Open Continuum

D4.4 PROGRESS TOWARDS A EUROPEAN ECOSYSTEM FOR THE COMPUTING CONTINUUM

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Abstract	This deliverable will report the outcomes of the different joint actions that have been undertaken following the plan proposed in D4.3. The report will also include a set of recommendations spanning beyond the life of the project to promote the sustainability of the strategy defined by the continuum computing project portfolio (T4.1).
Keywords	Ecosystem, Building blocks, Interoperability, Standardisation

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DISCLAIMER

Project co-funded by the European Commission in the Horizon Europe Programme		
Nature of the deliverable:	**R**	
Dissemination Level		
PU	Public, fully open, e.g. web	**X**
SEN	Sensitive, limited under the conditions of the Grant Agreement	
Classified R-UE/ EU-R	EU RESTRICTED under the Commission Decision No 2015/ 444	

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* R: Document, report (excluding the periodic and final reports)

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

DATA: Data sets, microdata, etc

DMP: Data management plan

ETHICS: Deliverables related to ethics issues.

SECURITY: Deliverables related to security issues

OTHER: Software, technical diagram, algorithms, models, etc.

EXECUTIVE SUMMARY

The deliverable

- summarizes the background for a future continuum computing ecosystem, and the plan proposed at month 6 of the project (February 2024); and

- describes the OpenContinuum plan to support the growth of the ecosystem, the approach adopted to foster the ecosystem, and actions carried out which include

  - the work carried out by EUCloudEdgeIoT task force 3 on architecture and task force 2 on open source,

  - OpenContinuum workshops,

  - EC research support,

  - EC standardisation support, and

  - the organisation of a workshop during the ISO/IEC JTC1/SC41 plenary.

  More details concerning the actions are provided in 6 annexes.

- reports on the outcomes of the different joint actions that have been undertaken following the plan proposed in D4.3 (towards an ecosystem for the computing continuum);

  - a new standard preliminary work item (Architecture considerations for IoT, edge and cloud) has been established in ISO/IEC JTC 1/SC 41 (IoT and digital twin) that will enable contributions on architecture,

  - with the support of other EU initiatives, the development of a new standard has started (ISO/IEC 21823-5 - Behavioural and policy interoperability that will enable contributions on interoperability, and

  - with the support of other EU initiatives, the approval for a ballot on a standard on the connection of IoT and digital twins to data spaces (ISO/IEC 30152) that will enable contributions on continuum capabilities involving data.

- finally provides recommendations beyond the project:

  - continue contribution to the wealth of standardisation initiatives,

  - leverage AIOTI community support (for community concertation and standardisation contribution),

  - leverage EC liaison support (for standardisation engagement), and

  - legacy transfer activities for the next wave of computing continuum projects.

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ABBREVIATIONS

AIOTI   Alliance for IoT and Edge Computing Innovation

CEI   Cloud, Edge and IoT

EC   European Commission

MetaOS   Meta Operating System

OSD   Open Source Development

IEC   International Electrotechnical Commission

IoT   Internet of things

ISO   International Organisation for Standardisation

ITU-T   ITU Telecommunication Standardization Sector (ITU-T)

SDO   Standard Development Organisation

1   INTRODUCTION

1.1   PURPOSE

This document provides an account of the work following the plan proposed in D4.3 Towards a European Ecosystem for the Computing Continuum. This plan was produced in February 2023, six-month after the start of the project.

1.2   REMINDER OF THE BACKGROUND ON THE COMPUTING CONTINUUM

D4.3 provides the detail of the background on the EU initiative on the computing continuum.
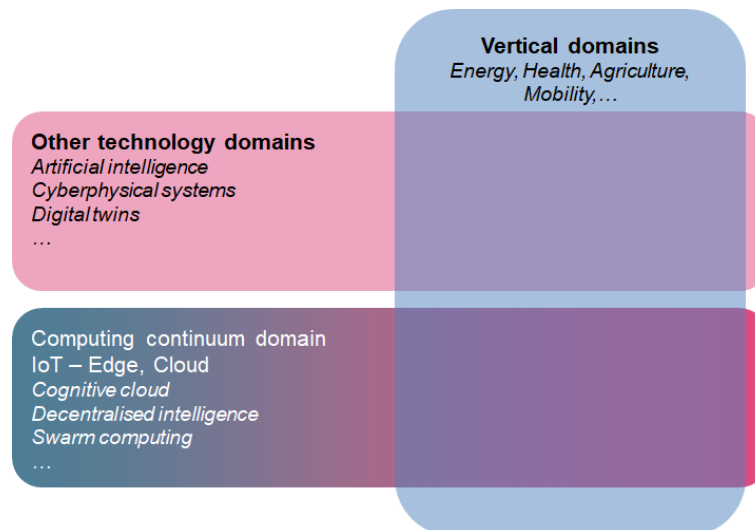
FIGURE 1 – POSITIONING OF THE COMPUTING CONTINUUM DOMAIN (FROM D4.3)

Figure 1 describes the resulting integration needs in an ecosystem:

- The lower horizontal layer focuses on the computing continuum technical domain.
- The upper horizontal layer addresses other technology domains that will rely on the computing continuum, such as artificial intelligence, cyber physical system or digital twins.
- Finally, the vertical layer focuses on the support of application domains, such as energy, health, agriculture or mobility.

In order for Europe to play a leading role in the computing continuum it has to influence and possibly lead this integration in the ecosystem.

1.3 STRUCTURE OF THIS DOCUMENT

This document has the following structure:

- section 2 summarises the plan that was published at month 6 of the project (in D4.3),

- section 3 describes the actions that were carried out and the outcome,

- annex A describes the contribution of the OpenContinuum workshops to the ecosystem,

- annex B describes the contribution of AIOTI support to the ecosystem,

- annex C describes the contribution of EC support to the ecosystem,

- annex D describes the contribution of EUCloudEdgeIoT community to standardisation (SC41),

- annex E describes the outcomes at the standardisation level, and

- annex F describes the contribution of TF3 and TF2 to the ecosystem.

2 OPENCONTINUUM PLAN TO SUPPORT THE GROWTH OF THE ECOSYSTEM

This section summarizes the plan finalised in D4.3 which provided an initial landscape of projects, based on available information (web sites) of projects. At the time of D4.3, most projects could only provide intentions on technology enables since most of them were also in the process of implementing them.
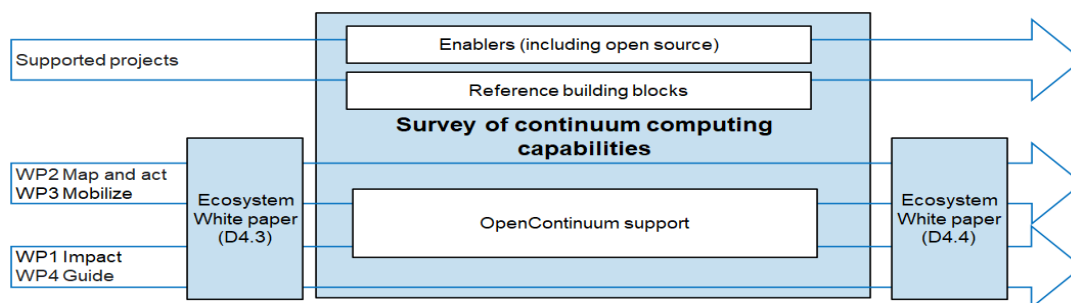
FIGURE 2 – OPENCONTINUUM STRATEGIC APPROACH (FROM D4.3)

Figure 2 shows the relations between OpenContinuum work packages and D4.3 and D4.4 deliverables:

- D4.3 served as the plan.
- OpenContinuum engaged with projects (innovation vectors) through WP3 – Mobilization, on a mapping of enablers (including open source) and reference building blocks.
- OpenContinuum supported projects in constructing, identifying impact vectors, or common building blocks and implementation enablers, and prepare standardisation (role of WP2 – Map and act).

Figure 2 shows the defined standardisation roadmap:

- During the project, phase A took place. It consisted in identify building blocks and providing contributions on architecture. This was done by running task force 3 of EUCloudEdgeIoT (Architecture)

Beyond the project, two phases were identified and confirmed

- Phase B focuses on standardising a computing continuum reference architecture.
- Phase C consists in participating to a community where European stakeholders can publish patterns/enablers.
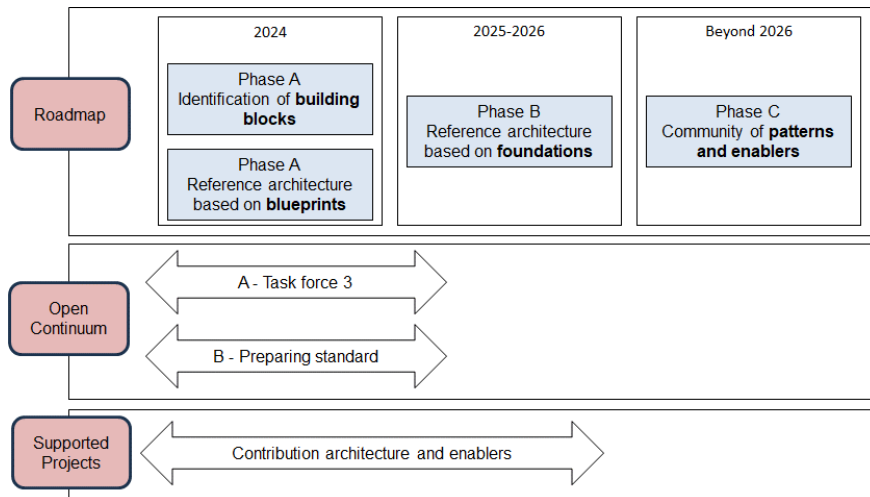
FIGURE 3 – OPENCONTINUUM STANDARDISATION ROADMAP (FROM D4.3)

The planned work was the following

- Strategic task 1: engagement with projects in the continuum so that they participate to EUCloudEdgeIoT tasks forces (TF2 and TF3).

- Strategic task 2: lead the work in TF3 in order to prepare a report explaining the taxonomy of building blocks and identify the implementation enablers proposed by participating projects.

- Strategic task 3: lead the work in TF2 in order to assist projects in the open source development plans and help identify synergies.

3 OPENCONTINUUM WORK FOR THE ECOSYSTEM

3.1 APPROACH TO FOSTER THE ECOSYSTEM

The approach was explained in section 4.1 of D4.3. Figure 4 shows an updated figure which reflects evolutions that have taken place since 2023 on the standardisation of architectures:

- the upper-side (reference architecture) shows the trends concerning future standards on architectures:
    - Future reference architectures standards will follow an approach based on reference architectures and construction patterns (D1.2 provides more info).
    - Consequently, the OpenContinuum approach is to construct and provide contributions that can be aligned, by starting with a taxonomy of computing continuum reference building blocks that will serve for the construction of a computing continuum architecture, and to disseminate the results so that standardisation projects on the topic are submitted. This has led to the submission to ISO of a PWI – Architecture considerations for IoT, edge and cloud (showed in yellow).
- the lower-side (implementation architecture) shows how the industry will leverage standards:
    - Computing continuum derived requirements, construction patterns and guidance are created that guide implementation architectures and computing continuum systems
    - Consequently, the OpenContinuum approach is to ensure that research projects provide a wealth of implementation architecture (e.g. blueprints) and computing continuum systems.
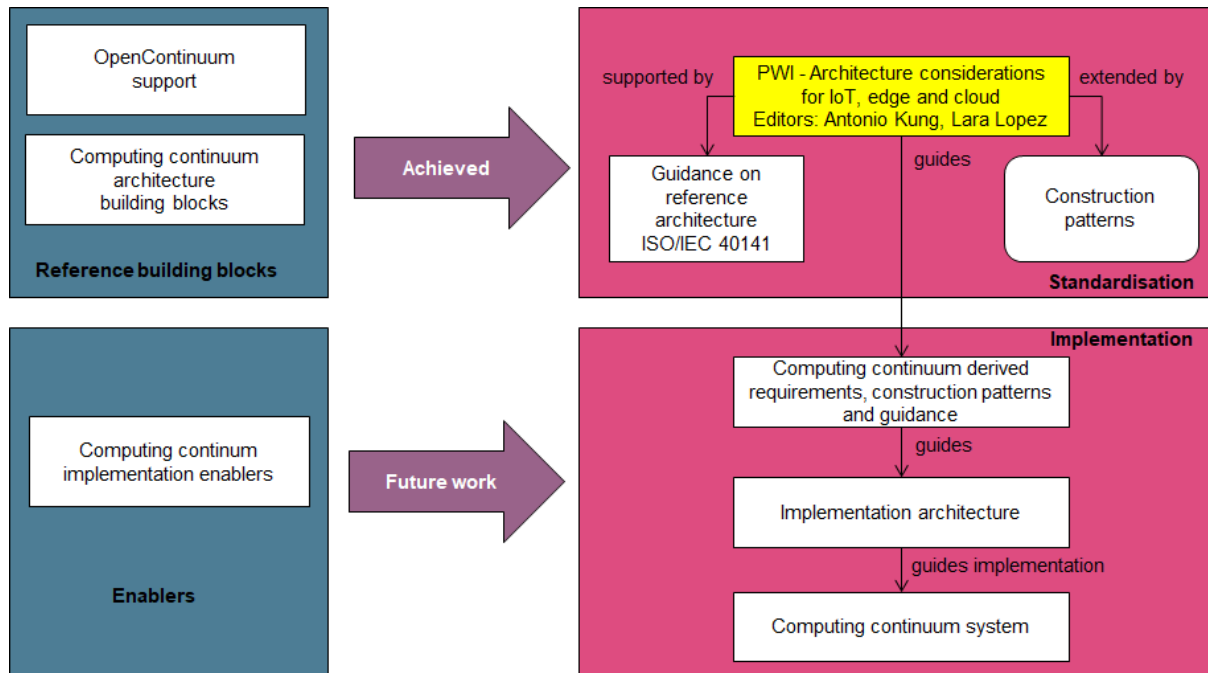
FIGURE 4 – OPENCONTINUUM APPROACH FOR IMPACT (UPDATE FROM D4.3)

3.2 ACTIONS CARRIED OUT TO FOSTER THE ECOSYSTEM

This section presents the salient actions that were carried out to foster the ecosystem, summarised by Figure 5. Note that a more complete of actions, including those led by the Unlock-CEI projects can be found in the EUCloudEdgeIoT website[1], covering the period from June 2022 to 2024.

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[1] https://eucloudedgeiot.eu/event
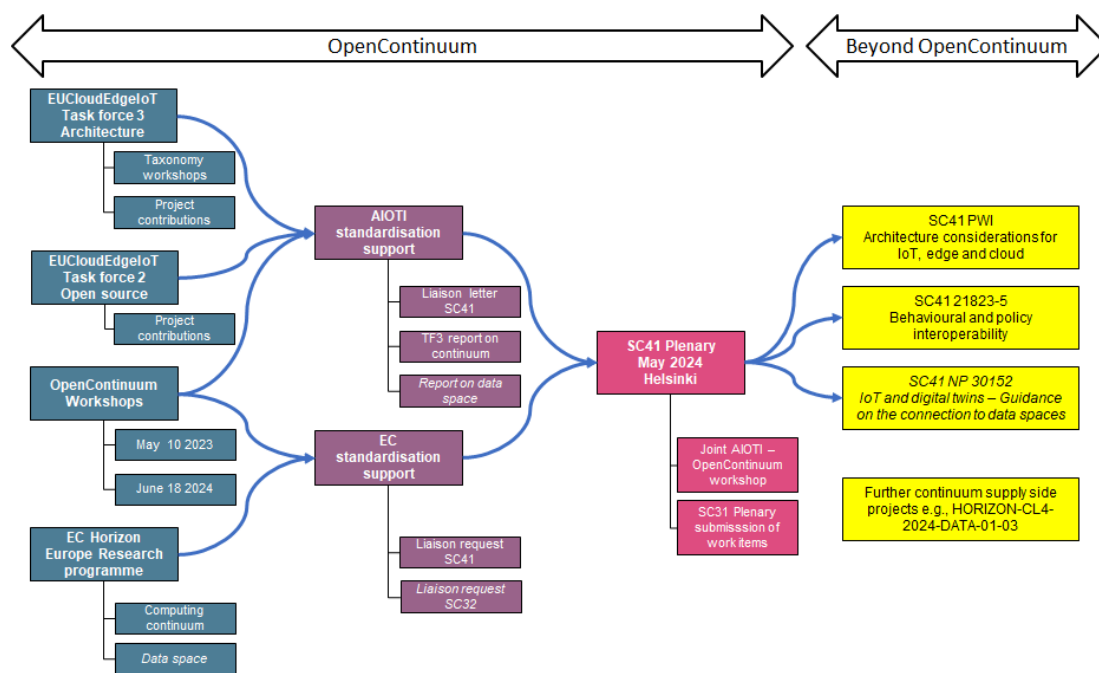
FIGURE 5 – OPENCONTINUUM ACTIONS TO FOSTER THE ECOSYSTEM

Figure 5 shows on the left actions that were carried out during the project, and on the right the planned actions to be carried out beyond the project. The actions are described in Table 1.

TABLE 1: ECOSYSTEM ACTIONS TOWARDS STANDARDISATION

Action	Description / Outcome
EUCloudEdgeIoT Task force 3 Architecture	**Description:** Task force 3 has focused on creating synergy at architecture level. Webinars and workshops have been organised involving all metaOS projects, as well as any other ongoing research project addressing challenges in any of the building blocks for the continuum previously identified, including on the legacy of previous projects. A taxonomy document has been produced which takes into account the current evolution of architecture standards. This document was submitted by AIOTI to ISO/IEC JTC1/SC41 (IoT and digital twins) **Outcome:** A taxonomy agreed by the experts of the research projects that could be used to create the foundation of architecture standards on the continuum. More information is available in Annex F.
EUCloudEdgeIoT Task force 2 Open source	**Description:** Task force 2 has focused on creating synergy at open source level. Webinars and a workshop have been organised involving all metaOS projects A workshop has been organised which involved all metaOS projects (aerOS, FLUIDOS, ICOS, NebulOus, NEMO, NEPHELE).

	In doing so, insight has also been gained concerning the architecture of the metaOS projects.
	Outcome: the computing continuum community has gained common insight on the practice of open source, the possible European synergies, and gaps where opportunities can be sought.
	More information is available in Annex F.
OpenContinuum workshops	**Description:** Two workshops organised with the support of the European commission on May 10th, 2023 and on June 18th, 2024. The first workshop allowed for exchange on the challenges and the opportunity to discuss further synergy on the continuum, involving more than 40 research projects. The second workshop allowed OpenContinuum to inform on the progress of work carried out on the taxonomy, on the milestones reached concerning standardisation actions, and to present the need for further participation of the community.
	Outcome: the awareness created in the computing continuum community has allowed for increasing participations to standardisation.
	More information is available in Annex A.
EC Horizon Europe research support	**Description:** While the computing continuum initiative is mainly based on the projects that are funded by CL4-2021-DATA-01-05 (Future European platforms for the Edge: Meta Operating Systems (RIA)), other research topics can also have a relation, in particular concerning data spaces (e.g., DIGITAL-2021-CLOUD-AI-01-SUPPCENTRE and the DSSC project, or HORIZON-CL5-2021-D3-01-01 on a common European energy data space). OpenContinuum has taken advantage of the multiple priorities of the Horizon Europe programme to create more synergy at the level of standardisation concerning architecture, interoperability for the continuum and for data spaces.
	Outcome: a stronger contribution to standardisation has been facilitated by joint contributions related to digital twins, interoperability, and data spaces.
AIOTI standardisation support	**Description:** AIOTI groups the EU research community on IoT. It created a liaison with ISO/IEC JTC1/SC41 (IoT and digital twins) in 2018. The liaison allows its members to make proposals for the development of standards in SC41. AIOTI has prepared a report based on the computing continuum taxonomy work of EUCloudEdgeIoT and has submitted it to ISO, as well as a report on the integration of digital twin in data spaces

	Outcome: AIOTI has created awareness at ISO level on the wealth of work in Europe on IoT, digital twins, architecture, and computing continuum. More information is available in Annex B.
EC standardisation support	**Description:** The EC also has liaison with ISO committees. During a meeting with the commission on the energy data space cluster, Antonio Kung suggested that the EC sets up a liaison with SC41 (IoT and digital twin) that would strengthen the recently set up liaison with SC32 (Data management and interchange). As a result, the commission attended the SC41 plenary and made a presentation on the computing continuum. **Outcome:** ISO is now informed that the computing continuum (as well as data spaces) is a research policy priority. More information is available in Annex C.
SC41 Plenary May 2024 Helsinki	**Description:** Leveraging the reports prepared by AIOTI for ISO, the new liaison created by the EC, the following actions were undertaken: ● There is a common practice that the hosting country of an ISO plenary has the possibility to organise a side workshop where ISO experts are invited. AIOTI and OpenContinuum negotiated with the Finnish national body to organise a workshop on EU innovation. The organisation of the workshop was started on November 2023. The workshop took place on May 28th, 2024 and focused on both the continuum and data spaces. ● AIOTI submitted a request to make a presentation on the continuum taxonomy, which was accepted by SC41/WG3 (IoT foundational standards). ● The computing continuum taxonomy was consequently presented on May 29th, 2024 in a working session and a request for a preliminary work item was made which was accepted with Antonio Kung and Lara Lopez being editor and co-editor. ● In parallel AIOTI organised other working sessions related to interoperability and IoT digital twin integration to data spaces. These works are related to two other standards under development. AIOTI also a negotiated a slot during the ISO plenary itself to present this work in order to approve the submission of ISO/IEC 30153 (IoT and digital twins – guidance on the connection to data spaces). **Outcome:** ISO has approved a preliminary work item on Architecture considerations for IoT, Edge and Cloud. More information is available in Annex D

3.3 OUTCOME OF THE ACTIONS TOWARDS STANDARDISATION

Table 2 summarises the outcome of OpenContinuum towards standardisation.

TABLE 2: OUTCOME OF ECOSYSTEM ACTIONS TOWARDS STANDARDISATION

Outcome	Description and further work
New standard preliminary work item established on the continuum SC41 PWI - Architecture considerations for IoT, edge and cloud Editors from OpenContinuum: Antonio Kung, Lara Lopez	**Description:** this preliminary work item was registered by ISO further to the SC41 plenary in plenary, further to the presentation made by Lara Lopez with the following scope ***Provide a technical report on the architecture in the IoT, edge and cloud with the goal to contribute to the reference architecture in the form of construction patterns.*** Notes ● the term continuum is not in use in ISO. It has been therefore replaced by IoT-Edge-Cloud ● we have changed the order, i.e. IoT-Edge-Cloud instead of Cloud-Edge-IoT as the new standard item is managed by ISO/IEC JTC 1/SC 41 (IoT and digital twin) **Further work beyond OpenContinuum:** the computing continuum community to contribute (1) to the standard and (2) to implementations
Approved standard development established for interoperability SC41 21823-5 Behavioural and policy interoperability Editor from OpenContinuum: Antonio Kung	**Description:** this project was approved by ISO at the end of 2023, mainly as the results of actions related to EU projects and initiatives of interoperability (e.g. SAREF) with the following scope ***This part of ISO/IEC 21823 specifies interoperability from a behavioural and policy viewpoint. In this document, the following specifications for interoperability from a policy and behavioural point of view are included:*** - ***a principle of how to achieve behavioural and policy interoperability;*** - ***requirements on information related to behavioural and policy interoperability, and*** - ***a framework for processes on developing information exchange rules from a behavioural and policy viewpoint*** **Further work beyond OpenContinuum:** the computing continuum community to contribute (1) to the standard and (2) to implementation architectures concerning interoperability in the continuum.

Approval to launch a ballot on a data space related standard SC41 NP 30152 IoT and digital twins – Guidance on the connection to data spaces Editor from OpenContinuum: Antonio Kung	**Description:** this project proposal is under ballot, further to standardisation worked led by AIOTI to promote standards related to data space with the following scope *This document provides guidance on the connection of IoT systems and digital twins in data spaces, including principles, architecture and lifecycle considerations. It is based upon* - *concepts and characteristics described in ISO/IEC 20151 (Dataspace concepts and characteristics),* - *architecture considerations described in ISO/IEC 30141 Ed2 (IoT reference architecture) and ISO/IEC* - *30188 (Digital twin reference architecture), and interoperability aspects described in the ISO/IEC 21823 series (Interoperability for IoT systems)* **Further work beyond OpenContinuum:** the computing continuum community to contribute to computing continuum patterns connecting IoT to data spaces.

3.4 LEGACY BEYOND OPENCONTINUUM - RECOMMENDATIONS

Even though OpenContinuum is completing in August 2024, it is critical to ensure a continuation in order to create the impact envisioned by EU research. Table 3 summarises the assets that were consolidated during OpenContinuum and lists recommendations for continuation.

TABLE 3: RECOMMENDATIONS BEYOND OPENCONTINUUM

Consolidated assets	Description and recommendation
Wealth of standardisation initiatives	**Description:** Table 2 above lists standards under development that have directly influenced by OpenContinuum work. D1.2 also provides a description of other standards that have benefited from EU work. **Further work beyond OpenContinuum:** the computing continuum community should continue contributions and possible identify further work.
AIOTI community support	**Description:** AIOTI was created in 2015 with the support of the commission as a community placeholder to support the implementation of a leading European IoT and edge computing ecosystem. It currently includes 5 horizontal groups (ICT for CO2 reduction methodologies, policy, research and innovation,

	standardisation, testbeds) as well as 5 vertical groups (agriculture, energy, health, manufacturing, mobility). The WG standardisation was instrumental in helping EUCloudEdgeIoT define and implement a standardisation strategy **Further work beyond OpenContinuum:** the computing continuum community can take advantage of AIOTI current engagement with standardisation bodies to implement a computing continuum standardisation roadmap.
EC liaison support	**Description:** The EC has established strong instruments to support EU projects on standardisation (e.g. StandICT, HSBooster). Further the EC has also established liaison with standardisation bodies, including in 2024 with SC41 (IoT and digital twin) and with SC32 (Data management and interchange data). Through the liaison the EC can request presentations on topics of interest for Europe (e.g. presentation of regulation roadmaps, or research roadmaps and of standardisation roadmaps. **Further work beyond OpenContinuum:** coordination with the EC, in particular with the EC liaison officer in order to plan for common actions.
Further continuum supply side projects e.g., HORIZON-CL4-2024-DATA-01-03	**Description:** further continuum supply side projects are available and funded. **Further work beyond OpenContinuum:** the computing continuum community should plan for legacy transfer activities.

4 CONCLUSION

This deliverable has reported the outcomes of the different joint actions that have been undertaken following the plan proposed in D4.3 in T4.1 with positive results (1) on fostering the ecosystem, (2) on standardisation achievement and (3) on recommendations:

As explained in section 3.2, the strategic tasks led to the following outcomes:

- From strategic task 1 (engagement with projects):
  - The awareness created in the computing continuum community has allowed for increasing participations to standardisation (as showed in the Helsinki workshop)
  - A stronger contribution to standardisation has been facilitated by joint contributions related to digital twins, interoperability, and data spaces.
  - AIOTI has created awareness at ISO level on the wealth of work in Europe on IoT, digital twins, architecture, and computing continuum.
  - ISO is now informed that the computing continuum (as well as data spaces) is a research policy priority.
- From strategic task 2 (lead the work in TF3):
  - A taxonomy agreed by the experts of the research projects that could be used to create the foundation of architecture standards on the continuum
- From strategic task 3 (lead the work in TF2):
  - The computing continuum community has gained common insight on the practice of open source, the possible European synergies, and gaps where opportunities can be sought.

As explained in section 3.3, the associated participation to standardisation point of view has led to the following outcome:

- A new standard preliminary work item was approved in May 2024 by ISO/IEC JTC1/SC41, (PWI Architecture considerations for IoT, edge and cloud) with Antonio Kung and Lara Lopez acting as editors.
- A new standard development was approved on interoperability (ISO/IEC 21823-5 IoT behaviour and policy interoperability) with Antonio Kung acting as editors.
- Launching a ballot to approve ISO/IEC 30152 (IoT and digital twins – Guidance on the connection to data spaces)

As explained in section 3.4, recommendations have been identified:

- Continue contributions on the computing continuum
- Take advantage of instruments such as AIOTI
- Coordination with the EC in terms of liaison with ISO/IEC JTC1/SC41
- The computing continuum community to plan for legacy transfer activities.

As a conclusion, we would like to point out conditions that were important for the success of the project:

- Contribution from research projects to standardisation was effective because task forces benefitted from strong participation from projects. The support from the EC was paramount to make it happen.
- Preparation of contributions to standardisation requires strategic anticipation and synergistic actions in liaison activities (as many partners do not have direct access) from partners (e.g. Trialog), associations (e.g., AIOTI), and the commission (e.g., a liaison category A was set up between the commission and SC41).

We hope that these favourable conditions will persist in the future.

ANNEX A: CONTRIBUTION OF OPENCONTINUUM WORKSHOPS TO THE ECOSYSTEM

The following two events were important as they gathered the community.

- The concertation and consultation on computing continuum (10-11 May 2023 in Brussels). More information can be found in https://eucloudedgeiot.eu/event/concertation-and-consultation-on-computing-continuum-from-cloud-to-edge-to-iot/.

  While this meeting had a larger scope, it was organised by OpenContinuum with the objective to present and discuss the EUCloudEdgeIoT cooperations mechanisms (task forces). This took place on May10th at the session from 11.45 to 12.15 on EUCloudEdgeIoT cooperation mechanisms:

  - TF1 Strategic Liaisons
  - TF2 Open Source
  - TF3 Architecture
  - TF4 Ecosystem Engagement
  - TF5 Market and Sectors
  - TF6 Communications

- The EUCloudEdgeIoT OpenContinuum final conference (18 June 2024 in Brussels). More information can be found in https://eucloudedgeiot.eu/event/euceis-open-continuum-final-conference-registration-now-open/.

  The table below contains a summary of the final conference.

TABLE 4: SUMMARY OF FINAL OPENCONTINUUM FINAL CONFERENCE

THE VALUE OF CLOUD-EDGE-IOT RESEARCH PROJECTS IN THE INDUSTRY SECTOR

INTRODUCTION

The European Cloud, Edge, and IoT (EUCloudEdgeIoT, EUCEI) initiative is crucial for promoting digital autonomy in Europe. Supported by the OpenContinuum and Unlock CEI projects, EUCEI aims to advance cloud, edge, and IoT technologies, creating a robust computing ecosystem. This white paper provides an in-depth analysis of the insights and outcomes from the EUCEI's OpenContinuum Final Conference, highlighting the transformative impact of these technologies on various industrial sectors.

Albert Seubers (Coordinator at EUCEI's OpenContinuum) opened the conference,

emphasising the participation of 30 projects focused on <u>swarm computing, cognitive cloud, cognitive computing, next generation IOT, metaOS and Open Source.</u> These projects are critical in building a digitally autonomous Europe, showcasing the collaborative spirit driving these initiatives.

Luis Busquets Pérez (Programme Officer, European Commission) highlighted the European Commission's commitment to ICT, emphasising the value of elastic and scalable edge computing. He outlined the EC's investment strategy across networking, digital services, and Horizon Europe, aiming to ensure Europe's digital sovereignty by promoting innovation and integration across the computing continuum. <u>In his presentation he highlighted the Digital Decade objectives by 2030 and the 4 pillars for the European Data Strategy.</u>

In the following sections, we will summarize the main objectives, achievements, and insights from the EUCEI initiative, highlighting how it has driven digital innovation and integration across Europe.

OBJECTIVES AND ACHIEVEMENTS

The EUCloudEdgeIoT (EUCEI) initiative has been instrumental in advancing a resilient and interoperable computing ecosystem within Europe. Through its multifaceted objectives, the initiative aims to promote an open ecosystem, map the supply-side landscape, and engage the demand side in early development stages to bridge the gap between supply and demand. These efforts have significantly driven digital innovation and integration across Europe, helping to position the region as a leader in the global computing continuum landscape.

PROMOTING AN OPEN ECOSYSTEM

A primary objective of EUCEI is to establish a European industrial ecosystem grounded in open source and open standards. This approach ensures interoperability, scalability, and security across the computing continuum. Collaborating with key initiatives such as the Alliance for Internet of Things Innovation (AIOTI), the European Cyber Security Organisation (ECS), and Gaia-X, EUCEI has created a collaborative environment that enhances the overall impact of the initiative.

- Interoperability and Standards: By promoting open standards, EUCEI ensures that different systems and technologies can work together seamlessly. This is crucial for creating a unified computing continuum where resources and data can be shared and utilised effectively.

- Scalability and Security: The emphasis on open source not only fosters innovation but also ensures that solutions are scalable and secure. This is particularly important in the context of the computing continuum, where the need for robust, scalable, and secure solutions is paramount.

- Collaborative Projects: Initiatives like AIOTI, ECS, and Gaia-X provide platforms for collaboration and standardisation. These collaborations have led to the development of common frameworks and guidelines, which are essential for the cohesive growth of the computing ecosystem.

MAPPING THE SUPPLY-SIDE LANDSCAPE

A comprehensive analysis of the European computing continuum landscape has revealed

several key insights, which are crucial for understanding the roles and contributions of various actors in this ecosystem. This mapping exercise has facilitated the creation of a robust supply-side community that engages both industrial and research actors cohesively.

- Identifying Key Players: The landscape includes major corporations, SMEs, research institutions, and public sector bodies. Each of these actors plays a vital role, from developing new technologies to implementing standards and driving market adoption.

- Trends and Innovations: The analysis highlighted trends such as the increasing focus on interoperability, the adoption of open-source solutions, and the emphasis on scalability and efficiency. These trends are shaping the future of the computing continuum in Europe.

- Community Building: By identifying and engaging key players, EUCEI has created a cohesive community that works towards common goals. This community is essential for driving innovation and ensuring the successful implementation of new technologies.

- Standardisation: The launch of a standard in ISO/IEC JTC 1/SC 41 (Architecture considerations on IoT, edge and cloud) as a result of joint OpenContinuum-AIOTI collaboration canl pave the way for a serie of standards on the continuum.

ENGAGING THE DEMAND-SIDE

Engaging the demand-side is essential for understanding market dynamics and exploring business opportunities. EUCEI has conducted systematic assessments to gain insights into the current state of the European CEI demand landscape.

- Market Insights: Through these assessments, EUCEI has developed a deep understanding of market needs and dynamics. This includes identifying key sectors and applications where CEI technologies can have the most significant impact.

- CEI Readiness Framework: The insights gained from the demand-side assessments have informed the development of a CEI Readiness Framework. This framework prepares the market for the adoption of CEI technologies by identifying potential barriers and facilitators.

- Business Opportunities: Engaging the demand-side has also highlighted new business opportunities, helping to align technological developments with market needs. This alignment is crucial for driving the adoption and commercialization of CEI technologies.

BRIDGING SUPPLY AND DEMAND

Creating a productive interface between supply and demand is crucial for the successful adoption of new technologies. EUCEI has made significant strides in this area by building the CEI Industry Constituency, which aggregates demand needs and identifies key demand-pull drivers.

- CEI Industry Constituency: This constituency brings together various stakeholders, including industry leaders, policymakers, and researchers, to discuss and align on the needs and priorities of the CEI market.

- Demand-Pull Drivers: By identifying key demand-pull drivers, EUCEI has been able to focus on the most critical areas where CEI technologies can meet market needs. This has helped in prioritising research and development efforts and ensuring that they are aligned with

market demands.

- Effective Communication Channels: Establishing effective communication channels between supply and demand sides has been a key achievement. These channels facilitate the exchange of information and feedback, helping to refine and improve CEI technologies to better meet market needs.

RESEARCH PANELS AND STRATEGIC INSIGHTS

The EUCEI's Open Continuum Final Conference featured research panels on critical areas of cloud, edge, and IoT technologies. Experts from various projects discussed advancements, challenges, and future directions in cognitive cloud, next-generation IoT, meta operating systems, and open source standards. These panels highlighted the transformative potential of these technologies in driving digital innovation across Europe. The following sections summarise the key discussions and takeaways, providing an overview of the current state and future prospects of the computing continuum landscape.

Cognitive Cloud

The Cognitive Cloud panel, moderated by Giovanni Rimassa, highlighted the transformative potential of cognitive cloud technologies on European industries, focusing on interoperability, AI-enhanced performance, and smart city applications. Experts from projects such as COGNIFOG, AC3, ACES, Sovereign Edge, and MLSysOps shared insights on leveraging AI and ML to manage complex systems and improve efficiency. Key projects emphasised the importance of achieving interoperability at both architecture and application levels, using AI for lifecycle management, and deploying AI/ML in dynamic node monitoring and energy grid management. The discussion also covered practical applications, like MLSysOps' use of ML in smart agriculture and Sovereign Edge's dynamic node deployments in urban settings.

The panellists identified several challenges and future directions, including the need for standardisation, enhanced energy efficiency, and advanced cybersecurity measures. They emphasised the importance of developing standardised approaches to ensure seamless integration across diverse platforms and technologies. Addressing data collection challenges and integrating AI models for better system performance were also highlighted as crucial areas for ongoing research. The Cognitive Cloud panel provided valuable insights into driving innovation and efficiency across various sectors, underscoring the critical role of cognitive cloud technologies in shaping the future of European industries.

Next-Generation IoT & Swarm

The Next Generation IoT & Swarm panel, moderated by Albert Seubers, delved into advancements in IoT architectures and swarm intelligence, featuring insights from leaders of projects like OASEES, TERMINET, OpenSwarm, Assist-IoT, INCODE, VEDLIoT, and TardIS. Panellists discussed the development of decentralised systems, emphasising the importance of data-driven, energy-aware AI and smart programs. They highlighted innovative use cases across sectors such as smart agriculture, medical applications, supply chain, and energy management. Security was a significant focus, with discussions on enhancing security through modular architectures, trusted execution environments, and virtualization techniques to address the dynamic nature of IoT environments.

The panel also explored the challenges of developing autonomous systems and their potential applications in various industries. Security measures, including sandboxing and the zero-trust model, were discussed as critical for ensuring robust IoT deployments. The dynamic and evolving nature of application requirements was acknowledged, with emphasis on the need for continuous updates and adaptability. The conversation underscored the necessity of collaboration between different IoT projects to achieve interoperability and scalability, thereby driving the next generation of IoT and swarm technologies forward in Europe.

MetaOS

The MetaOS panel, moderated by Golboo Pourabdollahian, brought together experts from projects such as aerOS, Nephele, NebulOUS, FluidOS, ICOS, and NEMO. The discussion focused on the development of meta operating systems designed to interconnect various modules and applications across the computing continuum. Panellists highlighted the significant challenges in achieving interoperability and emphasised the need for a unified definition of the computing continuum. They discussed strategies for integrating diverse technologies and ensuring that different systems can work together seamlessly, thereby facilitating widespread adoption of these advanced technologies.

A key topic of the panel was the importance of creating a transparent and standardised approach to managing the computing continuum. Projects like FluidOS and aerOS shared their efforts in developing reference architectures and protocols to enhance interoperability. The panellists also addressed the issue of exploiting project results post-completion, suggesting the development of specific software stacks for commercial applications. The discussion underscored the importance of aligning with common standards and leveraging widely adopted technologies to ensure the success and scalability of meta operating systems in the European digital landscape.

Open Source & Standards

The Open Source & Standards panel, led by Antonio Kung, started with the announcement of the successful organisation of a workshop during the ISO/IEC JTC 1/SC 41 (IoT and digital twins) plenary in Helsinki and the approval for a standard project on the continuum.

The panel featured insights from representatives of Vitamin-V, Riser, FluidOS, aerOS, and FOCETA. The discussion centred on the pivotal role of open source and standards in fostering innovation within the computing continuum. Panellists emphasised that open source projects, aligned with international standards, are crucial for ensuring interoperability, scalability, and security across diverse systems. They highlighted the contributions of their respective projects to the open source community, including software for RISC-V architecture, transparent cloud services, and Kubernetes-based solutions.

The panel also addressed the challenges of maintaining and integrating open source projects into standardised frameworks. They discussed the importance of planning, investment, and continuous maintenance in successful open source endeavours. The panellists shared their experiences with standardisation efforts, noting that standards not only create a robust development environment but also facilitate widespread adoption and trust in the technologies. The discussion underscored the need for a continuum of standards, from high-

level protocols to detailed implementation guidelines, to support the seamless operation of the computing continuum.

Cognitive Computing

The Cognitive Computing panel, moderated by Monique Calisti, brought together experts from EMPYREAN, INTEND, and ENACT to discuss the integration and application of AI within the computing continuum. The panel explored how various AI technologies, including machine learning (ML), federated learning (FL), and swarm computing, are being utilised to optimise and manage complex systems. Panellists highlighted the use of AI for smart city applications, decentralised computing, and enhancing human-machine interactions. They emphasised the importance of AI in building trust, ensuring data integrity, and optimising deployments within the continuum.

Discussions also covered the role of AI in creating a fluid and dynamic continuum, where the level of knowledge and capability can vary from local to near-global scales. The panellists noted that the computing continuum must support a decentralised intelligence model, where no single agent has complete knowledge of the entire system. This approach is essential for managing the complexity and scale of modern computing environments. The conversation underscored the need for robust AI models to navigate the challenges of interoperability and seamless integration across diverse technologies and applications within the computing continuum.

Industry Panel discussion

The preliminary results and achievements but also research challenges presented by the projects were discussed in a panel composed of representatives from different industries like Energy production and distribution, Automotive, Healthcare, Manufacturing, Telecommunication network services.

Handover & Awards

The handover from Open Continuum to Nexus Forum marked a significant transition for the EUCEI initiative. Speakers including Sachiko Muto, Thomas Ohlson Timoudas, Chiara Zincone, and Giovanni Rimassa discussed the future direction of the initiative. The Nexus Forum aims to build on the achievements of Open Continuum, continuing to foster collaboration and innovation within the computing continuum. The focus will be on engaging a broader range of stakeholders, including investors and member state representatives, to drive forward the goals of digital sovereignty and innovation in Europe.

The conference featured an exhibition area where projects showcased their achievements through roll-up banners and networking opportunities. This provided a platform for peer engagement and collaboration. The awards ceremony celebrated outstanding projects within the EUCEI community, recognizing their contributions to advancing cloud, edge, and IoT technologies.

CONCLUSION

The EUCEI's Open Continuum initiative has significantly advanced the integration and innovation within the cloud-edge-IoT landscape. By promoting open standards, fostering collaboration, and driving strategic investments, the initiative has laid a strong foundation for

Europe's digital sovereignty. The insights and outcomes from the conference highlight the transformative potential of these technologies and provide a roadmap for future research and development efforts.

Funded by Horizon Europe
Framework Programme of the European Union

ANNEX B: CONTRIBUTION OF AIOTI SUPPORT TO THE ECOSYSTEM

AIOTI was created in 2015 with the support of the commission as a community placeholder to support the implementation of a leading European IoT and edge computing ecosystem.

It currently includes 5 horizontal groups (ICT for CO_2 reduction methodologies, policy, research and innovation, standardisation, testbeds) as well as 5 vertical groups (agriculture, energy, health, manufacturing, mobility).

The WG standardisation was instrumental in helping EUCloudEdgeIoT define and implement a standardisation strategy. It created a liaison with ISO/IEC JTC1/SC41 (IoT and digital twins) in 2018, and a liaison with ITU-T in 2022. Some members of AIOTI have strong involvement in standardisation

- Antonio Kung is the current chair of WG standardisation. He acts as the liaison officer from AIOTI to SC 41. He is also chairing to advisory groups in SC41, acts as liaison officers in many liaisons and has edited or is editing about 20 standards

- Marco Carugi is a member of the WG and the rapporteur of Q2/20 (Requirements, capabilities and architectural frameworks across verticals enhanced by emerging digital technology) of ITU-T SG20 (Internet of things (IoT) and smart cities and communities (SC&C)

- Georgios Karagiannis was previously the chair of the WG standardisation. He is now the chair of the horizontal group "ICT for CO_2 reduction methodologies", currently working on contributions to ITU-T SG5 (Environment, climate change and circular economy)

The following actions were undertaken by AIOTI to support OpenContinuum:

- Sending two liaison statements,

  - one on "Guidance for the Integration of Digital Twins in Data Spaces", with a request to plan for a presentation as shown in Table 5.

  - one on "Towards a Computing Continuum Reference Architecture", with a request to plan for a presentation as shown in

TABLE 5: AIOTI LIAISON LETTER TO SC41 ON DATA SPACES

ISO/IEC JTC 1/SC 41 N2649

ISO/IEC JTC 1/SC 41	
Internet of Things and Digital Twin	
Secretariat: KATS (Korea, Republic of)	

Document type:	Liaison organization contribution
Title:	AIOTI liaison statement to JTC 1/SC 41
Status:	For your information.
Date of document:	2024-05-16
Source:	AIOTI
Expected action:	
Action due date:	
No. of pages:	2
Email of CM:	Ms. Jooran LEE <jooran@ksa.or.kr>

Alliance for IoT
and Edge Computing
Innovation

Brussels, 13 May 2024

Attn.
François Coallier, Chair ISO/IEC JTC 1/SC 41 (francois.coallier@etsmtl.ca)
Jooran Lee, Committee Manager ISO/IEC JTC 1/SC 41 (jooran@ksa.or.kr)

Subject: Alliance for IoT and Edge Computing Innovation (AIOTI) Liaison statement to ISO/IEC JTC 1/SC 41

From: Antonio Kung, Liaison officer AIOTI WG Standardisation to ISO/IEC JTC 1/SC 41, antonio.kung@trialog.com

The Alliance for IoT and Edge Computing Innovation (AIOTI) would like to thank ISO/IEC JTC 1/SC 41 for the category A liaison established in October 2018, the participation of one of its members (Pedro Malo) as a co-editor of ISO/IEC TR 30194 (Best practices for use case projects), and the creation of AG31 (External liaisons collaboration). AIOTI would like to inform JTC 1/SC 41 on the following publications since October 2023:

- 02/05/2024: "**Computing Continuum Scenarios, Proof of Concepts, Requirements and Optical Communication Enablers Report R2**", which can be downloaded here.
- 30/04/2024: "**Edge IoT Industrial Immersive Technologies and Spatial Computing Continuum, Release 1**", which can be downloaded here.
- 08/03/2024: "**AIOTI White Paper IoT/Edge Computing and Health Data and Data Spaces**", which can be downloaded here.
- 19/02/2024: "**AIOTI Report on DLT-IoT-AI Technological Convergence R2**", which can be downloaded here.
- 29/01/2024: "**Edge driven Digital Twins in distributed energy systems paper**", which can be downloaded here.
- 26/01/2024: "**High Priority IoT Standardisation Gaps and Relevant SDOs R3**", which can be downloaded here.
- 15/12/2023: "**IoT and Edge Computing EU funded projects landscape Report R2**", which can be downloaded here.
- 30/11/2023: "**IoT and Edge Computing impact on Beyond 5G: enabling technologies and challenges Release 3.0**", which can be downloaded here.

Further, please find attached a draft report, "**Guidance for the Integration of Digital Twins in Data Spaces**", which can be useful to 30188 (Digital twin RA), PWI JTC1-SC41-16 (Digital Twin – Extraction and transactions of data components) and PWI JTC1-SC41-17 (Guidance on the integration of IoT and digital twins in data spaces). AIOTI kindly request AG31 to plan for a short presentation during the plenary in Helsinki.

Sincerely,

Antonio Kung,
Chair of AIOTI WG Standardisation

Alliance for IoT and Edge Computing Innovation IVZW | Avenue Louise 65, B-1050 Brussels, Belgium | RPM Brussels 0663895516
Contact: info@aioti.eu | T: +32 (0)2 535 77 92 | EU Transparency Register: 380738729287-22

TABLE 6: AIOTI LIAISON LETTER TO SC41 ON THE COMPUTING CONTINUUM

ISO/IEC JTC 1/SC 41 N2656

	ISO/IEC JTC 1/SC 41 **Internet of Things and Digital Twin** **Secretariat: KATS (Korea, Republic of)**

Document type:	Liaison organization contribution
Title:	AIOTI second liaison statement to JTC 1/SC 41
Status:	For your information.
Date of document:	2024-05-16
Source:	AIOTI
Expected action:	
Action due date:	
No. of pages:	2
Email of CM:	Ms. Jooran LEE <jooran@ksa.or.kr>

Alliance for IoT
and Edge Computing
Innovation

Brussels, 15 May 2024

Attn.
François Coallier, Chair ISO/IEC JTC 1/SC 41 (francois.coallier@etsmtl.ca)
Jooran Lee, Committee Manager ISO/IEC JTC 1/SC 41 (jooran@ksa.or.kr)

Subject: Alliance for IoT and Edge Computing Innovation (AIOTI) Liaison statement to ISO/IEC JTC 1/SC 41

From: Antonio Kung, Liaison officer AIOTI WG Standardisation to ISO/IEC JTC 1/SC 41, antonio.kung@trialog.com

This is an additional liaison statement which follows this first that was sent on 13 May, 2024. The Alliance for IoT and Edge Computing Innovation (AIOTI) would like to make available to SC 41 a draft report, "Towards a Computing Continuum Reference Architecture".
This joint AIOTI, EUCloudEdgeIoT and OpenContinuum report will be published shortly. It focuses on computing continuum architecture aspects.
A presentation will be made during the workshop on Tuesday May 28th, 2024. The Alliance for IoT and Edge Computing Innovation (AIOTI) would also like to thank ISO/IEC JTC 1/SC 41/WG 3 for arranging a WG3 presentation on Wednesday 29th, 2023, 9.00. Both presentations will be made by Lara Lopez on behalf of AIOTI.

Sincerely,

Antonio Kung,
Chair of AIOTI WG Standardisation

- Making the two presentations, and submitting the launch of the PWI on architecture considerations for IoT, edge and cloud, as well as the launch of the ballot for ISO/IEC 30153 IoT and digital twin – guidance on the connection to data spaces.

ANNEX C: CONTRIBUTION OF EC SUPPORT TO THE ECOSYSTEM

The European Commission has a total of 198 liaisons with ISO[2]:

- In November 2023, the commission made a request for a liaison to ISO/IEC SC 32 (Data management and interchange). The commission sent in May 2024 a liaison letter pointing out the availability of the following document: Programme for European Standardisation 2024[3] and pointing out the action "EU Trusted Data Framework".

- In the frame of the EU initiative for a European Energy Data Space[4], a coordination meeting took place in Brussels on January 24th, 2024, where AIOTI suggested to the commission to establish a liaison with SC41, in order to help push its agenda on both the computing continuum and on data spaces. The request for a liaison was submitted in February 2024, and accepted further to the SC41 plenary in Helsinki (May 2024). The request is showed in Table 7.

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[2]https://www.iso.org/organization/3182.html

[3]https://single-market-economy.ec.europa.eu/publications/annual-union-work-programme-european-standardisation-2024_en

[4]https://energy.ec.europa.eu/publications/common-european-energy-data-space_en

TABLE 7: LIAISON REQUEST TO SC41 FROM THE EUROPEAN COMMISSION

ISO/IEC JTC 1/SC 41 N2560

ISO/IEC JTC 1/SC 41
Internet of Things and Digital Twin
Secretariat: KATS (Korea, Republic of)

Document type: Liaison organization contribution

Title: EC request to establish a Category A liaison with JTC 1/SC 41

Status: This request is submitted to the IEC Secretariat to issue a Questionnaire within SC 41.

Date of document: 2024-02-14

Source: EC

Expected action:

Action due date:

No. of pages: 3

Email of CM: Ms. Jooran LEE <jooran@ksa.or.kr>

**INTERNATIONAL
ELECTROTECHNICAL
COMMISSION**

Application form for international organizations wishing to create a liaison with an IEC technical committee

Technical Committee or Subcommittee concerned (TC number and title)

ISO/IEC JTC 1/SC 41 Internet of things and digital twin

Applicant Organization:

European Commission, DG Connect, Unit E.4 Internet of things

Liaison category (see the ISO/IEC Directives Clause 1.17.2 for details):

☒   A (at the Committee level)

☐   B (at the Committee level)

☐   C (at the Working Group level)

Background

The European Commission has set up the European Multi-Stakeholder Platform on ICT standardisation (2011 C 349/04) to advice on all matters related to European ICT standardisation policy and its effective implementation, receive inputs from a broad range of stakeholders and to perform other related tasks. It has already set up liaisons e.g., with ISO/IEC JTC1, ISO/IEC JTC1/SC27, ISO/IEC JTC1/SC37, ISO/IEC JTC1/SC42, ISO/IEC JTC1/SC40, and ISO/IEC JTC1/WG11.

A copy ot the treaty on the functioning of the European Union is available here: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A12012E%2FTXT

Detailed information concerning the general requirements applicable to liaisons, different categories of liaisons, eligibility criteria, rights and obligations of liaison organizations is contained in the ISO/IEC Directives, Part 1 and IEC Supplement, Clause 1.17.

- As a result, Svet Mihaylov (EC), representative of the commission, attended the ISO/IEC JTC1/SC41 plenary in Helsinki in May 2024, and presented the research programme of the EC, highlighting in particular innovation on the computing continuum and on data spaces.

ANNEX D: CONTRIBUTION OF EUCLOUDEDGEIOT COMMUNITY TO THE ECOSYSTEM

As the May plenary of ISO/IEC JTC 1/SC41 (IoT and digital twin) was taking place in Helsinki, AIOTI contacted the national body of Finland and suggested the organisation of a workshop to promote research innovation in Europe with a view that it would support the submission of standards proposal.

The preparation of a workshop involved AIOTI, EUCloudEdgeIoT community. Several zoom meetings took place (December 5th 2023, January 3rd 2024, April 3rd 2024), as well as one face-to-face meeting in Stockholm (February 14th 2024) which involved members of the Finnish, Danish, Swedish national bodies as well as Antonio Kung representing OpenContinuum and AIOTI.

Research projects were contacted, and the following projects agreed to participate:

- NEPHELE (meta OS),
- AEROS (meta OS),
- FLUIDOS (meta OS),
- INTNET (Interoperability in energy data spaces),
- Enershare (energy data spaces),
- Omega-X (energy data spaces),
- SPADE (digital twins for agriculture),
- AURORAL (digital ecosystems for rural areas),
- INSTAR (international cooperation on standards)
- BEGONIA (cross-border use cases of Operational Digital Platforms (ODPs) in the energy and transport sectors)

The intention was also to have a face-to-face meeting so that EU project experts could meet ISO experts. A summary of the workshop is showed in Table 8. The Finnish national body has also published a webpage where all presentations are available[5].

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[5] https://sesko.fi/en/workshop-a-glimpse-of-europe-innovation/

TABLE 8: SUMMARY OF HELSINKI WORKSHOP

REPORT ON HELSINKI TECHNICAL WORKSHOP
A GLIMPSE OF EUROPE INNOVATION, MAY 28TH, 2024

ORGANISATION

Host	SESKO, Finland National Electrotechnical Standardization Organization
Co-organisers	AIOTI, OpenContinuum
Workshop facilitator	Antonio Kung, AIOTI, OpenContinuum
Sponsoring projects	Aeros, AURORAL, Begonia, Enershare, Fluidos, Int:net, Instar, Omega-X, Spade

PROGRAM

UTC	US East (EDT)	Europe (CEST)	Helsinki	China (CST)	Japan (JST) Korea (KST)	Australia (ACT)
12.00-15.30	08.00-11.30	14.00-17.30	15.00-18.30	20.00-23.30	21.00-00.30	22.00-01.30

15.00	Welcome	Jukka Alve, SESKO Damir Filipovic, AIOTI Albert Seubers, OpenContinuum
15.15	Standardisation and Europe innovation context	François Coallier, ISO/IEC JTC 1/SC 41 Chair. *ISO/IEC Standardization strategy on IoT and Digital Twin*
		Svet Mihaylov, European Commission. *European projects on IoT and digital twins*
15.45	Enablers and use cases for the computing continuum	Lara Lopez, Eviden. *Taxonomy for the computing continuum*, Anastasios Zafeiropoulos, NTUA. *Enablers and use cases in NEPHELE* Alejandro Fornés, UPV. *Enablers and use cases in AEROS* Albert Seubers, Martel-innovate. *Enablers in FLUIDOS*)
16.25	Enablers and use cases for energy data spaces	Alberto Dognini, Fraunhofer-FIT. *INT:NET project and Energy Data Spaces* Charukeshi Joglekar, Fraunhofer-FIT. *The Enershare Reference Architecture* Bruno Traverson, EDF. *An ontology development methodology for Smart Energy (Omega-X)*
17.00	Use cases in Europe and in Finland	Aris Tagarakis, CERTH. *The SPADE project: A multi-purpose physical-cyber Agri-forest drones ecosystem for governance and environmental observation* Asbjørn Hovstø, Hafenstrom. *AURORAL Architecture for Unified Regional and Open digital ecosystems for Smart Communities and*

		Rural Areas Large scale application Jussi Numminen, Wirepas. ***DECT-2020 NR for industrial uses*** Mika Karaila, Valmet. ***OPC UA and FMU Digital Twin***
17.50	Cooperation	Damir Filipovic, AIOTI. ***INSTAR: International cooperation for digital standardisation*** Razgar Ebrahimy, DTU. ***Digital Solutions for Energy and Transport Sector (BEGONIA)***
18.15	A vision of the future	Jarkko Pellikka, Nokia. ***Towards Sustainable Industrial Metaverse***

REPORT

The workshop was hosted by SESKO, the Finland National Electrotechnical Standardization Organization, and jointly organized by AIOTI, the Alliance for IoT Innovation and OpenContinuum, the Horizon Europe Coordination and Support Action for the ***Cloud-Edge-IoT*** domain.

The purpose of the workshop was to provide an overview of European innovation combining

- A presentation of Finnish projects
- A presentation of European innovation projects and how they can contribute on standardization.

The workshop covered 6 topics

- Standardisation and Europe innovation context.
- Enablers and use cases for the computing continuum
- Enablers and use cases for energy data spaces
- Use cases in Europe and in Finland
- Cooperation
- Conclusion

Standardisation and Europe innovation context

François Coallier, chair of ISO/IEC JTC 1/SC 41 highlighted the need to cover

- data-driven systems of systems,
- information technology and operational technology convergence, and
- the double horizontality of SC41 (i.e. IoT and digital twin are cross-cutting to other technologies and to application domains).

Svet Mihaylov from the European Commission presented the EC policies:

- digital decade,
- digital strategy, in particular for common European data spaces, and
- digital legislation.

Enablers and use cases for the computing continuum

Lara Lopez, chair of the EUCloudEdgeIoT task force on architecture reported the work of 46 EU projects on the creation of a taxonomy for the computing continuum, the identification of eight

building blocks (security & privacy, trust & reputation, data management, resource management, orchestration, network, monitoring & observability, and AI), and on the definition of a methodology for a shared architecture approach.

Anastasios Zafeiropoulos, coordinator of the NEPHELE EU project presented the innovation work on an IoT and Edge computing software stack leveraging virtualisation et the edge, and on a meta-orchestration framework, highlighting a system of systems approach, the concept of virtual object and composite virtual object, a reference architecture based on the foundational pattern of ISO/IEC 310141 Ed2, and an ECLIPSE based open source ecosystem.

Alejandro Fornés presented enablers and use cases of the AerOS EU project. The use cases included manufacturing, renewable energy, machinery, maritime ports, smart buildings. The enablers include a distributed state repository for domains federation, a two-layer service orchestration, on ontology of IoT-Edge-Cloud continuum, data fabric and supporting technologies, and enablers to automate the continuum through scripting DecPrivSecOps. Open calls were also announced.

Albert Seubers presented the FLUIDOS EU project and pointed out the need for deploy, communication and resource transparency in the making of solutions for virtual spaces spanning across multiple technological and administrative boundaries. He presented technology pillars: node and protocols, meta orchestrator, security, energy and open sources as well of use cases: smart viticulture, intelligent power grid and robotics logistic.

Enablers and use cases for energy data spaces

Alberto Dognini, coordinator of the int:net coordination and support action presented the objectives and outcomes of the int:net project in the area of energy data spaces. The objectives included a common knowledge base for interoperability services on energy services in Europe, a comprehensive interoperability maturity model, a framework for interoperability testing, and a community network of standards and regulatory environment. The outcomes includes an extension of the smart grid architecture model (SGAM), the support of two layers of projects (5 energy data space project – Data cellar, Enershare, Omega-X, Eddie and Synergies, and 5 user projects – Odeon, Interstore, Begonia, Hedge-IoT and Twin EU), and the publication of a Blueprint of the common European energy data space.

Charukeshi Joglekar presented how Enershare has constructed an architecture combining energy aspects (SGAM, BRIDGE), and data spaces initiative (IDSA, GAIA-X, DSCC), ensuring alignment with current standards. The resulting reference architecture was defined further to use case analysis consisted of five horizontal layers (business, function, information, communication, component) and vertical split to support local functionalities for specific use cases. The implementation of use cases also included three digital twins, for optimal data-driven power-to-gas optimal planning, for observation and monitoring algorithms and generation of synthetic failures data, and for flexible energy networks.

Bruno Traverson presented an ontology development methodology for smart energy used to ensure that data providers and service provides in the data space have a common understanding of shared data sets. The outcome is the AIME methodology (Agile Interaction, model-based Methodology for Energy data spaces) and CSDM (Common Semantic Data Model), a multidimension knowledge representation. Four interoperability levels were presented (intra use case (renewables, electromobility, flexibility, local energy communities), inter use case (infrastructure, metering, property, scheduling, quality, energy data sets, energy role, time series), sister projects (Data cellar,

Enershare, Eddie and Synergies), and alignment with standards (semantization of data models, alignment of reference ontologies, IEC 63417 - Guide and plan to develop a unified IEC Smart energy Ontology).

Use cases in Europe and in Finland

Aris Tagarakis, coordinator of SPADE presented the rationale for the project (risks related to drone operations, regulation, emergence of new service and complexity of architecture). He presented the types of drones considered (swarm of drones, cooperating drones, large single drones), the pilots (forestry in Norway, crop in Mallorca, livestock in Greece), the resulting ecosystem consisting of a distributed system platform supporting cybersecurity, connectivity and interoperability, digital twins, and a market place for data providers and service providers). He finally pointed out the need to support four types of policies (operational, technical, data, environmental and ethics) and to align with standards on digital twins, their security and privacy, as well as system of system drone based architectures.

Asbjørn Hovstø presented the AURORAL project, the aim of which is to bridge vertical services on different rural domains with horizontal services and online digital marketplaces, demonstrated in 5 use cases on tourism (Portugal), farming (Italy), health (Norway), Energy (Sweden) and Mobility (Finland). An architecture consisting of three layers is used (market place, horizontal services, and vertical services and tools), with a data brokerage middleware offering interoperability-as-a-service. The expected impact is to increase services, strengthen links, create opportunities, increase number of platforms, overcome the digital divide and improve quality of life in rural areas. Open calls where also announced.

Jussi Numminen from Wirepas presented the use of the DECT NR+ for industrial use. The technology is part of IMT-2020 (5G) and it addresses requirements of the ETSI TS 103 636 standard series. DECT NT+ is designed to scale in high-density area in de-centralised mesh configurations, allowing a better coverage for metering. A comparison was presented on the use of cellular networks versus the DECT NT+ mesh network.

Mika Karaila from Valmet presented the use of two important free standards, OPC UA (Operational Communication Platform Unified architecture) and FMI (Functional Mock Up Interface) digital twin as part of the virtual see trial project for ship commissioning. The OPC UA provides data models freely available. The FMI defines a standard to exchange dynamic simulation models. To types of simulation models are used, for model exchange and for co-simulation. A digital twin consisting of a OPC UA server with Functional mock-up capability was presented with three elements: the digital twin element to combine the OPC UA server with the functional mock-up, the OPC UA client (variable updater) and the OPC UA server (Distributed Control System).

Cooperation

Damir Filipovic presented the INSTAR EU recently started coordination and support action for international cooperation for digital standardisation. INSTAR addresses six topics: AI (Secure, trustworthy and ethical development and use of AI system), cybersecurity (Cybersecurity & electronic identification in industries such as healthcare, manufacturing, financial services, energy, automotive), data (Data quality, syntactic, semantic and pragmatic characteristics of data), IoT and Edge (Cloud, Edge (Near vs. Far edge), IoT in manufacturing, precision agriculture, mobility, energy grids, smart cities, healthcare etc.), 5G+ (Convergence of communications, sensing, sustainable services & AI) and

quantum (Quantum computing, communication, sensing, cryptography and post-quantum cryptography). INSTART has set up tasks forces to create reports on international standardisation priorities and share them with EU Digital Partnerships and the EU-US Trade and Technology Council.

Razgar Ebrahimy, coordinator of BEGONIA, presented the objectives of the recently started EU coordination and support action: identify cross-border use cases of operational digital platforms (ODPs) in the energy and transport sectors. Seven EU countries will be involved including more than 10 cross-border and possibly cross-sector use cases. presented the objectives has the objective to identify cross-border. An example of use case, is cross-border flexibility procurement for ancillary services in the grid. Standardisation issues include interoperability (data spaces and services), use for dedicated reference architectures, and compliance with local policies and regulations.

Conclusion

To conclude the workshop, **Jarkko Pellikka** from Nokia presented the trend towards sustainable industrial metaverse. He presented a vision based on two metaverse enablers, human augmentation, and digital-physical fusion, and three opportunities: consumer metaverse, enterprise metaverse (IT-centric) and industrial metaverse (OT-centric). He explained that current market research predic that industrial metaverse leveraging digital twin and simulation and industrial extended reality is expected to lead metaverse deployment. However, the triple challenge of new service needs, security and cost of energy require interoperability and standardization. This calls for ecosystem collaboration on technology enablers for industrial metaverse, architecture and platforms for sustainable industrial metaverse, AI/ML-enabled industrial applications and industrial metaverse ecosystem, new business opportunities and commercialization.

ANNEX E: OUTCOMES AT STANDARDISATION LEVEL

As a result of the Helsinki workshop and of the presentation on the taxonomy arranged on request from AIOTI, the SC41 agreed (resolution 518) on a preliminary work item on architecture considerations for IoT, edge and cloud, as showed in Table 9.

TABLE 9: RESOLUTION FOR A WORK ITEM ON THE CONTINUUM

Resolution 518 - PWI for TR on Architecture considerations for IoT, edge and cloud

Based on the AIOTI contribution (SC41N2657), JTC 1/SC 41 decides to register the following PWI for a TR:

Title: Internet of Things (IoT) − Architecture considerations for IoT, edge and cloud

Scope: Provide a technical report on the architecture in the IoT, edge and cloud with the goal to contribute to the reference architecture in the form of construction patterns.

JTC 1/SC 41 assigns this PWI to WG 3 and appoints Antonio Kung (FR) as a PWI Editor and Lara Lopez (AIOTI) as a PWI Co-Editor.

JTC 1/SC 41 requests WG 3 to seek cooperation and invite interested experts to participate in the development of this PWI.

As a result of the Helsinki workshop and of the presentation on the taxonomy arranged on request from AIOTI, the SC41 agreed (resolution 513) on the launching of a ballot on ISO/IEC 30152 on guidance on the connection to data spaces, as showed in Table 10.

TABLE 10 − RESOLUTION FOR A BALLOT ON GUIDANCE ON THE CONNECTION TO DATA SPACES

Resolution 513

Noting the WG 6 consensus on PWI JTC1-SC41-17 (WG6N257), JTC 1/SC 41 instructs its Committee Manager to launch the NP ballot on PWI JTC1-SC41-17, once having received the NP form and the initial WD.

WG 6 should seek cooperation prior to NP submission and invite interested experts to participate in the development of this NP.

During the previous SC41 plenary in Seoul (November 2023), the committee agreed (resolution 485) on the launching of a ballot on ISO/IEC 21823-5, as showed in Table 11. The ballot led to the official launch of the project in April 2024[6].

TABLE 11 − RESOLUTION FOR A BALLOT ON POLICY AND BEHAVIOUR INTEROPERABILITY

Resolution 485

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[6] https://www.iec.ch/dyn/www/f?p=103:38:500029219336663::::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:
20486,23,108353

Noting the WG 6 consensus on PWI JTC1-SC41-17 (WG6N257), JTC 1/SC 41 instructs its Committee Manager to launch the NP ballot on PWI JTC1-SC41-17, once having received the NP form and the initial WD.

WG 6 should seek cooperation prior to NP submission and invite interested experts to participate in the development of this NP.

ANNEX F: CONTRIBUTION OF EUCLOUDEDGEIOT TASK FORCES TO THE ECOSYSTEM

OpenContinuum led the management of two EuCloudEdgeIoT task forces:

- Task force 3 Architecture. The work of TF3 is reported in the following AIOTI document: *Towards a Computing Continuum Reference Architecture*, which was submitted to ISO/IEC JTC 1/SC41. The document is appended.

- Task force 2 Open Source. The work carried out in TF2 is in D1.1 and D1.2, and references to other publications are included in D2.2. so it is not reported her.