noise, food pollutants and radiation. By end of 2022, air pollution was reported to be responsible of an excess mortality of 311.000 people per year in the UE-27, driving not only premature deaths but also an increased risk of vascular diseases such as ischemic heart disease, stroke, and other non-communicable non-vascular diseases like chronic respiratory diseases or depression. Some newly considered stressors such as electromagnetic field, and light exposure are also susceptible to affect human health (e.g. ocular and dermatological NCD diseases).

ENACT aims at building a pathway to generate clinical, technological, and economic short & long-term impact targeting local and regional stakeholders and create impact by: developing a state-of-the-art environmental risk score and analyser driven framework and platform to predict, monitor and prevent the exposomic risk of acute and chronic health conditions of chronic vascular and non-vascular NCDs.

This shall be based on collection of diverse IoT environmental multiparametric data from a variety of sources, ranging from official data from European Environmental Agency (EEA) and National Agencies, participatory data from Open Data Repositories, data from Earth Observation (e.g. Copernicus) and in-situ indoor/outdoor sensors custom developed in the ENACT project. Such a data will be correlated using both deterministic and Artificial Intelligence algorithms with physiological IoT data from wearables and in-situ sensors monitoring wellbeing and health condition of test subjects in five major representative cities across Europe, thus to determine causality relationships among environmental stressors and physiological conditions, looking into ways of reducing risk factors and improving health and wellbeing.

The new exposomic risk scores and analysers are being developed to support (a) patients, (b) health professionals/hospitals, and (c) policy makers; aiming at reducing the human and financial burden of NCD, considering potential individual vulnerability factors, and reinforcing both a clinical and a policy implementation that enables prevention and disease management for higher quality of life.

Starting and (target) end time of project:

01/01/2025 – 30/06/2028

IoT and/or Edge Computing research challenges:

Environmental stressors share some common properties; all can promote both chronic and acute diseases and their health effects are related to the concentration of exposure, following a linear or a curvilinear dose-effect relationship. However, still several challenges need to be overcome for elucidating their role. In the case of fine particle pollutants or radiation for example, there is no clear threshold of effect appearance. In other cases, such as the ocular diseases, Ophthalmoscopy (Fundoscopy) and Optical Coherence Tomography (OCT) are the only ways to detect retinal damage only in progressive stage in a less invasive and more comfortable manner.

However, current OCT devices and ophthalmoscopes are still invasive, and there have been concerns about their accuracy and cost. Similar is the case of dermatological diseases (biopsy and dermascopy still invasive). Non-invasive measurement systems have not yet been achieved and there is a lack of representative data for Artificial Intelligence (AI) model training and retraining that address data security and privacy concerns. In addition, even though the health effects of environment are well documented, the understanding of the effects of the environment on NCDs is limited and a holistic and coordinated approach to prevention and care is still an underinvested area; this is potentially driven by several factors:

- Most of the studies have focused on the effects of one single type of pollutant or stressor. Consequently, the synergistic effects of exposure to multiple environmental stressors are not enough addressed.
- most of the scientific literature regarding the effects of air pollution and noise relies on a quantitative assessment, considering only the concentration of pollutants or the level of noise exposure
- Very few studies have until now considered some possible predispositions to the effects of environment
- There is still a lack of evidence on the environmental impact of the healthcare sector, and a lack of standard methods and reliable tools for collecting data on emissions, consumption, and waste generation.
- Most technological tools for hospital management (e.g., patient workflow management, clinical engineering tools) do not account for analysing the environmental impact.
- Despite dedicated environmental policy interventions, their application is hampered by the lack of implementational protocols guiding healthcare decision-makers and operators in greening hospitals.

While environmental management systems standards exist (e.g., ISO 14001:2015, ISO 14040:2016, etc), they are not compulsory for healthcare organizations. Overall, there is a global lack of communication and consensual approaches between experts in environmental sciences and policies and healthcare experts. Furthermore, very few studies embodied a co-creation and a bottom-up approach capable of eliciting and understanding the real stakeholders' needs and expectations at their different levels to support a positive societal impact.

Currently, to reduce NCD risk main efforts are focused on achieving primary disease prevention. The current guidelines recommend the use of standardized risk estimation tools or calculators that are based on risk-scoring algorithms and estimate the 10-year risk of a first NCD event, enabling physicians to suggest lifestyle modifications to individuals at risk and guide preventive treatment. Although very beneficial, these scoring tools suffer from several limitations, the most important of which is their low sensitivity.

Another prime limitation of these tools is that the number of parameters they consider is very restricted. Most importantly, the current models are mainly directed at physicians and do not incorporate real-time data nor dynamic and/or interactive capabilities that could continuously assess NCD risk and inform both physicians/healthcare systems and individuals, or just individuals themselves, about their health risk.

Hence, there is a pressing need to critically analyse environmental parameters and their influence on well-being, by addressing in a coupled manner their short-term and long-term effects on health, using cutting-edge strategies and techniques, and involving from the outset all levels of key stakeholders. As presented in detail in the following, the ENACT proposal has been designed to respond to these challenges looking at, firstly, complex interactions between pollutants and causalities acting at both the population and individual level, and secondly the link with individual medical and socioeconomic vulnerabilities. ENACT will use risk modelling based on the risk of hospitalization for acute states of NCDs while linking it with the environmental events, to capture through time how pollutants and environment affect important NCD states that need intervention.

The list of addressed IoT Research Challenges includes:

- *Data Heterogeneity & Integration:* collecting and integrating multiparametric environmental and physiological IoT data from diverse sources (EEA, Copernicus, Open Data, in-situ sensors, wearables).
- *Sensor Development & Deployment:* developing and deploying custom in-situ indoor/outdoor sensors to monitor a wide range of environmental stressors and physiological responses.
- *Non-Invasive Monitoring:* lack of accurate, cost-effective, non-invasive IoT-based monitoring tools for health conditions like retinal and dermatological diseases.
- *Data Gaps & Accessibility*: lack of representative and comprehensive datasets for different environmental stressors and their effects on health.

Additional Edge Computing Research Challenges cover:

- *Real-Time Risk Assessment*: need for real-time data processing at the edge to enable dynamic health risk estimation and immediate interventions.
- *Data Privacy & Security:* ensuring secure, localized data processing at the edge to protect sensitive physiological and environmental data.
- *Latency & Reliability:* managing low-latency, high-reliability data communication between distributed IoT devices and health information systems.
- *Resource Constraints:* processing complex AI models on edge devices with limited computational and energy resources.

Moreover, Artificial Intelligence (AI) Research Challenges are as follows:

- *Causal Inference from Complex Data:* determining causal relationships between environmental stressors and physiological outcomes using AI.
- *Training Data Limitations:* lack of quality, annotated data for robust AI model training and retraining, particularly for rare or long-latency health conditions.
- *Multivariate & Synergistic Effects:* developing models capable of analysing synergistic effects of multiple stressors rather than single-stressor assessments.
- *Sensitivity & Personalization:* existing AI-based risk scoring tools have low sensitivity and are not personalized; AI needs to consider individual vulnerabilities and real-time context.
- *Dynamic and Interactive Capabilities*: the AI tools need dynamic adaptability and interactive interfaces for continuous monitoring and feedback to users and healthcare providers.

Lastly, several Cross-Cutting Research Challenges apply:

- *Standardization Gaps:* insufficient standard tools and metrics for evaluating environmental impacts on health and hospital sustainability.
- *Lack of Interdisciplinary Integration:* inadequate communication and shared methodology between environmental science, healthcare, and policy communities.
- *Co-Creation and Stakeholder Engagement:* limited involvement of stakeholders (patients, clinicians, policymakers) in the design and validation of AI/IoT systems.

Expected activities on "Dissemination and Impact on Standards":

Relevant standards: environmental management (e.g., ISO 14001:2015, ISO 14040:2016, etc

IoT and/or Edge computing related of SDO and Alliances:

- Alliance for AI, IoT and Edge Continuum Innovation (AIOTI), being the coordinating organisation in the ENACT project, throughout the whole project the AIOTI shall manage analysis of relevant standards, policies, procedures, and regulations relevant to key strategic objectives of the project, publishing the results both in project impact-related deliverables as well as in the standardisation landscape reports published regularly by its working group: WG3 (Standardisation).
- International Standards Organisation (ISO), once potential opportunities for amendments to either existing ISO standards shall be identified in ENACT, those shall be communicated to the relevant ISO working groups. This process shall be ongoing throughout the whole project.

1.2.18 GREET: Generative Explainer-aware Explainability and Transparency in Proactive Cyber-Physical Eco-Environments

URL/Reference:

- https://cordis.europa.eu/project/id/101226624

Abstract:

As an interdisciplinary endeavor, the GREET network brings together leading institutions and companies in Cyber-Physical System (CPS), AI, software engineering and cognitive interaction research across Europe with the aim of training a new generation of scientists, technologists, and entrepreneurs that will move Europe into a leading role in the scientific and technological innovation in Generative AI-driven CPS, its proactivity and explainability.

Linking the leading academic and industrial partners in the above areas, GREET will form an effective and unique training network powerfully combining the best research training with a range of academic and industrial placements, specialist research and knowledge transfer workshops. It will develop and train a new generation of young researchers through a set of key research projects, developing breakthrough CPS systems and services that feature generative cognition, explainer-aware generative explainability, and transparent proactivity in highly secured CPS eco-environments.

It will shape the delivery of training in the novel generative AI-driven CPS across Europe: delivering key insights into the science and models of the proposed CPS, setting up its scientific foundation, and equipping the DN's recruited Doctoral Candidates with skills to drive the next innovative steps in this key area of generative AI-driven CPS. These steps include building a sustainable innovation ecosphere and community, disseminating and exploiting this new CPS's learning and understanding of the eco-internals, eco-surroundings

and eco-dynamics in many vital societal and economic services, including Industry 5.0, smart city, healthcare, energy, emergency handling, social robotics and elderly care. The innovation perspective of these new CPS is substantial, which will be particularly important for handling services that involve humans and in critical situations, e.g., in emergency and hazardous environments.

Starting and (target) end time of project:

01/10/2025 – 31/09/2029

IoT and/or Edge Computing research challenges:

As a rapidly expanding technology, CPS is entering every corner of the economy and society. It plays critical roles in many emerging application domains such as healthcare, smart cities, manufacturing and energy. The role of CPS has imposed several challenges on their development, operation and evolution.

Firstly, a modern CPS is a physically entangled system of systems in which each hardware device, software module and human user should be viewed as an agent in an ecosystem. These agents need to be self-learning, proactive and dynamically composable.

As a large hybrid system, it is essential for a CPS to be proactive and self-developing and such proactivity must be explained in an explainer-aware and transparent manner to build the best trust and to achieve smooth and trustworthy cooperation among these agents. Secondly, such proactivity and self-development need to be based on the holistic and real-time cognition of each agent including its ambience, external situations and internal intentions.

However, acquiring such cognition is often impossible in a CPS due to the limited available information an agent can get and the very large hybrid and dynamically changing system structure within the CPS. Thirdly, existing AI learning methods are not based on a full awareness of the ambience, situations and intentions of the CPS agents, provide little learning explanation among them, and hence are unfocused and lack proactivity and explainability.

Anticipating upcoming problems and possibilities is a powerful characteristic of intelligent behavior. Humans reason about future or hypothetical situations and do not just reflexively react to the challenges at hand. The ability of prediction is the basis for proactive system behavior. This applies both to virtual CPS-related problems as well as real-world problems. GREET will uniquely address these problems with a unified learning method that focuses on adaptation and prediction. Proactive self-learning is a key but sophisticated feature for CPS to be proactive; it involves several disciplines to collaborate in realizing it at advanced levels. Although recently the research communities have introduced machine learning into CPS, existing approaches fail to set a dynamic and cognition-matching goal for the learning, which limits the efficacy of the learning and the CPS actions and adaptations. Latest, explainable AI starts to enter the vision of CPS research, however the explainability is never linked with CPS cognition or CPS proactivity. Furthermore, existing adaptation technologies are insufficient for CPS services because the adaptations are not cognition-driven due to the absence of the holistic cognition or the autonomous matching mechanisms between the cognition and the CPS service specifications. The adaptability is limited to passive or purely responsive actions in a non-proactive and non-intelligent manner.

Although explainability is now a key issue in AI, particularly for machine learning and deep learning, so far existing research has not been able to provide the explainability in a generative or explainer-aware manner either for the cognition of CPS agents or for the proactivity decisions among the agents in CPS systems. Both the cognition and the proactivity of CPS need to be explained according to the ambience, situations and intentions of the explainers. Such explainability in CPS faces several challenges including: (1) to ensure that the explanation is accurate, in-depth, matching with the explainer's context, and presented in an appropriate way; (2) to produce the explanation in real-time so as to meet the performance requirement; and (3) to ensure that explanation is feasible for extreme and unexpected circumstances.

Cloud computing provides a global and effective platform for sharing IoT-based CPS services. Cloud and edge computing can deal with CPS services in a more distributed and dynamic manner and support "thin CPS device" and CPS service sharing. Further, to improve latency and privacy, edge computing emerges to minimize service latency in CPS applications. The cybersecurity of CPS has always been a serious problem. CPS introduces security risks and challenges to the IoT devices and the communication layer & system they are connected to. Despite the efforts to improve, there is a lack of holistic and robust architectures enhancing the security of CPS.

The projects will tackle the following list of research challenges:

Internet of Things (IoT) & Cyber-Physical Systems (CPS) Challenges

- *Agent-Based System Complexity*: modern CPS are systems-of-systems with heterogeneous agents (HW/SW, humans). Designing systems where these agents operate cohesively remains a challenge.
- *Dynamic Composability*: the IoT components must be able to reconfigure and compose dynamically in real-time to meet changing requirements and environments.
- *Resource Constraints*: many IoT devices operate under stringent computational and energy limitations, demanding highly optimized and lightweight processing and communication models.

- *Interoperability*: seamless interaction between diverse IoT systems, platforms, and communication standards is still lacking.
- *Security of IoT-CPS Integration*: integrating IoT devices with CPS introduces security vulnerabilities, especially at the device, communication, and system layers.

Edge Computing Challenges:

- *Real-Time Processing*: edge computing must handle data-intensive tasks in real time, including cognitive and proactive decision-making processes.
- *Latency Reduction*: developing architectures that reduce service latency in CPS applications.
- *Distributed Intelligence*: designing distributed learning and cognition models for edge nodes.
- *Data Privacy*: ensuring that sensitive CPS and IoT data remain secure when processed at the edge.
- *Thin Device Support*: supporting devices with minimal computational power through effective edge-cloud synergy.

Artificial Intelligence (AI) & Machine Learning Challenges:

- *Proactive Learning*: current machine learning methods lack mechanisms for anticipatory or proactive learning based on future state reasoning.
- *Explainable AI (XAI) in CPS:* both generative and explainer-aware explainability models and real-time generation of contextualized explanations matching the user's (explainer's) perspective.
- *Cognition-Aware AI:* embedding holistic cognition into AI agents, accounting for internal states, external environments, and ambient dynamics as well as aligning AI goals with dynamic, context-aware cognition in CPS.
- *Adaptation Based on Cognition*: existing adaptive systems do not effectively match adaptations with the agent's situational cognition and goals.
- *Multi-Agent Learning and Collaboration*: ensuring that CPS agents learn collaboratively, share learning outcomes, and explain their actions in multi-agent environments.

Cross-Domain Challenges:

- *Standardization & FAIR Principles*: promoting standardized models and datasets (via FAIR principles) to enable cross-domain interoperability and reproducibility.
- *Extreme-Case Explainability*: ensuring explanations are feasible and effective even in unexpected or extreme operational conditions.
- *Hybrid Systems Modelling*: the CPS includes both discrete and continuous components; modelling and reasoning across these hybrid systems is challenging.
- *Trustworthy AI Systems*: establishing transparent, explainable, and secure systems to build trust among human users and machine agents.
- *Sustainable Innovation Ecosystem*: building and maintaining an innovation community that evolves with emerging CPS, AI, and IoT needs.

Expected activities on "Dissemination and Impact on Standards":

The GREET framework is expected to be widely accepted and contribute to the global and EU open standards via our effective dissemination and exploitation activities by the influential partners in our consortium. The industrial partners SP, ICOM, AVL, ITTI and IRIS will work with standard organizations such as ISO Cyber-Physical Systems and EU Agency for Cybersecurity (ENISA) to promote the GREET technology, ensuring that a full impact of the project work is achieved, as well as organizations and communities, e.g. NIST CPS Public Working Group, and Open Connectivity Foundation (OCF).

GREET plans to join the European Open Science Cloud (EOSC) Partnership and endorse its Rules of Participation. We will engage the platforms and repositories of EOSC to store, share and reuse research data across borders and scientific disciplines, aiming to achieve Findable, Accessible, Interoperable, Reusable (FAIR) principles of the models, publications, software and data from GREET as FAIR research digital objects, leading to more insights and innovation, and citizen science. The partners use Open-Source code in their deliverables when possible and will contribute deliverables to the Open-Source communities.

1.2.19 CyberNEMO: End-to-end Cybersecurity to NEMO meta-OS

URL/Reference:

EC page: https://cordis.europa.eu/project/id/101168182

Project official page: https://cybernemo.eu/

Abstract:

CyberNEMO provides end-to-end cybersecurity and trust on the IoT-Edge-Cloud-Data Continuum framework as introduced by NEMO project. CyberNEMO architecture supports resilience, risk preparedness, awareness, detection and mitigation within Critical Infrastructures deployments and across supply chains. The project aims to achieve technology maturity by leveraging existing by-design, by-innovation, and by-collaboration zero-trust cybersecurity and privacy protection systems, and introduce novel concepts, methods, tools, testing facilities and engagement campaigns to go beyond today's state of the art. The project toolchain aims to provide a low level Zero-Trust Network Access layer up to a human AI explainable Situation Perception, Comprehension & Protection (SPCP) framework and tools, collaborative micro-services Auditing, Certification & Accreditation and a pan-European Knowledge Sharing, risk Assessment, threat Analysis and incidents Mitigation (SAAM) collaborative platform in all layers of the IoT-Edge-Cloud continuum. The project's output will be validated in a set of Critical Infrastructure providers in diverse domains including energy, water, healthcare, media distribution, agrifood and fintech supply chain.

Starting and (target) end time of project:

01/10/2024 – 30/09/2027

IoT and/or Edge Computing research challenges:

A list of IoT and/or Edge Computing research challenges, related to CyberNEMO thematic areas include the following:

- Zero Trust and Identity Management in dynamic environments: To apply Zero Trust principles to continuum computing by ensuring dynamic, and verifiable identity, role, and trust management across cloud, edge and IoT devices.
- Runtime Threat Detection and Self-Healing Architectures: To design and implement mechanisms to detect anomalies and allow for coordinated response, and resilience through self-healing and containment.
- Secure and Privacy-Preserving AI at the Edge: To protect the confidentiality and integrity of AI/ML models and training data at the edge through federated learning and differential privacy.

- Tailored security for constrained IoT devices: To design, implement, measures applicable to low-power IoT nodes, without compromising performance.
- Secure AI/ML Model Lifecycle at the edge: To secure the entire ML lifecycle, including model training, deployment, update, and inference at the edge.
- Federated and Decentralized Security Management: To design federated access control, trust negotiation, and policy enforcement in decentralized environments.
- Collaborative and cross-domain Cyber Threat Intelligence (CTI) sharing across the continuum: To design a secure framework to collect, extract, and exchange Cyber Threat Intelligence (CTI), enabling collaborative and real-time threat awareness within the CC and involving IoT devices.
- Secure and resilient computing continuum: To design the appropriate measures to ensure trust and security across distributed, heterogeneous resources among IoT, Edge, and Cloud dynamic environments.
- Lifecycle and update Management for secure continuum services: To manage updates, patches, and software lifecycle operations across distributed and heterogeneous IoT/Edge devices.

Expected activities on "Dissemination and Impact on Standards":

CyberNEMO monitors and is expected to interact with the following (not exclusive) list of organizations, mainly in the areas of AI-driven security and risk management, trusted edge computing, resilience and CTI sharing. Interaction will be pursued through project partners participating in the organizations, mainly in the third year of the project.

- AIOTI to leverage the multistakeholder approach to IoT trust, privacy-by-design principles, and interoperability for secure multi-party CTI exchange and federated threat response models.
- ENISA (European Union Agency for Cybersecurity) in the context of guiding EU-wide cybersecurity frameworks, supporting national strategies, CSIRT cooperation, CTI sharing and development of cybersecurity certification schemes.
- European Telecommunications Standards Institutein the context of ISG ZSM (Zero Touch Network & Service Management), TC DATA (the Technical Committee on Data Solutions), TC CYBER (cybersecurity), TC SAI (Securing Artificial Intelligence) and ISG ENI (on AI application to network management).
- IETF in the context of mechanisms for device attestation, supply chain transparency, and cryptographic trust anchors (e.g., RATS, SCITT) supporting secure IoT communications, device identity management, and cross-domain trust federation for CTI sharing at scale.
- ECSO (European Cyber Security Organisation) in the context of EU cybersecurity industrial strategy, secure-by-design IoT/AI solutions and EU certification and compliance.
- CEN-CENELEC Joint Technical Committee 21 (CEN-CENELEC JTC21) in the context of EU AI Act and Cyber Resilience Act.
- CNCF (Cloud Native Computing Foundation) Linux Foundation project in the context of CNCF Sandbox for early-stage projects.
- GAIA-X in the context of federated CTI exchange architectures and trust establishment between data owners, providers, and cybersecurity stakeholders.
- 6G-IA – Smart Networks and Services Industry Association and specifically the Security WG in the context of CTI sharing, trust infrastructure, and privacy-preserving data exchange mechanisms.

1.2.20 MODUL4R: Industrial Manufacturing strategies for Distributed control and Resilient, Rapidly Responsive and Reconfigurable supply chains

URL/Reference:

Modul4r official website: https://www.modular-project.eu/

CORDIS: https://cordis.europa.eu/project/id/101091859

ZENODO: https://zenodo.org/communities/modul4r-project/records?q=&l=list&p=1&s=10&sort=newest

Abstract:

MODUL4R envisions reliable, maintainable, affordable, (re)usable, and changeable SME-friendly autonomous modular factories and supply chains, with the ability to manufacture new product in low-volume production and the ability to rapidly respond to unexpected events as well as the overall supply chain. MODUL4R proposes a holistic I4.0/I5.0 framework applicable both to new and existing manufacturing lines to achieve flexibility, rapid responsiveness, and sustainability.

Starting and (target) end time of project:

01/01/2023 – 30/06/2026

IoT and/or Edge Computing research challenges:

MODUL4R is focused on four pillars, offering novel Hardware and Software components:

- Pillar 1: Resilience against changes in customer and societal demands and disruption on the supply chain.
- Pillar 2: Modular Technologies for flexible manufacturing operations.
- Pillar 3: Simulation and interfaces to the Industrial Metaverse.
- Pillar 4: Human centred technologies and upskilling.

Hardware components:

- Innovative CPPS modular manufacturing models.
- Unified interface for static tool changing and dynamic reconfiguration of the manufacturing process.
- Metrology, Condition Monitoring and Quality Inspection equipment.
- Smart IEC61499 automation objects with integrated interfaces allowing connection with 3rd party I/O systems.
- Edge devices, connectors, and controllers to connect with current legacy infrastructure (CPS-izers)

Software components:

- Swarm and augmented intelligence for predicting and anticipating disruptions and behaviour.
- Risk-based optimization of supply chain based on technical, sustainability, and acceptance requirements.
- Innovative virtual commissioning for distributed automation
- Service-oriented platform enabling multi-level communication and computation of CPPSoS networks.
- AAS interfaces for the industrial metaverse and simulations of operations
- Multi-level decision support system for resilient supply chain processes
- AR/VR models for training and simulation; Customisable & Accessible UIs/HMIs for modular lines.
- Scalable industrial strategies for modular and responsive manufacturing

Expected activities on "Dissemination and Impact on Standards":

For MODUL4R when it comes to major research findings, visibility matters. These efforts are part of a strategic plan that has been carried out in a systematic way for amplifying visibility, enhancing awareness and maximising impact. The MODUL4R team has already participated in more than twenty high-valued events specifically targeted to raise awareness and forge interactions with valuable target groups including professionals from research and academia, industry, technology, and more. Take participation in SPS 2024 fair as an example where discussions with Universal Automation.org (UAO) members emerged around potential adoption of new IEC 61499 solutions. Beyond that, social media campaigns on LinkedIn and X and the release of various videos on YouTube, the most popular streaming app, have fortified the communication goals.

MODUL4R has also prioritized collaboration with more EU funded projects, forming the AMiMO Cluster (together with One4All, MARS, MODAPTO and DMaaST) to unite efforts behind a common goal: spreading awareness of their research findings. Among various joint activities, the cluster organised a standardisation workshop on 21 November 2024, led by an expert at UNI-Italian Standards Body, to strengthen their understanding and knowledge in this area.

It is expected that results of the MODUL4R project will be disseminated towards:

- IEC 61499 standard
- OPC Unified Architecture (OPC-UA) standard
- QIF (Quality Information Framework) standard

1.2.21 TechUPGRADE: Thermochemical Heat Recovery and Upgrade for Industrial Processes

URL/Reference:

https://techupgrade.eu/

https://cordis.europa.eu/project/id/101103966

Abstract:

The TechUPGRADE project aims to develop and validate, up to TRL 5, a novel thermochemical technology for waste heat recovery and temperature upgrading in industrial processes. The system will efficiently and sustainably upgrade waste heat to 150–250 °C. IoT and edge computing play a crucial role in enabling real-time monitoring, control, and predictive maintenance. Quanterall Ltd., a project partner, contributes with expertise in IoT hardware infrastructure, edge software, secure data communication, and digital twin technologies.

Starting and (target) end time of project:

01/05/2023 – 30/04/2027

IoT and/or Edge Computing research challenges:

- Real-time monitoring and control of thermochemical heat systems
- Edge data processing in high-temperature industrial environments
- Secure and reliable data transmission across industrial sites
- Integration of sensor networks for predictive maintenance
- Energy-efficient edge computing solutions

Expected activities on "Dissemination and Impact on Standards":

The *TechUPGRADE* project is currently in an intensive research and development phase. At this stage, there is no direct participation in standardisation working groups. It is important to note, however, that *TechUPGRADE* will deliver the first industrial-scale thermochemical reactor of its kind, and scientific publications are planned on various aspects of the project.

These results are expected to pave the way for future standardisation processes, in which the consortium intends to be actively involved. It is expected that until the end of this project the results of the project will be disseminated to the following SDOs and Alliances:

- ETSI, ISO/IEC, IEEE, AIOTI

Expected Interaction: Participation in standardisation working groups, contribution of project use cases and results to technical reports and white papers, alignment with ongoing initiatives on IoT for industrial energy systems

Expected Timescales: Initial inputs from Q2 2025, with full contributions during 2026–2027

1.2.22 ENACT (HE CL4) Adaptive Scheduling and Deployments of Data Intensive Workloads on Energy Efficient Edge to Cloud Continuum

URL/Reference:

- https://cordis.europa.eu/project/id/101135423
- https://enact-horizon.eu/

Abstract:

The cloud-edge continuum has developed many forms of flexibility and adaptation, yet it lacks disruptive technologies to deal with the new forms in which content will be distributed and consumed. The ENACT project brings together a team of 16 experienced partners from 9 EU countries with the aim of delivering breakthrough techniques and disruptive technology solutions to target this need for efficient and intelligent content and data processing, using all suitable resources available in the edge-cloud continuum. ENACT addresses directly the demands to build a computing continuum with cognitive Web3 capabilities that can effectively manage the explosion of locally generated content for next generation hyper-distributed services, while respecting European values and the regulatory frameworks set by the European Data Act and complementary legislation. ENACT develops cutting-edge techniques and technology solutions to realise a Cognitive Computing Continuum (CCC) that can address the needs for optimal (edge and Cloud) resource management and dynamic scaling, elasticity, and portability of hyper-distributed data-intensive applications. Moreover, the outcomes of these research and development activities will be delivered as open-source solutions, with the goal of allowing European businesses to enhance their competencies and upgrade their IT services with latest innovations.

Starting and (target) end time of project:

01/01/2024 – 31/12/2026

IoT and/or Edge Computing research challenges:

- Security and Trust: Enhancing the protection of IoT and Edge systems against cyber threats and ensuring trusted data exchange among heterogeneous and distributed components.
- Resource Management and Orchestration: Developing mechanisms to manage and orchestrate resources dynamically across cloud-to-edge continua, considering constraints such as latency, bandwidth, and energy efficiency.
- AI Integration at the Edge: Enabling the deployment of lightweight AI models at the edge to support local decision-making, minimize latency, and reduce data transmission needs.
- Scalability and Adaptability: Ensuring that the IoT and Edge systems can scale efficiently and adapt to changing workloads and environments.
- Monitoring and Self-Healing: Implementing advanced monitoring and self-healing mechanisms to ensure resilience and continuous operation of IoT/Edge applications.

Expected activities on "Dissemination and Impact on Standards":

SDOs/Alliances: ETSI - A new work item **Ensuring AI Compliance through Advanced Verification** has started within the ETSI TC MTS AI Working Group. Scope of work to be undertaken: *Definition of an approach to assist AI providers in assessing compliance with the EU AI Act.*

This includes the description of an AI Act Compliance Checker service, focusing on the following core functionalities: AI system categorization, Document validation, and Compliance evaluation.

Activities: Scientific publications, consortium workshops. Contributing to ongoing standardisation activities. Promoting its outcomes as inputs to relevant working groups. Participating in technical discussions and public consultations.

Timeline: The interaction with SDOs and alliances is planned to be continuous throughout the project lifecycle, with:

- Initial engagement and contribution planning in the early stages of the project (Year 1).
- Active participation and contribution during the core execution phase (Years 2–3).
- Consolidation and dissemination of contributions in the final year of the project (Year 4).

1.2.23 CoEvolution: A comprehensive trustworthy framework for connected machine learning and secure Interconnected AI solutions

URL/Reference:

https://coevolution-project.eu/
https://cordis.europa.eu/project/id/101168560

Abstract:

The AI landscape requires a comprehensive framework to address threats and vulnerabilities but lacks a system for managing weaknesses in the AI supply chain. The EU-funded CoEvolution project is developing an integrated security, trust, and robustness (STR) assessment solution that combines AI models with context awareness and an AI model bill of materials (AIMBOM). The project aims to establish a universal STR risk assessment and security assurance hub aligned with EU regulatory frameworks. This initiative introduces new AI model descriptions and security monitoring to ensure compliance with EU directives on trust, fairness, data governance, and GDPR guidelines. Open-source trusted datasets and AI models developed by CoEvolution will enhance the hub's ability to address evolving AI cybersecurity threats.

Starting and (target) end time of project:

01/22/2024 – 31/07/2027

IoT and/or Edge Computing research challenges:

Strong focus is on Secure, Trustworthy, and Robust AI at the Operational Edge of Manufacturing and Mobility Systems with following challenges:

- Secure AI Lifecycle Management at the Edge: protected deployment, runtime validation and trustworthy updates of AI models on edge devices
- Federated Learning with Adversarial Resilience: protected decentralised training processes against poisoning and privacy attacks while enabling collaborative intelligence
- Resource-Constrained Security Solutions: efficient security mechanisms suitable for resource-constrained, latency-sensitive edge platforms
- Context-Aware Threat Detection and Risk Assessment: integrated operational context into threat detection and AI decision monitoring at the edge
- Supply Chain Transparency and AIMBOM: track and assess embedded AI model components and dependencies to manage supply chain risks
- Cross-Domain Interoperability of Edge AI Systems: secure integration of edge AI systems across sectors, aligned with trust, privacy and safety regulations
- Risk-Informed System Architecture for Edge Deployment: translate high-level risks into modular, certifiable edge system designs that evolve over time

Expected activities on "Dissemination and Impact on Standards":

CoEvolution's standardisation work turns research into tools and rules that regulators, buyers and integrators can use. The purpose is to codify the AI Model Bill of Materials (AI MBOM) and the project's Security, Trust and Robustness approach, so that conformity assessment, market surveillance and supply chain assurance are practical under the EU AI Act and GDPR. The main hurdles are fragmented efforts, the absence of a mature, cross-domain AI MBOM, fast-moving regulation, and the need to link AI management to established information security and safety standards while keeping solutions feasible on resource-constrained edge devices. In response, the project will define an AI MBOM profile mapped to recognised standards. Possible target standards include ISO/IEC 42001, 27001, 27005, 23894 and 24029; ISO/SAE 21434 and ISO 34502; ECMA-424 CycloneDX; ISO/IEC 5962 SPDX; ITU-T X.590; ETSI SAI 005 and 006; and the NIST AI 100-2 (2025) profile as a complementary reference. Expected outputs are a public AI MBOM profile with conformance tests and mappings, contribution texts and gap analyses, reference implementations and guidance that ties evidence collection to EU AI Act duties. The result is procurement-ready documentation, repeatable STR assessments and continuous assurance for AI in mobility, manufacturing and other sectors.

1.2.24 Averato Park: An innovative system for reliable control of parking lots through a user-friendly interface

URL/Reference:

https://www.quanterall.com/
https://www.iot-ngin.eu/

Abstract:

AVERATO Park is an innovative smart parking system developed by Quanterall under the IoT-NGIN project (H2020 -957246). It provides a user-friendly, fully automated solution for access control and contactless payments in parking facilities. The system leverages IoT infrastructure and edge computing to manage hardware (barriers, sensors) and software components for real-time event monitoring, mobile-based access, payment processing, and remote management. Quanterall's AVERATO platform ensures seamless integration of IoT devices with payment providers and backend systems.

Starting and (target) end time of project:

01/07/2022 – ongoing;

- Note that on 30/06/2023, the experiment duration under IoT-NGIN Open Call #2 ended). However, the implementation phase of the Averato Park project is still ongoing and currently supported by private funding.

IoT and/or Edge Computing research challenges:

- Integration of heterogeneous IoT components with legacy systems
- Real-time communication between edge devices and backend systems
- Secure processing of user data and transactions
- Interoperability with external sensors, barriers, and mobile apps
- Efficient edge-based control logic and monitoring for parking automation

Expected activities on "Dissemination and Impact on Standards":

- SDOs and Alliances: AIOTI, ETSI, ISO/IEC
- Interaction: Participation in IoT-related conferences and workshops, open-sourcing of the communication protocol between parking system and backend, contribution to community-led standardisation initiatives
- Timescales: Dissemination throughout 2023 – up to date: via online media, newsletters, industry expos, and collaborative events in the AIOTI network and EU IoT ecosystem.
- At present, there is no direct participation in standardisation working groups.

1.2.25 Visualization of the IoT EU funded ongoing projects landscape

This section provides a landscape visualization of the ongoing IoT EU funded projects, introduced in this report.

The figures included in this section cover ongoing IoT projects that are described in Section 1.2 of this release (Release 4.0).

The "IoT EU funded ongoing projects landscape (Technology and Marketing Dimensions)", shown in Figure 4, is a graphical representation that highlights the main activity (up to the day of generating this representation) of the ongoing projects in the area of IoT, according to the Business to Consumer (B2C) vs. Business to Business (B2B) (horizontal axis) and the Connectivity vs. Service & App (vertical axis) classifications.

The projection of these ongoing projects into vertical industry domains is shown in **Figure 5** and for standardisation activities in different SDO's and initiatives is shown in **Figure 6**.

The dimensions, the vertical/horizontal domains and standardisation organisations and initiatives of the landscapes and the method used to visualize ongoing projects into these landscapes shown in **Figure 4**, **Figure 5** and **Figure 6**, respectively, are the same ones as defined in Section 1.1.4.

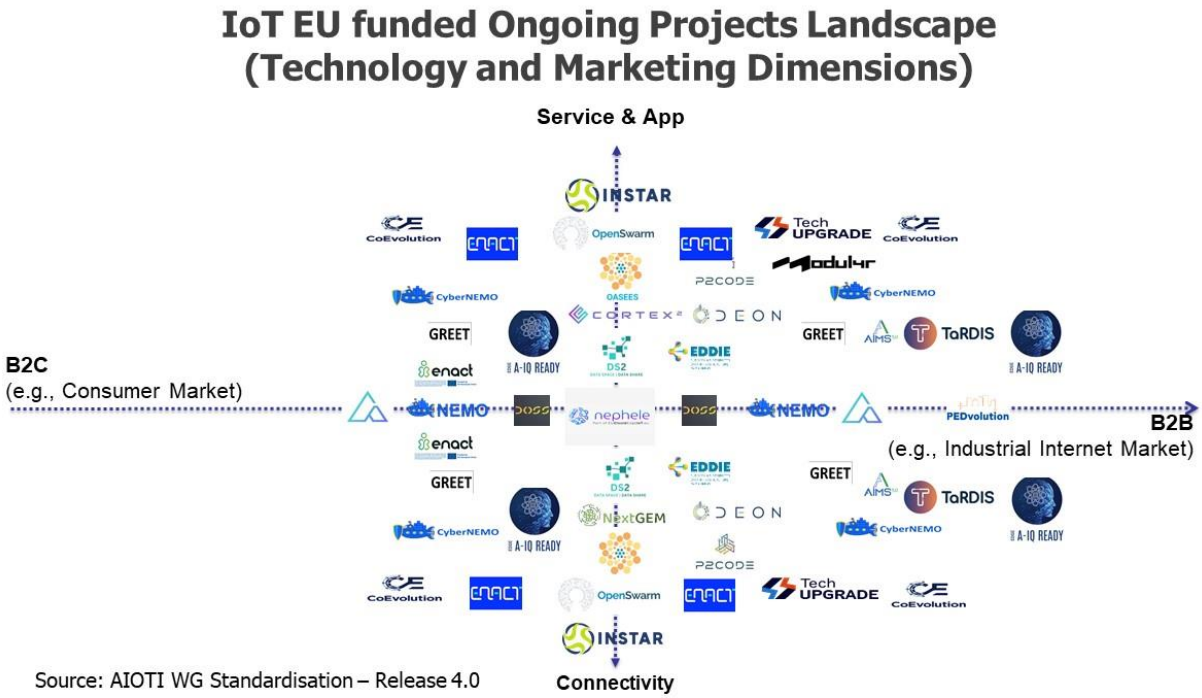


Figure 4: IoT EU funded ongoing projects landscape, when Technology and Marketing Dimensions are used.

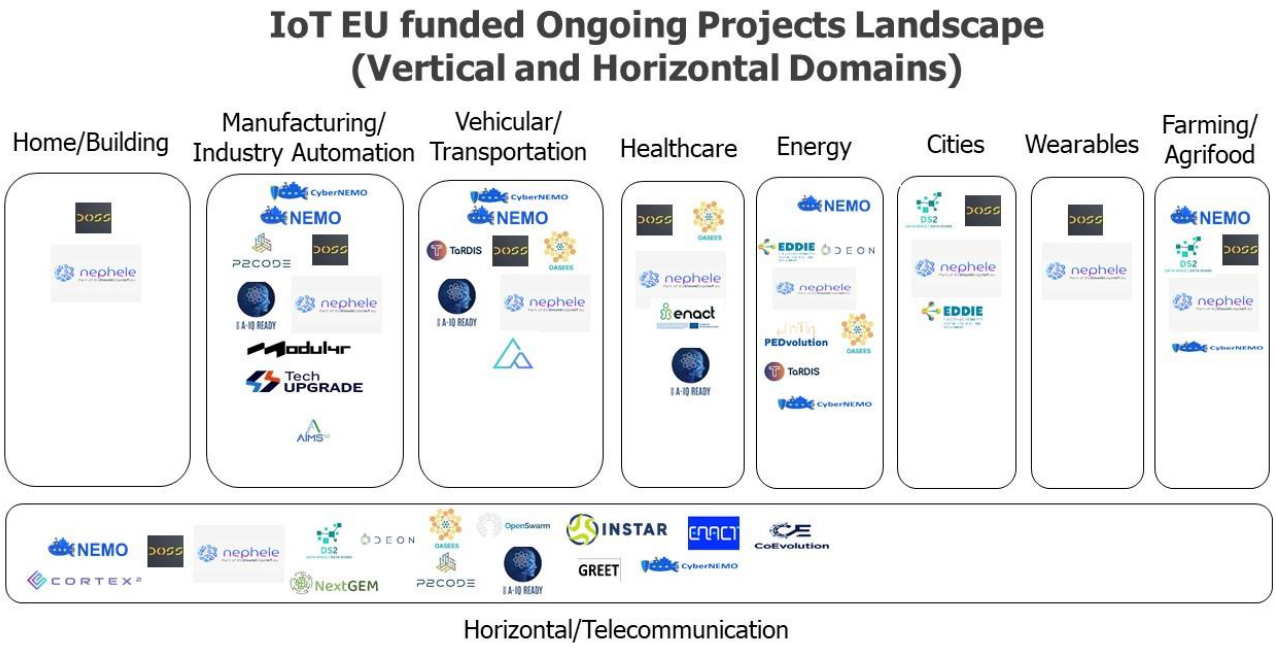


Figure 5: IoT EU funded Ongoing Projects Projection on Vertical and Horizontal Domains.

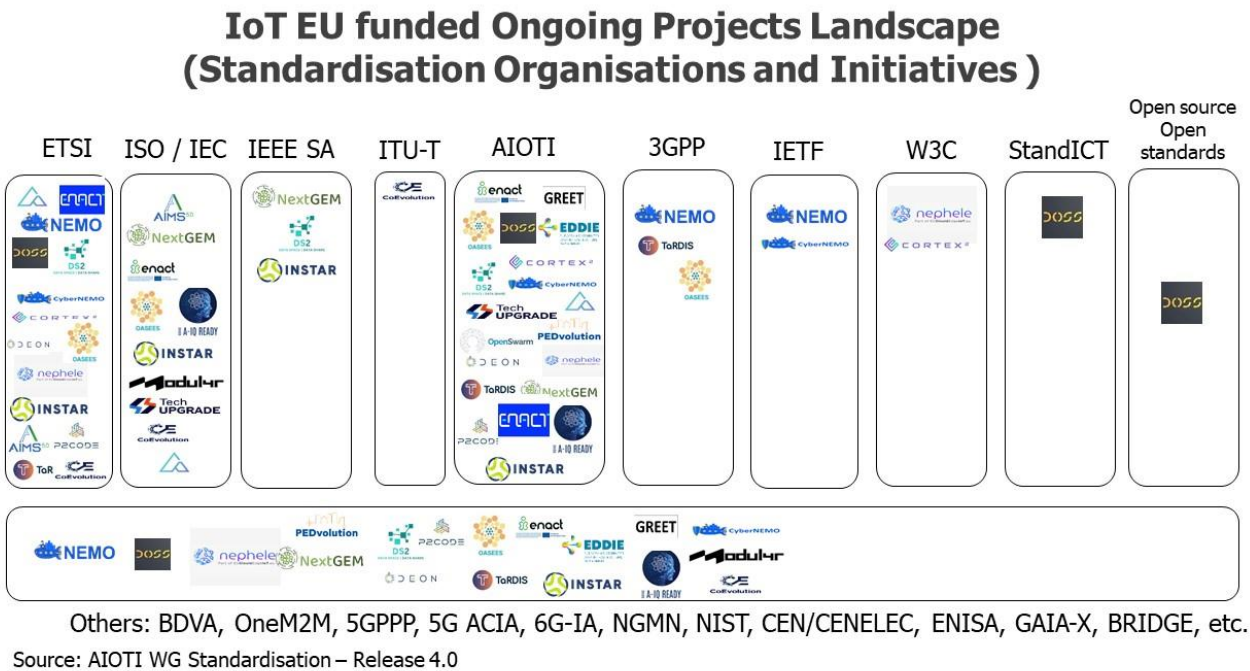


Figure 6: IoT EU funded Ongoing Projects Projection on Standardisation Organisations and Initiatives.

2. Edge Computing EU funded projects landscape

This section provides information on Edge Computing EU funded projects, which are grouped in completed and ongoing projects. The information related to each EU funded project, included in this section, has been collected using the template provided in Annex I of this report.

2.1 Completed Projects

This section provides a description of Edge Computing EU funded projects that are completed.

2.1.1 AI4CSM: Automotive Intelligence for Connected Shared Mobility

URL/Reference:

https://ai4csm.eu/

https://cordis.europa.eu/project/id/101007326

Abstract:

The AI4CSM project will develop advanced electronic components, systems and architectures for future mass-market Electric, Connected, Automated and Shared (ECAS) vehicles for the digital transformation in the automotive sector to support the mobility trends and accelerate the transition towards a sustainable ecosystem based on the "Green Deal" principles. The EC is taking initiatives to ensure that digital technologies such as AI, 5G, IoT and cloud/edge computing can accelerate the transition of the automotive industry to electrical, autonomous, connected, and shared vehicles. AI4CSM will deliver key innovations in technical areas including sensor fusion and perception platforms; efficient propulsion and energy modules; advanced connectivity for cooperative mobility applications; vehicle/edge/cloud computing integration concepts; new digital platforms for efficient and federated computing; and intelligent components based on trustworthy AI techniques and methods. AI4CSM will design scalable and embedded intelligence for edge and edge/cloud computing. AI4CSM consists of 8 collaborative R&D clusters, gathering 41 partners from 10 countries. AI4CSM will reinforce user acceptance and affordability by convenience and services for the major transition to a diverse mobility. AI4CSM addresses the increasing demand of mobility, supporting future traffic concepts and strengthen the European automotive manufacturing base as a global industry leader.

Starting and (target) end time of project:

01/05/2021 – 28/02/2025

IoT and/or Edge Computing research challenges:

In the eight collaborative R&D clusters will be worked on the following IoT and Edge research challenges and innovations (only these innovations are referenced, of course there are others to meet too):

- Development of smart edge- and cloud-based building bricks for autonomous mobility interconnected with secure communication architectures and systems, particularly on secure edge/cloud data utilization
- Architectures and platforms (semiconductors, software, systems) on in-car, edge and cloud level
- C-ITS and cloud connectivity
- Driver's health monitoring
- Natively integrated telematics
- Cloud fusion of edge perception results into the digital twin

- Low-latency vehicle/edge/cloud connectivity
- Sensor-network fusion and AI-based perception
- Automated cloud-based learning and scenario generation
- Standardized data exchange for digital twins (via edge-cloud)
- Collaborating with standardization organizations on IoT, cloud, AI and automotive standardization for advanced and highly automated vehicles and intelligent transport systems.

Expected activities on "Dissemination and Impact on Standards":

One of the eight collaborative R&D clusters is dedicated to "Impact on Green Deal, Standardization, Certification, Ethical Aspects" in collaboration with the other seven R&D clusters.

- Evaluate the results of technology development and the experiences achieved in the demonstrators (use cases, in context of edge- and cloud computing, like robot taxi, virtual City routing, lessons from critical scenarios, trustworthy and secure AI in combination with cloud-based learning and scenario generation, C-ITS and cloud computing for multimodal connectivity, health monitoring supported by intelligent cloud data to achieve preventive maintenance, etc.),
- Raise awareness of existing and evolving standards in the addressed areas of interest (including IoT, Edge/cloud computing, connectivity, and others) and their application,
- Collaborate with/join relevant standardization groups in ISO, IEC, ETSI, and ISO/IEC JTC1 SC41 (IoT), SC 38 (Cloud computing and distributed platforms) and SC42 (AI) and related automotive standardization groups in ISO TC22 SC32 (road vehicles, e.g., automated driving systems, connected vehicles end-to-end safety), ISO TTC22 SC31 (Extended Vehicles) and others to contribute to standards and influence evolving standards based on AI4CSM experiences and results.
- Dissemination of the results among stakeholders, including standardization committees and authorities, and the industrial and scientific communities on fares, exhibitions and conferences
- Align stakeholders and relevant groups in the semiconductor industry and the automotive industry to support the green-deal initiative.

Acknowledgement:

AI4CSM project has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 101007326. The JU receives support from the European Union's Horizon 2020 research and innovation programme. It is co-funded by the consortium members and grants from Germany, Netherlands, Czech Republic, Austria and Norway, Belgium, Italy, Latvia, India.

2.1.2 AURORAL: Architecture for Unified Regional and Open digital ecosystems for Smart Communities and Rural Areas Large scale application

URL/Reference:

https://www.auroral.eu/#/

https://cordis.europa.eu/project/id/101016854

Abstract:

AURORAL focuses on delivering interoperable, open and integrated digital platforms that serve rural regions and contribute to a European, globally competitive, ecosystem of digital services and businesses to empower Smart Communities. AURORAL aims to deliver a dense network of Smart Communities under a common multi-interoperability framework aimed at succeeding the just, fair and open digital transformation.

AURORAL pilot regions implement the concept throughout Europe, targeting an investment platform of innovative services, primary focusing Smart Communities onto rural areas.

AURORAL digital environment is demonstrated by cost-efficient and flexible cross-domain applications through large-scale pilots in eight European regions: **Alentejo (PT), Southern Burgenland (AT), Penedès (ES), Piemont (IT), Lapland (FI), Hålogaland (NO) – Tourism, Hålogaland (NO) – Health, Västerbotten (SE). AURORAL is expected to be a driver** of the emergence of a widespread network of Smart Communities in Europe and ultimately it is expected to contribute to balance urban and rural opportunities for all Europeans.

Starting and (target) end time of project:

01/01/2021 – 31/03/2025

Challenges:

In situations where life is at risk, technology and operators need to be efficient and well-coordinated. Technology for managing and navigating unstructured data need to in place and well-maintained. Knowledge of topography, available resources, previous experience and planning skills will be used to assist UAS (Unmanned Aerial System) in training, planning, tactical and operational missions.

The architecture of the AURORAL platform allow for sharing of horizontal services through agents. Data management is handled through VICINITY which offer a privacy-by-design approach. Thus, satellite data from ESA through the Copernicus network and situational alerts received from public databases can support local awareness. Furthermore, UAV planning tools from the aerial authorities provide information on no-fly zones and assist in relocating resources. Maps and GIS data with information on topography and infrastructure at land and at sea can further be used to identify areas of interest or concern. Other resources are based on public base maps, weather information and prognosis to further support local preparedness and contingency plans.

Collecting and processing data can be handled by service providers that offer the relevant subsets through the AURORAL platform. Thus, services can be replicated and scaled up based on need and location.

The health use case benefits from this approach. Scenarios such as search-and-alert along trails, search-and-rescue for lost persons in predefined geo-zones, assistance in on-site activities or observation along a predefined path can be built on shared resources.

In particular drones (UAV) hosting LiDAR, video and IR-camera supporting various filters, sensors measuring particles, humidity, temperature, geomagnetic changes are a source for up-to-date information relevant in assisting ongoing missions.

- Registering geolocations using coordinates alongside metadata, and identify points of interest based on dynamic geo-zones, i.e., interchangeable based on existing plans or to support planned or ongoing missions

- Local assignment of predefined settings based on priority and frequency, i.e., emergency, alert, regular services

- Automatic (in-situ) configuration of equipment based on task, i.e., transport of commodity vs. biological material, observation of area for changes in sediments, unauthorized entrance etc.

- Prognosis on scheduled actions based on machine-learning trained on rulesets for events such as entering no-fly zones, monitoring animal well-fare and tourists being caught in natural disasters (such as landslides, flooding, avalanches) at land or at sea.
- Automatic planning and strategy development and assisting in tactical and operational missions
- Establishing digital twin operating on dataspace with topographic data using content from UAV and previous missions
- Identify sources through open data, proprietary data and automatic registration
- Plan for flight and areas to traverse based on 5G coverage map and deploy equipment to alleviate poor reception in areas with ongoing rescue operations
- Integrate IoT devices from field personnel – volunteers, rescue dogs and mobile equipment
- Offering methodologies to reduce complexity in navigating static data and dynamic data from sensors.

Expected activities on "Dissemination and Impact on Standards":

Participation in ISO/IEC JTC 1/SC41:

- Further active participation in ISO/IEC work as mirror group leader.
- Follow up for new Task Forces and new work items.
- Participation in Working Groups for forthcoming standard actions.
- Cooperation using AIOTI for contribution to ISO/IEC TR and evaluation of the AIOTI reports and standards.

Participation in AIOTI:

- Participation in the AIOTI Board that will take place in IoT Week 2022 (Dublin, Ireland).
- Enrolled in WG Standardisation to participate in the SDOs exploration and alignment.
- Enrolled in WG Standardisation to actively contribute to the next release of HLA.
- Contribution to white papers in data spaces subject.
- Enrolled in AIOTI WG Energy, WG Mobility, WG Agriculture.

2.1.3 ICOS: Towards a functional continuum operating system

URL/Reference:

https://www.icos-project.eu/

Abstract:

This project will cover challenges of the IoT-edge-cloud paradigm, proposing an approach to embed a set of functionalities, defining an IoT-Cloud Operating System (ICOS). Its aim is to design, develop and validate a meta-operating system by addressing the challenges of device volatility and heterogeneity, continuum infrastructure virtualisation and diverse network connectivity, optimised and scalable service execution and performance, as well as resources consumptions.

It will also cover security, privacy, and trust, and reduce integration costs and effective mitigation of cloud provider lock-in effects, in a data-driven system built on openness, adaptability, data sharing and a future edge market scenario for services and data.

Starting and (target) end time of project:

01/09/2022 – 31/08/2025

IoT and/or Edge Computing research challenges:

The project has just been initiated. The following challenges are mentioned:

- Design of an intelligent meta OS for the continuum
- Exploiting novel intelligent data and resource utilization methods
- Enforce trustworthy yet open operation
- Demonstrate the project outcomes in key relevant scenarios
- Building an open innovation environment and fostering the creation of new applications in the continuum as well as the science and engineering community

2.1.4 VERGE: AI-powered eVolution towards opEn and secuRe edGe architEctures

URL/Reference:

https://www.verge-project.eu

Abstract:

Edge computing involves a connected and distributed ecosystem of highly heterogeneous computing elements, located anywhere across the path between end-devices, access and core network, also sharing boundaries with central cloud infrastructures [VEREGE1] – [VERGE4]. Edge computing can facilitate the implementation of several key innovations in the optimization of Beyond 5G (B5G) networks, such as dynamic network slicing, flexible functional splits or adaptive virtual network functions (VNFs) placement and scaling. Furthermore, the introduction of artificial intelligence (AI) and machine learning (ML) in resource orchestration solutions is enabling a completely new level of closed-loop programmability and automation, especially when near real-time decisions need to be made while handling massive amounts of data, close to the end users. In addition to empowering B5G network optimization and automation, edge computing is a key vertical service enabler across multiple sectors [VERGE5]. Such vertical applications pose significant and diverse challenges on existing network and computing infrastructures. Current edge-enabled 5G architectures lack the required level of flexibility, openness and automation, and the mechanisms to support distributed and disaggregated application and network designs that are needed by such next generation services. Besides, even though edge computing has been widely considered within 5G networks, the adopted approaches have been mainly driven by specific use case requirements leading to a fragmented architectural landscape with respect to the edge deployments and performance aspects [VERGE6][VERGE7]. Hence, further evolution and closer synergy between the B5G and the edge computing paradigms are needed to ensure the real-time responsiveness and fast computation capacity needed to ensure enhanced and dynamic user experience [VERGE8]. To address the above-mentioned gaps and to fully exploit the potential of edge computing, the EU-funded collaborative research project VERGE [VERGE9] [VERGE10] proposes an evolved edge computing architecture integrated with the B5G network fabric. The proposed design aims to enable the seamless execution of cloud-native services, including disaggregated Radio Access Network (RAN) and core network functions, distributed AI and big data workflows, while leveraging data-driven, AI/ML-based solutions for edge and network optimization. Simultaneously, it ensures that the AI-based solutions are secure and trustworthy.

The proposed architecture is modular and scalable, powered through secure data-driven and AI-based solutions that enable its adaptability to the requirements of B5G and forthcoming 6G applications.

In particular, the proposed design aims to enable the seamless execution of cloud-native services, including disaggregated Radio Access Network (RAN) and core network functions, distributed AI and big data workflows, while leveraging data-driven, AI/ML-based solutions for edge and network optimization. Simultaneously, it ensures that the AI-based solutions are secure and trustworthy. The proposed architecture is modular and scalable, powered through secure data-driven and AI-based solutions that enable its adaptability to the requirements of B5G and forthcoming 6G applications.

Starting and (target) end time of project:

01/01/2023 – 30/06/2025

IoT and/or Edge Computing research challenges:

The main goal of VERGE is to provide an integrated approach on how to tackle the challenges of edge computing evolution, described around three main pillars:

- "Edge for AI", namely a flexible, modular and converged edge platform design, unifying the lifecycle management and closed-loop automation for cloud-native applications, Multi-access Edge Computing (MEC) and network services across the edge-cloud compute continuum for ultra-high computational performance.

- "AI for edge", namely an AI-powered portfolio of solutions leveraging the multitude of collected metrics for intelligent management and orchestration.

- "Security, Privacy and Trustworthiness of AI-based models at the edge", providing a suite of methods to protect AI models against adversarial attacks, increase their explainability and reliability, and ensure data privacy.

VERGE has devised two use cases to showcase its innovations: i) "An XR-driven edge-enabled industrial B5G applications" and ii) "Autonomous tram services for safety and entertainment in a smart city environment". The latter was described in [VERGE11], together with the expected VERGE innovations and improvement areas that each of the innovations is expected to contribute in the context of B5G and edge computing scenarios. The elaboration of the use cases and associated service requirements led to the initial version of the VERGE system architecture [VERGE12], depicted in **Error! Reference source not found.**, as well as the initial versions of the three architectural pillars, namely Edge4AI [VERGE13], AI4Edge [VERGE14] and SPT4AI [VEREGE15]that form the proposed architecture for B5G edge evolution. The work is continuing and is expected to help in overcoming the following barriers:

Barrier #1 Data intensive processing at the Edge continuum: dealing with highly distributed and heterogeneous compute resources

Unlike cloud computing where the processing is spread over homogeneous computing and memory resource clusters, edge computing needs to contemplate a heterogeneous panoply of highly distributed processing elements, with different performance and power consumption budgets, memory solutions and interconnectivity standards. These processing elements range from micro-controllers, micro-processors, Graphics Processing Units (GPUs) and Field Programmable Gate Arrays (FPGA) accelerators, to complex multi-processor System on a Chip (SoC) devices, Application-Specific Integrated Circuits (ASICs) and AI-optimized processors. There is a need for targeted solutions that fully leverage the massive parallelism capabilities of the HW-accelerated platforms for intensive and ultra-low latency processing. On the other hand, the complexity of parallel programming techniques for such heterogeneous scenarios can be daunting, stressing the need for programming models capable of providing the right level and granularity of abstraction to express the performance capabilities of the underlying HW platforms, with the lowest possible overhead.

Barrier #2 Learning at the edge: the scarce resources challenge

Edge intelligence, defined as the application of AI and ML at the network edge, has been identified as a key element in 6G, leveraging the multitude of data generated by the network and applications to learn and predict the runtime conditions and service requirements, thus enabling the proactive solutions for reduced latency and overall better performance and automation. However, the constraints on the training of such complex AI models over limited edge resources, the absence of sufficient local context information or data interpretation and the privacy concerns regarding the transfer of sensitive user datasets to the cloud, stress the need for decentralized leaning solutions.

Barrier #3 Lack of a unified e2e AIOps framework and AI conflict management

AI at the edge has been used for proactive network management, such as channel modelling and prediction, traffic and mobility forecasting, network resource allocation, task offloading, etc. However, while most AI solutions have been designed addressing stand-alone problems, the development of unified frameworks capable of overseeing end-to-end operations are not well investigated. In this direction, efficient collision-free AI solutions will be needed, able to work in a harmonized way when dealing with closely related problems, such end-to-end slicing, optimally splitting DU and CU functions across the edge-cloud compute continuum, or resource allocation of network and computation resources under edge constraints. Besides, AI techniques are expected to exploit the huge amount of data collected at the edge for achieving an optimized operation.

Barrier #4 Orchestrating the orchestrators

One of the most radical changes brought by 5G is the high network programmability, driven by Network Function Virtualization (NFV) and Software Defined Networking (SDN). The current trend for RAN disaggregation enables the flexible and dynamic placement of VNFs across the network infrastructure to meet specific performance requirements. At the same time, applications are adopting cloud-native design principles, breaking computation into microservices or even serverless functions, and enabling novel split and distributed computation execution models. Hence, it becomes evident that as we move towards 6G, there is a need to create an integrated communication and computation environment where network and application services can be seamlessly deployed, executed and orchestrated. This makes the management and orchestration of services and resources very challenging, further aggravated by the heterogeneous, multi-tenant and multi-site edge-enabled topologies. Moreover, the existence of different orchestration solutions in the compute continuum spanning from coarse grain multi-site orchestration to single site intend driven orchestration, all the way down to fine grain distributed task-level orchestration reaching even at System-on-Chip (SoC) device level, makes the cognitive coordination of the different orchestrators a new challenge to consider.

Barrier #5 Understanding the adversaries: Trustworthiness and explainability

Trustworthy AI covers a wide range of concerns such as robustness, safety, security, privacy, explainability, fairness and reliability that are being increasingly mandated. Despite the distributed nature of the communication domain and the network heterogeneity, we still have the risk of adversarial attacks in a telco environment, targeting the robustness of AI models by compromising the decision-making process (evasion attacks) or undermining the training data, thus leading to performance deterioration (poisoning attacks). Because of their small footprints, adversarial ML-based attacks are more covert and difficult to detect, calling for novel solutions to ensure that the AI models' decisions are robust in the face of minor changes to the input data.

On the other hand, understanding of how an AI model makes particular decisions and contributes to achieving the goals of the stakeholder is a key component of the trustworthiness of the AI system. Hence, the concept of explainable AI (XAI) has been gaining a lot of attention. However, many studies have considered XAI, scalability and feature dependence are still an open issue. For example, providing explanation for each task of the model is challenging when the number of task increases, stressing the need for task-aware XAI models.

Feature dependence also causes problems in explanation, especially when features are correlated, making it very difficult to attribute the importance of each feature in the output of the XAI model.

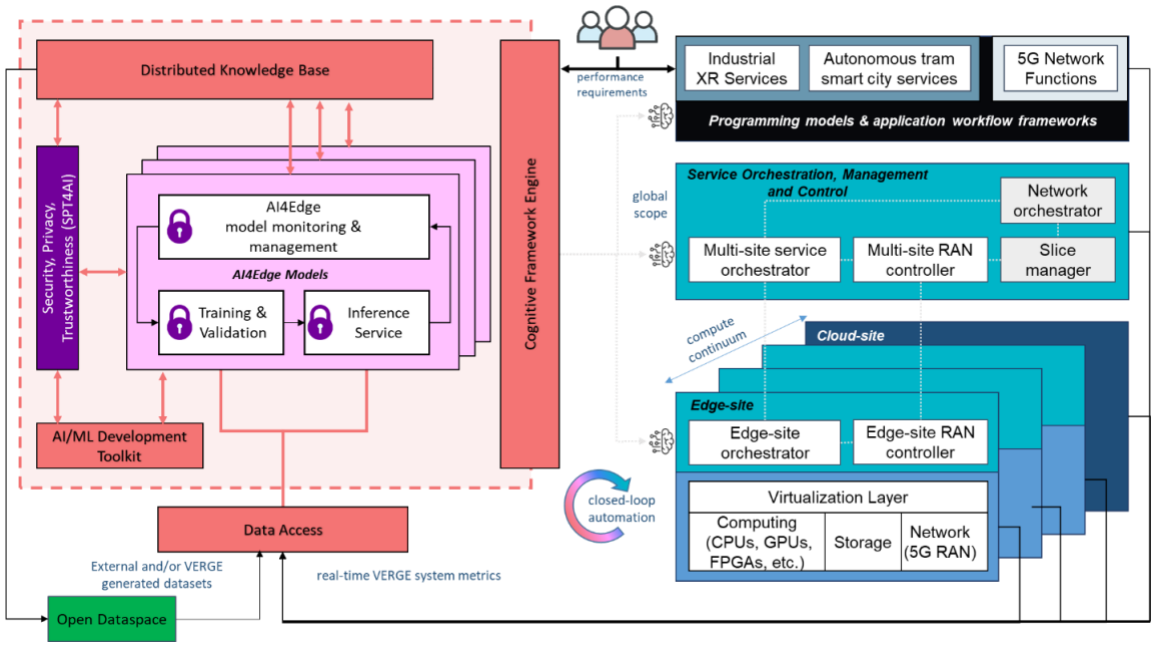


Figure 7: Overview of the VERGE initial system architecture.

Use Case: Autonomous tram services for safety and entertainment in a smart city environment

The concept of autonomous driving in Light Rail Transit (LRT) tram public transport systems heavily relies on multiple sensors, such as cameras, radars, light detection and ranging (LIDAR) systems, etc., which coupled with AI processes can provide the necessary level of perception and actuation in real-time. However, the implementation of such autonomous systems poses challenging requirements since these services are exposed to several critical uncontrollable events such as pedestrians, vehicles, and obstacles, demanding a much higher level of situational awareness and more dynamic interaction. Edge computing together with orchestration of tram autonomy functions, dedicated network slices for safety-related critical and non-critical data and B5G communication technologies can play a fundamental role towards addressing these challenges, by offering the necessary ultra-reliable low-latency connectivity, high computational capability closer to the data sources, mobility support and dynamic reconfigurability needed to implement different services of the autonomous tram of the future. At the same time, smart cities are adopting sensing, computing and communication technologies to provide innovative services for a more efficient, safe and sustainable city management and enhanced quality of life.

Fuelled by the wide IoT penetration, cities are collecting massive volumes of data, which, through AI and big data technologies, is transformed into valuable and actionable knowledge, able to automate and optimize several city aspects. In such highly distributed and heterogeneous environments, edge computing is a key enabling technology, making it possible to fuse together information coming from both the sensor-equipped trams and the city to better detect and anticipate hazards that may lie along the trajectory of the tram, beyond the visibility of the tram sensors. Furthermore, innovative XR entertainment services with demanding latency and processing requirements can be supported, e.g., providing immersive touristic information for people moving by tram or other means within specific areas of interest. **Error! Reference source not found.** illustrates the components of this use case, which involves applications (e.g., track occupation monitoring and obstacle/hazard detection) aimed at improving the safety and operational efficiency of the autonomous tram in a smart city environment, and at providing immersive entertainment services for passengers.

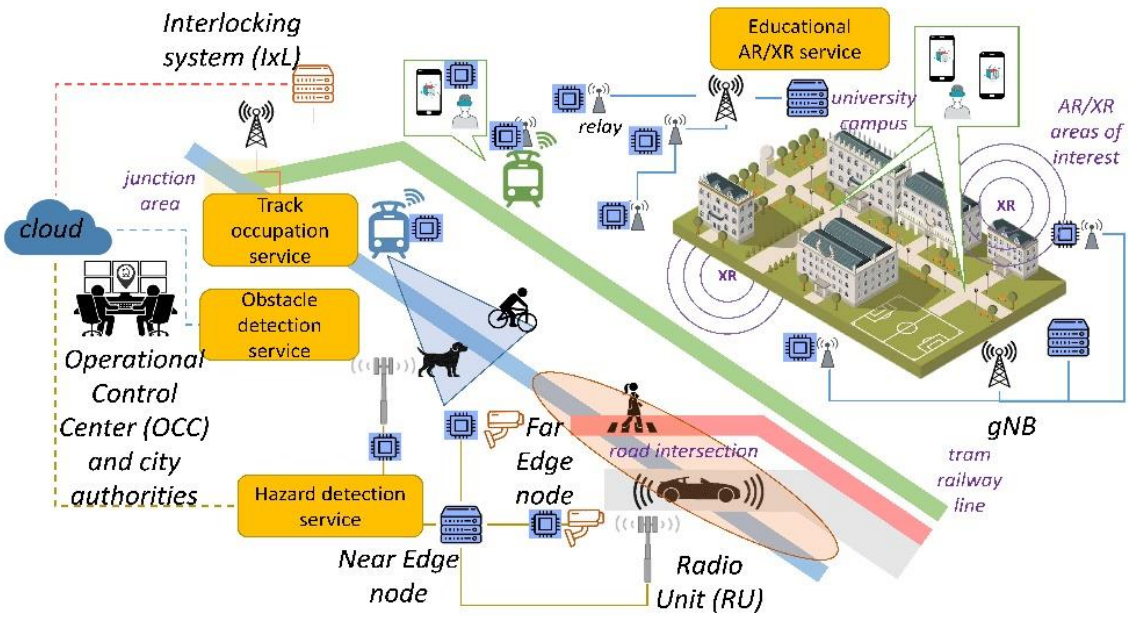


Figure 8: Autonomous tram services for safety and entertainment in a smart city environment use case scenario

VERGE created four user stories that present a number of services to enhance the operation and safety of the autonomous tram by implementing complex AI pipelines for sensor fusion and computer vision applications, while also providing AR/XR-enabled entertainment services to passengers. These services impose demanding Service Level Requirements (SLRs), motivating the need for novel edge-assisted solutions to handle the increasing amount of computation needed in near real-time conditions, coupled with efficient and dynamic network reconfiguration techniques to meet the service connectivity requirements especially in terms of latency, bandwidth and reliability. Furthermore, the use of AI brings new challenges with respect to the safety and trustworthiness of the employed methods, which must be highly accurate and robust against the variability of the operation conditions. The considered user stories are the following ones:

- User story 1, entitled "track occupation and speed monitoring", consisting of an onboard service that tracks the position and speed of the tram and an edge-enabled interlocking system, which coordinates the track occupation status of the tram junction areas.

- User story 2, entitled "obstacle detection and tracking (ODT)", consisting of an onboard service that fuses data from onboard tram sensors to identify and track obstacles that lie in the tram frontal area, alerting the driver accordingly.

- User story 3, entitled "edge-enabled hazard detection service", deployed at the infrastructure side across the tram railway lines, performing real-time detection of traffic hazards in an extended area and alerting both the tram, extending its situational awareness, and relevant city authorities.

- User story 4, entitled "provision of AR/XR entertainment and educational services along the tram route", intended for passengers onboard the tram and for students in an adjacent university campus area close to a tram stop.

In this context, VERGE has identified eight specific technical challenges which will be addressed by innovative technical solutions developed within the lifetime of the project and supported by the novel VERGE architecture and AI-enabled framework for the evolution of edge computing within the 5G/B5G ecosystem. The overview of this approach is illustrated in **Error! Reference source not found.**, linking the proposed innovations with the described user stories and the relevant validation methods. It should be noted that this is meant to be a starting point for the technical contributions of the project, which will be further refined and consolidated within the projects' lifetime.

Table 1: VERGE innovations and related user stories

VERGE innovations	Related user stories	TRL
Advanced orchestration of AI-enabled smart city services in distributed edge environments.	3	4-5
Dynamic computation splitting for real-time services.	2, 4	2-3
AI-driven network slicing for XR and for IoT-enabled autonomous tram services.	1, 2	3-4
Relays with edge computing capabilities for supporting XR services.	4	2-3
Smart micro-orchestration of disaggregated RAN elements over FPGA platforms.	3	2-3
AI model generalization for robustness to scenario changes.	2	2-3
Causal discovery and hazard prediction using structural causal models.	3	2-3
Secure edge intelligence empowered by advanced learning solutions.	3	2-3

Table 2: Improvement areas for the identified VERGE innovations in the use case

VERGE innovations	Reduced latency	Enhanced service availability	Enhanced service reliability	Efficient resource utilization	Energy efficiency	Flexibility/scalability	Enhanced computation	Efficient AI model training	AI safety	AI explainability
Advanced orchestration of AI-enabled smart city services in distributed edge environments.	✓			✓		✓	✓			
Dynamic computation splitting for real-time services.	✓		✓	✓	✓	✓				
AI-driven network slicing for XR and for IoT-enabled autonomous tram services.	✓	✓	✓	✓		✓		✓	✓	
Relays with edge computing capabilities for supporting XR services.	✓	✓	✓	✓	✓			✓		
Smart micro-orchestration of disaggregated RAN elements over FPGA platforms.	✓		✓	✓	✓	✓	✓			
AI model generalization for robustness to scenario changes.								✓	✓	✓
Causal discovery and hazard prediction using structural causal models.				✓					✓	
Secure edge intelligence empowered by advanced learning solutions.					✓			✓	✓	✓

Expected activities on "Dissemination and Impact on Standards":

VERGE has a plan to impact standardization bodies that are relevant for the project. At this stage of the project execution, the contributions have focused on ETSI MEC, as described in the following:

ETSI MEC #35 meeting

The document MEC(23)000403: "Joint communications and computing resources prioritization based on 5QI" was presented at MEC #35 Meeting, 18-22 September 2023. The contribution considered the possibility of enabling a harmonized management of the computing resources and communication resources in a 5G network with edge computing capabilities. For this purpose, a consistent prioritization of resources in the radio network and edge computing domains based on the 5G Quality of Service (QoS) Indicator (5QI) parameter standardized by 3rd Generation Partnership Project (3GPP) for the radio segment was proposed. In addition to introducing the concept, possible implementations for extracting the 5QI value from the 5G core network were discussed involving the use of the Network Exposure Function (NEF) of the 5G core and the Radio Network Information Service (RNIS).

ETSI MEC #36 meeting

The ETSI MEC #36 Meeting was held on 4-8 December 2023. In this meeting, the contributions of the project have been more focused towards the following work items (WI):

- Work item MEC-0043 on "Abstracted Radio Network Information for Industries", intended to study use cases, key issues and recommendations related to exposing abstracted radio network information for the industries. The aim for the abstraction is to provide a developer-friendly API that hides the complexity and requires only little technical skills or knowledge of the underlying Radio Network. Targeted industry segments and areas include e.g. Augmented reality and Virtual reality, Vehicle-to-everything, Logistics, Future Factories, Coordinated Robots and Drones.

- Work item MEC-0044 "Study on MEC Application Slices", which studies the potential requirements and enhancements to the MEC system needed to support MEC Application Slices, i.e., the slicing of the MEC applications. The WI also studies the necessary changes to align the MEC support for network slicing and the concept of MEC application slice, relationship and alignment with MEC system support for network slicing, as well as potential requirements and enhancements to the MEC system architecture and functions.

With the focus on these two WIs in mind, two contributions were presented.

- Document MEC(23)000535 "Addition of abstracted information for the V2X use case": The contribution provided a text proposal introducing the Service Priority as an abstracted radio network information for the V2X use case in the current draft document of the WI MEC-0043.

- Document MEC(23)000536 "Introducing a new key issue about the mapping of QoS requirements between MEC Application Slices and Network Slices". This contribution targeted the current draft document of the WI MEC-0044 and proposed a new key issue for the mapping of the QoS requirements between MEC application slices and network slices. The proposal considered the use of the 5QI for conducting this mapping and presented an example.

Furthermore, VERGE partners are active contributors in several pre-standardization Work Groups (WG) of European associations, e.g., the 5G-AA, the 6G-IA and the AIOTI WGs dedicated to standardization, as well as in standardization developing organizations (SDOs), also serving in key driving roles. For instance, INTEL personnel have just been appointed for the next four years 3GPP Service and System Aspects (SA) Chairman, which is one of the most influential and critical standards leadership roles in the global cellular industry. 3GPP is chartered to develop 5G Advanced/6G software-defined infrastructure for native AI applications and workload. Those are topics of strategic importance for VERGE, which is therefore in the best position to seize the opportunity to push its results into the 3GPP work. That will be in fact facilitated by the role of the SA Chairman, who will be responsible for overseeing the definition and specifications of the global cellular system overall architecture and service capabilities, including Services Requirements/Use case (SA1), System Architecture (SA2), Security and Privacy (SA3), Management, Orchestration and Charging (SA5), all areas where VERGE outcomes can have a tangible impact.

INTEL personnel also cover key roles in ETSI, e.g., board of directors member and the chair role of the Operational Co-ordination Group on Artificial Intelligence (OCG AI); OCG AI manages the information flow to CEN/CENELEC JTC21 in support of the AI Act [VERGE16]. ETSI has a number of Technical Committees and Industry Specification Groups (ISG) developing AI solutions, partly in support of the European AI Regulation as summarized in a recent ETSI White Paper [VERGE17]. ETSI is also important due to the several AI-related actions, like the Cyber Resilience Act (CRA) [VERGE18], issuing rules to ensure safer HW and SW, and the Radio Equipment directive (RED) [VERGE19], which establishes a regulatory framework for placing radio equipment on the market, assessing new market access requirements for all future products. Both CRA and RED are very relevant for VERGE use cases. Finally, INTEL has also the chairmanship of ISO/IEC JTC1, developing standards in the information technology domain.

Of course, having a VERGE consortium member in a driving role in an SDO does not per se imply an immediate impact of VERGE on that SDO. In order to impact an SDO, a project-wide team-work needs to be in place, and the partner or the set of partner, which can present a VERGE contribution to an SDO, needs to have that contribution aligned with the partner's overall SDO strategy.

In any case, before committing to any SDO contribution, there must be some results produced by the project, and those results are not supposed to appear before the end of the first year of VERGE (2023). Anyway, at the current status of the project schedule, the following SDOs are expected to be potentially impacted by VERGE contributions:

- ETSI (Zero-touch network and Service Management – ZSM, Multi-access Edge Computing – MEC)

- 3GPP (several WGs)

- GSMA Operator Platform Group

- ONF (Open Network Foundation)

- O-RAN (WG3, WG6)
- NGMN (WG on 6G Use Cases)
- NGMN (Network Automation and Autonomy based on AI Working Group)

Presented contribution:

A VERGE representative (Dr. Irene Vilà from Universitat Politècnica de Catalunya) presented to the ETSI MEC#35 meeting, hold in September 2023, the contribution "MEC(23)000403: Joint communications and computing resources prioritization based on 5QI". 5QI stands for 5G Quality of service Identifiers. The basic idea is to propose traffic prioritization based on the 5QI associated to each traffic flow. The contribution was very well received by the ETSI WG and follow ups have been asked for.

Next steps:

The following contributions are planned to happen in the next months:

- Ongoing work in SA3 related to VERGE focus areas will be monitored and if necessary, liaison statement(s) will be sent to inform the progress in the project and to inform requirement of studies in 3GPP to address the security and privacy issues in ML with possible solutions that require standardization because of interoperability issues.
- Contribution on a Reinforcement Learning solution that learns to obtain the optimal CU-DU functional split (based on the traffic dynamics, the SLAs, etc.) could have a potential impact to O-RAN Alliance WG3: The Near-Real-Time RIC and E2 Interface Work Group.
- Presentation to the AIOTI standardization WG a plan of action from several VERGE tasks work.
- Presentation to the 6G-IA Pre-Standardization WG a plan of action from several VERGE tasks work.
- Follow up on the presentation to ETSI MEC in Q1 2024.

Finally, on all the mentioned above SDOs and pre-standardization WGs, a constant monitoring activity will be performed by several VERGE partners, and when a decision is deemed affecting the ongoing discussions in VERGE, a report will be made to VERGE partners by the partner that identified the potential interlock between the SDO and VERGE work.

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[VERGE18] https://digital-strategy.ec.europa.eu/en/policies/cyber-resilience-act
[VERGE19] https://single-market-economy.ec.europa.eu/sectors/electrical-and-electronic-engineering-industries-eei/radio-equipment-directive-red_en.

2.1.5 Hexa-X-II: A holistic flagship towards the 6G network platform and system, to inspire digital transformation, for the world to act together in meeting needs in society and ecosystems with novel 6G services

URL/Reference:

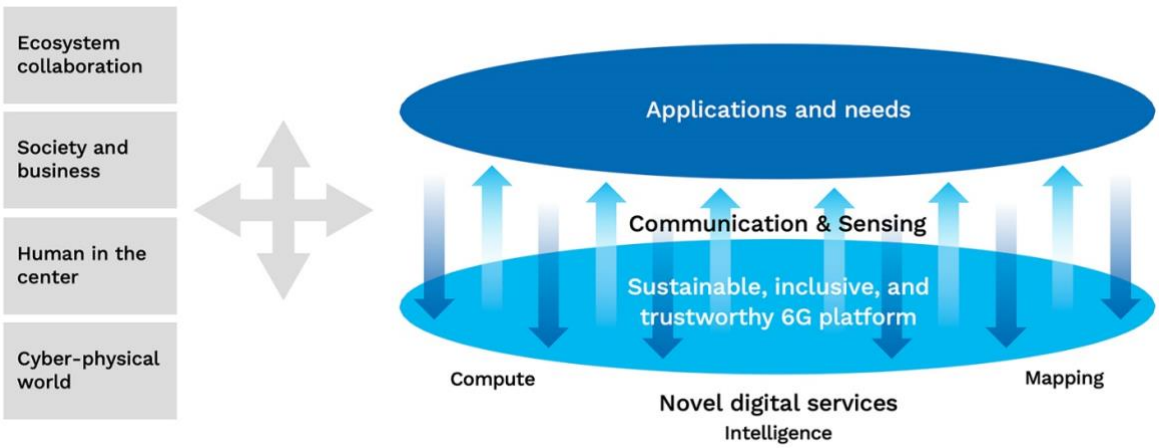
https://hexa-x-ii.eu/

Abstract:

The Smart Networks and Services Joint Undertaking (SNS JU) 6G Flagship project Hexa-X-II leads the way to the end-to-end (E2E) system design (based on integrated and interacting technology enablers) and the enabling platform delivering novel services for the next generation (6G) of wireless networks. The project will continue on the tracks of the Horizon Europe project ***Hexa-X***, which has laid the foundation for the global communication network of the 2030s by developing the 6G vision and basic concepts, including candidate key technology enablers. The work in Hexa-X-II expands from research to systemization analysis, early validation, and proof of concept. It progresses from the 6G key enablers that connect the human, physical, and digital worlds to advanced technology readiness – validated technology – including key aspects of modules, protocols and interfaces, and data. Hexa-X-II will design a system blueprint aiming at the sustainable, inclusive, and trustworthy 6G platform that should meet the future needs of serving and transforming society and business, as is illustrated in Figure below.

Hexa-X-II will also address implementation aspects of the 6G platform and encompass a full scope consisting of:

- Defining use cases, services, and requirements, ensuring the value for society
- Designing the platform and system, ensuring global impact on 6G development
- Assuring technology readiness in critical areas, ensuring EU strategic autonomy.



Starting and (target) end time of project:

01/01/2023 – 30/06/2025

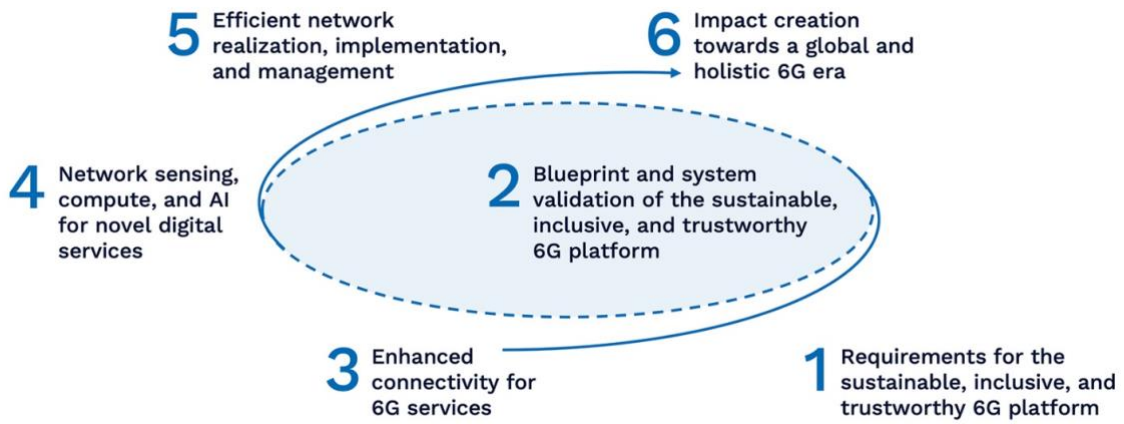
IoT and/or Edge Computing research challenges:

Hexa-X-II will address implementation aspects of the 6G platform and encompass a full scope consisting of:

- Defining use cases, services, and requirements, ensuring the value for society
- Designing the platform and system, ensuring global impact on 6G development
- Assuring technology readiness in critical areas, ensuring EU strategic autonomy.

Hexa-X-II will move ahead of the current state of the art of 6G research and add on to the technical substance by building advanced technology readiness demonstrated with Proof of-Concepts (PoCs), by further integrating towards a 6G platform for the delivery of services, and by fostering international harmonisation of 6G development. In order to achieve this, Hexa-X-II has defined six main objectives.

- As the foundation, the project will analyse needs and develop a consolidated set of requirements in terms of Key Performance Indicators (KPIs) and KVIs for the future 6G platform, considering the key values of sustainability, inclusion, and trustworthiness (Ob. 1).
- The 6G platform will be systemized and integrated into a blueprint considering the key values, involving an evaluation of KPIs, which in turn will provide a validation of the project's developed design and content (Ob. 2).
- The 6G system will enable breakthrough technologies and interfaces for connectivity services (Ob. 3), building on the progress of 5G-Advanced and meeting the demands of the 2030s.
- Expanding the scope of networks, the project will develop enabling technologies and interfaces for novel digital services building on new network capabilities of sensing, compute, and AI (Ob. 4).
- The project will further ensure that the 6G system is realizable, implementable, and manageable in a resource-efficient manner (Ob. 5).
- Finally, Hexa-X-II will contribute to a holistic European 6G view and will be a leading voice in the globally aligned roadmap towards 6G by impacting standardisation activities (Ob. 6).



Expected activities on "Dissemination and Impact on Standards":

In Deliverable D7.5 Impact to industry activities, standardisation and regulation – intermediate release the following planned contributions to various SDOs and industry groups are included:

- 3GPP SA1, Use cases, corresponding requirements and key performance/value indicators.

- 3GPP SA2, Develop the overall 3GPP system architecture and services including access network, core network, architecture modularisation, AI/ML usage, RAN-CN interface, UE-CN and CN-Application (e.g., network exposure) interfaces.

- 3GPP SA3, Security and privacy threats, and their impact on system resilience, and the techniques to address them. Distributed and trustworthy AI, Quantum-safe crypto Distributed ledgers, Remote attestation, Context-awareness, etc.

- 3GPP SA5, Intent reporting Intent conflict administration, 3rd party services. Trustworthy AI/ML-based control ML training and analysis. Trustworthy management, zero-touch multiple closed loop coordination.

- 3GPP RAN, Radio interface architecture and protocols (e.g., MAC, RLC, PDCP, SDAP), the specification of the radio resource control protocol and the radio resource management procedures. Intelligent radio air interface design, flexible spectrum access solutions, Non-Terrestrial Networks solutions, joint communication and sensing Evolution of cellular IoT, enhancement of RedCap devices (eRedCap), Ambient IoT (potential future topic).

- ITU-R SG1, Spectrum management

- ITU-R SG5, Terrestrial services

- ITU-R WP 5D, 6G vision and requirements.

- ITU-T SG5, Environment, climate action, sustainable digitalisation and circular economy.EMF D-MIMO.

- ETSI ZSM, Security and privacy threats Intent based management, digital twins, service management automation, smart contract based closed loop governance, closed loop governance. Programmability, zero-touch automation, AI-based network management and orchestration, trustworthy management and integration fabric, interdomain network and service management. Integration fabric (reference implementation), smart contract based closed loop governance.

- ETSI MEC, Security and privacy threats, the techniques to address them, and the use of NDT techniques to evaluate threats and mitigation strategies Edge computing, extreme edge computing

- ETSI THz ISG, Channel modelling, sub-THz radio RF impairment modeling / sub-THz radio aspects

- ETSI NFV, Security and privacy threats. Cloud evolution e.g., dynamic discovery and monitoring different extreme edge nodes, resource allocation

- ETSI ISG SAI, Understanding of the risks associated to widespread use and support to AI by networks, including the realisation of relevant proofs of concept

- ETSI ENI, Integration fabric (reference implementation), smart contract based closed loop governance.

- ETSI OSM, Management and orchestration

- ETSI RIS, RIS

- NGMN, Use cases and requirements

- O-RAN nGRG, Use case and requirements. Architectural aspects

- GSMA, Use cases and requirements
- IETF DetNet, Deterministic network (data plane) and orchestration (control plane)
- IETF RAW, Deterministic network (data plane) and orchestration (control plane)
- IETF dmm, Mobility management
- IETF Security Area, On the application of attestation techniques, quantum-safe technologies, and automated certificate and key management procedures to improve security and privacy in next-generation networks.
- IRTF NMRG, AI-based orchestration
- BEREC, Environmental sustainability

Beside planned contributions there are many contributions already submitted to all above mentioned SDO and standardization initiatives – included in Deliverable D7.2.

2.1.6 ERATOSTHENES: Secure management of IoT devices lifecycle through identities, trust and distributed ledgers

URL/Reference:

www.eratosthenes-project.eu

Abstract:

ERATOSTHENES will devises a novel distributed, automated, auditable, yet privacy-respectful, Trust and Identity Management Framework intended to dynamically and holistically manage the lifecycle of IoT devices, strengthening trust, identities, and resilience in the entire IoT ecosystem, supporting the enforcement of the NIS directive, GDPR and Cybersecurity Act. ERASTOSTHENES has leveraged breakthrough solutions: (a) the first-ever enclosure of cybersecurity features in IoT devices through deployment of Trust Agents and continuous trust evaluation within the network in a contextual and social approach; (b) decentralised identity management mechanisms to conciliate requirements of self-sovereignty and privacy preservation in a distributed/transparent trust model along with disposable identities; (c) self-encryption/decryption at device-level with a whole system automated recovery process (incl. software, crypto-key material, identities) after an attack based on a multi-layer recovery model; (d) threat-analysis models based on federated learning and edge execution to continuously monitor devices and detect attacks; (e) collaborative IoT threat intelligence sharing across ledgers to adapt detection/defense mechanism to the evolving security conditions and assist the IoT life-cycle; (f) integration of Physical Unclonable Functions in trust framework and distributed ledgers. Finally, it supports enforcement of the NIS directive with a security information sharing mechanism based on inter-ledger technologies to support exchange of trust and security information among stakeholders, enhancing collaboration, vulnerabilities disclosure, and secure management of software updates. The overall vision of ERATOSTHENES is to provide core cybersecurity features to be adopted by manufacturers as baseline certification elements in the production of devices and throughout their entire lifecycle. The solution will be validated in 3 industrial cases: Automotive, Health, Industry 4.0.

More details are provided in Section 1.1.3.

2.1.7 COMMECT: Bridging the digital divide and addressing the need of Rural Communities with Cost-effective and Environmental-Friendly Connectivity Solution

URL/Reference:

https://www.horizoneurope-commect.eu/

https://cordis.europa.eu/project/id/101060881

Abstract:

Over the last few years, the importance and need for broadband and high-speed connectivity have constantly increased.

The Covid-19 pandemic has even accelerated this process towards a more connected society. But this holds mainly true for urban communities. In Europe, a 13% lack of access persists and mainly concerns the most rural and remote areas. Those are the most challenging to address since they are the least commercially attractive. COMMECT aims at **bridging the digital divide** by providing quality, reliable, and secure access for all in rural and remote areas. The **goal of extending broadband connectivity in rural and remote areas** will be achieved by *integrating Non-Terrestrial Networks with terrestrial cellular XG networks and low-cost Internet of Things (IoT). Artificial Intelligence, Edge and Network Automation will reduce energy consumption both at the connectivity and computing level.*

A participatory approach with end-users and ICT experts working together on development challenges will be the key **to the digitalization of the sector**. To ensure the rich exchange of best-practice and technical knowledge among the actors of the agro-forest value chain, COMMECT will set up **five Living Labs across and outside Europe**, *where end-users' "pain" and (connectivity) "gains" will be largely discussed, from different perspectives.*

COMMECT aims to contribute to a balanced territorial development of the EU's rural areas and their communities by making smart agriculture and forest services accessible to all. COMMECT will facilitate that by developing a ***decision-making support tool*** *to advise on the best connectivity solution according to technical, socio-economic, and environmental considerations. This tool, incorporating collaborative business models, will be a key enabler for jobs, business, and investment in rural areas and for improving the quality of life in areas such as healthcare, education, and e-government, among others.*

More details are provided in Section 1.1.1.

2.1.8 Visualization of the Edge Computing EU funded completed projects landscape

This section provides a landscape visualization of the completed Edge Computing projects funded by the EU, that are introduced in this report.

The figures included in this section cover (1) completed Edge computing projects that are described in Section 2.1 of this release (Release 4.0) and (2) as well completed Edge computing projects that can be retrieved via Section 2.1 of AIOTI IoT and Edge Computing EU Funded Projects Landscape, Release 3.0, see as well the Introduction section of this release (Release 4.0). The "Edge Computing EU funded completed projects landscape (Technology and Marketing Dimensions)", shown in **Figure 9**, is a graphical representation that highlights the main activity (up to the day of generating this representation) of the ongoing projects in the area of Edge Computing, according to the Business to Consumer (B2C) vs. Business to Business (B2B) (horizontal axis) and the Connectivity vs. Service & App (vertical axis) classifications.

The projection of these edge computing completed projects into vertical industry domains is shown in **Figure 10** and for standardisation activities in different SDO's and initiatives is shown in **Figure 11**. The dimensions, the vertical/horizontal domains and standardisation organisations and initiatives of the landscapes and the method used to visualize completed projects into these landscapes shown in **Figure 9**, **Figure 10** and **Figure 11** respectively, are the same ones as defined in Section 1.1.4.

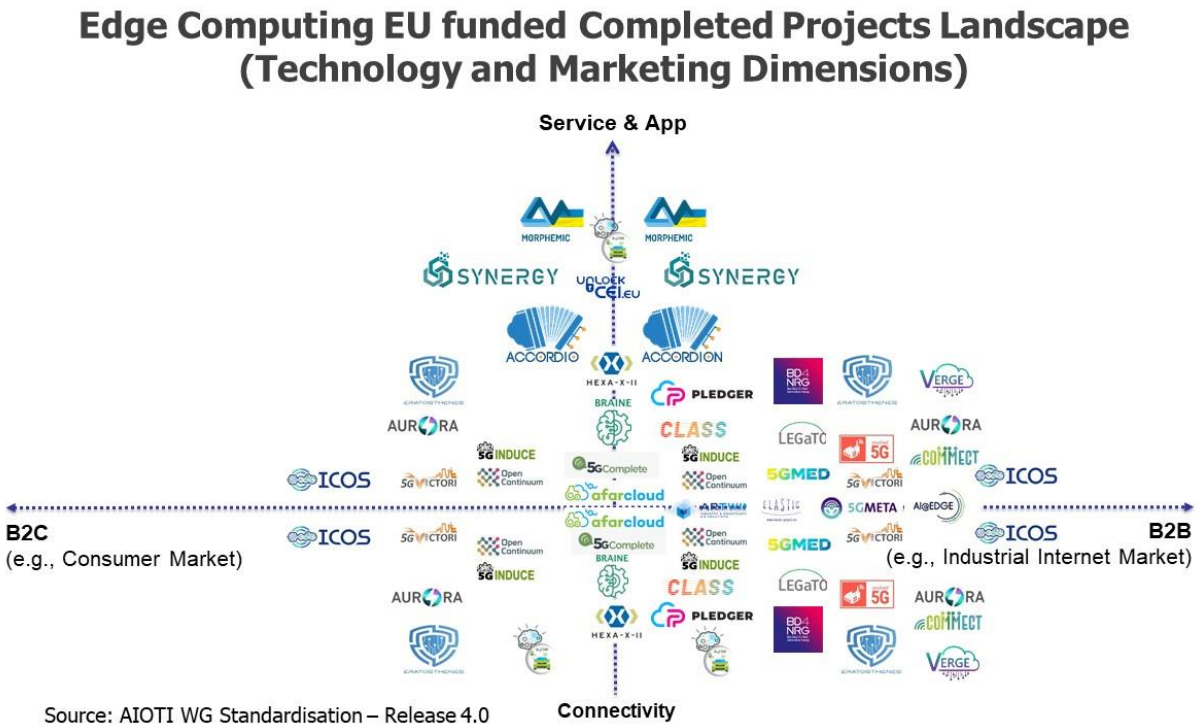


Figure 9: Edge Computing EU funded Completed Projects Landscape, when Technology and Marketing Dimensions are used

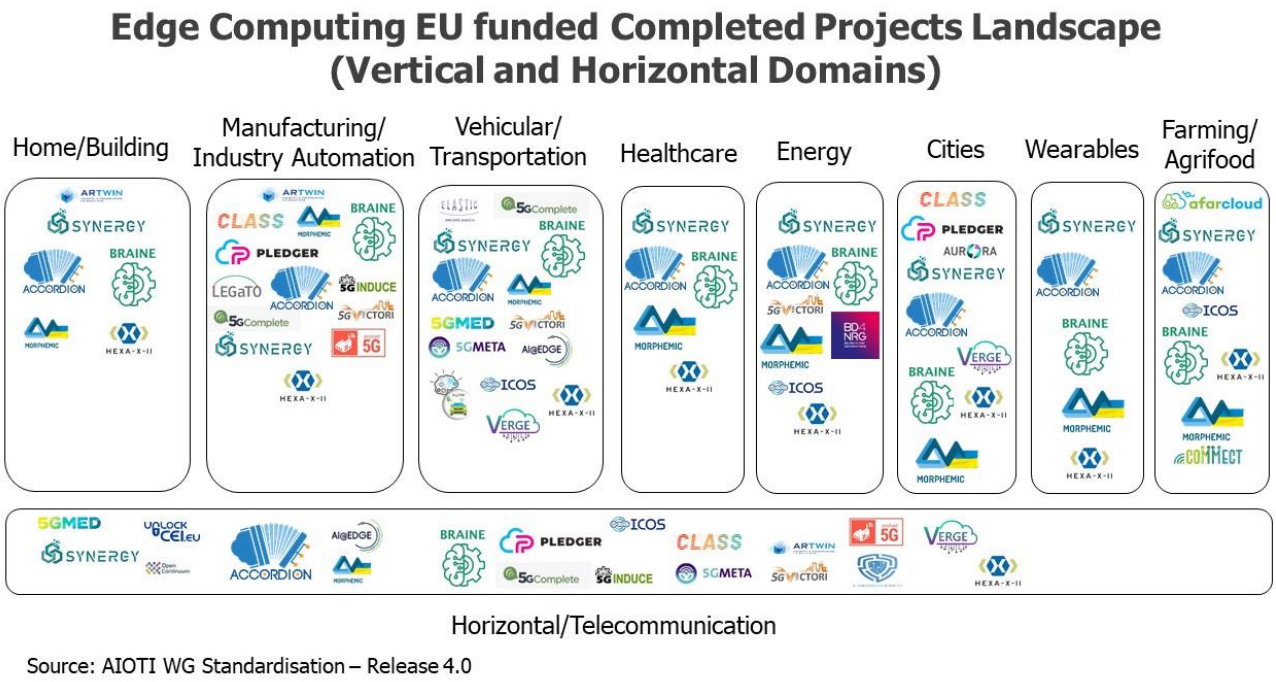


Figure 10: Edge Computing EU funded Completed Projects Projection on Vertical and Horizontal Domains

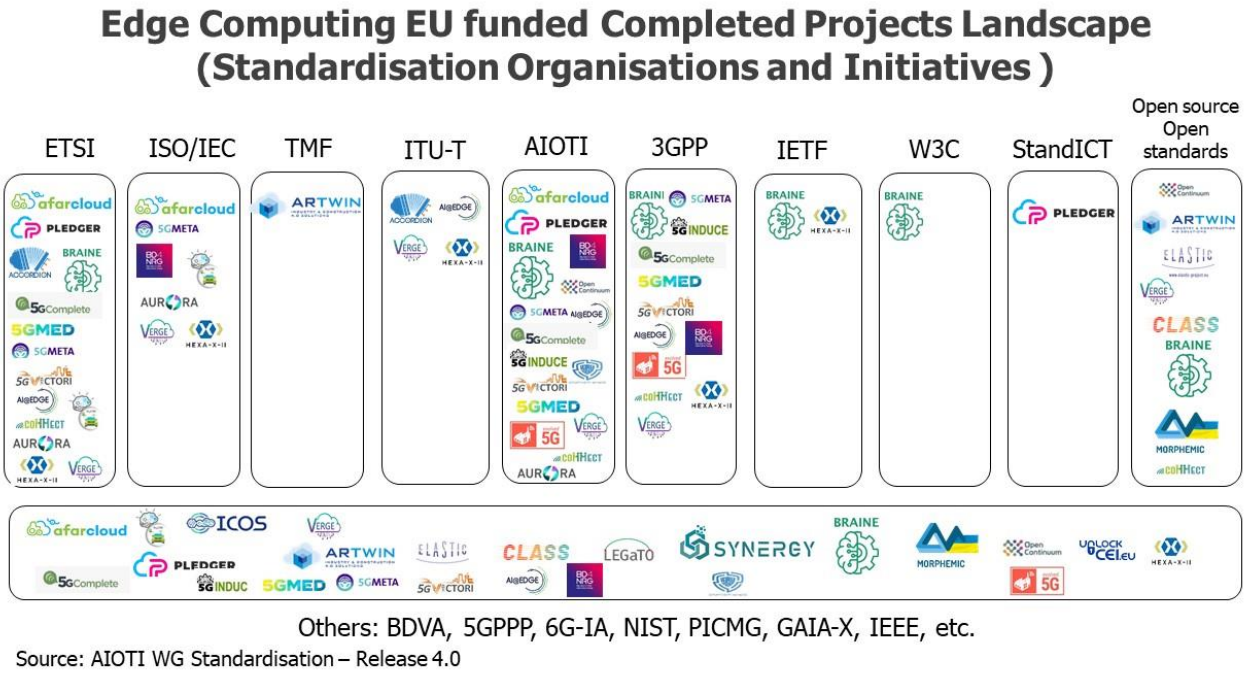


Figure 11: Edge Computing EU funded Completed Projects Projection on Standardisation Organisation and Initiatives

2.2 Ongoing Projects

This section provides description of Edge Computing EU funded ongoing projects.

2.2.1 aeROS: Autonomous, scalablE, tRustworthy, intelligent European meta Operating System for the IoT edge-cloud continuum

URL/Reference:

https://aeros-project.eu/

Abstract:

The project will deliver common virtualised services to enable orchestration, virtual communication (network-related programmable functions), and efficient support for frugal, explainable AI and creation of distributed data-driven applications. aerOS will be based on continuum infrastructure elements like smart devices, tiny/far/near edge computing nodes, and public/private clouds (including virtual services and NetApps), providing scalable and secure access to applications and services while keeping its data autonomy. The solution will be generic and directly applicable to any vertical, cross-vertical business process, and several different physical or virtual platforms.

Starting and (target) end time of project:

01/09/2022 – 31/10/2025

IoT and/or Edge Computing research challenges:

The project has just been initiated. The following challenges are mentioned:

- Optimal orchestration
- Definition and implementation of distributed AI components with explain ability
- Definition and implementation of decentralised security, privacy and trust
- Specification and implementation of a data autonomy strategy for the IoT edge cloud continuum
- Intelligent realisation of Smart Network Functions
- Global ecosystem creation, maximisation of impact and open call conduction
- Definition, Deployment and Evaluation of real-life use cases

2.2.2 FluiDOS: Flexible, scaLable, secUre, and decentralIseD Operating System

URL/Reference:

https://www.fluidos.eu/

Abstract:

This project will deliver a fluid, dynamic, scalable, and trustworthy computing continuum, spanning across devices and unifying edge and cloud in an energy-efficient manner. FluiDOS will build on consolidated operating systems and orchestration solutions, resource sharing in the computing continuum, AI-based optimisation for cost and energy, and a zero-trust paradigm to enable an open, collaborative ecosystem that will support European digital autonomy. Stakeholders will be involved through pilots and demonstrators in the fields of agriculture, energy, and logistics, challenging the project's ability to adapt to different environments and operating conditions, showcasing its true innovation potential

Starting and (target) end time of project:

01/09/2022 – 31/09/2025

IoT and/or Edge Computing research challenges:

The project has just been initiated. The following challenges are mentioned:

- OPTIMAL ORCHESTRATION Fluidify the edge and unify it with the cloud through a borderless, decentralised continuum leveraging automatic, autonomous resource discovery and integration.
- Move the gravity outside the data centre, creating a cross-provider, community-based computing and service fabric leveraging open-source software.
- Orchestrate services and hyper-distributed applications in a continuous, automated fashion over multiple devices and domains, leveraging energy-efficient AI learning algorithms and training for mobility/behaviour prediction and traffic forecasting.
- Introduce a Zero Trust paradigm aimed at securing the access of geographically scattered resources in an authenticated, authorised manner.
- Enable the emergence of a multi-stakeholder market of edge services and apps, independent from cloud providers and crucial to ensuring European digital autonomy.

2.2.3 NebulOus: A META operating system for brokering hyper-distributed applications on cloud computing continuums

URL/Reference:

https://cordis.europa.eu/project/id/101070516

Abstract:

NebulOus will contribute to research in cloud and fog computing brokerage, by introducing advanced methods to enable secure and optimal application provisioning, resource adaptation and reconfiguration. It will contribute to the cloud computing continuum through the development of a meta-operating system and platform to exploit edge and fog nodes, in conjunction with multi-cloud resources, to cope with requirements posed by low latency applications.

Starting and (target) end time of project:

01/09/2022 – 31/12/2025

IoT and/or Edge Computing research challenges:

The project has just been initiated. The following challenges are mentioned:

- Development of appropriate modelling methods and tools for describing the cloud computing continuum, application requirements, and data streams; these methods and tools will be used for assuring the QoS of the provisioned brokered services. Efficient comparison of available offerings, using appropriate multi-criteria decision-making methods that are able to consider all dimensions of consumer requirements.
- Intelligent applications, workflows and data streams management in the cloud computing continuum. Addressing in a unified manner the security aspects emerging in of transient cloud computing continuums (e.g. access control, secure network overlay etc.). Conducting and monitoring smart contracts-based service level agreements.

2.2.4 NEMO: Next Generation Meta Operating System

URL/Reference:

EC project URL: https://cordis.europa.eu/project/id/101070118

Project Official Page URL: https://meta-os.eu/

Abstract:

With the rapid increase in domains of IoT and data analytics the need for more effective operations on data and human-machine interactions, management and analytics is mandatory. Based on this need, the concept of Artificial Intelligence of Things (AIoT), was introduced as an imminent solution. Based on this, the EU-funded NEMO project aims to establish itself as a pivotal player in the AIoT-edge-cloud continuum proposing the next generation of open, modular and cybersecure meta-operating systems. By exploiting existing well-established and open-source technologies and standards while introducing new concepts, methods and tools, NEMO will bring intelligence closer to the data and make AI-as-a-Service an integral part of micro-services' lifecycle management. NEMO builds on easy development, ZeroOps deployment data monetisation and new business models, engaging communities and ecosystems to enable sustainability. Through piloting activities in five diverse domains and two open call rounds, NEMO aims to be validated in a plethora of use cases to demonstrate the benefits of the work carried out within the project.

More details are provided in Section 1.2.2.

2.2.5 NEPHELE: A lightweight software stack and synergetic meta-orchestration framework for the next generation compute continuum

URL/Reference:

https://nephele-project.eu/

https://cordis.europa.eu/project/id/101070487

Abstract:

The next generation IoT and Edge Computing technologies are evolving at a rapid pace. This evolution moves in parallel with the increase in the heterogeneity of the IoT technologies. To efficiently manage hyper-distributed applications across heterogeneous infrastructure in the Cloud-to-Edge-to-IoT continuum, convergence of IoT technologies and development of synergetic orchestration mechanisms has to take place. NEPHELE aims to tackle these challenges and enable the efficient, reliable and secure end-to-end orchestration of hyper-distributed applications over programmable infrastructure across the compute continuum, considering the integration of IoT devices with the rest part of the infrastructure. NEPHELE aims to introduce two core innovations, namely: (i) an IoT and edge computing software stack for leveraging virtualization of IoT devices at the edge part of the infrastructure and supporting openness and interoperability aspects in a device-independent way; and (ii) a synergetic meta-orchestration framework for managing the coordination between cloud and edge computing orchestration platforms, through high-level scheduling supervision and definition, based on the adoption of a "system of systems" approach. A set of use cases across various vertical industries are considered, including disaster management, logistic operations in ports, energy management in smart buildings and remote healthcare services.

Starting and (target) end time of project:

01/09/2022 – 30/09/2025

The detailed description of the NEPHELE project can be found in Section 1.2.4 of this report.

2.2.6 HiPEAC: High Performance, Edge And Cloud computing

URL/Reference:

https://cordis.europa.eu/project/id/101069836

Abstract:

HiPEAC will reinforce the development of Europe's computing ecosystem to support our digitalisation by guiding the research and innovation (R&I) of key emerging technologies, sectors, and value chains. Its goal is to strengthen European leadership in the global data economy and accelerate the digital and green transitions through human-centred innovation.

This will be achieved by mobilising partnerships and stakeholders to provide roadmaps on the creation of next-generation computing technologies, infrastructures, and platforms. The aim is to contribute to the technological development and market uptake of advanced applications across the value chain. This next generation of computing will increase European autonomy in the data economy, which is required to support future hyper-distributed applications and provide opportunities for the digital transformation of our economy and society, new business models, economic growth, and job creation.

Starting and (target) end time of project:

01/12/2022 – 31/07/2026

IoT and/or Edge Computing research challenges:

The key aim is to support and contribute to rapid technological development, market uptake and digital autonomy for Europe in advanced digital technology (hardware and software) and applications across the whole European digital value chain. HiPEAC will do this by connecting and upscaling existing initiatives and efforts, by involving the key stakeholders, and by improving the conditions for large-scale market deployment. The next-generation computing and systems technologies and applications developed will increase European autonomy in the data economy. This is required to support future hyper-distributed applications and provide new opportunities for further disruptive digital transformation of the economy and society, new business models, economic growth, and job creation.

2.2.7 CloudSkin: Adaptive virtualization for AI-enabled Cloud-edge Continuum

URL/Reference:

https://cloudskin.eu/

https://cordis.europa.eu/project/id/101092646

Abstract:

As of today, 80% of the data processing and analysis occurs in cloud data centres, and only 20% of processing occurs at the edge. CloudSkin aims to design a cognitive cloud continuum platform to fully exploit the available Cloud-edge heterogeneous resources, finding the "sweet spot" between the cloud and the edge, and smartly adapting to changes in application behaviour via AI.

CloudSkin's three main innovations are the following:

1. The CloudSkin platform will leverage AI/ML to optimize workloads, resources, energy, and network traffic for a rapid adaptation to changes in application behavior and data variability, re-configuring the "sweet spot" between the cloud and the edge in the face of the rapid varying conditions;
2. The CloudSkin platform will also help users to achieve "stack identicality" across the Cloud-edge continuum, whereby the same (legacy) software stacks (e.g., MPI programs) running in data centres can seamlessly run at remote edges. The development of a new lightweight, portable virtualization abstraction will be paired with the development of new confidential abstractions to protect data while it is in use; and
3. CloudSkin will also contribute to prepare the needed infrastructure to integrate the new virtualized execution abstractions into the virtual resource continuum, particularly, for those Cloud-edge applications composed of small tasks with fast data access and sharing requirements.

Starting and (target) end time of project:

01/01/2023 – 31/12/2025

IoT and/or Edge Computing research challenges:

CloudSkin aims to design a cognitive cloud continuum platform to fully exploit the available Cloud-edge heterogeneous resources, finding the "sweet spot" between the cloud and the edge, and smartly adapting to changes in application behavior via AI. To facilitate automatic deployment, mobility and security of services, CloudSkin will build an innovative universal container-like execution abstraction based on WebAssembly that allows the seamless and trustworthy execution of (legacy) applications across the Cloud-edge continuum.

The goals of CloudSkin are the following:

- Smart management for the Cloud-edge continuum: The overall objective is to leverage the generated knowledge from state-of-art AI methods to transparently orchestrate Cloud-edge resources. The key goal is to build a "Learning Plane" that, in cooperation with the application execution framework and continuum infrastructure, can enhance the overall orchestration of Cloud-edge resources. Such plane is the materialization of the cognitive cloud, where decisions on the cloud and the edge are driven by the continuously obtained knowledge and awareness of the computing environment through AI, and particularly, neural networks and statistical learning, taking the challenge of enabling these methods into low-power edge devices.

- Virtual execution for the Cloud-edge continuum: This goal focuses on a new universal and flexible execution abstraction, we called it "Cloud-edge cells", that will enable the execution of legacy and highly granular applications in the cloud continuum. The new container-like execution abstraction will be based on WebAssembly technology. It will enable the execution of the same computation on a wide range of cloud and embedded devices and make task execution "migratable" across different servers and devices in the continuum infrastructure. We will integrate our WebAssembly executor with Kubernetes. More specifically, we will contribute new features to Kubernetes that will support the efficient migration of WebAssembly containers between different levels of the continuum, exploiting WebAssembly's capability for state serialization.

- Infrastructure support for the Cloud-edge continuum: This objective is to prepare the infrastructure to turn it into a virtual resource continuum, where the large set of Cloud-edge cells composing applications can be allocated flexible resources, according to their dynamically changing needs. One of the major challenges here is to design an infrastructure to support extremely short-lived Cloud-edge cells and tasks (of 1 to 10ms, or less) and extremely intense bursts with fast data access requirements. This requires delivering bare metal resource performance to storage, despite virtualization and dynamic reallocation, which today is not possible in the cloud continuum. CloudSkin will achieve this by leveraging high-performance I/O (RDMA networking) and near-storage CPU compute capacity (GPUs, FPGAs) to the fine-grained application tasks.

CloudSkin technology will be demonstrated with four use cases, from four different domains:

- **5G automotive** - Orchestration of edge apps with matching cloud performance and the creation of AI video-analytics.

- **Metabolomics** - Edge/on-premises batch analytics and reduction of cloud offloading for Hybrid Metaspace.

- **Surgery** - Real-time edge video analytics with dynamic resource allocation and Private Deep & Federated Learning at the edge.

- **Agriculture IoT** - Dynamic cloud offloading to match detail level and creation of an IoT-based agriculture data space.

Expected activities on "Dissemination and Impact on Standards":

The project will exchange information with the other RIA projects of the topic HORIZON-CL4-2022-DATA-01-02 in order to exploit results, synergies and maximize impacts and coordinate dissemination activities of the swarms project portfolio. As a facilitator to carry out this duty, the CloudSkin project has already joined the EUCloudEdgeIoT.eu community as a member of the Cognitive Cloud working projects. In the next months, the project is expected to enrol in some of the six individual task forces, offered by the EUCloudEdgeIoT.eu initiative, such as the task force in communication, namely, TF6 Communication.

Since we are in the first year, the dissemination activities will be mainly carried out through the participation of the project in specific venues to share the vision and objectives of the project with other related EU-funded projects.

In this sense, we are organizing the Cloud-Edge Continuum (CEC) workshop (on October 10, 2023, in Reykjavik, Iceland), which will be co-located with IEEE ICNP'23. A key point of the workshop will be exploiting shared interests among multiple European projects on similar topics. In the workshop, there will be a specific poster walk session where representatives of several projects will be able to interact with each other to find synergies:

- NearData: Extreme Near-Data Processing Platform
- INTEND: Intent-Based Data Operation In The Computing Continuum
- CLEVER: Collaborative edge-cLoud continuum and Embedded AI for a Visionary industry of thE futuRe
- GLACIATION: Green responsibLe privACy preservIng dAta operaTIONs
- CloudSkin: Adaptive virtualization for AI-enabled Cloud-edge Continuum
- SmartEdge: Semantic Low-code Programming Tools for Edge Intelligence
- CAMEO: Creating an Architecture for Manipulating Earth Observation data
- AI for Edge: The Future of Orchestration in the Computing Continuum

The workshop topics of interest clearly align with CloudSkin objectives (e.g., network optimizations, novel system architectures, security/privacy, AI-enabled resource allocation, for the Cloud-Edge Continuum). Of course, we will continue contacting other projects to encourage them to participate. This will be an effective approach to gather researchers from multiple projects related to cloud-edge environments to share insights and foster collaboration.

Moreover, we will also take advantage of conferences and workshops where partners of the project will present their contributions to actively disseminate the project, such as ACM/IFIP Middleware'23 and WoSC9.

By now, they are not planned standardization activities in the project. But several companies in the consortium are expected to actively contribute to standards by the third year of the project (e.g., Gaia-X, or dataspaces).

2.2.8 CODECO: COgnitive Decentralised Edge-Cloud Orchestration

URL/References:

https://he-codeco.eu

https://cordis.europa.eu/project/id/101092696

Abstract:

The overall aim of CODECO is to contribute to a smoother and more flexible support of services across the Edge-Cloud continuum via the creation of a novel, cognitive Edge-Cloud management framework. To achieve this aim, CODECO proposes a unique, smart, and cross-layer orchestration between the decentralised data flow, computation, and networking services, to address Edge-Cloud challenges derived from the rising Internet and IoT service decentralisation. CODECO is developing an ecosystem consisting of open-source toolkits, large-scale experimentation, training tools and events, use-cases across 4 vertical domains (Smart Cities, Energy, Manufacturing, Smart Buildings), multiple events integrated into a unique Innovation and Research Community Engagement Programme.

Starting and (target) end time of project:

01/01/2023 – 31/12/2025

IoT and/or Edge Computing research challenges:

- Automated configuration and cognitive Edge-Cloud management, considering a cross-layer behaviour (application to the network), data and meta-data management, and policy enforcement. Privacy and security automation are aspects also addressed in this first layer of automation.

- Privacy preserving decentralised learning and context-awareness, addressed in a cross-layer manner, and focusing on beyond federated learning approaches that may better suit the orchestration of data workflow-computation-networking, addressing application requirements, node usage, prediction of mobility patterns, desired levels of privacy, security, among others.

- Dynamic scheduling and workload migration. Addresses challenges derived from the higher degree of automation due to container and workload mobility between nodes in a single cluster and across different clusters, e.g., optimal placement of workloads according to application requirements; status synchronisation; which information to exchange and to disclose; safe handover. Context-awareness and ML are applied in this context to assist in understanding the system conditions, triggering changes, and on the overall offloading process.

- Joint orchestration of computational and networking resources. On the one hand, the networking infrastructure needs to become more flexible, intent and context-driven, i.e., the network should be seen and worked upon as being a single system. On the other hand, joint computational and networking paradigms, that integrate, by design, aspects such as security/trustworthiness, mobility support, decentralised and flexible naming spaces are key to build a smart, decentralized Edge ecosystem.

- Global view of data in the IoT-Edge-Cloud continuum. Where are datasets stored, what are their characteristics, and what constraints limit how data can be processed and replicated? To achieve this, CODECO collects and manages metadata ("data that provides information about other data") and makes this metadata available to the orchestration and other system components.

CODECO proposes the following assets:

A1: Open, cognitive toolkits and smart Apps, integrating the elastic and advanced concepts to manage, in a smart and flexible way, containerized applications across Edge and Cloud (dynamic cluster and multi-cluster environment

A2: A developer-oriented open-source software repository, to be available in an early stage of the project, thus allowing for early exploitation of initial, advanced results and a better adaptation throughout the project lifetime

A3: Training tools, to support the development of services based on the CODECO framework;

A4: Use-cases across 4 domains (Smart Cities, Energy, Manufacturing, Smar Buildings), as the basis for experimentation and demonstrations

A5: a Research and Innovation community engagement program, based on the different use-cases and including the different CODECO stakeholders

A6: CODECO integration into the large-scale EdgeNet, experimental infrastructure, to assist in the building of experimentation and novel concepts by the research community

Expected activities on "Dissemination and Impact on Standards":

The CODECO consortium and the nature of the CODECO software brings in the possibility to explore liaisons towards different standardisation bodies, pre-normative entities, and standardisation alliances/consortia.

The standardisation work in CODECO is supported by Task 6.3. (October 2023 until December 2025). To best explain the initial points of contributions, Table 3 summarises the standardisation efforts that partners are already planning, where strong contributions to Gaia-X, AIOTI, ETSI, IETF and BDVA are expected. The contributions shall be developed in a consolidated way, coordinated via the T6.3 leader (IBM), where each industrial partner shall have a representative to support an adequate development of standardisation contributions.

Table 3: Initial planned standardisation liaisons

Entity	Group	Partners	CODECO Contributions	Verification Measures
EUCloudEdgeIoT	**Multiple**	**FOR, ATOS, ECL**	**Architecture, taxonomy, contributions to specific standards, white papers**	
Gaia-X	OWP Data Exchange	FOR, IBM	Contributions to the Gaia-X reference architecture on CODECO data management models; *NetMA; MDM; SWM; ACM*.	Gaia-X white papers: WP3 deliverables; WP6 deliverables.
Gaia-X	Sub-WG Interconnection and networking	FOR	Contributions to network service composition models, based on the CODECO learnings; *NetMA; MDM*.	Gaia-X reference architectures and catalogue; Gaia-X white papers.
AIOTI	WG Standardisation	ICOM, FOR	Raise awareness to the role of CODECO in the context of Smart Cities; integrate the cross-layer CODECO perspective on data management, computation and networking. *All components*.	WG03 reporting; joint standardization meetings organized in CODECO
AIOTI	WG Testing and Experimentation Environments	FOR	CODECO use-cases and EdgeNet interconnections as a reference testbed, aligned with the AIOTI testbed methodology. *All components, use-case customization.*	IG Testbeds events in 2022 and 2023; white papers.
ETSI	CSC[4]	ICOM	Contributions in the context of Cloud/Edge application of CODECO. *ACM, NetMA*	White papers and testbeds.
IETF	ALTO[5]	TID	CODECO application-network integration contributions to existing RFCs. *NetMA*	IETF ALTO draft and RFCs; WP6 reports.

4 http://csc.etsi.org/

5 https://datatracker.ietf.org/wg/alto/about/

Entity	Group	Partners	CODECO Contributions	Verification Measures
EUCloudEdgeIoT	**Multiple**	**FOR, ATOS, ECL**	**Architecture, taxonomy, contributions to specific standards, white papers**	
IETF	RAW[6]	FOR	CODECO extensions and support for decentralized Edge computing services. *NetMA; use-case requirements*.	IETF draft; contributions to existing drafts and RFCs.
IRTF	DINRG[7]	FOR, ATH	Integrate the CODECO findings about fields such as networking management; IoT; decentralised Internet services. *All components.*	IETF draft; joint events.
5GPPP	Experts Group	FOR, I2CAT, ATOS	Integrate the CODECO ideas and the role of an automated management of containers in 5G interoperability support for Edge computing. *ACM*	Smart networks vision white papers.
BDVA		IBM, UPRC, ATOS INTRA, I2CAT	Contributions to CODECO on AI engineering and trustworthiness aspects in data spaces. Contributions are also envisioned to CEN-CENELEC JTC 21 on AI[8] *PDLC*	White paper contributions.
ETSI	ENI[9]	ICOM, TID	Contributions in intent-based Edge Service Management for resource and energy efficiency. *PDLC, NetMA*	Proof of Concept (PoC).

2.2.9 dAIEDGE - A network of excellence for distributed, trustworthy, efficient and scalable AI at the Edge

URL/Reference:

https://daiedge.eu

Abstract:

The vision of dAIEDGE Network of Excellence (NoE) is to strengthen and support the development of the dynamic European edge and distributed Artificial Intelligence (AI) ecosystem as an essential ingredient in the growth and competitiveness of European industrial sectors. The dAIEDGE Network aims to reinforce the research and innovation value chains to accelerate the digital and green transitions through advanced edge AI technologies, applications, and innovations, building on Europe's existing assets and industrial strengths. In parallel, it will fortify the edge AI research and industrial communities through technological developments beyond state of the art and become a dependable and strategic pillar for the European AI Lighthouse.

This will be achieved by mobilising and connecting the European AI and edge AI constituency, the relevant stakeholders, European partnerships, and projects, to provide roadmaps, guidelines and trends supporting the next-generation edge AI technologies. The key aim is to support and ensure rapid development, market uptake and open strategic sovereignty for Europe in the critical technologies for distributed edge AI (hardware, software, frameworks, tools). The dAIEDGE NoE will play a catalyst role in building a solid

6 https://datatracker.ietf.org/wg/raw/documents/

7 Decentralised Internet Infrastructure Research Group. https://datatracker.ietf.org/rg/dinrg/about/

8 https://www.bdva.eu/node/1814

9 https://www.etsi.org/technologies/experiential-networked-intelligence

edge AI virtual network of research facilities and laboratories to benefit the European research and industrial community. The NoE multidisciplinary concept provide an arena for matchmaking, exchanging ideas, tools, and services, by bringing together the leading research centres, AI-on-demand platforms, digital innovation hubs, AI projects and initiatives. The ultimate goal for the dAIEDGE NoE is to support Europe to become a global centre of excellence with unique human-centred edge AI competence addressing the social and economic challenges and the needs of the citizens and society.

Starting and (target) end time of project:

01/09/2-23 – 31/08/2026

IoT and/or Edge Computing research challenges:

1. Edge AI Methodology and software
   - Robustness and specialization
   - On-device learning
   - On-device communication
2. Edge AI hardware and infrastructure:
   - Creation and assimilation of new hardware
   - Integration in AI continuum
   - Code generation, tuning, deployment
3. Ease of deployment and reuse
   - Benchmarks
   - Sharing and optimization of AI resources
   - Marketplace
4. Edge AI security, privacy, fairness and reliability
   - Security aspects
   - Privacy and ethical aspects
5. Establishing edge AI capability
   - Use cases in multiple domains
   - Demonstrator deployment
6. Edge AI interoperability (SW/HW)
   - Context challenge
   - Spatial challenge
   - Operational challenge
   - Legislative challenge

These challenges encompass various aspects of edge computing, including infrastructure management, virtual lab design, scheduling optimization, model deployment, and

integration into a broader ecosystem. The project aims to address these challenges to advance the state of edge computing research and development.

Expected activities on "Dissemination and Impact on Standards":

The project employs a dedicated strategy to expedite the transition from research to exploitation in Europe. This involves leveraging the participation of major European industry leaders, including ST, THALES, SED, SYNOPSYS, VERSES, and expanding the network to include a wider range of stakeholders in AI at the edge. This network includes high-potential start-ups and scale-ups, facilitating the dissemination of dAIEDGE enabling technologies to the enterprise world. A specific task is dedicated to proactively identifying innovative solutions with potential for exploitation. Each innovation undergoes systematic analysis and assessment, considering three main axes:

- Industrial exploitation (identifying industry potential for new products and services).
- Standardization (assessing potential for global standardization).
- Sustainable Development Goals (evaluating potential contribution to the UN's 17 SDGs)

The project will engage with the following AI networks related to edge computing:

1. **AI-on-Demand Platform (ICT-49):**
   - Strategic alignment with representatives from AI-on-Demand platform.
2. **Bonseyes AI Marketplace:**
   - Integration with the Bonseyes AI Marketplace for collaborative tools and services.
3. **AI4EU:**
   - Integration and merging with the AI on-demand platform developed by AI4EU.

Moreover, three Open Calls (OCs) (task starts at month 8) will be defined and managed as exchange programmes (1 OC) and collaborative projects (2 OCs) following EC procedures and rules.

2.2.10 AIMS5.0: Artificial Intelligence in Manufacturing leading to Sustainability and Industry5.0

URL/Reference:

https://www.aims50.eu/

https://cordis.europa.eu/project/id/101112089

Abstract:

AIMS5.0, a collaborative Innovation Action, aims at strengthening European digital sovereignty in comprehensively sustainable production. The project and its well-balanced consortium with 53 ambitious academic and industry partners intends to boost the economy by adopting, extending and implementing AI-enabled hardware and software components and systems across the whole industrial value chain.

New technologies from IoT and based on Semantic Web ontologies, enhanced Digital Twin, ML (Machine Learning) and AI (Artificial Intelligence) will help European manufacturers to shift from Industry4.0 to Industry5.0, creating human-centric workplace conditions and a climate-friendly production. Above all, sustainability and resilience will be improved.

We will see AI enabled fabs way more productive and eco-efficient. This will go hand in hand with shorter supply chains, a better resilience, a higher sustainability and global competitiveness keeping the main production in Europe.

AIMS5.0 a collaborative Innovation Action aims at strengthening European digital sovereignty in comprehensively sustainable production, by adopting, extending and implementing AI-enabled hardware and software components and systems across the whole industrial value chain to further increase the overall efficiency.

Vulnerability of existing supply chains in crisis shows the need for shorter supply chains and for keeping production in Europe. AI enabled fabs will be given more output and higher sustainability, which makes them more competitive on a global scale.

20 use cases in 9 industrial domains will validate the project's findings in an interdisciplinary manner. A professional dissemination, communication, exploitation and standardization will ensure the highest impact possible.

Fields of Science (EU Cordis assignment): Internet of things, AI, semantic web, ontology

More details related to this project are provided in Section 1.2.5 of this report.

2.2.11 ODEON – federated data and intelligence Orchestration & sharing for the Digital Energy transition

URL/Reference:

https://odeonproject.eu/

https://cordis.europa.eu/project/id/101136128

Abstract:

Even if significant progress has been made towards the Twin Transition, the recent energy crisis revealed the EU energy system's vulnerability and dependence on external energy sources and highlighted the need for intensifying the integration of RES in electricity, transport and building (heating) sectors. To achieve on this, the energy system shall transform from a centralised/fossil-fuel-based to an energy efficient, RES-based and interdependent system, operating with a high degree of flexibility offered by distributed assets. ODEON is conceived under the principle that this can only be realized through the creation of an inclusive ecosystem of stakeholders characterized a mesh of Data, Intelligence, Service and Market flows, jointly enabling the resilient operation of the energy system under increased RES integration and distributed flexibility. ODEON introduces a sound, reliable, scalable and openly accessible federated technological framework (i.e. ODEON Cloud-Edge Data and Intelligence Service Platform and corresponding Federated Energy Data Spaces. AI Containers, Smart Data/AIOps orchestrators) for the delivery of a wealth of services addressing the complete life-cycle of Data/AIOps and their smart spawn in federated environments and infrastructures across the continuum. It will integrate highly reliable and secure federated data management, processing, sharing and intelligence services, enabling the energy value chain actors and 3rd parties to engage in data/intelligence sharing, towards the delivery of innovative data-driven and intelligence-powered energy services in accordance to the objectives set by the Digitalisation of Energy Action Plan. ODEON results will be extensively validated in 5 large-scale demonstration sites in Greece, Spain, France, Denmark and Ireland involving all required value chain actors, diverse assets, heterogeneous grid and market contexts, and multi-variate climatic and socio-economic characteristics to support its successful replication and market uptake.

More details are provided in Section 1.2.7.

2.2.12 P2CODE - Programming Platform for Intelligent Collaborative Deployments

URL/Reference:

https://p2code-project.eu/consortium/

Abstract:

The P2CODE project aims at innovating and creating a wide-open, secure and trusted IoT-to-edge- to-cloud compute continuum that will realize the true potentials of edge intelligence. To this aim, the P2CODE project will design and develop an open platform for the deployment and

dynamic management of end-user applications, over distributed, heterogeneous and trusted IoT-Edge node infrastructures, with enhanced programmability features and tools. The platform will do so by implementing innovative design approaches and will constitute a fully-integrated infrastructure under the cloud–managed P2CODE architecture. P2CODE will contribute to the wider scope of reinforcing Europe's position in the market of next generation smart systems (sensors and devices) integrated in an evolving Internet of Things and cyber-physical ecosystems with strong capacities at the edge.

More details are provided in Section 1.2.8.

2.2.13 OASEES - Open Autonomous programmable cloud appS & smart EdgE Sensors

URL/Reference:

https://oasees-project.eu/

Abstract:

The IoT, connected smart devices interacting with each other and people and collecting all kinds of data, is exploding. The massive amount of data created is processed centrally at the cloud, which helps scalability by providing on-demand access to computing resources. Centralised processing and cloud hosting bring data governance and identity management issues to the user. Similarly, existing edge device authentication solutions require a centralised entity to authenticate data. The EU-funded OASEES project aims to create an open, decentralised, intelligent, programmable edge framework for swarm architectures and applications. The framework will leverage the decentralised autonomous organisation paradigm and integrate human-in-the-loop processes for efficient decision-making.

More details are provided in Section 1.2.9.

2.2.14 OpenSwarm - Orchestration and Programming ENergy-aware and collaborative Swarms With AI-powered Reliable Methods

URL/Reference:

https://openswarm.eu/

Abstract:

Low-power wireless technology tends to be used today for simple monitoring applications, in which raw sensor data is reported periodically to a server for analysis. The ambition of the Horizon Europe OpenSwarm project is to trigger the next revolution in these data-driven systems by developing true collaborative and distributed smart nodes, through groundbreaking R&I in three technological pillars:

- Efficient networking and management of smart nodes
- Collaborative energy-aware Artificial Intelligence (AI)
- Energy-aware swarm programming.

The EU-funded OpenSwarm project aims to take the technology further by developing collaborative and distributed smart nodes. To do so, it will explore efficient networking and management of smart nodes, collaborative energy-aware AI and energy-aware swarm programming. The energy-aware, collaborative swarms will be demonstrated in labs equipped with two 1 000-node test beds. They will then be validated in five real-world use cases in application domains such as industrial, health, environmental and mobility.

More details are provided in Section 1.2.10.

2.2.15 TaRDIS - Trustworthy and Resilient Decentralised Intelligence for Edge Systems

URL/Reference:

https://www.project-tardis.eu/about-tardis/

Abstract:

Developing and managing distributed systems is a complex task requiring expertise across multiple domains. This complexity considerably increases in swarm systems, which are highly dynamic and heterogeneous and require decentralised solutions that adapt to highly dynamic system conditions. The project TaRDIS focuses on supporting the correct and efficient development of applications for swarms and decentralised distributed systems, by combining a novel programming paradigm with a toolbox for supporting the development and executing of applications. TaRDIS proposes a language-independent event-driven programming paradigm that exposes, through an event-based interface, distribution abstractions and powerful decentralised machine learning primitives. The programming environment will assist in building correct systems by taking advantage of behavioural types to automatically analyse the component's interactions to ensure correctness-by-design of their applications, taking into account application invariants and the properties of the target execution environment. TaRDIS underlying distributed middleware will provide essential services, including data management and decentralised machine learning components. The middleware will hide the heterogeneity and address the dynamicity of the distributed execution environment by orchestrating and adapting the execution of different application components across devices in an autonomic and intelligent way. TaRDIS results will be integrated in a development environment, and also as standalone tools, both of which can be used for developing applications for swarm systems. The project results will be validated in the context of four different use cases provided by high impact industrial partners that range from swarms of satellites, decentralised dynamic marketplaces, decentralised machine learning solutions for personal-assistant applications, and the distributed control process of a smart factory.

More details are provided in Section 1.2.11.

2.2.16 SmartEdge: Semantic Low-code Programming Tools for Edge Intelligence

URL/Reference:

https://www.smart-edge.eu

https://cordis.europa.eu/project/id/101092908

Abstract:

Swarm intelligence consists of a network of endpoint devices that are able to generate and process data at source. An entire network becomes more intelligent and flexible when individual edge devices can identify and share vital information with peers. From healthcare systems to self-driving vehicles, sharing this information must be done without compromising reliability, security, privacy and scalability. The EU-funded SMARTEDGE project will provide a solution in a low-code programming environment using three tools: continuous semantic integration, a dynamic swarm network and a low-code toolchain for edge intelligence. The solution will be demonstrated in the automotive and health sectors, among others.

Starting and (target) end time of project:

01/01/2023 – 31/12/2025

IoT and/or Edge Computing research challenges:

The objective of the SMARTEDGE project is to enable the dynamic integration of decentralised edge intelligence at runtime while ensuring reliability, security, privacy and scalability. We will achieve this by enabling a semantic-based interplay of the edge devices of such systems via a cross-layer toolchain that facilitates the seamless and real-time discoverability and composability of autonomous intelligence swarm. Hence, an application can be freely built by distributing the processing, data fusion and control across heterogeneous sensors, devices and edges with ubiquitous low-latency connectivity. The goal of this project is to develop a SMARTEDGE solution with a low-code tool programming environment with various tools: (1) Continuous Semantic Integration (CSI); (2) Dynamic Swarm Network (DSW); and (3) Low-code Toolchain for Edge Intelligence. CSI allows the SMARTEDGE solution to interact with devices according to a (i) standardized semantic interface, via a (ii) continuous conversion process based on declarative mappings and scalable from edge to cloud, and (iii) providing a declarative approach for the creation and orchestration of apps based on swarm intelligence. DSW provides (i) automatic discovery and dynamic network swarm formation in near real time, (ii) hardware-accelerated in-network operations for context-aware swarm networking, and (iii) embedded network security. The low-code tool chain provides (i) semantic-driven multimodal stream fusion for Edge devices; (ii) swarm elasticity via Edge-Cloud Interplay; (iii) adaptive coordination and optimization; (iv) cross-layer toolchain for Device-Edge-Cloud Continuum. The SMARTEDGE solution will be comprehensively demonstrated over four application areas: automotive, city, factory and heath via the strong collaboration of eight industrial partners, Dell, Siemens, Bosch, IMC, Conveq, Cefiel and NVIDIA with eight research institutes.

Expected activities on "Dissemination and Impact on Standards":

SmartEdge enables seamless integration of SmartEdge devices via standardized semantic interfaces. Standardized semantic interfaces provide a common way to access the devices' data from the application level. For the different use-cases covered by the project, there is a need for seamless communication across diverse protocols, such as OPC UA, MQTT, and DDS. Ensuring interoperability at the protocol level is essential to make use of these interconnected systems. Table 4 provides a list of technologies and as well some of the used standards.

Table 4: Technologies applied in SmartEdge Various Use Cases

UC	Communication protocol	Serialization format	Semantics
1	W3C WoT (different protocols)	RDF Turtle, JSON/JSON-LD	(Use-case specific ontologies)
2	C-V2X/ETSI-G5, MQTT/NATS	JSON/JSON-LD	Smart Traffic Ontology
3	DDS, Zenoh	ROS2 Binary, JSON-LD	Robotics Ontology
4	OPC UA	XML	OPC UA FX and OPC UA companion specifications
5	BLE, DDS, MQTT	JSON	Healthcare Ontology

Standardization: W3C Web of Things advancements

During 2023, noteworthy milestones were reached within the W3C Web of Things (WoT) and its related activities, with participation from SmarEdge's partners.

- The WoT 1.1 normative specifications have been officially published as W3C Web standards. Concurrently, efforts have commenced on the development of the 2.0 specifications.

- The W3C WoT Community Group (WoTCG) hosts monthly online meetups, resulting in over 50 hours of video content showcasing how organizations worldwide leverage WoT.
- The WoTCG Discord server boasts over 110 participants actively discussing recent WoT developments and assisting one another.

In traditional Internet of Things (IoT) projects, developers grapple with the complexity of diverse systems and services from different vendors, hindering flexibility and interoperability. Customers want to be able to choose devices from multiple vendors without redesign.

The W3C Web of Things (WoT) simplifies IoT application development by offering standardized building blocks. The WoT uses web technology to harmonize access to diverse IoT devices and breaks silo walls. This allows WoT applications to be written on top of a single, portable interaction abstraction.

Many sectors benefit from WoT standards, e.g. smart homes, smart cities, smart industry, smart agriculture, smart healthcare and many more.

2.2.17 DECICE: DEVICE - EDGE – CLOUD Intelligent Collaboration framEwork

URL/Reference:

https://www.decice.eu/

Abstract:

DECICE is a Horizon Europe project that is developing an AI-enabled open and portable management framework for automatic and adaptive optimization and deployment of applications in computing continuum encompassing from IoT sensors on the Edge to large-scale Cloud / HPC computing infrastructures.

Starting and (target) end time of project:

01/12/2022 – 30/11/2025

IoT and/or Edge Computing research challenges:

3. A cloud management framework that can seamlessly connect and deploy applications to devices across the HPC, Cloud and Edge continuum
4. A digital twin that models the compute, memory, storage and network resources and the application tasks using simulation and real time monitoring at the Edge and Cloud
5. AI-scheduler that produces scheduling decisions on placement of job and data as well as conducting rescheduling to adjust to system changes in Cloud and Edge

Expected activities on "Dissemination and Impact on Standards":

Standardization bodies and entities focused on the development of interoperable IoT solutions and services, such as ETSI, IEEE, CNCF, the OPC Foundation, the Industrial Internet Consortium, IETF, W3C, and 3GPP; pre-normative bodies such as IRTF, specific study groups and task-forces of ETSI, 3GPP, IEEE; open-source initiatives such as FOSDEM, IOTA, OpenStack, FIWARE, Linux Foundation, Apache, Eclipse Foundation

Please note there is no effort at the moment in standardizing at the moment as it is in active development phase

2.2.18 6G-Cloud: Service-oriented 6G Network Architecture for Distributed, Intelligent, and Sustainable Cloud-native Communication Systems

URL/Reference:

https://www.6g-cloud.eu/

Abstract:

One key innovation in the 6G era will be the new design of the system architecture to support the extreme cloud continuum, where network functions from different 6G network segments can be composited flexibly and dynamically based on service needs in diverse cloud environments. With this in mind, 6G-Cloud aims to go far beyond the current 5G architecture design with disruptive and innovative approaches and solutions. It will research, develop, and validate key technologies to realize an artificial intelligence (AI)-native and cloud-friendly system architecture atop the cloud continuum. It will integrate cloud resources offered by multiple stakeholders and allow network functions from different 6G network segments to be composed flexibly and dynamically based on service needs in hybrid cloud environments using orchestration.

Starting and (target) end time of project:

01/01/2024 – 30/06/2026

IoT and/or Edge Computing research challenges:

- Define the overall AI-native and cloud-friendly 6G system architecture able to realize an end-to-end service-oriented 6G network atop multi-stakeholder cloud environment.
- Develop Cloud Continuum Framework for resource management and exposure with relevant business interfaces to allow flexible network composition of RAN-Core-Edge-Extreme-Edge networks in a dynamic multi-tenant environment.
- Bring service-oriented design and realize an end-to-end 6G service-based solution composed of smoothly integrated RAN and core, with the ability to act in the network-of-networks scenario.
- Develop a distributed management and orchestrated framework capable of scalable management and orchestration of network services atop the cloud continuum.
- Develop a native and network digital twin-enabled AI/ML framework to serve as an overarching cognitive plane of the 6G-Cloud architecture.
- Develop a unifying and open programable control framework for fine-grain network function coordination, resource allocation, and third-party control app integration in service-oriented 6G networks.
- Study energy efficiency, security, reliability, and sustainability aspects of the service-oriented system architecture and develop disruptive solutions for high-value applications.
- Develop proof-of-concepts to validate the architecture design and demonstrate the overall 6G-Cloud concept.
- Bring significant contributions to support early architectural standardization work.

Expected activities on "Dissemination and Impact on Standards":

- 3GPP: As it is known, 3GPP is organised in Working Groups (WG). The WGs of the radio access part (i.e. RAN2, RAN3, RAN4) are the ones most relevant for the project together with the SA5 WG that is dealing with management and orchestration aspects of RAN. In addition, SA1 and SA2 are standardization targets for new use cases and topics related to System Architecture.
- ETSI Technical Committees (TC) and Industry Specification Group (ISG) relevant for the project are ISGs: NFV, MEC, ZSM and Management & Orchestration (MANO).
- O-RAN Alliance: Its main focus is to define open interface specifications in the RAN segment. Another target of the O-RAN group is to support a full automation in the RAN

domain with benefits for the operators in terms of OPEX; in fact O-RAN considers in its architecture the presence of an orchestration framework and a radio controllers enabling AI/ML algorithms that support the automation of several aspects.

- Open Network Automation Platform (ONAP) project: Linux Foundation networking launched ONAP project in February of 2017, and it is the largest open source networking project that exists today in the industry and it provides an open-source network automation platform for real-time, policy-driven orchestration and automation of physical and virtual network functions that enables software, network, IT and cloud providers and developers to rapidly automate new services and support complete lifecycle management.

- ETSI Open-Source MANO (OSM) Community: OSM is a community-based project under the umbrella of ETSI created with the intention to provide an open-source reference implementation of a Management and Orchestration solution aligned with ETSI NFV standards. This project helps improve ETSI NFV standards by proposing changes to ISG NFV based on its implementation experiences.

- ETSI MEC Industry Specification Group (ISG): MEC offers application developers and content providers cloud computing capabilities and an IT service environment at the edge of the network. This environment is characterized by ultra-low latency and high bandwidth, as well as real-time access to radio network information that can be leveraged by applications. NCSRD is an active member of ETSI MEC focused on activities related to the security of edge telco environments.

- ITU-T SG13, Q20/21. ITUT-SG13 is working on many aspects of future networks, including network virtualization, cloud technologies, SDN, business models, network slicing, and AI/ML technologies applied to network management. OPL has been an active contributor in SG13 for many years. Please note that the NoN concept, due to the need for integration of different networking solutions, including the legacy ones, requires standardization that at present is beyond the 3GPP scope.

2.2.19 6G-BRICKS: Building reusable testbed infrastructures for validating cloud-to-device breakthrough technologies

URL/Reference:

https://6g-bricks.eu

https://cordis.europa.eu/project/id/101096954

Abstract:

Sixth generation (6G) wireless technology, which currently only exists as a concept, will create seamless connectivity between the physical and cyber worlds. The technology will use higher frequencies than 5G networks and provide substantially higher capacity and lower latency. Academia and industry are investigating a new generation of smart networks with enhanced capacity (by at least one order of magnitude) and new infrastructures to deploy these very dense networks. The EU-funded 6G-BRICKS aims to establish an experimental research facility to evaluate two key 6G candidate technologies: reconfigurable intelligent surfaces and cell-free massive multiple input multiple output. Novel unified control paradigms based on explainable AI and machine reasoning will also be explored.

Starting and (target) end time of project:

01/01/2023 – 31/12/2025

IoT and/or Edge Computing research challenges:

6G networks, currently only existing as concepts, are envisioned as portals to a fully digitized society, where the physical and virtual world are blended via boundless Extended Reality (XR), and also as an enabler for the Digital and Green transformation of the European Industries. To support this vision, the network capacity must be increased at least by an order of magnitude, while infrastructures must be transformed into a very dense continuum. Thus, academia and industry have shifted their attention to the investigation of a new generation of Smart Networks and infrastructures.
It is clear that to win this race towards shaping the next-generation communication ecosystem, a new generation of testbed infrastructures and breakthrough research and technology development is needed needed, as well as a new generation of testbeds to support future research initiative. To this end, 6G-BRICKS aims to deliver a new 6G facility, building on the baseline of mature ICT-52 platforms, that bring breakthrough cell-free and RIS technologies that have shown promise for beyond 5G networks. Moreover, novel unified control paradigms based on Explainable AI and Machine Reasoning are explored. All enablers will be delivered in the form of reusable components with open APIs, termed "bricks ". Finally, initial integrations with O-RAN are performed, aiming for the future-proofing and interoperability of 6G-BRICKS outcomes.

Expected activities on "Dissemination and Impact on Standards":

Standards body/forum	Working Group (WG)	6G-BRICKS contribution
3GPP	WG: RAN1	Monitor standardization activities in RAN1 and give input to the project consortium on standardization roadmap decisions. Potential opportunities for active participation in RAN1 for example through liaison statements and white papers will also be monitored and leveraged if appropriate.
3GPP	WG: S4	Monitor standardization activities in RAN4 and give input on interfaces and test requirements to the project consortium to adapt logging and monitoring interfaces that may comply with test solutions and can be utilized by experimenters.
ETSI	ISG: RIS	Proactive engagement and dissemination of the results of 6G-BRICKS into ISG RIS through technical contributions, proof-of-concepts, and potential new work item proposals. Partner in the project (IDE) is the chair of this ISG.
ETSI	ISG: ENI	Contribute to ISG's PoC activities by proposing and implementing a PoC on intent-based multi-domain cloud-native management of Edge and Deep Edge resources, which will showcase mechanisms developed within the 6G-BRICKS PaaS-based resource management and abstraction framework and the XAI-driven DMO mechanisms
O-RAN	WG2 WG3	**WG2** - Monitoring work on non-real-time RIC enhancements; Reporting to project consortium to prepare architecture for future ORAN incorporation of new APIs and interfaces.
O-RAN	WG4	Monitoring 5G and 6G advancements of open fronthaul to report towards project consortium on possible changes and adaptions
O-RAN	WG1 WG4	Include **RIS** as part of the **O-RAN** architecture, and target standardization of 6G-BRICKS components for distributed cell-free synchronization, Fronthauling, and RIS integration
AIOTI	WG Standardisation	Raise awareness to the role of 6G-BRICKS in interoperability between Edge, Deep Edge and IoT domains.
ISO/IEC JTCI SC29	MPEG	Monitoring relevant activities at **MPEG** (Media coding and delivery (MPEG Systems, JVET, MIV), with contributions relevant to Metaverse.

2.2.20 SUNRISE-6G: Sustainable federation of research infrastructures for scaling-up experimentation in 6G

URL/Reference:

https://sunrise6g.eu

https://cordis.europa.eu/project/id/101139257

Abstract:

6G represents the future of technology, promising exceptional performance through innovative access technologies. It is poised to prompt a complete re-evaluation of network architecture design, with new stakeholders entering the value chain of future networks. The EU-funded SUNRISE-6G project aims to develop a massively scalable internet-like architecture for all public and private infrastructures. Additionally, it seeks to establish a pan-European facility to support converged workflows and tools, offering a unified catalogue of 6G enablers and facilitating cross-domain vertical application onboarding through a Tenant Web Portal. The project will focus on four pillars: implementing new 6G enablers, a compliant Federation solution, a Federated AI plane, and a commonly adopted Experimentation Plane.

Starting and (target) end time of project:

01/01/2024 – 31/12/2026

IoT and/or Edge Computing research challenges:

The 6G is expected to emerge as key enabler for the intelligent digital society of 2030 and beyond, providing superior performance via groundbreaking access technologies, such as joint communication and sensing, cell-free, Radio Intelligent Surfaces, and ubiquitous wireless intelligence. Most importantly, 6G is expected to trigger a total rethink of network architecture design, which builds on a key idea of new stakeholders entering into a value chain of future networks. The SUNRISE-6G approach is inspired by the "network of networks" concept of 6G Networks, aiming to integrate all private and public infrastructures under a massively scalable internet-like architecture.

SUNRISE-6G similarly aspires to create a federation of 6G test infrastructures in a pan-European facility that will support converged Testing as a Service (TaaS) workflows and tools, a unified catalogue of 6G enablers publicly accessible by experimenters, and cross-domain vertical application onboarding. Experimentation and vertical application onboarding are offered via a Tenant Web Portal, that acts as a single-entry point to the facility, serving end users (e.g. experimenters) and tenants (e.g. vertical developers, infrastructure owners, 6G component manufactures).

The project execution is based on 4 pillars, delivering:

a) Implementation of new 6G enablers, complementary to existing ones being developed in SNS Phase 1 projects

b) A truly scalable and 3GPP compliant Federation solution that provides access to heterogeneous resources and devices from all Europe

c) Federated AI plane aligned with AIaaS and MLOPS paradigms, which promotes a collaborative approach to AI research which benefits immensely from scaling-up datasets and models

d) Commonly adopted Experimentation Plane, which offers common workflows to experimenters.

Expected activities on "Dissemination and Impact on Standards":

SDO	Working Group	Expected Contribution
ITU-T	ITU-T Q.4068	Contribute to Common Interfaces and APIs, Data Models and Formats, Reference Architectures (e.g., ITU-T Q.4068). Path towards impacting IMT 2030 developments.
ITU-T	WP 5D	To follow activities of ITU-R WP 5D on 6G definition (IMT-2030). UOULU's 6G Flagship representative is nominated as Finnish national representative to WP5D work which offers a clear pathway for SUNRISE-6G to affect the development of IMT-2030.
ETSI	RIS	To contribute by including the creation of technical reports and studies that explore the potential benefits, applications, and challenges of RIS in the context of future communication networks, such as 6G systems, as well as potential new requirements.
ETSI	NFV	To provide use cases and requirements for incorporating NFV technologies into 6G networks. This includes exploring new service models, network architectures, and management and orchestration (MANO) approaches that leverage the benefits of virtualization in 6G systems.
ETSI	MEC	To allow containerized MEC apps to be disaggregated at any MEC host with the extension of the Mobile Edge platform at the system and host level.
ETSI	ZSM	To contribute with the development of proof-of-concept implementations and demonstrators showcasing the integration of ZSM technologies in 6G systems, providing valuable insights into the practical challenges and opportunities of deploying automated network management functions in next generation networks.
ETSI	ENI	To follow and contribute with technical reports and studies to ETSI ENI and its system architecture aspects on intent LCM, closed loops automation, Federated Administrative Domains and knowledge management. Moreover, ICOM will lead the start of an ETSI Software Development Group (SDG) on a Federation Framework that will devise, in collaboration with consortium partners who are ETSI members, an open Federator SDK.
ETSI	OpenCAPIF (OCF) SDG	CAPIF open-source framework will be integrated as part of the Exposure Gateway to ensure secure and trustworthy exposure of resources especially when they belong to different trust domains. Under discussion how CAPIF can be applied in the project. OCF was recently created and is not included in DoA.
3GPP	RAN1	Monitor standardization activities in RAN1 and give input to the project consortium on standardization roadmap decisions. Potential opportunities for active participation in RAN1 for example through liaison statements and white papers will also be monitored and leveraged if appropriate.
3GPP	SA1	To contribute with the outcome of the NTN communication in SA1 for use cases and requirements
3GPP	SA2	**SA2** for integration into architectures of existing mobile communication networks
3GPP	SA5	**SA5** for operations and management of NTN and NTCS in 6G
CAMARA	Edge Cloud API QoS on Demand	Monitor and align API requirements, publish API definitions and advancing current APIs, enabling seamless access to Telco network capabilities (5G and 6G). Aiming to extend the Camara Initiative APIs, offering unified developer APIs towards SUNRISE-6G use-cases and components (e.g. Open-source implementation of exposing NTN emulator components, aligned with CAMARA APIs).
O-RAN	Next-Gen Research Group (nGRG)	SUNRISE-6G will follow and contribute to the discussions in the O-RAN's next Generation Research Group, which specifically focuses on the O-RAN development needs towards 6G. The most relevant nGRG research streams for the SUNRISE-6G topics will be: • **RS02**: Architecture • **RS05**: Management

SDO	Working Group	Expected Contribution
		• **RS06**: Cross Domain • **RS08**: nG Research Platforms
O-RAN	WG1, WG2, WG3	**WG1** - Include RIS as part of the O-RAN architecture, and target standardization of SUNRISE-6G components for distributed cell-free synchronization, and RIS integration. Moreover, include the Cell-free and JCS as a part of the overall O-RAN architecture. **WG2** - Monitoring work on non-RT RIC enhancements; Reporting to project consortium to prepare architecture for future ORAN incorporation of new APIs and interfaces.
CNCF	DevOps	Share paradigm, protocols, and implementations of declarative APIs target end-to-end automations of infrastructures and services.
TM-FORUM	Open API DG	Application of TMF Open APIs for the SUNRISE-6G capability exposure, feasibility checks, tests across testbeds.
AIOTI	WG Standardisation	Raise awareness to the role of SUNRISE-6G in interoperability between Edge, Deep Edge and IoT domains

2.2.21 ExtremeXP: Experiment driven and user experience oriented analytics for extremely precise outcomes and decisions (HORIZON-CL4-2022-DATA-01 "ExtremeXP")

URL/Reference:

https://extremexp.eu

https://cordis.europa.eu/project/id/101093164

Abstract:

Extreme data characteristics represent a challenge for advanced data-driven analytics and decision-making in critical domains such as crisis management, predictive maintenance, mobility, public safety and cyber-security. Data-driven insights must be timely, accurate, precise, fit-for-purpose and reliable, considering and learning from user intents and preferences. The EU-funded ExtremeXP project will create a next-generation decision support framework that integrates novel research from big data management, machine learning, visual analytics, explainable AI, decentralised trust, and knowledge engineering. The framework will aim at optimising the properties of complex analytics processes (e.g. accuracy, time-to-answer, specificity, recall, precision, resource consumption) by associating different user profiles with computation variants, promoting a human-centred, experimentation-based approach to AI and complex analytics. The project will perform five pilot demonstrations.

Starting and (target) end time of project:

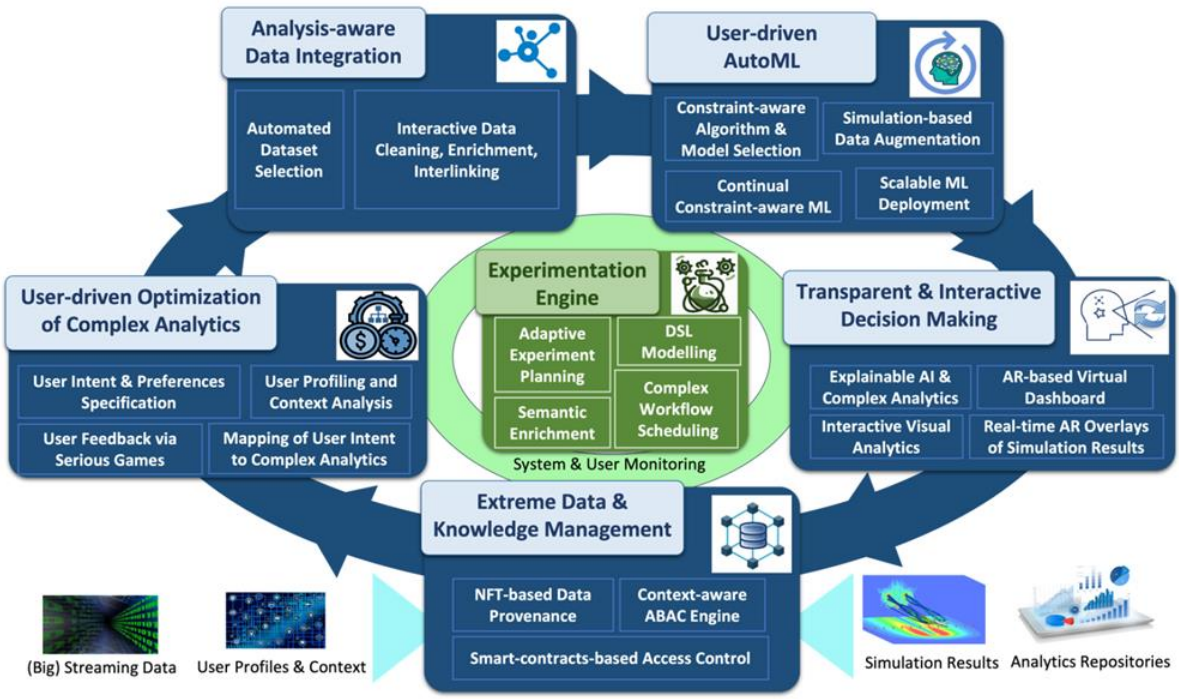
01/01/2023 – 31/12/2025

IoT and/or Edge Computing research challenges:

Decisions based on data-driven insights can be vital and have a phenomenal impact on the environment, society, and business. Many critical domains such as crisis management, predictive maintenance, mobility, public safety, and cyber-security become increasingly disrupted by new means to harness the extreme proliferation of data for effective decision making. Generating data-driven insights that can be used and trusted by decision-makers is, however, still far from trivial. On the one hand, (big) data analytics solutions need to cope with data of extreme (exabyte) scale, low quality (sparse/missing/insufficient values), different modalities (raw data, text, images), and different owners.

On the other hand, complex data analytics comprising machine learning (ML) and simulation tasks need to provide outcomes (i.e., predictions, visualizations) that are both accurate, precise, and fit for purpose. While accuracy refers to outcomes that are close to reality and precision to

being focused and not dispersed, fit-for-purpose refers to their actual usefulness in decision making. On top of these needs, insights are not used in decisions if they cannot be trusted; therefore, increased trustworthiness in data-driven insights is pivotal in the adoption of data-driven decision making, in life-critical domains.



Existing R&D efforts typically target only one of the aspects of the data analytics conundrum: they focus either on resource efficiency and scalability, data management, ML performance, AI explainability, or data visualization. Several existing big data frameworks and architectures (Lambda, Data Lakes, etc.) provide support of processing, analytics, ML, simulations, and visualizations for large data volumes, given the proper infrastructure; however, they mainly focus on efficiency and scalability in pre-designed data analytic workflows. Automated ML (AutoML) streamlines the whole process of providing optimised ML models from data ingestion and pre-processing to model selection and training, to model execution and result visualization; however, it does not involve end (business) users in the loop. Explainable AI aims at ML models that can explain their generated results, increasing the understanding and ultimately the trust of end users in data-driven insights; It typically focuses on individual ML models and does not consider the user intents and preferences. Current visualization techniques mostly focus on visually representing the outcomes of analytics processes in one direction, from data processing outputs to graphs, charts etc., neglecting interaction with end users, which can further expose user requirements in an incremental manner and hint towards the data processing that fits their needs. Overall, past work contributes to data quality, without sufficient attention to the user intent. We need to embed the user in data production and management; and ways to detect (and correct) when the data (and ML-driven systems) diverge from such intent.

In response to this dire need for decision making based on accurate, precise, fit-for-purpose, and trustworthy data-driven insights, ExtremeXP proposes a new paradigm for data analytics, which we call experimentation-driven analytics. The main contribution is that it puts the end user, i.e., requirements, preferences, constraints, interpretation, explanations, feedback, and decision making, at the centre of complex analytics processes (from data discovery to novel interactions), proposing a human-in-the-loop, experimentation approach for gaining knowledge and making decisions from data with varying and extreme characteristics (Figure 1).

An experiment for ExtremeXP considers alternative means (datasets, features, algorithms, models, simulations, visualizations) of responding to an end user intent – knowledge requirement, executes a particular variant for each user, and evaluates it based on both system-level metrics (latency, accuracy, precision, specificity, anonymity) and feedback from the user in an

automated or semi-automated way. This way, it gradually builds up knowledge to associate users to complex analytics workflows that meet their needs, i.e., consider their constraints and preferences regarding outcome attributes such as latency, precision, and anonymity. ExtremeXP integrates interactive visualization and explainability techniques to increase the trustworthiness of not only the outcomes but also of the process to reach such outcomes. Towards the latter, it is important to transparently and immutably persist any access control decisions regarding datasets used for deriving valuable insights and highlight their characteristics and therefore potential value in terms of the data analysis workflow. The provided framework automates the process of (i) running complex analytics as part of experiments and of (ii) building up the knowledge base for user-experience-driven analytics, reducing the complexity associated with manual tuning of complex analytics.

The ExtremeXP project will deliver the following assets:

ER1: Modelling framework and reference architecture for complex experiment-driven analytics

ER2: Experiment engine for automating scheduling, evaluation, and adaptation of complex analytics

ER3: Analysis-aware data integration concept and methods

ER4: Methods for Automated ML (AutoML) with user constraints

ER5: Support for user involvement in complex experiment-driven analytics

ER6: Explainability-oriented user interaction toolset

ER7: Interactive visualisation support including augmented reality and serious games

ER8: Holistic data and knowledge management supporting privacy and security

ER9: 5 pilot demonstrators to validate results through deployment in relevant environments

Expected activities on "Dissemination & Impact on Standards":

The ExtremeXP consortium will leverage the participation of partners in several initiatives, **standardisation** bodies, collaboration platforms and hubs related to AI, Data, European Open Science Cloud (EOSC) and Industry in general. In particular:

BU will liaise with *BDVA* and *AIOTI*

ICOM will contribute to *AIOTI* and participate in *ETSI CIM* (Standards – Context Information Management), *ETSI ENI* (Experiential Networked Intelligence) as well as to *TM Forum* (active in AIOps)

AE will work with *OW2* to promote Market Readiness for open-source project developments

ARC will cooperate with EOSC Association

ICCS will work with *BDVA*, *IDSA*, *NESSI* and Gaia-X

Direct access and open communication channels with these entities are available to the consortium through the engagement of the partners. Such liaisons will significantly strengthen the ExtremeXP capacity for reaching many stakeholders and disseminating the project results.

2.2.22 6G-INTENSE: Intent-driven native AI architecture supporting compute-network abstraction and sensing at deep edge (HORIZON-JU-SNS-2023 "6G-INTENSE")

URL/Reference:

https://6g-intense.eu/

https://cordis.europa.eu/project/id/101139266

Abstract:

The 6G Smart Networks of the future will provide the high-performance and energy-efficient infrastructure on which next-generation internet and other future-looking applications can be developed and deployed. 6G will foster an Industry revolution and digital transformation and

will accelerate the building of smart societies leading to quality-of-life improvements, facilitating autonomous systems, haptic communication, and smart healthcare.

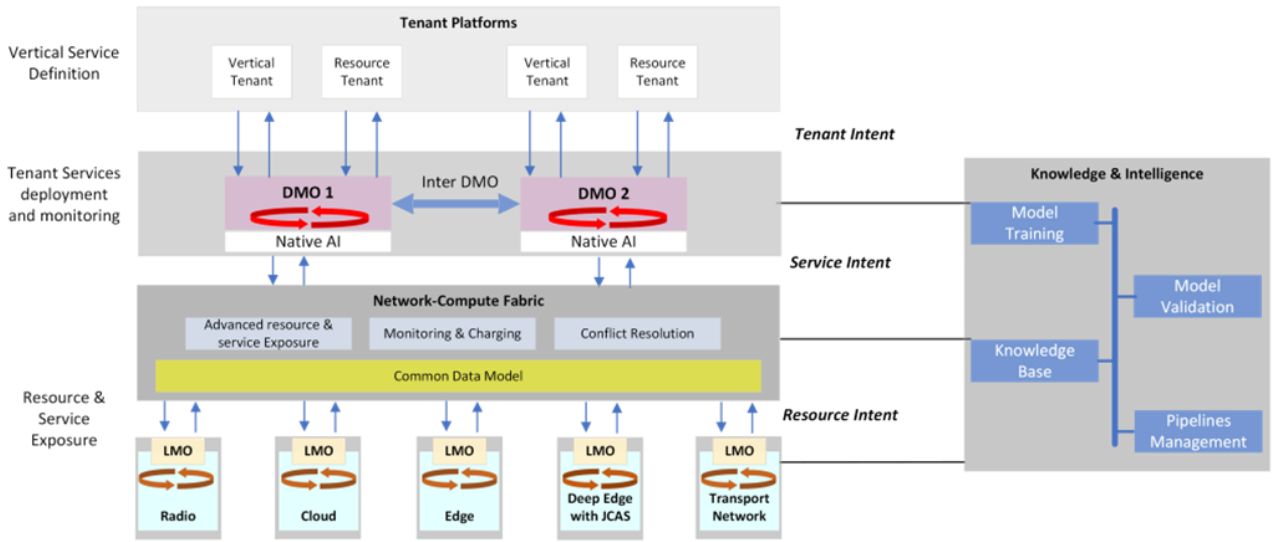
To achieve the objectives sustainably, it is well understood that new approaches are needed in the way the telecom infrastructures are architected, federated, and orchestrated. These new approaches call for multi-stakeholder ecosystems that promote synergies amongst the Mobile Network Operators and owners of all kinds of computational and networking resources that will share the extraordinary costs of yet another generation upgrade from 5G to 6G, while facilitating new business models. New architectural paradigms are making things more complex due to their large scale and diverse orchestration domains. As a result, automation needs to step up to handle this complexity. That is why 6G is aiming for the ambitious goal of pervasive AI-driven intelligence, known as Native AI. However, the multi-stakeholder infrastructures foreseen in 6G as per the "network of networks" concept, will add a level of unprecedented management complexity due to a sheer scale and heterogeneity of involved orchestration domains.

Starting and (target) end time of project:

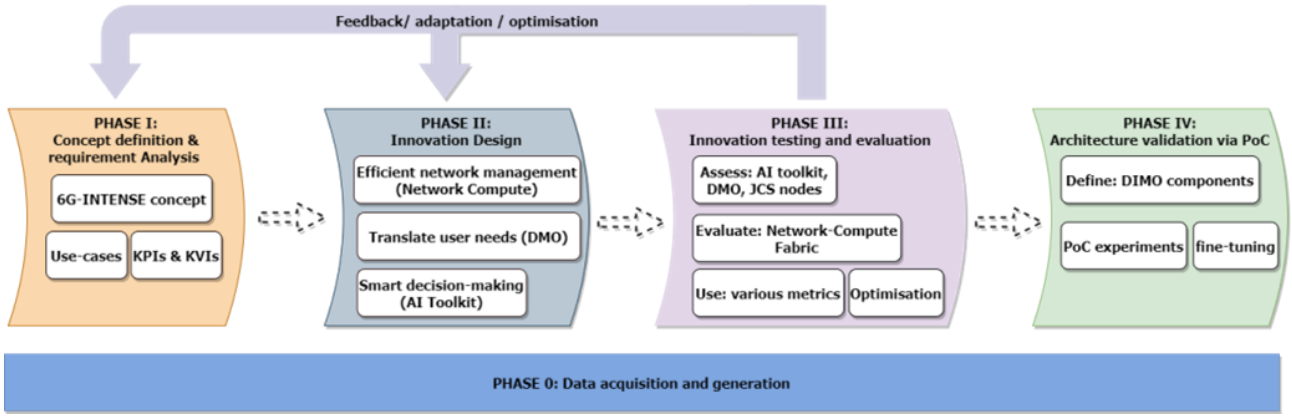
01/01/2024 – 31/12/2026

IoT and/or Edge Computing research challenges:

This is where 6G-INTENSE steps in, proposing a new System Architecture for 6G, as illustrated below, to deliver "6G as a Smart Service Execution platform", fully in line with the vision of sustainable infrastructure sharing to reduce space and energy costs and encouraging collaboration among all members of the value chain under a unified Network-Compute fabric. A key contribution is a novel automation architecture with a Native AI toolkit facilitating intent declaration, negotiation, and decision automation across autonomous domains, termed Distributed Intent-driven Management and Orchestration (DIMO). Moreover, sensing is adopted as a key enabler, helping to navigate the complexities and lack of reliability of the Deep Edge.



The 6G-INTENSE project introduces a transformative scientific approach, uniting all computational and networking resources under a revolutionary, open controllability framework. The project aims to drive innovations across business, management, and infrastructure layers. Through a systematic five-phase methodology, as depicted in the figure below, 6G-INTENSE pursues ambitious goals. These include advancing 6G technologies to enhance performance, efficiency, and capabilities, establishing a single, unifying framework that redefines controllability in network infrastructure.



The 6G-INTENSE project will validate its key technologies and innovations through relevant Proof-of-Concepts (PoCs). Embracing technologies like AI/ML, edge computing, and intent-driven orchestration, the project employs cutting-edge platforms, such as the infrastructural platforms provided by Orange Romania, Eurecom and Athena/ISI. These platforms form the backdrop for a diverse set of experiments, exploring distributed continuum computing, metaverse services, and pervasive location awareness. With a commitment to fostering progress, 6G-INTENSE also places a significant focus on data acquisition, creating open datasets to fuel ongoing research in the dynamic 6G landscape. This holistic approach positions 6G-INTENSE at the vanguard of shaping the future of wireless networks. PoCs are listed below:

Distributed Continuum towards pervasive computing (PoC-1)

Experiment 1 *"Pervasive Computing in a Distributed Continuum":*

It explores efficient media content distribution across diverse domains using a converged infrastructure. It employs dynamic Edge Cache instances for reliable streaming, adapting to user connectivity, content popularity, and network conditions. The 6G-INTENSE framework enables hierarchical, intent-driven automation for optimal Edge Cache services, including auto-scaling, auto-healing, and migration. INTRACOM's content delivery network platform is deployed in various environments, and a multi-testbed setup showcases the INTENSE-6G Orchestration Continuum with πEdge local managers and orchestrators orchestrating Edge Cache container network functions. It aims to:

- Manage smart services through the Network-Compute Fabric, trained by Generative AI models
- Ensure security in the Deep Edge infrastructure by monitoring links and performance

Experiment 2 "*Edge intelligence and Compute interconnection*":

It evaluates the Composable AI and learning capabilities of the 6G-INTENSE system in the context of distributed content delivery network video streaming. It introduces an automated service level objective setting and adjustment across domains, utilising Machine Learning as a Service (MLaaS) for domain adaptation. The experiment demonstrates automated resource brokerage, knowledge sharing, and cognitive enablement to ensure consistent service level agreement assurance across domains. It aims to:

- Efficiently connect network points using smart network technologies for enhanced video streaming
- Flexibly use resources within the system to optimize video streaming
- Ensure reliable quality of service through monitored intentions
- Improve video streaming quality by smartly training models on the edge

Metaverse (PoC-2):

Experiment 3 "*Joint Communication and Sensing for optimal user tracking in the Metaverse*"

It focuses on intelligent algorithms for Joint Communication and Sensing in future 6G systems, specifically in user equipment tracking scenarios. While current algorithms excel outdoors, their precision diminishes indoors, impacting users connecting to Deep Edge devices via non-3GPP access. Sensing user location is crucial for predicting disruptions and enhancing location awareness. The scenario involves users connected through non-3GPP access to a 6G-INTENSE distributed intent-driven management and orchestration-deployed Metaverse service. Distributed intent-driven management and orchestration, relying on communication and sensing, showcases components translating users' intents and demonstrating resource-level optimisation, such as handovers triggered by sensed information. Its objectives are to:

- Demonstrate joint communication & sensing to provide pervasive location awareness by Metaverse
- Explore trade-offs on sensing accuracy vs. energy efficiency at the Deep Edge

Experiment 4 "*Fully autonomous Metaverse fault, configuration, accounting, performance and security management, sensing, continuum abstraction*"

It showcases distributed intent-driven management and orchestration end-to-end functionality, emphasising intent translation and propagation. Orange and Eurecom testbeds, interconnected via 6G-INTENSE domain management and orchestration, convey preferences through intent. A Metaverse Service Mesh aligns with 6G-INTENSE, featuring cloud-native network functions, micro-services, and a cyber-physical systems service. Domain management and orchestration autonomously handles onboarding and intent negotiation, while testbeds deploy services via their Network-Compute Fabric abstraction frameworks. Its objectives are to:

- Showcase how Native AI mechanisms drive intent (re-) negotiation at the Tenant domain
- Deliver the Orchestration Continuum vision at the Service domain
- Demonstrate adaptation based on inputs of a Sensing service being part of a generalized Service Mesh

Local managers and orchestrators like Eurecom O-RAN and Intracom pi-Edge orchestrate resources. The experiment tests adaptability, intra- and inter-domain coordination, and conflict resolution, highlighting Native AI toolkit's hierarchical reinforcement learning capabilities. Fault, configuration, accounting, performance and security management decisions include intent adaptations, service migrations, and resource scaling, illustrating collaborative orchestration by O-RAN and pi-Edge local managers and orchestrators.

Expected activities on "Dissemination & Impact on Standards":

6G-INTENSE will achieve long-lasting impact by influencing standards, thus obtaining the seal of approval for its newly implemented components. Key industrial consortium partners as active members in various key standardisation organisations (3GPP, TMForum, IETF/IRTF, and ETSI) will contribute to new standards bringing in new requirements to identify and fill gaps, as well as evolve existing standards related to 6G architectures.

Participation in 6G initiatives: 6G-INTENSE will contribute to 6G-IA activities and it will participate in any Working Groups. Moreover, the consortium has already identified several relevant projects, while during the project active monitoring of any other initiatives that might be essential to liaise with or contribute to will be also actively pursued (e.g. IEEE Future Networks Enabling 5G and beyond, IEEE 5G Summit). Moreover, 6G-INTENSE consortium commits its presence in EuCNC (2023-2026), where demos of the project's solutions will be presented.

Standards body/forum	Working Group (WG)	Planned 6G-INTENSE contributions

IETF	Routing Area WG (RTGWG)	Contribute with the research activities on SDWAN. More precisely, devised 6G-INTENSE mechanisms to interconnect, manage and orchestrate Cloud Edge Interconnection using SD-WAN.
IRTF	Network Management Group	Contribute to the intent-based network management using 6G-INTENSE native AI kit.
3GPP	Experts Group SA6	Contribute with business intent translation replacing classical BSS model with a fully distributed systems using LLM and Generative AI.
	Experts Group SA5	Contribute with the programmable intent model translation and propagation, paving the road to the beyond 5G SBA architecture by replacing classical API by intents.
ETSI	ENI	Contribute to ETSI ENI ISG with technical reports and PoC activities on intent-driven, hierarchical closed loop automation solutions developed within 6G-INTENSE.
	ZSM	E2E and domain specific management architecture and AI based closed-loop automation. Contribution to ZSM016 (Intent Driven Closed Loop Automation). Contribute to ISG PoC activities through proposing and implementing a PoC on intelligent predictive, intent-based declarative multi-domain monitoring, which will showcase mechanisms developed within the 6G-INTENSE
	MEC	Contribute with extension of the Mobile Edge platform at the system and host level, to allow containerized MEC apps to be disaggregated at any MEC host. Also to contribute with CNIT JCS using MEC.
ITU-T	ITU Focus Group on Autonomous Networks (FG-AN)	Contribute with the Native AI tool kit applied to support zero-touch management and orchestration toward supporting autonomous network management
O-RAN	Non-Real-time RAN Intelligent Controller and A1	Contribute the integration of intent propagation and translation mechanism to O-RAN SMO.
OAI Alliance	Open Air Interface	Contribution of the developed modules integrating Intent to SMO and their enforcement using OAI 5G RAN.
TM Forum	Catalyst projects	Participate a TM Forum's Catalyst project to promote 6G-INTENSE intent-driven processes for intelligent continuum management

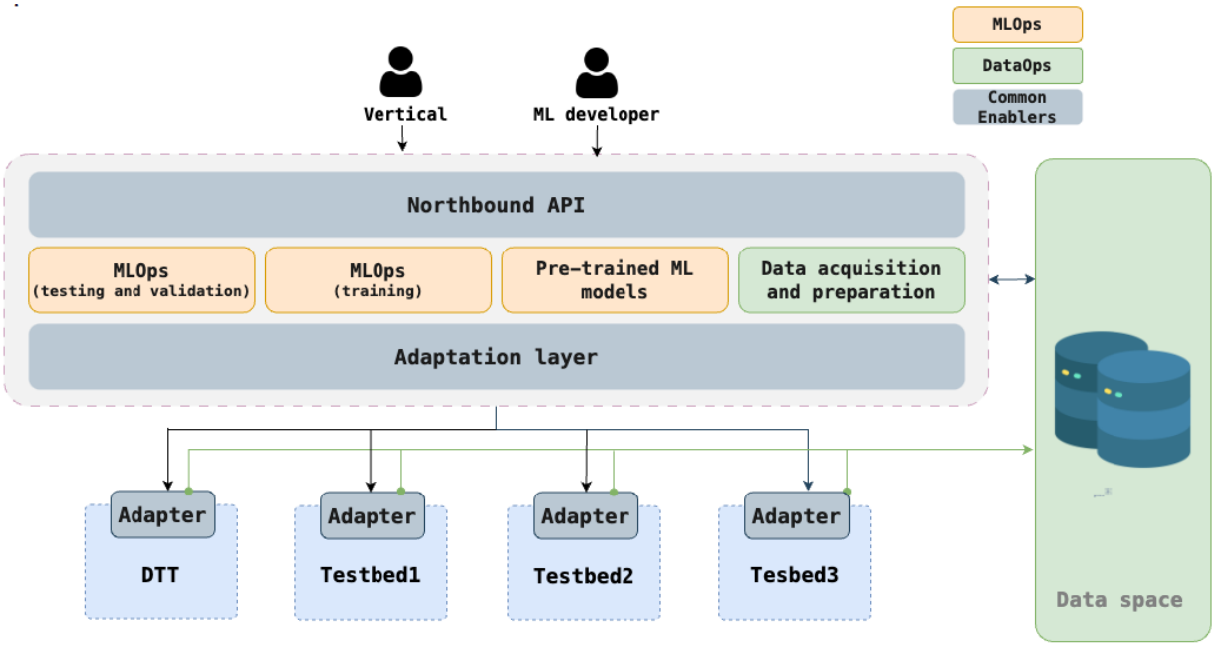
2.2.23 6G-DALI: 6G Data and ML operations automation via an end-to-end AI framework (HORIZON-JU-SNS-2024 "6G-DALI")

URL/Reference:

https://cordis.europa.eu/project/id/101192750

Abstract:

One of the key enablers of 6G is undoubtedly the Native support of AI/ML at all the system levels, components, and mechanisms, from the orchestration and management levels to the low-level optimization of the infrastructure resources, including Cloud, Edge, RAN, Core Network, as well as a transport network. Despite the opportunities, there are several gaps that hinder the adoption of AI/ML in 6G, such as the lack of extensive and high-quality datasets that are required to train the models. On the other hand, AI model testing and performance evaluation in a representative staging environment (by emulation or real deployment) is also challenging without access to an end-to-end 6G testbed or representative Digital Twin environment.



Hence, 6G-DALI will deliver an end-to-end AI framework for 6G, structured in two pillars:

(1) AI experimentation as a service via MLOps

It will deliver an AIaaS framework for 6G experimentation, aiming for highly efficient and automated ML operations (MLOps). A meta-orchestration solution encompassing heterogeneous MLOps/RLOps software stacks will be delivered, covering all the steps constituting the life cycle of development of AI and ML models, i.e., training, validation, finetuning, hyperparameter optimization, and performance benchmarking. The 6G-DALI e2e AI framework supports a wide range of ML algorithms, including federated learning (FL) models, time series models, and reinforcement learning.

(2) Data and analytics collection and storage via DataOps

The AI framework will deliver an intent-driven DataOps framework that allows users to find datasets to train their models and also improves the collected data to ensure high quality and increase their quantity if more data is needed (data augmentation). In regard to data generation and collection, we distinguish between cold data, which correspond to datasets available at the 6G Dataspace, i.e., those already collected via precedent experiments or produced by other projects or third-tier experiments, and hot data that need to be generated using one or more testbeds connected to the framework. In 6G-DALI, we embrace the Extract Load Transform (ELT) pipeline approach for DataOps.

The 6G-DALI DataOps pillar provides the mechanisms for preparing clean and processed data that are stored within a 6G Dataspace and are made available for training and validating machine learning models as a service, a part of the MLOps Pillar. The end-to-end framework also delivers continuous monitoring, drift detection and retraining of models. Finally, 6G-DALI will deliver open datasets, a 6G Dataspace for dataset storage and secure sharing, and a Digital Twin testbed for data generation on demand.

Starting and (target) end time of project:

01/01/2025 – 31/12/2027

IoT and/or Edge Computing research challenges:

This is where 6G-DALI steps in, building a novel e2e AI framework that aims to connect 6G data with verticals and ML developers and experimenters, while relying on 6G testbeds selected from the flagship SNS C phase 2 (SUNRISE-6G) project.

To this end, 6G-DALI is bringing together 3 communities; experts on the design and experimentation on 6G systems, experts on AI and MLOps with a good mix of industry and

academic experience, and finally experts on DataOps and the Gaia-X community, that all collaborate for the first time to build an efficient, realistic, and trustworthy framework for e2e AI/ML experimentation for 6G. The 6G-DALI will pursue the following challenging objectives:

Objective 1: Deliver a user-friendly e2e AI framework for DataOps and MLOps in 6G

Devise a user-friendly e2e AI framework for 6G, structured in two interdependent pillars; a DataOps pillar that provides the clean, processed data that are stored in the 6G Dataspace and are available for training and validating machine learning models a part of an MLOps Pillar. Deliver high-level user interfaces (graphical and API-based) to interact with the 6G-DALI's DataOps and MLOps systems, offering AI experimentation as a service as well as intent-based approaches and Large Language Models (LLM). The envisioned interfaces will allow

(i) to discover available datasets following the Gaia-X approach

(ii) to express data request as intent

(iii) to run data generation and quality improvement

(iv) to trigger the test of trained ML models

(v) to test and validate the ML model by deploying it on top of the existing testbeds, including the 6G-DALI Digital Twin Testbed (DTT).

Objective 2: Deliver Gaia-X & Extract Load Transform (ELT) for DataOps in 6G environments

Deliver procedures to satisfy user requests, either for cold data (i.e., available datasets at the local or data space catalogues) or hot data via the AI experimentation as service using the 6G testbeds as well as DTs that collect and construct the needed datasets. Adopt the Gaia-X approaches for cold data search (service catalogue) and data security (trust and security) and integrate these procedures to the user interface (Obj. 1). Regarding hot data, devise and implement ELT pipelines to collect datasets if they are not available in the 6G data space. The ELT process, specifically Transform phase, will be improved by novel data augmentation and cleaning algorithms devised in 6G-DALI. Indeed, one of the key criteria that guarantees an accurate and performing ML model is the quality of the used dataset. Finally, the DataOps of 6G-DALI will not only support the project, but it will also be open to other SNS projects that generate data sets using their testbed and PoCs to share the data through the envisioned 6G Data space, ambitioning to end up being a common and a reference data space that can be harmonized with other SNS JU projects, including the EU-US 6G-XCEL project (through IBM who is also involved), to support their activities on ML and AI for 6G.

Objective 3: Streamline 6G testbed's trustworthy AI/ML operations via MLOps and AutoML

Deliver efficient, automated and trustworthy ML operations (MLOps) for 6G via AutoML and AutoRL workflows, covering the entire life cycle of AI and ML models, i.e., training, validation, finetuning, hyperparameter optimization, and performance benchmarking, an approach termed as AIaaS for 6G experimentation. Also Incorporate Reinforcement Learning operations (RLOPS) as well as Federated learning (FLOps) on top of 6G testbeds and Digital Twins. Devise a meta-orchestration solution encompassing heterogeneous MLOps/RLOps software stacks, covering all the steps constituting the life cycle of development of ML/RL/FL-based models by (i) providing pre-trained models via an ML catalogue and (ii) providing tools for ML model testing and validation (i.e., validate if the model runs as expected), on model performance (i.e., if the model is accurate and achieves the expected performances) and the model trustworthiness (in terms of drift and uncertainty quantification).

Objective 4: Deliver plug-able adapters to easily integrate 6G testbeds from future calls

One of the key objectives of 6G-DALI is to allow ML developers (including verticals) to collect data and train ML/RL models for 6G systems via DataOps and MLOps. To achieve this, it is important to rely on existing 6G testbeds and additional testbeds constituted of Digital Twins (DT) and emulation approaches.

Although the project has identified testbeds participating in the SUNRISE-6G federation as the initial testbeds for developing the experimentation facility, 6G-DALI aims to deliver an e2e AI framework that easily integrates new testbeds and additional enablers (e.g., THz) from future

calls. Consequently, the project aims to implement and release as open source 2 key innovations to ease the integration of the testbed:

- the adaptation layer at the AI framework level that allows having a common set of Northbound MLOps & DataOps APIs
- a set of adapters deployed at testbeds to translate the Northbound APIs to Southbound 6G testbed (and DT) APIs, and to the 6G Data space through Dataspace Connectors.

Though this modular approach 6G-DALI aims to allow new 6G testbeds, which will be developed by other ongoing or future SNS projects, to be integrated easily into the framework by building the adapter for the specific 6G testbed enabler and local experiment management system.

Objective 5: Build / Integrate Digital Twin Testbed to generate representative datasets for 6G

In complement to the existing 6G testbeds, in 6G-DALI, we will develop one reference Digital Twin Testbed (DTT) to allow running tests and create datasets including scenarios that require, for instance, large-scale deployment, such as connecting several cells to test mobility or generate a high amount of traffic via the connection of thousands of UEs. Such a scenario is difficult to deploy today in existing 6G testbeds, which lack scalability. The envisioned DTT will be enriched with a management layer that allows automating tests and experiments while being able to collect data to create a dataset. To create this reference DTT we combine the well-established OpenAirInterface (OAI) platform and the VIA´s testing tools to enable large-scale and high-fidelity DT of 6G (RAN and CN). We envision an Open RAN approach where the gNB is decomposed into CU, DU, RU.

Objective 6: Ethical data sets and validation methodologies and legislative compliance

6G-DALI will adopt a methodology to embed ethics into the design and implementation of a trustworthy e2e AI framework, aiming to ensure the societal acceptance, especially for the usage as well as the compliance of data sets and validation methodologies with the rules of current and forthcoming data legislation, e.g., GDPR, Data Governance Act, Data Act, AI Act. Moreover, 6G-DALI aims to provide final policy options for policy makers to cover eventual gaps as well as final recommendations for future endeavours in 6G field.

Expected activities on "Dissemination & Impact on Standards":

The 6G-DALI pillars relate to current standardization efforts and Open-Source frameworks that will be leveraged to implement both project Pillars. Pillar 1 will build a comprehensive AIaaS experimentation framework (Objectives 1 & 3) on top of Open Source MLOps toolkits (Kubeflow, Prefect, ZenML, MLFlow, RAY) that will provide full automation for ML models and AI software artifacts lifecycle management. The 6G-DALI e2e AI framework is also fully aligned with 3GPP standards. On the other hand, Pillar 2 is aligned with Data Spaces (IDS) and GAIA-X initiatives (Objective 2) aimed at establishing standards for data exchange and sharing among participating organizations. These initiatives empower entities to retain control and sovereignty over their data while facilitating the open accessibility of data and services. 6G-DALI will embrace the mechanisms proposed by Gaia-X and IDS for handling data life-cycle, which will be collected from 6G testbeds and DTT. Furthermore, 6G-DALI commits to open-source the adapter component to ease collaboration with other on-going and future SNS projects and integration of their testbeds. As per the standardisation activities, the DTT to be delivered by the project and NWDAF-based MLOps/RLOps/FLOps are 100% compliant with 3GPP specifications. In addition, all interactions with RAN to control it are based on O-RAN's well-established interfaces. Further, 6G-DALI has a specific standardisation plan (Table 2.4) that target contributions to key SDO groups (3GPP, ETSI, and IRTF), by formal contributions or PoC using DTT and other project artifacts.

Standards body/forum	Working Group (WG)	Planned 6G-DALI contributions
ISO/IEC	JTC1/SC42	Contribution to the ongoing initiative of a Joint Technical Committee (JTC1/SC42) for definition of "Reliability of AI systems".
EU Committees	CEN/CLC JTC21	Contribution to the ongoing initiative of the Joint Technical Committee (JTC21) of the CEN/CLC for the definition of "Data Governance and quality in AI"
IRTF	Network Management Group	Contribution to Network Digital Twins architecture and its involvement on network management aspects of future networks
3GPP	SA2/SA4	Contribute with the mechanisms related to data collection for AI/ML using NWDAF, MLOps and Federated learning relaying NWDAF.
	RAN1/2/3/4	Distillate appropriate contributions from DALI work towards relevant 3GPP activities, especially on AI/ML related study and specification work, such as AI for Air Interface
ETSI	ENI	Monitor and contribute LLM-based translation activities to the GS ENI 030 "Transformer Architecture for Policy Translation
	ZSM	Monitor the related standards evolution, with specific focus on AI-related enablers and services definition. Contribute to the proposal of ZSM PoC activities (e.g., implementing PoCs related to the MLOps work carried out in the project). NXW and VIAVI will coordinate these activities as both are ZSM members, while VIAVA is ZSM013 rapporteur on CI/CD automation.
ITU-T	Focus Group on Testbeds Federation for IMT-2020 and beyond	Monitor and make awareness of the 6G-DALI framework and its extensibility to integrate new testbeds and platform to participate to the 6G Dataspace
O-RAN	WG1/2/3/9/10	Monitor opportunities to contribute to testing aspects in O-RAN, including AI/ML specific requirements and use-cases, particularly with the support of the activities conducted in 6GDALI about Digital Twins Testbed (DTT) for RAN. All the experiments of PoC3 that uses DTT will uses O-RAN interfaces (E2, Fronthaul, O1, etc.).
OAI Alliance	Open Air Interface	EUR, founder of the OAI Alliance, will contribute to the software development of the 6G network stack and their control and management subsystems
TM Forum	Catalyst projects	Contribute to catalyst program on intent-driven automation of MLOps pipelines for network operation
Linux Foundation	Data and AI Foundation	IBM is a member of the Linux Foundation Data and AI Foundation, and will consider it as a target venue for donating the packages related to HPO Experiment as a Service
ZenML	ZenML Hub	ICOM, a telco vendor with significant industry experience, will implement and contribute back to the Open Source ZenML project the stack component flavours, pipelines, steps, materializers, and other pieces of code implemented within 6G-DALI as part of the 6G meta-orchestration solution.
SIMPL (Gaia-X)	SIMPL	Contribute and align the 6GDataspace using the SIMPL project open-source software including SIMPL middleware (Simpl-Open).
Garnet Framework	-	Contribute to the usage of the 6G-Data Space in the context of the Garnet Framework for storing and processing Smart City Data

2.2.24 A-IQ Ready: Artificial Intelligence using Quantum measured Information for real-time distributed systems at the edge

URL/Reference:

https://www.aiqready.eu

https://cordis.europa.eu/project/id/101096658

Abstract (IoT project):

The onset of climate change and widespread geopolitical conflicts and social inequalities showcase the need for innovation and change that require a better world.

Global environmental issues, social inequality and geopolitical changes will pose numerous problems for our society in the future.

To face these new challenges and deal with them, there is a need to understand and appropriately utilize new digital technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), robotics and biotechnologies. The EU-funded project A-IQ Ready proposes cutting-edge quantum sensing, edge continuum orchestration of AI and distributed collaborative intelligence technologies to implement the vision of intelligent and autonomous Electronic and Software-Based Systems for the digital age. Intelligent quantum sensing will improve timing and accuracy of autonomous agents and reduce false alarms or misinformation by means of AI and multi-agent system concepts. Edge continuum orchestration by AI will allow decentralizing the development of applications, while ensuring an optimal use of the available resources. The edge continuum will be equipped with innovative, multi-physical capabilities to sense the environment, distributed intelligence will enable emergent behaviour and massive collaboration of multiple agents towards a common goal. By exploring the synergies of these cutting-edge technologies through civil safety and security, digital health, smart logistics for supply chains and propulsion use cases, A-IQ Ready will provide revolutionary means for most services and industries. These technologies and their combination will propel the transition to a Europe of Society 5.0.

More details are provided in Section 1.2.12.

2.2.25 INSTAR: Shaping international standards for advanced technologies

URL/Reference:

https://www.instarstandards.org/

https://cordis.europa.eu/project/id/101135877/

Abstract (IoT project):

INSTAR is an EU-funded project that aims to support the implementation of Europe's Digital Partnerships and the EU-US TTC by working together with Australia, Canada, Japan, Singapore, South Korea, Taiwan and the USA to drive international common standards for AI, Cybersecurity, DigitalID, Quantum, IoT, 5G, 6G and data technologies. Following the EU Standardisation strategy of February 2022 that "*Europe needs to bring the European angle of standardization at international level, rather than create EU-specific standards.*" (Commissioner Thierry Breton), **INSTAR** helps achieve this by

- promoting EU's thought leadership for a common ICT standardization vision with strategic international partners on key advanced technologies,
- shaping the definition & uptake of standards in relevant target entities,
- delivering studies & analyses on ICT standards,
- monitoring international standards in trade & cooperation agreements

INSTAR works with Task Forces built up by a number of European experts in the following areas of advanced technologies to be addressed:

- TF1 – AI: Secure, trustworthy and ethical development and use of AI systems (ML algorithms, neural networks, analytics, autonomous systems), AI Act, ETSI's Operational Coordination Group on AI (OCG AI), CEN/CENELEC, ISO/IEC, and others.
- TF2 – Cybersec-eID: Cybersecurity & electronic identification in industries like healthcare, manufacturing, financial services, energy, automotive European Cyber Resilience Act (CRA).
- TF3 – Data: Data quality, syntactic, semantic and pragmatic characteristics of data (ISO 8000-1), Standards impact on policy & regulation, investment & innovation, cross-industry scenarios.

- TF4 – IoT Edge: Cloud, Edge (near vs. far edge), IoT in smart manufacturing, precision agriculture, mobility, energy grids, smart cities, healthcare etc.

- TF5 – 5G+: Convergence of communications, sensing, sustainable services & AI, Human-centric, cognitive network of networks system.

- TF6 – Quantum: Quantum computing, communication, sensing and cryptography, as well as post-quantum cryptography techniques, Specific focus on technologies that can be integrated into European infrastructure and interoperability aspects.

Key activities include setting up Roadmaps for each area, pointing at priority areas for standardization from the European point of view (ETF – European task Forces of experts) and then aligning with the international partners (ITF – International Task Force) in a collaborative communication process.

More details are provided in Section 1.2.13.

2.2.26 ENACT (HE CL1) Environmental Effect on Health Care and Wellbeing and Active Interventions

URL/Reference:

- https://cordis.europa.eu/project/id/101157151
- https://enact-he.eu

Abstract:

Non-communicable diseases (NCDs) account for 80% of the disease burden as well as for many premature deaths in the EU; diminishing the citizens' quality of life, life expectancy and increasing the financial burden (from those affected to the health system). During the last 3-decade environmental stressors have been addressed through numerous studies, which have raised concerns about the detrimental effects of the environment on human health. Most evaluated environmental stressors are air temperature, particulate and gaseous air pollutants, urban noise, food pollutants and radiation. By end of 2022, air pollution was reported to be responsible of an excess mortality of 311.000 people per year in the UE-27, driving not only premature deaths but also an increased risk of vascular diseases such as ischemic heart disease, stroke, and other non-communicable non-vascular diseases like chronic respiratory diseases or depression. Some newly considered stressors such as electromagnetic field, and light exposure are also susceptible to affect human health (e.g. ocular and dermatological NCD diseases).

ENACT aims at building a pathway to generate clinical, technological, and economic short & long-term impact targeting local and regional stakeholders and create impact by: developing a state-of-the-art environmental risk score and analyser driven framework and platform to predict, monitor and prevent the exposomic risk of acute and chronic health conditions of chronic vascular and non-vascular NCDs.

This shall be based on collection of diverse IoT environmental multiparametric data from a variety of sources, ranging from official data from European Environmental Agency (EEA) and National Agencies, participatory data from Open Data Repositories, data from Earth Observation (e.g. Copernicus) and in-situ indoor/outdoor sensors custom developed in the ENACT project. Such a data will be correlated using both deterministic and Artificial Intelligence algorithms with physiological IoT data from wearables and in-situ sensors monitoring wellbeing and health condition of test subjects in five major representative cities across Europe, thus to determine causality relationships among environmental stressors and physiological conditions, looking into ways of reducing risk factors and improving health and wellbeing.

The new exposomic risk scores and analysers are being developed to support (a) patients, (b) health professionals/hospitals, and (c) policy makers; aiming at reducing the human and financial burden of NCD, considering potential individual vulnerability factors, and reinforcing both a clinical and a policy implementation that enables prevention and disease management for higher quality of life. More details are provided in Section 1.2.17.

2.2.27 GREET: Generative Explainer-aware Explainability and Transparency in Proactive Cyber-Physical Eco-Environments (GREET)

URL/Reference:

- https://cordis.europa.eu/project/id/101226624

Abstract:

As an interdisciplinary endeavor, the GREET network brings together leading institutions and companies in Cyber-Physical System (CPS), AI, software engineering and cognitive interaction research across Europe with the aim of training a new generation of scientists, technologists, and entrepreneurs that will move Europe into a leading role in the scientific and technological innovation in Generative AI-driven CPS, its proactivity and explainability.

Linking the leading academic and industrial partners in the above areas, GREET will form an effective and unique training network powerfully combining the best research training with a range of academic and industrial placements, specialist research and knowledge transfer workshops. It will develop and train a new generation of young researchers through a set of key research projects, developing breakthrough CPS systems and services that feature generative cognition, explainer-aware generative explainability, and transparent proactivity in highly secured CPS eco-environments.

It will shape the delivery of training in the novel generative AI-driven CPS across Europe: delivering key insights into the science and models of the proposed CPS, setting up its scientific foundation, and equipping the DN's recruited Doctoral Candidates with skills to drive the next innovative steps in this key area of generative AI-driven CPS. These steps include building a sustainable innovation ecosphere and community, disseminating and exploiting this new CPS's learning and understanding of the eco-internals, eco-surroundings

and eco-dynamics in many vital societal and economic services, including Industry 5.0, smart city, healthcare, energy, emergency handling, social robotics and elderly care. The innovation perspective of these new CPS is substantial, which will be particularly important for handling services that involve humans and in critical situations, e.g., in emergency and hazardous environments.

More details are provided in Section 1.2.18.

2.2.28 CyberNEMO: End-to-end Cybersecurity to NEMO meta-OS

URL/Reference:

- https://cordis.europa.eu/project/id/101168182
- https://cybernemo.eu/

Abstract:

CyberNEMO provides end-to-end cybersecurity and trust on the IoT-Edge-Cloud-Data Continuum framework as introduced by NEMO project. CyberNEMO architecture supports resilience, risk preparedness, awareness, detection and mitigation within Critical Infrastructures deployments and across supply chains. The project aims to achieve technology maturity by leveraging existing by-design, by-innovation, and by-collaboration zero-trust cybersecurity and privacy protection systems, and introduce novel concepts, methods, tools, testing facilities and engagement campaigns to go beyond today's state of the art. The project toolchain aims to provide a low level Zero-Trust Network Access layer up to a human AI explainable Situation Perception, Comprehension & Protection (SPCP) framework and tools, collaborative micro-services Auditing, Certification & Accreditation and a pan-European Knowledge Sharing, risk Assessment, threat Analysis and incidents Mitigation (SAAM) collaborative platform in all layers of the IoT-Edge-Cloud continuum. The project's output will be validated in a set of Critical Infrastructure providers in diverse domains including energy, water, healthcare, media distribution, agrifood and fintech supply chain. More details are provided in Section 1.2.19.

2.2.29 MODUL4R - Industrial Manufacturing strategies for Distributed control and Resilient, Rapidly Responsive and Reconfigurable supply chains

URL/Reference:

Modul4r official website: https://www.modular-project.eu/

CORDIS: https://cordis.europa.eu/project/id/101091859

ZENODO: https://zenodo.org/communities/modul4r-project/records?q=&l=list&p=1&s=10&sort=newest

Abstract:

MODUL4R envisions reliable, maintainable, affordable, (re)usable, and changeable SME-friendly autonomous modular factories and supply chains, with the ability to manufacture new product in low-volume production and the ability to rapidly respond to unexpected events as well as the overall supply chain. MODUL4R proposes a holistic I4.0/I5.0 framework applicable both to new and existing manufacturing lines to achieve flexibility, rapid responsiveness, and sustainability.

More details are provided in Section 1.2.20.

2.2.30 TechUPGRADE - Thermochemical Heat Recovery and Upgrade for Industrial Processes

URL/Reference:

https://techupgrade.eu/

https://cordis.europa.eu/project/id/101103966

Abstract:

The TechUPGRADE project aims to develop and validate, up to TRL 5, a novel thermochemical technology for waste heat recovery and temperature upgrading in industrial processes. The system will efficiently and sustainably upgrade waste heat to 150–250 °C. IoT and edge computing play a crucial role in enabling real-time monitoring, control, and predictive maintenance. Quanterall Ltd., a project partner, contributes with expertise in IoT hardware infrastructure, edge software, secure data communication, and digital twin technologies.

More details are provided in Section 1.2.21.

2.2.31 ENACT (HE CL4) Adaptive Scheduling and Deployments of Data Intensive Workloads on Energy Efficient Edge to Cloud Continuum

URL/Reference:

- https://cordis.europa.eu/project/id/101135423
- https://enact-horizon.eu

Abstract:

The cloud-edge continuum has developed many forms of flexibility and adaptation, yet it lacks disruptive technologies to deal with the new forms in which content will be distributed and consumed. The ENACT project brings together a team of 16 experienced partners from 9 EU countries with the aim of delivering breakthrough techniques and disruptive technology solutions to target this need for efficient and intelligent content and data processing, using all suitable resources available in the edge-cloud continuum. ENACT addresses directly the demands to build a computing continuum with cognitive Web3 capabilities that can effectively manage the explosion of locally generated content for next generation hyper-distributed services, while respecting European values and the regulatory frameworks set by the European Data Act and complementary legislation.

ENACT develops cutting-edge techniques and technology solutions to realise a Cognitive Computing Continuum (CCC) that can address the needs for optimal (edge and Cloud) resource management and dynamic scaling, elasticity, and portability of hyper-distributed data-intensive applications.

Moreover, the outcomes of these research and development activities will be delivered as open-source solutions, with the goal of allowing European businesses to enhance their competencies and upgrade their IT services with latest innovations.

More details are provided in Section 1.2.22.

2.2.32 CoEvolution - A comprehensive trustworthy framework for connected machine learning and secure Interconnected AI solutions

URL/Reference:

https://coevolution-project.eu/
https://cordis.europa.eu/project/id/101168560

Abstract:

The AI landscape requires a comprehensive framework to address threats and vulnerabilities but lacks a system for managing weaknesses in the AI supply chain. The EU-funded CoEvolution project is developing an integrated security, trust, and robustness (STR) assessment solution that combines AI models with context awareness and an AI model bill of materials (AIMBOM). The project aims to establish a universal STR risk assessment and security assurance hub aligned with EU regulatory frameworks. This initiative introduces new AI model descriptions and security monitoring to ensure compliance with EU directives on trust, fairness, data governance, and GDPR guidelines. Open-source trusted datasets and AI models developed by CoEvolution will enhance the hub's ability to address evolving AI cybersecurity threats.

More details are provided in Section 1.2.23.

2.2.33 Averato Park - An innovative system for reliable control of parking lots through a user-friendly interface

URL/Reference:

https://www.quanterall.com/

https://www.iot-ngin.eu/

Abstract:

AVERATO Park is an innovative smart parking system developed by Quanterall under the IoT-NGIN project (H2020 -957246). It provides a user-friendly, fully automated solution for access control and contactless payments in parking facilities. The system leverages IoT infrastructure and edge computing to manage hardware (barriers, sensors) and software components for real-time event monitoring, mobile-based access, payment processing, and remote management. Quanterall's AVERATO platform ensures seamless integration of IoT devices with payment providers and backend systems.

More details are provided in Section 1.2.24.

2.2.34 Visualization of the Edge Computing EU funded ongoing projects landscape

This section provides a landscape visualization of the ongoing Edge Computing EU funded projects, introduced in this report.

The figures included in this section cover ongoing Edge Computing projects that are described in Section 2.2 of this release (Release 4.0).

The "Edge Computed EU funded ongoing projects landscape (Technology and Marketing Dimensions)", shown in **Figure 12**, is a graphical representation that highlights the main activity (up to the day of generating this representation) of the ongoing projects in the area of Edge Computing, according to the Business to Consumer (B2C) vs. Business to Business (B2B) (horizontal axis) and the Connectivity vs. Service & App (vertical axis) classifications.

The projection of these ongoing projects into vertical industry domains is shown in **Figure 13** and for standardisation activities in different SDO's and initiatives is shown in **Figure 14.**

The dimensions, the vertical/horizontal domains and standardisation organisations and initiatives of the landscapes and the method used to visualize ongoing projects into these landscapes shown in **Figure 12**, **Figure 13** and **Figure 14** respectively, are the same ones as defined in Section 1.1.4.

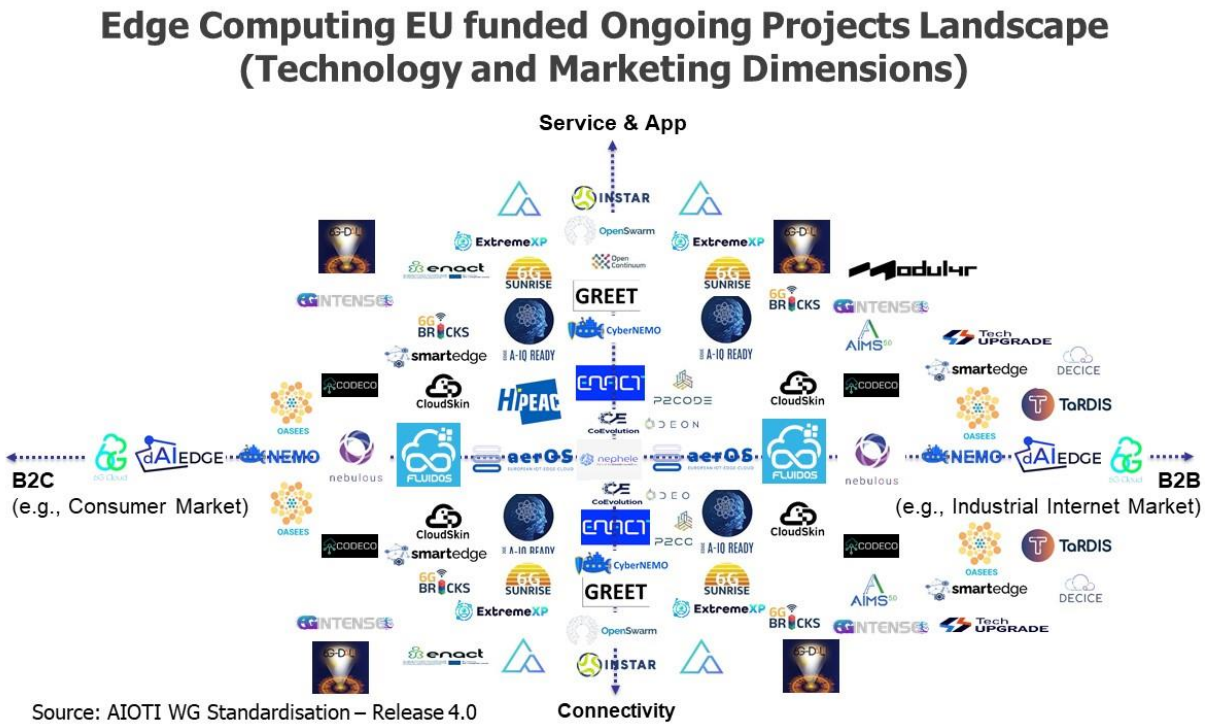


Figure 12: Edge Computing EU funded ongoing projects landscape, when Technology and Marketing Dimensions are used

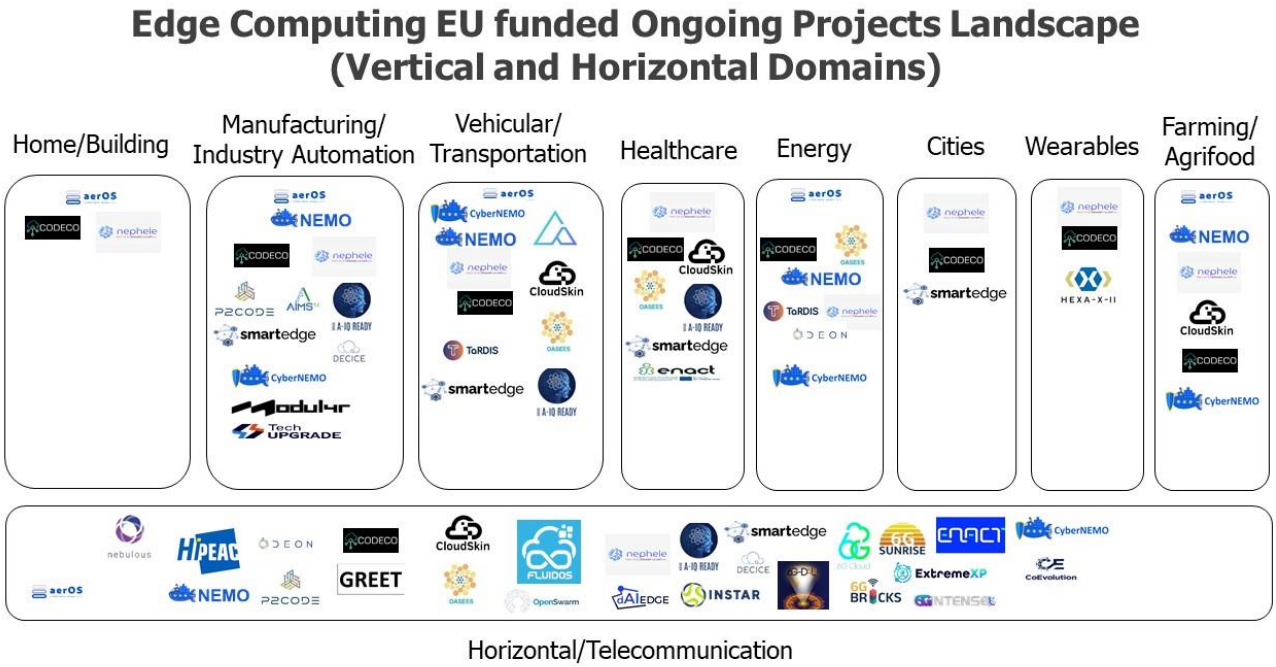


Figure 13: Edge Computing EU funded Ongoing Projects Projection on Vertical and Horizontal Domains

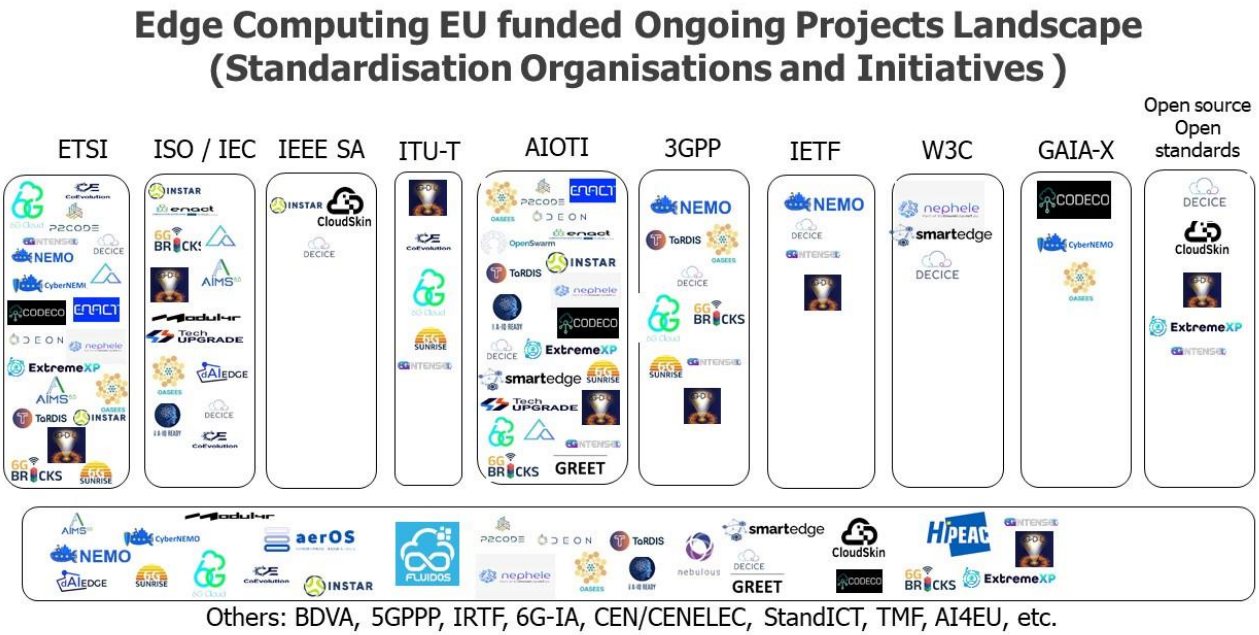


Figure 14: Edge Computing EU funded Ongoing Projects Projection on Standardisation Organisation and Initiatives

Annex I. Used Template for input collection

Proposed template for IoT and edge computing EU funded projects (version 25 February 2022)

This document includes the used template to collect contributions on IoT and edge computing EU funded projects; The key information to be collected is: (1) Title, (2) URL/Reference where information regarding the project can be found (Website, published documents (reports, position papers and reports, scientific papers), (3) abstract, (4) starting and (target) end time, (5) covered IoT and/or Edge Computing research challenges; Please fill in the Yellow coloured field; Note that if the required information is not available, please fill in "Unable to find information"

Title:

<<Please fill in the Project name>>

URL/Reference:

<<Location where information regarding the project can be found (Website, published documents (reports, position papers and reports, scientific papers). Please provide the URL/Reference of the project generated by the European Commission and the project official URL of your project (if available) >>

Abstract:

<<Provide the summary of the project, in particular emphasize the relation to IoT and/or edge computing>>

Starting and (target) end time of project:

<<Provide for the completed projects the start and end time; For the ongoing projects provide the starting and targeting end time>>

Format: DD/MM/YYYY – DD/MM/YYYY

IoT and/or Edge Computing research challenges:

<< List the IoT and/or Edge Computing research challenges that are being focused in the EU funded projects>>

Expected activities on "Dissemination and Impact on Standards":

<<Please provide information on:

(1) List of IoT and/or Edge computing related of SDO and Alliances that the project will interact with, on standardisation activities,

(2) How the project want to interact and

(3) timescales for this interaction>>

Contributors

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About AIOTI

AIOTI is the multi-stakeholder platform for stimulating AI, IoT and Edge Continuum Innovation in Europe, bringing together small and large companies, academia, researchers, policy makers, end-users and representatives of society in an end-to-end approach. We strive to leverage, share and promote best practices in the AI, IoT and Edge Continuum ecosystems, be a one-stop point of information to our members while proactively addressing key issues and roadblocks for economic growth, acceptance and adoption of the AI, IoT and Edge Continuum Innovation in society. AIOTI contributions goes beyond technology and addresses horizontal elements across application domains, such as matchmaking and stimulating cooperation by creating joint research roadmaps, defining policies and driving convergence of standards and interoperability.