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D1.1 Toward a strategy for European Digital autonomy through Open Source, Standard and alliances

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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.

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EXECUTIVE SUMMARY

This deliverable describes the OpenContinuum work on Open Source, Standards and Alliance establishment in the European environment.

OpenContinuum addresses the coordination and support actions of the Cloud-Edge-IoT domain, with a specific thematic focus on the supply-side of the computing continuum landscape. In this frame, the document reports the work carried on during the first period of the project in the context of "Work Package 1: OpenContinuum IMPACT".

This work package has, as main topic, three important aspects in the lifetime of a European projects: Open Source, Standards, and Alliances. Working with these three elements, the main objectives are:

- Elaborate a strategy for European digital autonomy through Open Source, Standards and Alliances, which ultimately will lead to the definition of common open architecture for the computing continuum.
- Raise awareness on good practises for open source and open standards. Consolidate the coordination between open source and open standard approaches.
- Support research projects in joint activities on open source and open standards looking at maximising the impact of their exploitation strategies.

In particular, the document provides detailed information about the initial work of the work package and describes the initial actions taken into consideration for putting solid basis on the future and final work. It describes OpenContinuum works on European Open Source initiatives, open source communities and Standardization as well as the liaison between EU Alliances and Open Ecosystem.

In the direction of the open source, the aim is to create awareness on open source best practices and in community building. A suite of seminars has been planned and organised with the aim of presenting the open source activities with different points of view as well as give to them information of important and well-known open source tools. In parallel with the seminars, and with the same aim, relevant events are identified or organised or co-organised for the stakeholders. Furthermore, the initial results presented here, and the face-to-face discussion with the projects, reinforce the idea of 'breaking the silos' between projects.

Standardization is a necessary support for the development of the computing continuum ecosystem. In this document have been presented and identified several approaches, activities and possible routes based on the main level addressed by projects: architecture level, trustworthiness level, interoperability level, and open source level.

European alliances, partnerships, and initiatives in the edge-to-cloud continuum are an important aspect for the strategy and they have been presented in this document along with their description and relation to the work.

Furthermore, to improve the impact of the European work in these directions, the European Cloud Edge & IoT initiative[1] has been created as the joint effort between two coordination and support action projects: Open Continuum and UnlockCEI.

[1] https://eucloudedgeiot.eu/

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This initiative launched 6 task forces dedicated to the different focus topics This document will also explain the work carried on by the Open Source Engagement Task Force 2 (TF2) related to the WP1 and his task dedicated to open source.

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ABBREVIATIONS

AIOTI	Alliance for IoT and Edge Computing Innovation
BDVA	Big Data Value Association
CC	Cloud Computing
CEI	Cloud, Edge and IoT
EC	European Commission
ECC	European Cloud Computing
EPI	European Processor Initiative
MetaOS	Meta Operating System
OSD	Open Source Development
IEC	International Electrotechnical Commission
IEEE SA	Institute of Electrical and Electronics Engineers Standards Association
IoT	Internet of things
ISO	International Organisation for Standardisation
ITU-T	ITU Telecommunication Standardisation Sector (ITU-T)
JTC	Joint Technical Committee
MEC	Multi-access Edge Computing
OSS	Open Source Software
RA	Reference Architecture
SDO	Standard Development Organisation

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1 Introduction

1.1 Purpose of the document

OpenContinuum project's core ambition is fostering European strategic autonomy and interoperability through an open ecosystem for the computing continuum.

An Open Ecosystem spanning from Cloud to Edge to IoT is key to unleash the potential of EU industry in driving the green and digital transformation while preserving EU strategic autonomy. The current impact of European industry and research on de facto standards promoted by Open Source projects in the field is rather limited, with major initiatives most often being contributed to (and hence driven) by US and China actors.

In this context, this document provides detailed information about the initial work of the Work Package 1 (WP1) 'OpenContinuum IMPACT' and describes the initial actions taken into consideration for putting solid basis on the future and final work.

In particular, it describes OpenContinuum works on European Open Source initiatives, Open source communities and Standardization as well as the liaison between EU Alliances and Open Ecosystem. It will promote the establishment of a global and open ecosystem for Cloud-Edge-IoT technologies by:

1. supporting EU industries and researchers to create impact in Open Source technologies;
2. promoting the link between open source de-facto standards and European standardisation fora;
3. engaging relevant industrial alliances in actions directed toward Open approaches.

Furthermore, a joint initiative of OpenContinuum and Unlock-CEI projects reinforces this commitment.

In this respect, through the European Cloud, Edge & IoT Continuum initiative, together with Unlock CEI, the main activities of the OpenContinuum Impact are to:

- Develop a strategy for European digital autonomy through Open Source.
- Contribute to the definition of a common open stack for the computing continuum.
- Explain to industry actors the potential of open source software to drive innovation and collaboration.
- Train industry on definition of a long term open source strategy and governance.
- Guide research projects into making process-compliant contributions to open source in terms of projects or communities.
- Foster synergies across research projects for open source contributions.
- Investigate needs to standardise open source development practices.
- Investigate approaches to support standards through associated open-source implementations.

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- Train research projects on successful processes to standardise open source outcomes.
- Support computing continuum research projects on pre-standardisation initiatives.
- Help provide common grounding for different organisations toward the creation of an Open Ecosystem for the computing continuum
- Foster the usage of open standards.

1.2 Structure of the document

The sections of the deliverable are organised as follows:

- Section 1: After the introduction and the structure of the document, the section presents a brief introduction to digital autonomy and on the joint European Cloud Edge & IoT initiative.
- Section 2: depicts the open source strategy and role, including the main objectives, the description of the target audiences and the strategic planning of the envisioned activities. Also defines the role of the Task Force and the strategy put in place for achieving the common vision among the 46 projects involved in the work, as well as presenting an overview of them.
- Section 3: presents the open standard overview providing the identification of several approaches and activities that will be used in order to support the project's work.
- Section 4: provides information about the EU Alliances and Open Ecosystem explaining the relation and the activities organised to facilitate this collaboration.
- Section 5: concludes the document.

1.3 Our Stakeholders

This section provides a high level overview of the projects potentially involved in the work. An exhaustive detailed description can be found in the document D4.3 named 'Toward an European ecosystem for the computing continuum Working version'.

Here we recall the list of the main topics:

- MetaOS Projects: research projects funded by CL4-2021-DATA-01-05 (Future European platforms for the Edge: Meta Operating Systems (RIA))
- Cognitive Cloud Projects: research projects funded by CL4-2022-DATA-01-02 (Cognitive cloud)
- Swarm Computing Projects: research projects funded by CL4-2022-DATA-01-02 (Programming tools for decentralized intelligence and swarms (RIA))
- Open Source for Cloud Services Projects: research projects funded by CL4-2022-DIGITAL-EMERGING-01-26
- Drones: project in the CL6-2021-GOVERNANCE-01-21 topic (Potential of drones as multi-purpose vehicle – risks and added values)

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- Data Space: projects in the HORIZON-CL4-2021-DATA-01-01 - Technologies and solutions for compliance, privacy preservation, green and responsible data operations (AI, Data and Robotics Partnership) (RIA)
- Next Generation Internet of Things: projects founded in the HORIZON-ICT-56-2020
- Cloud Computing: towards a smart cloud computing continuum: projects founded in the HORIZON-ICT-40-2020(RIA)
- Software technologies: projects founded in the HORIZON-ICT-40-2020(RIA).

Figure 1 shows a graphic overview.

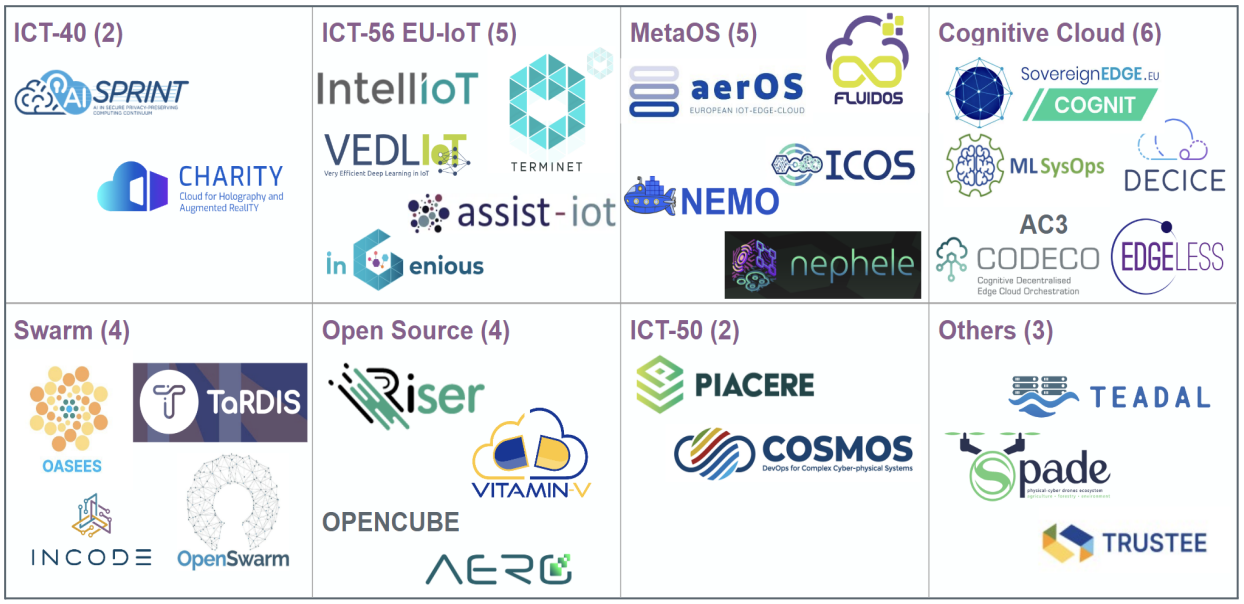

Figure 1 - Overview of European projects involved in the initiative

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2 OPEN SOURCE

2.1 OPEN SOURCE SOFTWARE APPROACH

2.1.1 What is an Open Source Software

The Open Source Initiative (https://opensource.org) provides a clear definition of an Open Source Software (OSS) in 10 criteria (https://opensource.org/osd-annotated):

1. **Free redistribution**: The license shall not restrict any party from selling or giving away the software as a component of an aggregate software distribution containing programs from several different sources. The license shall not require a royalty or other fee for such sale.
2. **Include source code**: The program must include source code, and must allow distribution in source code as well as compiled form.
3. Modifications and derived works: The license must allow modifications and derived works, and must allow them to be distributed under the same terms as the license of the original software.
4. **Integrity of author's source code**: The license may restrict source-code from being distributed in modified form only if the license allows the distribution of "patch files" with the source code for the purpose of modifying the program at build time. The license must explicitly permit distribution of software built from modified source code. The license may require derived works to carry a different name or version number from the original software.
5. **No discrimination against person and groups**: The license must not discriminate against any person or group of persons.
6. **No discrimination against fields of endeavor**: The license must not restrict anyone from making use of the program in a specific field of endeavor.
7. **Distribution of license**: The rights attached to the program must apply to all to whom the program is redistributed without the need for execution of an additional license by those parties.
8. **License not specific to a product**: The rights attached to the program must not depend on the program's being part of a particular software distribution.
9. **License not restricting other software**: The license must not place restrictions on other software that is distributed along with the licensed software.
10. **License technology neutral**: No provision of the license may be predicated on any individual technology or style of interface.

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2.1.2 Why do we need Open Source

From Small and Medium-sized Enterprises[2] to Large Organizations[3], a lot of companies have adopted and contributed to the one or more open source communities like the Eclipse Foundation, the Apache Software Foundation, and the Linux Foundation. Some of them have been involved for several decades already. This choice has nothing to do with altruism: it is a business strategy. In fact, the reasons why organisations prefer open source software to proprietary software are the following:

- Maturity of the model: There are numerous examples of projects and products based on the OSS which are more reliable and sustainable than other proprietary solutions.
- Cost of acquisition: Adopters of OSS obtain a financial gain for each stage of a project. For example:
  - **Free**: it's free to download and use.
  - **Try before buy**: because it is free, companies can try different OSS solutions before making the decision to invest time or resources in a specific one.
  - **Hiring is easier**: because OSS is free, many developers use it and become proficient with the software early on in their career or during their studies. This makes it easier and less expensive to find good developers that have experience with the open source technologies they have adopted for their project.
  - **Training:** it's easier to train a team with the assets produced by the OSS community of developer, due mainly to the accessibility, adaptability and the community support.
  - **Customizability**: open source software can be tweaked to suit various needs. Since the code is open, it's simply a matter of modifying it to add the functionality needed by the project.
  - **Time-to-Market is shorter**: products don't have to be built from scratch. Companies can rely on sustainable OSS and build their solution on top of it.
  - **Lower total cost of ownership:** companies can rely on the OSS community for maintenance and, by joining the community, they mutualized maintenance costs.
- **Dependence**: Organizations don't depend on the status of the subcontractor who originally built the software. In open source software, if a contributor stops working on a project for any particular reason, the source code stays accessible and someone else can take over the work.
- **Quality of the code:** OSS gets closer to what users want because those users can have a hand in improving it.
- **Security**: OSS is considered as more secure and stable than proprietary software, mainly because of its transparency (the source code can be easily examined), of its community which can test and audit it, its vulnerabilities can be rapidly fixed.

2.1.3 Why do we need Open Source Community

An OSS community is the keystone for the sustainability of our project. If we are not able to attract and convince people that our code is worth spending time and resources on testing it,

[2] Like CodeTrails (http://www.codetrails.com/) in Code Assistance, Micro-EJ (http://www.microej.com/) in IoT and OBEO (https://www.obeo.fr/en/) in Modelling.
[3] Like Amazon, Bosch, Google, IBM, Microsoft, Samsung, and Siemens.

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providing feedback, providing patches, and contributing in general, then all the intrinsic value of OSS is lost.

In other words, without Maturity, Quality, Cost of Acquisition, Control, and Security, the Sustainability of our code is nearly impossible. And vice-versa, Sustainability is a great indicator demonstrating the Maturity, the Quality, the Control and the Security of the code.

Open source code should be viewed as **common**, shared by code producers (developers) mutualizing their efforts and code consumers (users) reducing the total cost of ownership. Now managing common is not an easy task. It requires a certain level of governance. Open Source foundations such as the Eclipse Foundation provides this kind of processes and governance. It is inspired by Elinor Ostrom[4] principles.

Indeed, Elinor Ostrom, Nobel prize of Economy in 2009, designed 8 principles for managing stable Common Pool Resource (CPR):

1. **Clearly defined** (clear definition of the contents of the common pool resource and effective exclusion of external un-entitled parties);
2. The appropriation and provision of common resources that are **adapted to local conditions**;
3. **Collective-choice** arrangements that allow most resource appropriators to participate in the decision-making process;
4. **Effective monitoring** by monitors who are part of or accountable to the appropriators;
5. A scale of **graduated sanctions** for resource appropriators who violate community rules;
6. Mechanisms of **conflict resolution** that are cheap and of easy access;
7. **Self-determination** of the community recognised by higher-level authorities; and
8. In the case of larger common-pool resources, organisation in the form of **multiple layers of nested enterprises**, with small local CPRs at the base level.

At the Eclipse Foundation, the Development Process is well described by its handbook[5], from the creation of a project to its archiving, including open source principles, project roles, committer election, IP, or managing vulnerabilities. This documentation helps resolving most of the concerns and conflicts and provide good advice to build and maintain sustainable and "business-friendly" code. If a point is not covered, the Foundation staff is here to assist.

2.1.4 Why Europe needs Open Source

The open source approach aligns with the values of transparency, collaboration, security, and digital sovereignty that are important to many European countries and institutions. It offers practical advantages, cost savings, and opportunities for innovation that contribute to the region's technological advancement and competitiveness.

By relying on open-source software, European countries can reduce dependence on proprietary software vendors, many of which are based outside Europe. This helps to protect

[4] https://en.wikipedia.org/wiki/Elinor_Ostrom
[5] https://www.eclipse.org/projects/handbook/

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digital sovereignty, ensuring that European institutions have control over the technologies they use and are not subject to external influences.

Open source software also fosters collaboration among developers and encourages innovation. By allowing anyone to contribute and improve the software, open source projects can harness the collective knowledge and expertise of a global community. European countries recognise the potential for innovation and economic growth that open source ecosystems can bring.

There are several political reasons why Europe supports the open source approach. For example, Europe places a high value on data privacy and protection. Open source software provides greater transparency and control over the software's code, making it easier to ensure compliance with data protection regulations such as the General Data Protection Regulation (GDPR)[6]. European institutions prefer open source solutions to mitigate the risks of data breaches and unauthorised access.

Supporting the open source approach is seen as promoting European values of openness, transparency, and fairness. By endorsing open source software, European countries demonstrate their commitment to democratic principles, collaboration, and the free flow of information. It also helps to position Europe as a leader in technology governance and standards setting, by creating a stable, good quality and widely used software/product in Europe and the world.

And again, because open source software encourages innovation and entrepreneurship, European governments recognise the potential of open-source ecosystems to drive technological innovation, spur economic growth, and create job opportunities in the technology sector.

To summarise, these reasons reflect Europe's desire to assert its values, protect its interests, and shape the future of technology in a way that aligns with its own strategic goals and priorities.

2.1.5 Vision

One of the major roles of the Eclipse Foundation, and its OpenContinuum CSA partners, is to break down the idea that RIA (Research & Innovation Action) projects must develop in silos. We want to encourage project consortia to collaborate as much as possible, starting with the definition of a common core architecture on which most of them can build. We call this goal "Breaking down project silos".

Breaking the silos between RIA projects can indeed encourage reusability and interoperability, fostering collaboration, knowledge sharing, and accelerating advancements in research and innovation. We believe and recommend that the definition of a common open source software stack should be the basis for a number of projects.

Developing a common open source stack encourages **standardisation** across RIA projects. By defining a set of well-documented and widely adopted technologies, frameworks, and protocols, teams can ensure consistency in development practices. This standardisation promotes reusability by enabling components developed for one project to be easily integrated into others, reducing duplication of effort and increasing interoperability.

[6] https://gdpr-info.eu/

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A common open source stack motivates a **modular architecture,** allowing developers to build applications by assembling reusable components. These components can be developed independently and shared across projects, promoting reusability and interoperability. A modular approach also enables developers to focus on their specific project topic while leveraging existing modules for common functionalities and sharing efforts on the common stack.

Defining a common open source stack fosters **collaboration and community** involvement. By making the stack open source, developers from different projects can contribute to its development, improvement, and maintenance. This collaborative approach promotes knowledge sharing, resolves issues, and encourages the creation of a vibrant ecosystem around the stack. The community can provide support, share best practices, and develop additional reusable components, enhancing reusability and interoperability. A common open source stack can encourage **well-defined APIs** and support **open data formats** for seamless integration and data exchange between different projects. By adhering to open standards, consortiums can ensure interoperability and facilitate the reuse of data and services. Open APIs also allow developers to develop and share plug-ins or extensions that extend the capabilities of the common stack.

Last but not least, another aspect of developing a common open source stack for RIA projects is the ability to **recover certain components** that might not survive the end of their project's duration. This can greatly enhance reusability and prevent valuable work from being lost.

It is important to note that defining, even developing, a common open source stack requires coordination, governance, and community engagement.

2.2 Task Force 2: Open Source Engagement

The European Cloud Edge & IoT initiative[7] is the joint effort between two coordination and support action projects: Open Continuum and UnlockCEI.

This initiative launched 6 task forces[8] dedicated to the different focus topics:

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

In this context, the work carried on by the Open Source Engagement Task Force 2 (TF2) is managed by the Work Package 1.

The TF2 mission is twofold: on one hand, the focus is on the dissemination of the open source good practices and advantages; on the other hand, the aim is to collect useful information about the use of open source among the RIAs projects.

[7] https://eucloudedgeiot.eu/
[8] https://eucloudedgeiot.eu/cooperation-mechanisms/

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The main objectives of TF2 are:

- Raise awareness on good practices for open source;
- Raise awareness on good practices for open standards;
- Consolidate the coordination between open source and open standard approaches;
- Support research project in joint activities on open source and open standards looking at maximising the impact of their exploitation strategies.
- Develop a strategy for European digital autonomy in edge-to-cloud through Open Source
- Contribute to the definition of a common open architecture for the computing continuum
- Explain industry and research actors how Open Source can drive innovation and collaboration
- Train industry and research actors to embrace a long term Open Source strategy

2.2.1 Engagement

The goal of involving RIA projects, as already mentioned, is twofold: to provided and to collect information. In particular, from the perspective of the RIAs, TF2 performs the following actions:

- disseminate information (webinar, events)
- provide guidance on Open Source environment and best practices
- promote interoperability among the projects

On the other side, the TF2 receives and collects information about the open source approach and technologies RIAs are adopting.

Different channels have been used to reach the clusters: Miro, zoom, survey and e-mails.

The involvement of RIAs, presented in Section 1.3, in the task force began in stages. In fact, the involvement strategy consists of several steps and leverages different communication channels.

The communication between the task force and the RIAs takes place mainly online: via email, through mailing lists and with online events, webinars held on sharing platforms such as zoom.

2.2.1.1 IoT and Edge @ Eclipse webinar

As a first action, an overview of the Open Source IoT environment has been presented to the MetaOS cluster and the opportunity was taken to have a first presentation of the projects and an initial comparison between them. The following picture shows the event dissemination.

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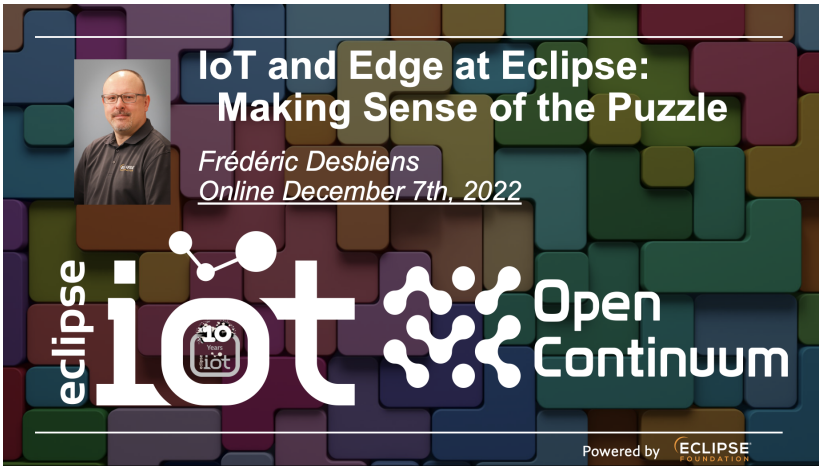

Figure 2 - Webinar on IoT and Open Source

All the MetaOS projects were presented and 38 attendees were counted.

After this first event, a physical meeting has been organized in order to connect the MetaOS RIAs among them and collect information about their open source approach. The next paragraph is dedicated to this meeting in Toulouse, France.

2.2.1.2 MetaOS open source stack @ Toulouse, France

The first physical meeting with the MetaOS projects took place in Toulouse, France. As it has been mentioned above, this **Workshop** brought together **all the projects** related to Meta-Operating System to start discussing a future open-source stack for the Meta OS. The Open Source Task Force, organised the first face-to-face meeting with the cluster of RIAs that have already started, the *HORIZON-CL4-2021-DATA-01-05: Future European Platforms for the Edge: Meta Operating Systems (2021-2017)*. The Task Force Impact provides strategy and tools to promote the establishment of a European industrial Open ecosystem for continuum computing based on open-source and open standards.

With this in mind, the aim of the meeting was to initiate a collaboration between several different projects involved in the Edge to Cloud continuum Open Source and Meta OS context.

Aiming to address the need to define a common open source stack for the meta operating systems defined in all the six projects involved. Indeed, by trying to define such a common stack, The Task Force increases the potential interoperability and portability of some of the developed components and, de facto, increases their sustainability.

The six project currently involved in the cluster, and attending the workshop, were:

- aerOS[9] – Autonomous, scalablE, tRustworthy, intelligent European meta Operating System for the IoT edge-cloud continuum
- FLUIDOS[10] – Flexible, scaLable and secUre decentralIzeD Operation
- ICOS[11]– Towards a functional continuum operating system

[9] https://aeros-project.eu/
[10] https://www.fluidos.eu/
[11] https://www.icos-project.eu/

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- NebulOus[12] – A meta operating system for brokering hyper-distributed applications on Cloud computing continuums
- NEMO[13] – Next Generation Meta Operating System
- NEPHELE[14] – A lightweight software stack and synergetic meta-orchestration framework for the next generation compute continuum

Figure 3 -Workshop in Toulouse

The meeting was designed to bring together and begin work together. Each project brought on the table their architectures and technical expertise with the Technical Managers of the cluster.

During the day, the six architectures have been presented and discussed. In order to learn from each other the architecture of their project and the planned open source components, the work proceeded with an intensive and interesting discussion on these different stacks. The six architectures have been mapped in a generic common subset sharing among the projects: IoT, Edge and Cloud.

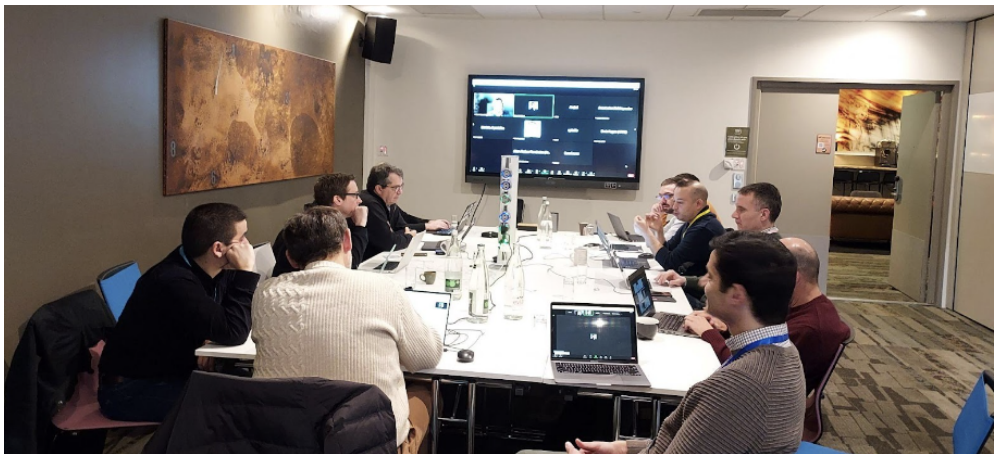

Figure 4 - Workshop in Toulouse

[12] https://www.nebulouscloud.eu/
[13] https://meta-os.eu/
[14] https://nephele-project.eu/

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The meeting was very fruitful and brought the six projects to look closely at the components and structures being used or in the making. The meeting was very important for sharing knowledge and best practices, as well as giving those who do not yet have a definition for some pieces, new ideas to work on. For our part, we put a knowledge base to start on the MetaOS.

This was the first step and involved only the projects concerning META-OS. Results are reported in the next section, although in the next paragraph the second physical meeting is briefly presented.

The work produced during this workshop has been used as a reference and starting point for the other task forces.

2.2.1.3 Concertation and Consultation Meeting on Computing Continuum, Brussels, Belgium

The second physical meeting tookplace in Brussels and involved all the RIAs projects selected for this CSA. The following figure shows the dissemination card of the event.

Figure 5 - Brussels meeting "Concertation and Consultation"

The Concertation and Consultation on Computing Continuum: From Cloud to Edge to IoT meeting was a 2-day physical event organised within the context of the European, Cloud, Edge and IoT Continuum initiative by the OpenContinuum consortium in close collaboration with the Unlock-CEI and SW Forum projects and guided by the European Commission DG CNECT E.2 and E.4 Units, in Brussels.

The event brought together all the stakeholders in order to establish liaisons and contacts within the European Cloud, Edge and IoT community to identify common interests and foster synergies and collaborations.

Furthermore, TF2 was presented and discussed with the audience in this context. The audience was very interested, and after the presentation, there was face-to-face discussion during the breaks.

After these two days meeting, the TF2 work continued with a new webinar that involves Linux Foundation.

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2.2.1.4 LF Webinar: Open Unification of Edge Compute

Following the idea of sharing useful information and vision about open source, TF2 prepared a webinar on edge computing presented by the Linux Foundation.

The webinar highlighted the most interesting projects in the Linux Foundation portfolio. The aim is to learn how open source organisations (such at the Linux Foundation's LF Edge) are collaborating to drive integration across industries, broader open source organisations, and standards & specifications bodies to unify edge computing across markets including Enterprise Edge, IoT edge, Telecom Edge and Cloud Edge.

The discussion and the questions raised outlined the problem of the continuum, the connection between the different actors inside the continuum, the challenges now faced by the RIAs: filling the gap between edge and cloud and the best solutions available for combining IoT and Edge. The following figure shows the dissemination card of the event.

Figure 6 - Linux Foundation webinar on Edge Computing

The speaker was Arpit Joshipura[15], General Manager of Networking, IoT & Edge at the Linux Foundation.

[15] Arpit is an executive leader and open source software evangelist across carriers, cloud and enterprise IT – spanning networking, orchestrations, operating systems, security, AI, edge, hardware and silicon. He was recently voted among the Top 5 Movers and Shakers in the Telecom Industry. At the Linux Foundation, Arpit leads open source networking, orchestration & edge/IOT, including LF Networking projects (ONAP, OPNFV, ODL, FDIO, OvS, DPDK, OpenSwitch, Akraino/Edge/IoT, etc.) as well as major industry disruptions including VNFs to CNFs (Cloud Native Network functions), 5G, AI, etc.
Arpit brings 30 years of networking expertise and vision to The Linux Foundation, with both technical depth and business breadth. He has orchestrated and led major industry disruptions across enterprises, carriers, and cloud architectures, including IP, broadband, optical, mobile, routing, switching, L4-7, cloud, disaggregation, SDN/NFV, and open networking, and has been an early evangelist for open source. Arpit has served in CMO, VP, and Engineering roles within both startups and larger enterprises.

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2.2.1.5 "The hitchhiker's guide to Eclipse IoT"

After the first webinars and physical events described above, in the time of this deliverable, another webinar has been planned: "The hitchhiker's guide to Eclipse IoT".

Figure 7 - Webinar on IoT and Eclipse

This webinar will provide an overview of the Eclipse IoT Toolkit, the industry's most relevant and extensive collection of IoT and edge computing open source building blocks. Some of the most popular projects will be introduced: from protocol to cloud IoT platforms, Eclipse IoT can have something for everyone. Furthermore, during this webinar RISC-V open-source processor cores from OpenHW Group will be discussed.

The speaker will be again Frédéric Desbiens[16], IoT and Edge Computing program manager at the Eclipse Foundation.

2.2.1.6 Planning

However, after all the events, after talking to most of the 46 projects, it was immediately clear that a change in approach was needed. As it had already been established, webinars will be complemented by information collection activities, but these activities will be divided and managed on different channels and through two modes: in the form of surveys and with dedicated online workshops.

The surveys will be calibrated and formulated in accordance with the maturity of the project to which they are submitted, and thus to the relevant subcluster. Dedicated surveys will then be created.

As for online workshops, again, the approach will be based on the technical maturity of the project. Dedicated workshops will be organized with all subclusters similar and mature in the same way, and this will be done until the youngest projects are covered. In this way, our goal is to try to create awareness about the other realities outside the projects and the specific cluster.

[16] Frédéric helps the community innovate by bringing devices and software together. He is a strong supporter of open source. In the past, he worked as a product manager, solutions architect, and developer for companies as diverse as Pivotal, Cisco, and Oracle. Frédéric holds an MBA in electronic commerce, a BASc in Computer Science, and a BEd, all from Université Laval (Québec City, Canada). Frédéric is the author of "Building Enterprise IoT Solutions using Eclipse IoT Technologies: An Open-Source Approach to Edge Computing," published in 2022 by Apress (ISBN: 978-1484288818).

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We will then try to get all 46 RIA projects to agree on the same architecture, by helping to define a white paper on the subject: "From Cloud to Edge continuum open source stack".

2.2.2 Results

During the workshop in Toulouse, information related to the open source component in the MetaOS projects has been collected and analyzed.

The discussion with the projects started with the base reference architecture shown in Figure 8 - Initial Reference Architecture. This architecture has been voluntarily left empty and with very high-level feature suggestions.

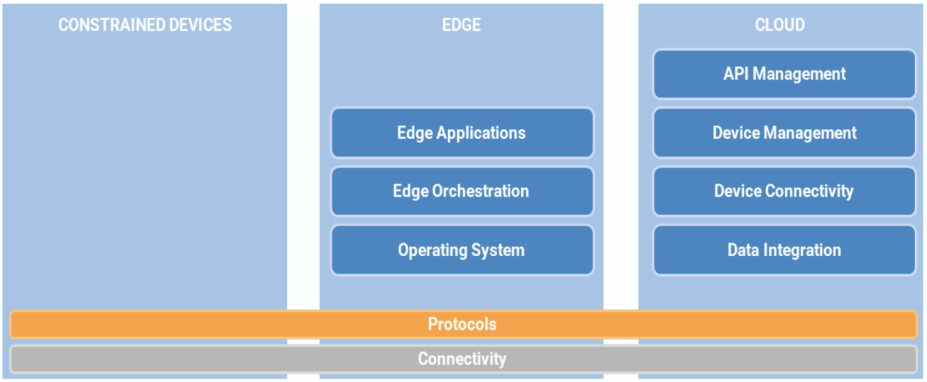

Figure 8 - Initial Reference Architecture

During the discussion the architecture was filled by using Miro[17] tool; a collaborative tool with a visualization board already prepared for the projects shown in Figure 10. Each project has his own color and the possibility to fill and 'stick' components.

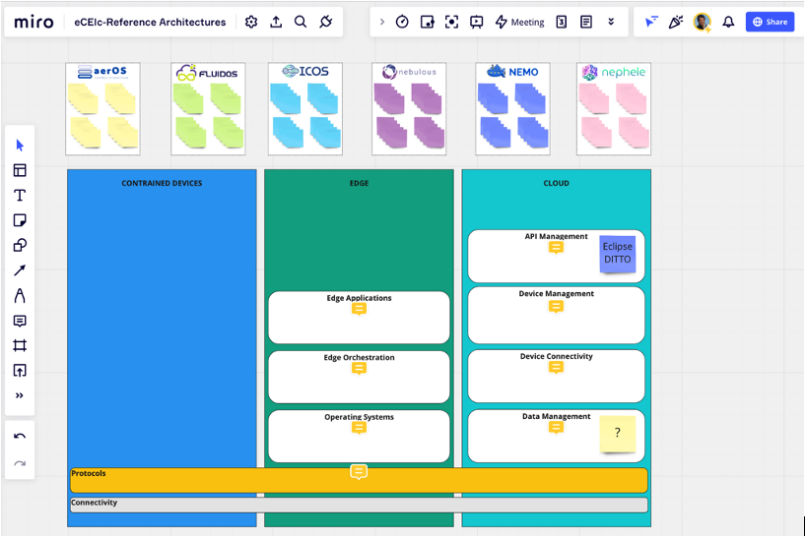

Figure 9 - MIRO board for the MetaOS projects

The following diagrams show the revived version of the diagram after the projects have mention some missing points.

[17] https://miro.com/

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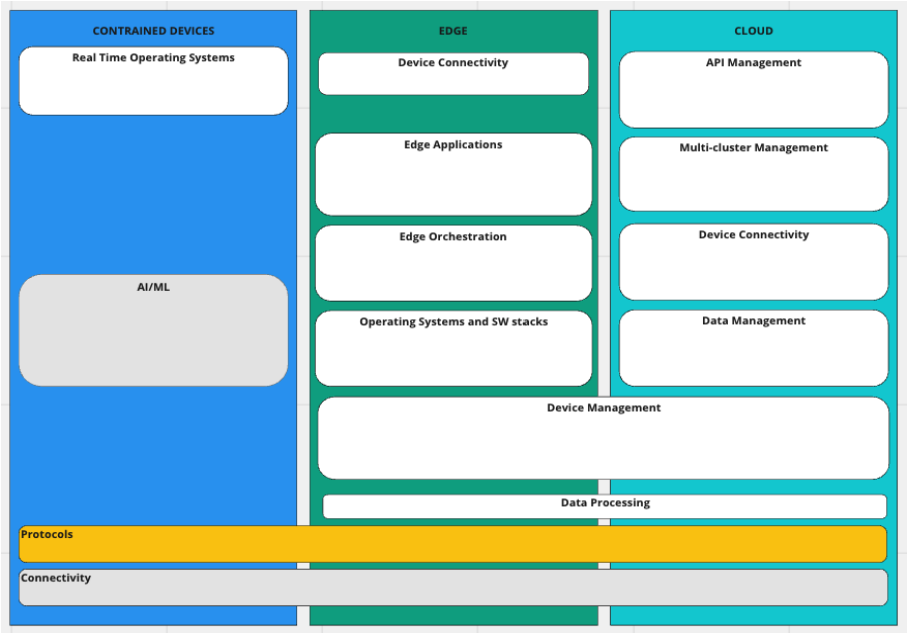

FIGURE 10 - REVISED REFERENCE ARCHITECTURES

The next picture presents a screenshot of the Miro board completed by the projects after the workshop.

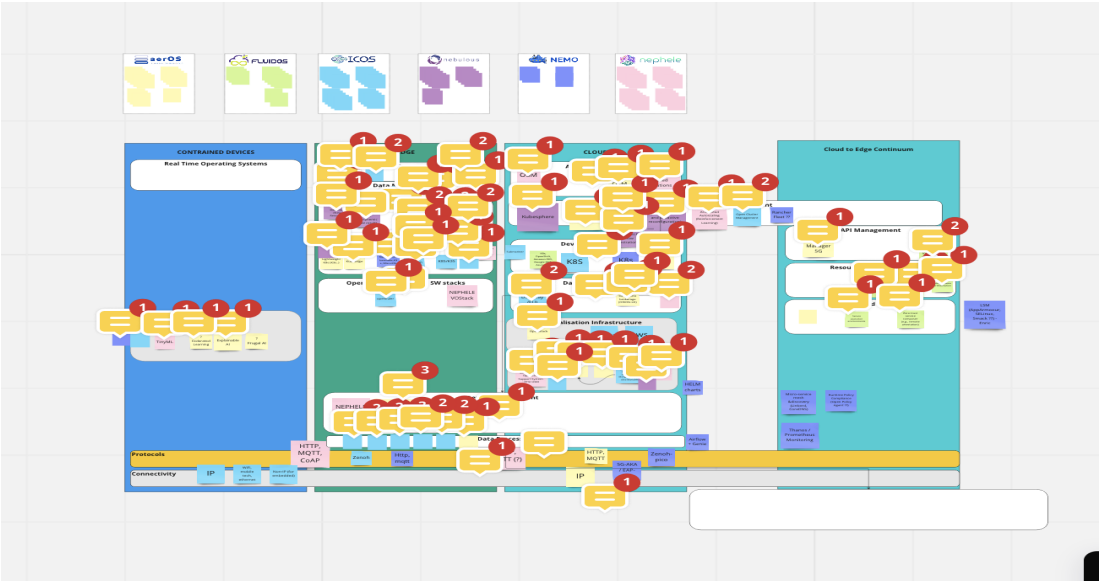

FIGURE 11 - MIRO BOARD AFTER THE WORKSHOP

From this initial vision, an updated reference architecture has been created and discussed (Figure 12). As we can see, the main discussion was focused on the 'continuum' and on the way to express it. In this matter, a new column was added in order to fulfill all the projects' needs.

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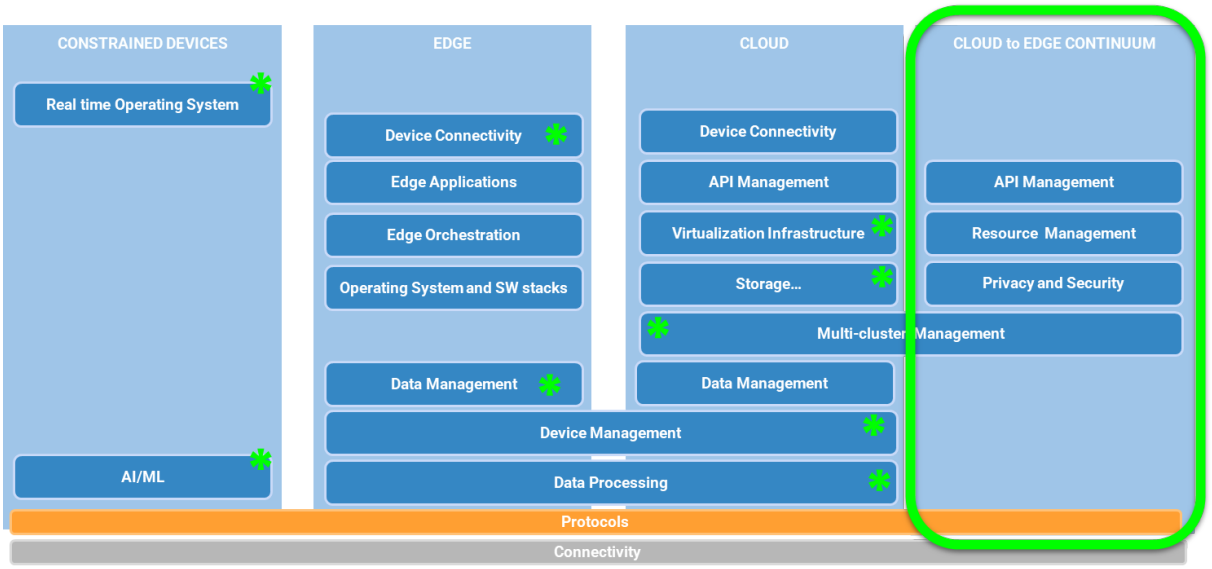

Figure 12 - Reference Architecture update after the discussion

The comments along with the components' blocks have been extracted and elaborated. From the elaboration, 126 components havebeen identified in the four main blocks presented in the reference architecture discussed before. This elaboration cleaned up all the components not explicitly open source and finalised the classification into the features labels. At the end, only open source technologies, also in the research domain along with open protocols and standards; as a result, 100 open source components have been clearly identified.

The following diagram depicts the distribution of these components among six main vertical domains that have been identified:

- 0-CROSS Architectures
- 1-Constrained Devices
- 2-Edge
- 2.5-Cloud/Edge
- 3-Cloud
- 4-Cloud to Edge Continuum

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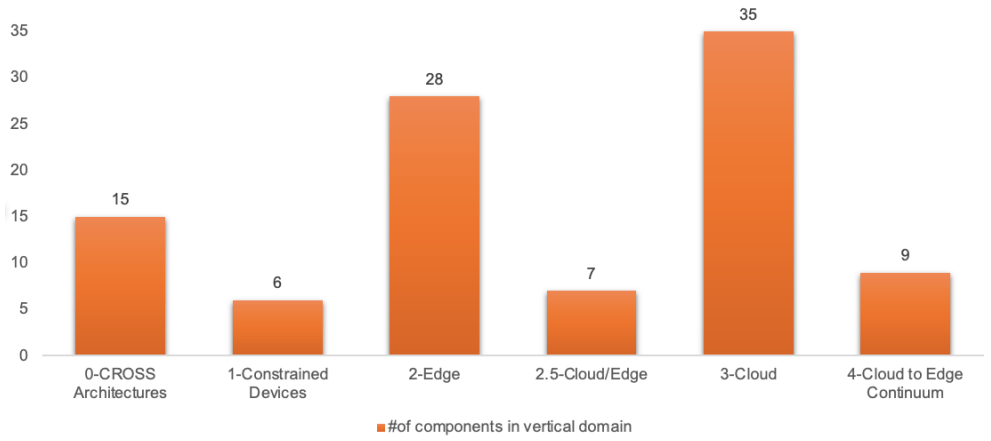

FIGURE 13 - METAOS CONTINUUM COMPONENTS DISTRIBUTION BEFORE ELABORATION

As the figure highlights, the MetaOS projects are considering mainly components in the "Edge" and "Cloud" vertical domains. This is an expected result given that we work with the cluster of projects dedicated to the cloud to edge continuum. Following this direction, the data has been further classified into "features".

In fact, these 100 components have been labelled and classified within 17 features according to their technology definition. These features are presented in the following diagram; a list of them is also reported here:

- AI/ML
- API Management
- Connectivity
- Data Broker
- Data Management
- Data Processing
- Device Connectivity
- Edge Applications
- Edge Orchestration
- Multi-cluster Management
- OS and SW stacks
- Privacy and Security
- Protocols
- Resource Management
- Storage and/or network and service fabric
- Virtualization infrastructure
- Workflow Management - Data Processing

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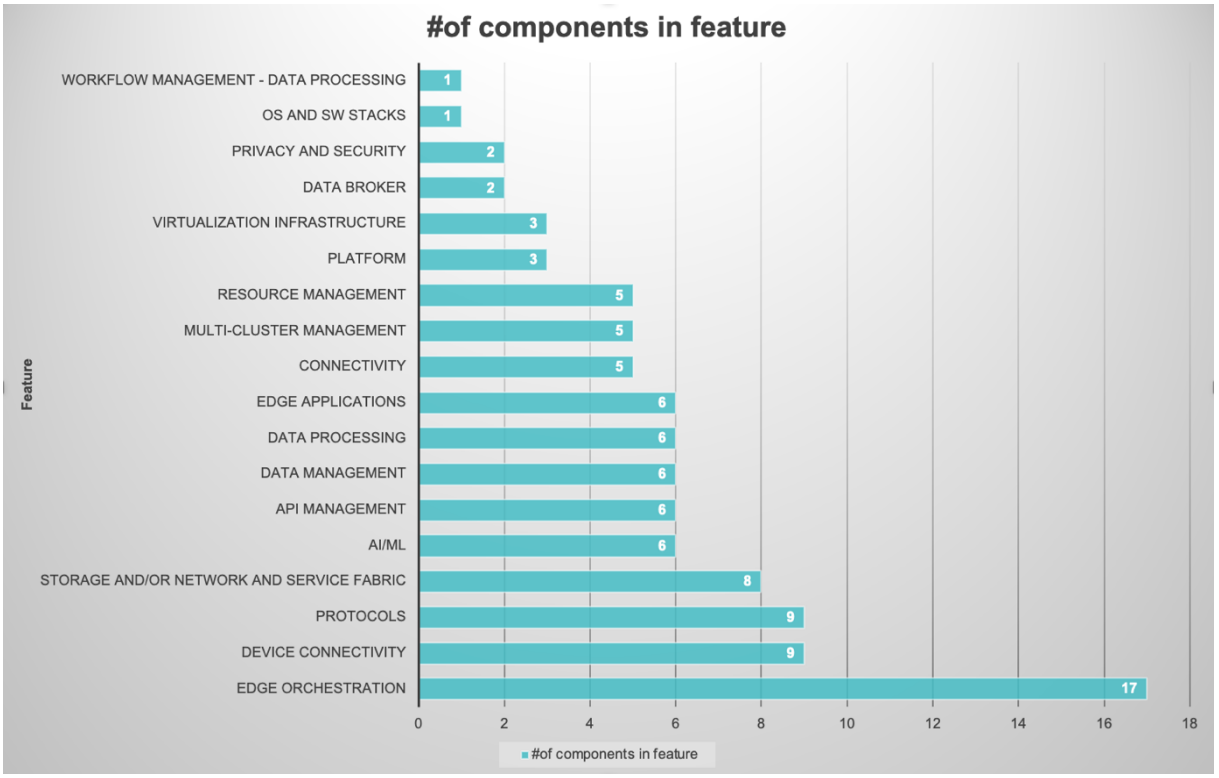

FIGURE 14 - RAW ANALYSIS OF THE COMPONENTS AND FEATURES DISTRIBUTION

This figure shows the number of components exposed in each feature. the dominance of edge orchestration containing 17 components is immediately visible. Once again, this result is reasonable since the data were produced by projects primarily working on the cloud-to-edge continuum prospective, so we can expect that orchestration is a key point for these projects.

One focus on this elaboration is to understand if the projects have common components and show that it is important to work together for avoiding duplicated work, reuse available resources and build a common open source stack.

As a result, the following diagram compares the number of components for each vertical domain, and the number of projects that have a component in that vertical domain, the turquoise bars.

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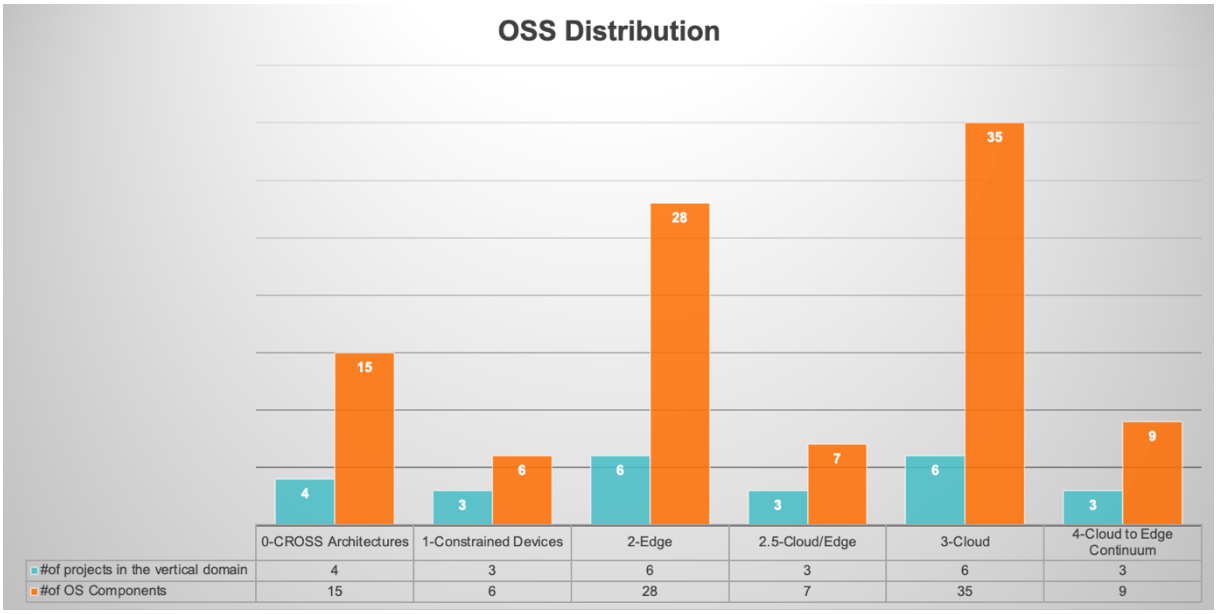

FIGURE 15 - OSS DISTRIBUTION AMONG PROJECTS

As is important to note, half of the projects or more use components from the same vertical domain. This is expected, since we start from a basic 'standard' reference architecture.

This is useful, but not as important as noting that for each vertical domain there are many open source components that are used. This tells us that although there may be a clear underlying architecture, there is no clear open source stack. Recall here that, during the workshop, projects were asked to map and list all their architectural components with a large degree of freedom: in fact, a domain was even added during the discussion (cloud-to-edge), shown above.

Furthermore, a visualisation in next diagram shows that some of these open source components are commonly used among the projects. For the sake of readability all the rest of components that resulted in only one project have been cut out from the graph for highlighting the result.

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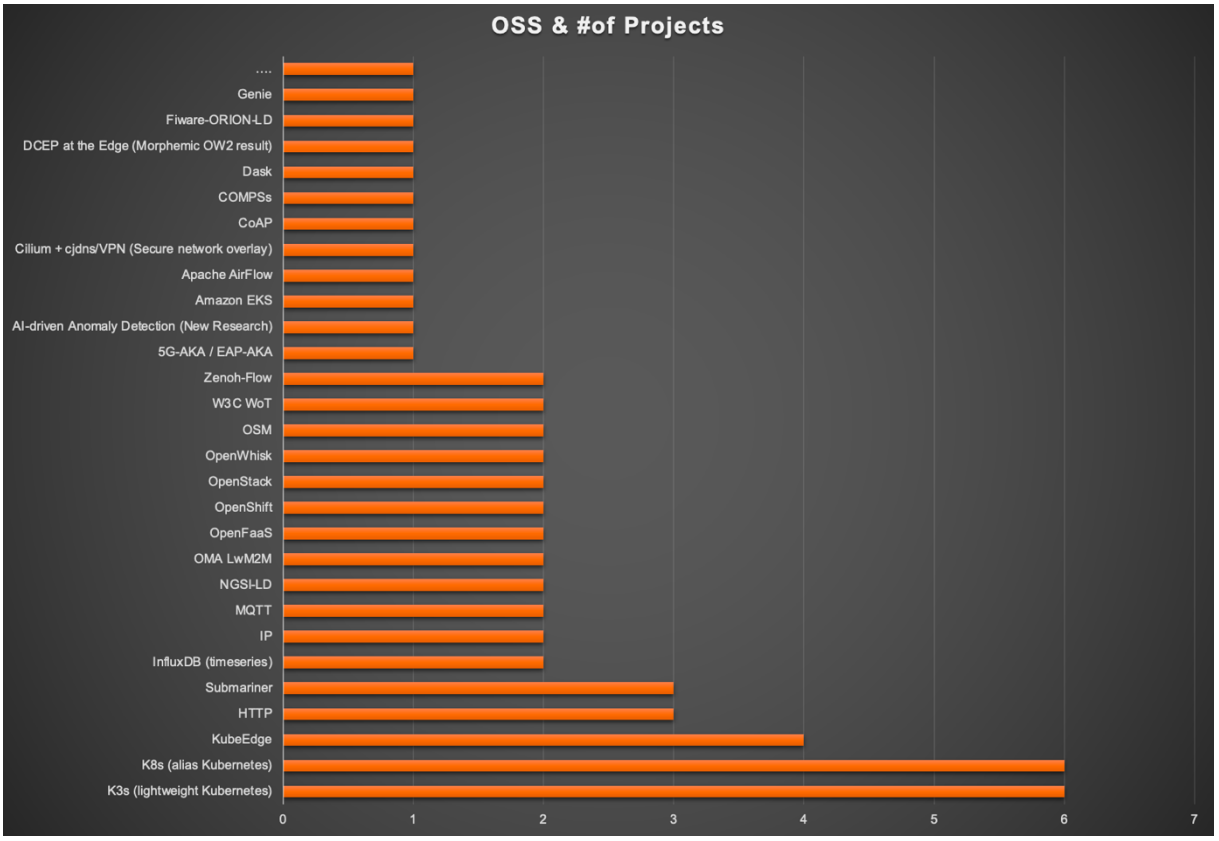

FIGURE 16 - OSS AND THEIR USAGE

In fact, the picture contains an orange bar and on the X-axis is shown the number of projects (6) and on the Y-axis the name of the OSS components.

This further corroborates the importance and necessity of having an open source stack that can be used as the basis for all future development. With the “breaking the silos” idea in mind it is possible so see also in these results how it is so important to create a community in which projects can communicate and collaborate on common aspects.

This data will be enriched and reworked with the data that will be collected on the other projects, and finally, this work will guide TF2 to create a landscape of OSS and identify and fill the gap that the projects have in OSS Stack. This work will be the basis for the collaboration between TF2 and the other Task Forces.

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3 STANDARDISATION TOWARDS A COMPUTING CONTINUUM ECOSYSTEM

The development of the computing continuum ecosystem will require standardisation support. We have identified several approaches:

- architecture level: fostering the development of building blocks that serve mainstream computing continuum architectures,
- trustworthiness level: fostering the development of building blocks that serve mainstream trustworthiness approaches,
- interoperability level: fostering the development of applications and building blocks that serve mainstream APIs and interoperability points, and
- open-source level: fostering the development of open source communities on the continuum.

We provide a landscape of existing standardisation activities and provide possible routes for projects to take.

3.1 Architecture Level

3.1.1 Approach

The promotion of computing continuum building blocks can be facilitated through contributions to architecture related standards. Table 1 describes standards that can be used to describe reference architectures.

Table 1 - Standartds to describe reference architectures

Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support from EUCloudEdgeIoT
Best practices and guidelines for Reference Architectures (RA) [12]	Provides guidance to facilitate the integration of Reference Architectures (RA) used in standards created by different organizations, by providing conventions and rules on RA standards. The intent is to promote a degree of commonality among JTC 1 RAs to address problems that dissimilar RAs create for standards and their constituents. This document provides a unified approach for using ISO/IEC/IEEE 42010 [13].	Provide a document structure which can be applied to continuum architecture building blocks. The document is not yet published externally[18]. Annex 1 provides a summary.	Use this guidance. Support can be provided by Trialog who is the editor of this document.

[18] Available in the ISO/IEC JTC 1/SC41 repository as SC41 N2306

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Architecture description ISO/IEC/IEEE 42010 [13]	This document specifies requirements for the structure and expression of an architecture description (AD) for various entities, including software, systems, enterprises, systems of systems, families of systems, products (goods or services), product lines, service lines, technologies and business domains.	Provide description concepts which can be applied to continuum architecture building blocks.	Use this reference

Figure 17 shows how implementations can conform to a reference architecture supporting the computing continuum:

- the ISO/IEC/IEEE 42010 standard and the best practices and guidelines for reference architecture help create a computing continuum reference architecture;
- the computing continuum reference architecture can be composed with other reference architectures (e.g., IoT reference architecture [16], or Cloud computing reference architecture [22]); and
- implementation architectures (or solution architectures) specialise the reference architecture (e.g., with solution building blocks provided by projects), which themselves are used in implementations.

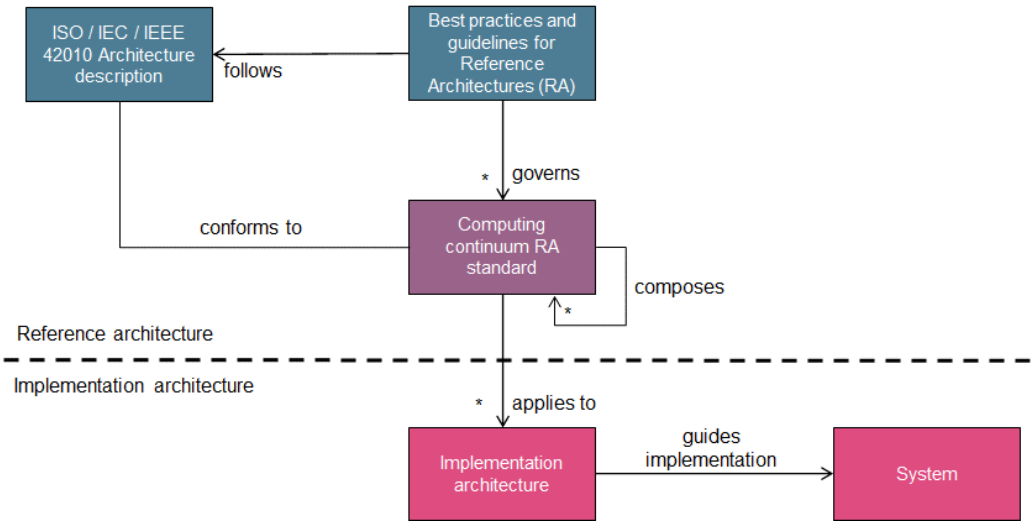

Figure 17 -Constructing a Computing continuum reference architecture and using it in implementations

3.1.2 Existing Standards

Table 2 lists standards of interest that can be composed with a computing continuum reference architecture:

- IoT reference architecture (first edition freely available, second edition underway),
- Digital twin reference architecture (second edition underway),
- Edge computing technical report,
- Cloud computing reference architecture (first edition freely available, second edition underway)
- Cloud computing vocabulary (second edition freely available),
- Cloud computing data spaces (underway),
- Integration of IoT and digital twins in data spaces (underway), and

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- Big data reference architecture.

Standards which are underway should also be monitored as they provide opportunities for contribution by the projects supported by EUCloudEdgeIoT.

TABLE 2 -STANDARDS THAT CAN BE COMPOSED WITH A COMPUTING CONTINUUM REFERENCE ARCHITECTURE

Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support from EUCloudEdgeIoT
ISO/IEC 30141 IoT Reference Architecture Edition 2 (underway [16]) Note that Edition 1 is freely available[19]	This document specifies an Internet of Things (IoT) reference architecture (IoT RA). The IoT RA is a generalisation of existing practice including the distinguishing characteristics of IoT systems and other fundamental characteristics exhibited by IoT systems. The IoT RA addresses stakeholder concerns related to the business value of IoT systems. The IoT RA also addresses the interactions between the IoT system, the users, and the physical environment. Implementation of IoT systems is also addressed in this IoT RA. Among the characteristics specified in the IoT RA are abstract functions within IoT systems and a variety of structures that are used to construct IoT systems. Note that this standard follows the standards of Table 1.	The description of a computing continuum reference architecture should allow for a composition with ISO/IEC 30141 Edition 2 to create an architecture profile integrating the continuum. Edition 2, is under development, it is consistent with the Best practices and guidelines for Reference Architectures and ISO/IEC/IEE 42010.	Use this reference. Support can be provided by Trialog who is participating to the edition of this standard
ISO/IEC 30188 Digital Twin Reference Architecture [18]	This document specifies a general Digital Twin Reference Architecture in terms of defining system characteristics, a Reference Model and architecture views for Digital Twins. Note that this standard follows the standards of Table 1.	The description of a computing continuum reference architecture should allow for a composition with ISO/IEC 30188 to create an architecture profile integrating the continuum.	Contribution to this standard is possible. Support can be provided by Trialog who is co-editor of this standard
ISO/IEC TR 30184:2020 Edge Computing [21]	This document describes the common concepts, terminologies, characteristics, use cases and technologies (including data management, coordination, processing, network functionality, heterogeneous computing, security, hardware/software optimization) of edge computing for IoT systems applications. This document is also meant to assist in the identification of potential areas for standardisation in edge computing for IoT.	The description of a computing continuum reference architecture should take into account this standard	Use this reference.
ISO/IEC 17789:2014 Cloud computing - Reference architecture	This Recommendation | International Standard specifies the cloud computing reference architecture (CCRA). The reference architecture includes the cloud computing roles, cloud computing activities, and the cloud computing functional	The description of a computing continuum reference architecture should allow for a composition with	Use this reference This standard is not based on [12] Note that a second edition is underway

[19] https://www.iso.org/standard/65695.html

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support from EUCloudEdgeIoT
[22]	components and their relationships.	ISO/IEC 17789 to create an architecture profile integrating the continuum	(ISO/IEC 22123-3)
ISO/IEC 22123-1:2023, Cloud computing - Part 1: Vocabulary [23]	This document defines terms used in the field of cloud computing.	The terminology of a computing continuum reference architecture should use this document	Use this reference
ISO/IEC PWI 20151, Cloud computing – Data spaces[20]	Investigate the following: Identification and review of existing projects and standards that relate to or support Dataspaces, including data sharing frameworks and applicable cloud deployment models Justification and market need for standards for Dataspaces vocabulary, concepts, and characteristics,	The description of a computing continuum reference architecture should allow for a composition with data space reference architecture	Contribution to these standards is possible. Support can be provided on "Guidance on IoT and digital twin integration in data spaces" by Trialog who is editor of this standard
ISO/IEC PWI Guidance on IoT and digital twin integration in data spaces[21]	This document provides guidance on the integration of IoT systems and digital twins in data spaces. It includes a section on data space principles, a section on lifecycle in data spaces, a section on the integration of IoT systems in data space ecosystems and a section on the integration of digital twins in data space ecosystems.		
ISO/IEC 20547-3:2020, Big data reference architecture — Part 3: Reference architecture [24]	This document specifies the big data reference architecture (BDRA). The reference architecture includes concepts and architectural views. The reference architecture specified in this document defines two architectural viewpoints: — a user view defining roles/sub-roles, their relationships, and types of activities within a big data ecosystem; — a functional view defining the architectural layers and the classes of functional components within those layers that implement the activities of the roles/sub-roles within the user view. The BDRA is intended to: — provide a common language for the various stakeholders;	The description of a computing continuum reference architecture should allow for a composition with big data reference architecture	Use this reference This standard is not based on [12]

[20] Presented in a SC38 roadmap report (SC38 N2540)
[21] First SC41 report published in June 2023 (SC41 N2335)

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support from EUCloudEdgeIoT
	— encourage adherence to common standards, specifications, and patterns; — provide consistency of implementation of technology to solve similar problem sets; — facilitate the understanding of the operational intricacies in big data; — illustrate and understand the various big data components, processes, and systems, in the context of an overall big data conceptual model; — provide a technical reference for government departments, agencies and other consumers to understand, discuss, categorize and compare big data solutions; and — facilitate the analysis of candidate standards for interoperability, portability, reusability, and extendibility.		

3.1.3 Opportunities

Several opportunities for contributions by projects are possible:

- Contribute to a technology domain reference architecture, e.g., a computing continuum reference architecture,
- Contribute computing continuum patterns to an existing reference architecture standard, e.g., the digital twin reference architecture,
- Contribute to the definition of architecture profiles supporting the integration of computing continuum.

3.2 Trustworthiness Level

3.2.1 Approach

Trustworthiness is defined as the ability to meet stakeholders' expectations in a verifiable way[22]. The promotion of computing continuum building blocks on trustworthiness can be facilitated through contributions to trustworthiness related standards. Trustworthiness includes characteristics such as security, privacy, safety, resilience, reliability, transparency, explainability, controllability, ethics and so forth. Associated requirements, often called non-functional requirements, have both an impact on architecture (e.g., a security capability), and on process (e.g., process to provide assurance on safety). Contributions can be either on architecture building blocks or on process building blocks, addressing challenges that have to be solved on trustworthiness such as:

- supporting a given characteristic,

[22] I SO/IEC TS 5723:2022 Trustworthiness — Vocabulary (https://www.iso.org/standard/81608.html=

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- expressing the relationships between key characteristics.

3.2.2 Existing Standards

Table 3 describes standards related to trustworthiness.

TABLE 3 -STANDARDS FOR TRUSTWORTHINESS

Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support from EUCloudEdgeIoT
ISO/IEC TS 5723 Trustworthiness – Vocabulary [25]	This document provides a definition of trustworthiness for systems and their associated services, along with a selected set of their characteristics.	All concepts apply to the computing continuum	Use as a reference
ISO/IEC PWI 9814 Trustworthiness - Overview and concepts	Provides an overview of trustworthiness and related concepts as it applies to an entity (where an entity can be an organisation, a system, software, a process, a person, or a service). Describes trustworthiness concepts. Provide guidance to assist organisations with common harmonised and standardized approach: (1) integrating trustworthiness into the entity life cycle process, (2) determining, generating, and collecting evidence for assurance.	The description of a computing continuum trustworthiness could be based on these future standards.	Contribution to these standards is possible
ISO/IEC PWI 18149 Trustworthiness ontology	Specification of a trustworthiness ontology taking into account. Will consider the use of ISO/IEC 21838 serie on top-level ontologies [26][27].		
ISO/IEC 30149 IoT trustworthiness principles [28]	This document provides elements of IoT trustworthiness based on ISO/IEC 30141 – IoT Reference Architecture		Use this reference
ISO/IEC TR 24028:2020 Overview of trustworthiness in AI	This document surveys topics related to trustworthiness in AI systems, including the following: — approaches to establish trust in AI systems through transparency, explainability, controllability, etc.; — engineering pitfalls and typical associated threats and risks to AI systems, along with possible mitigation techniques and methods; and — approaches to assess and achieve availability, resiliency, reliability, accuracy, safety, security and privacy of AI systems. The specification of levels of trustworthiness for AI systems is out of the scope of this document.	The description of a computing continuum trustworthiness involving AI should take into account this standard.	Use this reference
ISO/IEC 27090,	This document provides guidance for	The description of a	Contribution to these

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support from EUCloudEdgeIoT
Guidance for addressing security threats and failures in artificial intelligence systems [31]	organisations to address security threats and failures in artificial intelligence (AI) systems. The guidance in this document aims to provide information to organisations to help them better understand the consequences of security threats to AI systems, throughout their lifecycle, and descriptions of how to detect and mitigate such threats. This document is applicable to all types and sizes of organizations, including public and private companies, government entities, and not-for-profit organizations, that develop or use AI systems.	computing continuum trustworthiness involving AI should take into account this standard.	standards is possible
ISO/IEC WD 27091 Artificial Intelligence — Privacy protection [33]	This document provides guidance for organisations to address privacy risks in artificial intelligence (AI) systems and machine learning (ML) models. The guidance in this document helps organisations identify privacy risks throughout the AI system lifecycle, and establishes mechanisms to evaluate the consequences of and treat such risks. This document is applicable to all types and sizes of organisations, including public and private companies, government entities, and not-for-profit organisations that develop or use AI systems.		
ISO/IEC PWI 11034. Cloud computing – Trustworthiness of cloud services	The purpose of this document is to provide an overview, framework, and concepts for trustworthiness in cloud computing environment to provide the context for describing trustworthy cloud computing in terms of its characteristics, frameworks, and concepts, and to clarify the trustworthiness expectation in relation to the use, provision, management and support of cloud services.	The description of a computing continuum trustworthiness could be based on these future standards.	Contribution to these standards is possible
ISO/IEC NP 27115, Cybersecurity evaluation of complex systems – Introduction and framework overview	This document provides the foundations and concepts for the cybersecurity evaluation of complex systems. Two frameworks are defined: The first is used to specify the cybersecurity of a complex system, including system of systems. The second is used to evaluate the corresponding cybersecurity solutions. The frameworks use basic architecture concepts: to enable description of reference or	The description of a computing continuum trustworthiness could be based on this future standard.	Contribution to this standard is possible

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support from EUCloudEdgeIoT
	solution cybersecurity architectures; to support model-based, comprehensive and scalable security solutions and their evaluation; and. to allow for the definition of architecture-based cybersecurity profiles (ACP) and hierarchies of profiles.		
ISO 31700-1:2023, Consumer protection — Privacy by design for consumer goods and services — Part 1: High-level requirements [34]	This document establishes high-level requirements for privacy by design to protect privacy throughout the lifecycle of a consumer product, including data processed by the consumer. This document does not contain specific requirements for the privacy assurances and commitments that organizations can offer consumers nor does it specify particular methodologies that an organization can adopt to design and implement privacy controls, nor the technology that can be used to operate such controls.	This standard will be needed if the computing continuum is used in a consumer product.	Use this reference
ISO/IEC PWI 27568 Security and privacy of digital twins[23]	This report provides a landscape on standards that can have an impact on the security and privacy of digital twins, investigates stakeholders concerns on the security and privacy of digital twins, and discusses gaps and recommendations.	This standard will be needed if the computing continuum is used in a digital twin.	Contribution to this standard is possible

3.2.3 Opportunities

Several opportunities for contributions by projects are possible:

- Contribute computing continuum capabilities in trustworthiness related standards,
- Contribute computing continuum processes in in trustworthiness related standards,
- Contribute to the definition of trustworthiness profiles supporting the integration of computing continuum.

3.3 Interoperability Level

3.3.1 Approach

Interoperability is defined as the ability for two or more systems or applications to exchange information and to mutually use the information that has been exchanged [36][37][24]. Interoperability is critical in increasingly complex system infrastructure where multiple

[23] Underway in ISO/IEC JTC1/SC27.
[24] Definition proposed by the cloud computing community (SC38) and reused by the IoT community (SC41)

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stakeholders are involved in operating subsystems. Interoperability capabilities complete architecture building blocks and trustworthiness capabilities. They are essential

- As the representation of business agreements between operators of co-operating systems, and
- as the approach through which conformity testing can be supported.

The promotion of computing continuum building blocks for interoperability can be facilitated through contributions to interoperability related standards. They can address interoperability engineering processes for systems involving the computing continuum such as:

- ontology and model engineering,
- interoperability profiles engineering,
- verification and validation engineering.

3.3.2 Existing standards

Table 4 describes standards related to interoperability.

TABLE 4 -STANDARDS FOR INTEROPERABILITY

Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support from EUCloudEdgeIoT
ISO/IEC 21823 Interoperability for IoT systems — Part 1: Framework [36]	ISO/IEC 21823-1 provides an overview of interoperability as it applies to IoT systems and a framework for interoperability for IoT systems. This document enables IoT systems to be built in such a way that the entities of the IoT system are able to exchange information and mutually use the information in an efficient way. This document enables peer-to-peer interoperability between separate IoT systems. This document provides a common understanding of interoperability as it applies to IoT systems and the various entities within them.	Framework can be used for interoperability involving the computing continuum. It includes 5 interoperability facets: transport, syntactic, semantic, policy and behavioural interoperability	An extension of this framework is planned to integrate more operational aspects on behavioural interoperability. Contributions focusing on the computing continuum support is possible
ISO/IEC 21823-3 Interoperability for IoT systems — Part 3: Semantic interoperability [38]	This document provides the basic concepts for IoT systems semantic interoperability, as described in the facet model of ISO/IEC 21823-1, including: – requirements of the core ontologies for semantic interoperability; – best practices and guidance on how to use ontologies and to develop domain-specific applications, including the need to allow for extensibility and connection to external ontologies; – cross-domain specification and formalization of ontologies to provide harmonized utilization of existing ontologies;	The description of a computing continuum interoperability could be based on this standard	Can be used as a reference

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support from EUCloudEdgeIoT
	– relevant IoT ontologies along with comparative study of the characteristics and approaches in terms of modularity, extensibility, reusability, scalability, interoperability with upper ontologies, and so on, and; – use cases and service scenarios that exhibit necessities and requirements of semantic interoperability.		
ISO/IEC PWI IoT Policy and behavioural interoperability[25]	Based on ISO/IEC 21823-1, this document provides the basic concepts for IoT systems and digital twin systems behavioural and policy interoperability. This includes - requirements, - guidance on how to identify points of interoperability - guidance on how to express behavioural and policy information on capabilities - guidance on how to achieve trustworthiness interoperability, and - use cases and examples	Interoperability requirements related to the computing continuum could be based on these future standards.	Projects on the computing continuum can provide use cases supporting the requirements of future standards
SAREF public portal [39]	Repository of SAREF ontologies based on the ETSI forge.	Can be used in systems where the computing continuum is used	Ontologies related to the continuum (e.g., on behavioural interoperability) could be provided
ETSI TS 103 673. SAREF Development Framework [40]	The present document defines the development framework for the SAREF ontology and its extensions. The development framework defines the different workflows to be followed for new SAREF project versions, SAREF project version development, and SAREF project release. The present document is based on the requirements and guidelines defined in the associated ETSI TR 103 608 [42].		

3.3.3 Opportunities

Several opportunities for contributions by projects are possible:

- Contribute computing continuum capabilities in interoperability related standards,
- Contribute to the definition of interoperability profiles supporting the integration of computing continuum.

25 ISO/IEC JTC1/SC41/WG4 report published in June 2023 (SC41 WG4 N208)

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3.4 Open source Level

3.4.1 Approach

Open-source is one of the main approaches to pool development and maintenance resources, to foster transparency, and to make an impact on a market. Many computing continuum projects supported by EUCloudEdgeIoT plan to go this route.

The promotion of computing continuum building blocks can be facilitated through the following contributions to open-source related standards:

- Open-source building blocks conforming to standards related to architecture, trustworthiness and interoperability (see previous sections),
- Open-source building blocks based on open-source development standards as well as system development standards that address open-source specific issues (e.g., provenance of contributions, cybersecurity, version management, building capabilities)

3.4.2 Existing standards

Table 4 describes standards related to open source.

Table 5 -Standards for Open Source

Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support from EUCloudEdgeIoT
ISO/IEC 5230 OpenChain Specification	This document specifies the key requirements of a quality open source license compliance program in order to provide a benchmark that builds trust between organizations exchanging software solutions comprised of open source software	Can be used in open-source development related to the computing continuum	Can be used by computing continuum projects
ISO/IEC 18974 OpenChain security assurance specification	This document specifies the key requirements of a quality Open Source Software Security Assurance Program that establishes trust between organizations exchanging software solutions comprised of Open Source Software.		
ISO/IEC TR 6114 Cybersecurity – Security considerations throughout the product life cycle	This document describes security considerations throughout the product life cycle (SCLC), which is a framework that spans the entire ICT product life cycle. The aim of the framework is to align the industry and bring greater transparency to customers at every point on the ICT product life cycle. This document describes following items for supplier, end users (consumer), intermediaries of the ICT supply chain, service provider, and regulators: - definition of phases in ICT product life cycle from concept to retirement,	Can be used in open-source development related to the computing continuum	Can be used by computing continuum projects

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support from EUCloudEdgeIoT
	- threat vectors possible in each phase of the life cycle, - potential controls against those threat vectors. This document provides an end to end view of threats by phase to help the organisation shape their plans, procedures and policies.		

3.4.3 Opportunities

Several opportunities for contributions by projects are possible:

- Contribute computing continuum open-source related to architecture, trustworthiness and interoperability profiles,
- Contribute to standards focusing on the general practice of open source

3.5 Strategic Approach

This section is taken from OpenContinuum deliverable D4.3 Towards a European Ecosystem for the Computing Continuum [30]. Figure 18 shows the intended approach to foster the creation of a computing continuum ecosystem:

- On the left-hand side, OpenContinuum will engage projects with two objectives:
  - Create a taxonomy of computing continuum reference building blocks, what will serve for the construction of a computing continuum architecture.
  - Help projects work together towards the availability of implementation enablers (in particular open source enablers).
- On the right-hand side, OpenContinuum will engage projects towards
  - The specification of reference architectures based on ISO/IEC JTC1 practice [12] and ISO/IEC/IEEE 42010 [13] so that contributions can be made at standardisation level.

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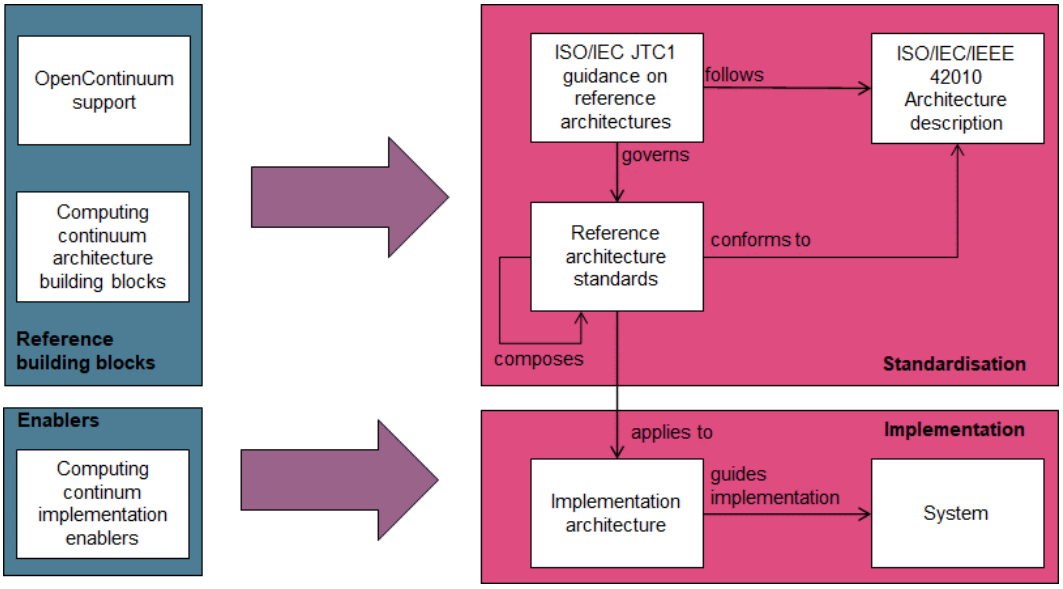

Figure 18 - OpenContinuum startegic approach for ecosystem impact

The proposed approach leverages the following references:

- An interoperability approach as envisioned by [14], [15].
- Alignment with the future IoT reference architecture standard, [16], and an approach based on patterns (as in [17])
- Alignment with the future Digital Twin reference architecture [18], and
- Support for domain specific standards such as RAMI for smart manufacturing [19] or SGAM for energy [20].

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4 ALLIANCES

Several European alliances, partnerships and initiatives are focused on the edge to cloud continuum, covering different parts of the value chain, adopting different technologies and with different objectives. The following figure illustrates the positioning of European alliances, partnerships, and initiatives in the edge-to-cloud continuum. Many relationships between these initiatives are already in place and synergies are often already established because they are sharing the same experts, they jointly participate in events, or they commonly define strategic agendas and their adoption, among other things. The coordination and alignment of these alliances, partnerships, and initiatives is important to reduce the overlapping and make them constructive/productive, optimise the use of resources and avoid fragmentation.

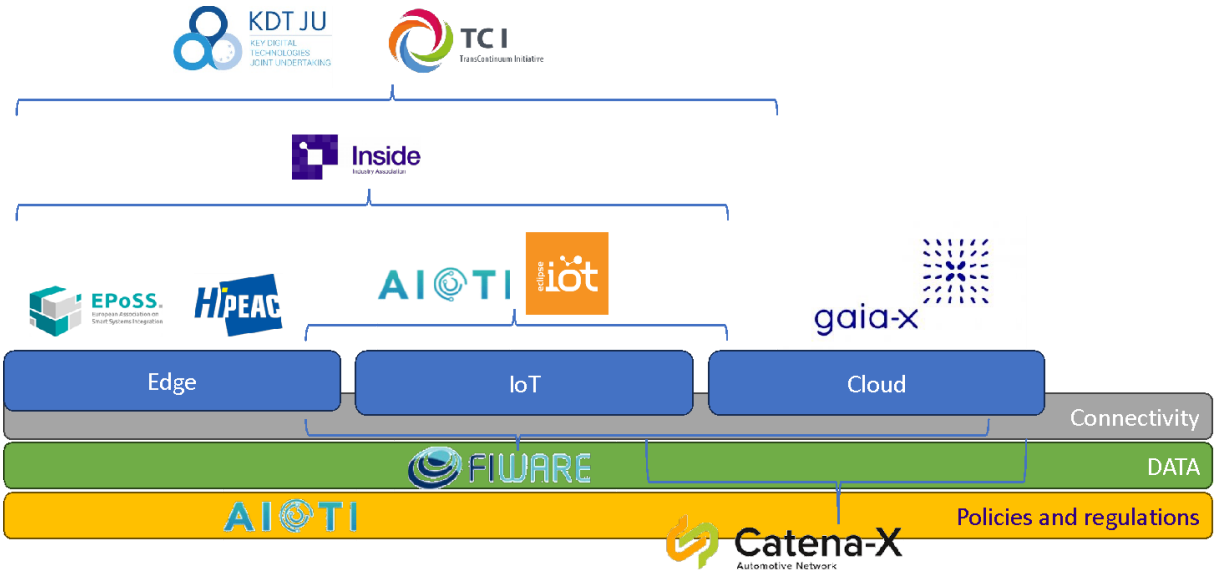

FIGURE 19 - RELEVANT EUROPEAN ALLIANCES, PARTNERSHIPS, AND INITIATIVES INVOLVED IN THE CLOUD TO EDGE CONTINUUM

HiPEAC[26] (High-Performance and Embedded Architecture and Compilation) is a European network that focuses on advancing the fields of high performance computing (HPC), embedded systems, and their related technologies. The network brings together researchers and industry experts to promote innovation, collaboration, and knowledge exchange. The network is focused mainly on scientific research and addresses the continuum technologies positioned on the edge, touching also IoT. Its primary objectives include advancing the state-of-the-art in architectures, design, and software support for efficient computing, with a specific focus on high-performance computing, parallel processing, embedded systems, etc.

HiPEAC is also largely focused on training and education, offering several opportunities to support the professional development of its members: it organises summer schools, tutorials, and workshops that provide in-depth knowledge on high-performance computing, embedded systems, and related topics. HiPEAC's training initiatives aim to bridge the gap between academia and industry, providing researchers and professionals with the skills and knowledge needed to address real-world challenges.

HiPEAC actively promotes technology transfer and industry engagement by facilitating collaborations between academia and industry: it tries to encourage researchers to explore

[26] https://www.hipeac.net

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practical applications of research results and supports their transfer into commercial products and solutions. HiPEAC organizes events and initiatives intended to connect researchers with industry partners.

HiPEAC facilitates networking among researchers and experts through conferences, workshops, summer schools, and other events to share ideas, present research findings, and discuss emerging trends. From a liaison perspective a coordination group has been setup including HiPEAC, EUCEI (OpenContinuum and Unlock CEI), SNSS, KDT and ETP4HPC. The objectives include coordination, alignment, joint event organisation and participation, roadmaps and strategic agendas alignment, etc. Considering the partners involved in this working group, it could serve as a liaison instrument for other initiative included in this chapter of D1.1. HiPEAC periodically publishes a vision document that should be aligned to the other European strategic agendas published in the edge-to-cloud continuum domain. An important HiPEAC asset is that it serves as a platform for a very wide network of researchers and industry professionals to collaborate on cutting-edge projects and initiatives, through conferences, workshops, summer schools, and other events to share ideas, present research findings, and discuss emerging trends.

4.1 **FIWARE**

FIWARE[27] is an open-source platform that provides a set of standardized APIs, software components, and frameworks for building and deploying smart applications and services in various domains, such as smart cities, agriculture, manufacturing, and transportation. The platform aims to enable the development of innovative smart solutions leveraging on standardisation and openness: the objective is to facilitate the creation of interoperable, scalable, and future-proof applications that leverage IoT, big data, and cloud technologies. FIWARE promotes the adoption of open standards, protocols, and APIs to ensure compatibility and ease of integration across different systems and devices. The FIWARE Foundation is an independent, non-profit organisation that oversees the governance, evolution, and promotion of the FIWARE platform. The foundation ensures the platform's long-term sustainability, facilitates collaboration among stakeholders, and manages certification programs to ensure compliance with FIWARE standards. It works closely with the community, industry partners, and standardisation bodies to drive the adoption and development of the FIWARE platform.

FIWARE platform is built on a modular and extensible architecture, allowing developers to choose and combine the components that best suit their requirements and the final application: components range from software modules and tools, including context management, data processing, access control, and visualization modules. Key components include the Orion Context Broker for real-time context data management, Cosmos for big data processing, Keyrock for identity and access management, and WireCloud for customisable dashboards and user interfaces.

As already mentioned, this initiative strongly leverages on the concept of standard APIs which, in FIWARE platform are known as NGSI (Next Generation Service Interfaces), for managing and accessing context information in a consistent and interoperable manner: these APIs enable applications to retrieve, update, and subscribe to real-time context data, allowing for seamless integration and data exchange between different systems and devices.

[27] https://www.fiware.org/

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They facilitate the development of context-aware applications that can react and adapt based on real-time information from IoT sensors, devices, and other data sources.

Open data and interoperability are important asset for FIWARE: interoperability allows applications and systems built on the platform to easily integrate with external components and technologies. For this motivation, the platform supports open standards and protocols, such as NGSI-LD (Linked Data) and MQTT, ensuring compatibility with a wide range of devices, sensors, and data sources.

FIWARE has a wide community composed of developers, start-ups, research institutions, and industry partners, contributing to the development and improvement of the platform by providing feedback, contributing with code development, and sharing best practices.

Regarding the liaison activities, we should focus on the open data and interoperability aspects on which FIWARE builds an important value and dedicate more resources, when compared with the other European initiatives. FIWARE organizes events, hackathons, and training programs to foster collaboration, innovation, and knowledge sharing within the community: they represent a good opportunity for liaison activities. FIWARE has already been involved in the EUCEI task forces to plan joint activities and ensure coordination and alignment.

4.2 Eclipse IoT Working Group

The Eclipse IoT Working Group `(IoT WG)[28] is a collaborative initiative within the Eclipse Foundation, which is a global community focused on open-source software development. The Eclipse IoT Working Group brings together individuals and organisations with an interest in advancing the adoption and interoperability of Internet of Things (IoT) technologies. The Eclipse Foundation has become a European organisation and gathers many European entities (developers, companies, academia) actively collaborating on projects related to edge computing, cloud platforms, and IoT standards.

The IoT WG intends to foster an open, collaborative ecosystem for IoT development and innovation, through the promotion of open-source software, definition of open standards, and providing a platform for collaboration and knowledge sharing among developers, vendors, and users of IoT technologies. The WG aims to address the challenges of IoT adoption, such as interoperability, security, and scalability, by developing and maintaining open-source projects and frameworks.

The IoT WG has accumulated a solid and concrete experience in the IoT domain hosting and supporting several open-source projects and frameworks focused on various aspects of IoT, ranging from device connectivity and data management to edge computing and cloud integration. Some examples include the MQTT broker called Eclipse Mosquitto, the Java-based IoT gateway framework called Eclipse Kura, the MQTT client library called Eclipse Paho, the IoT integration platform called Eclipse Kapua, and Eclipse SmartHome, an open platform for home automation.

In these projects, the IoT WG promotes interoperability among IoT devices and systems by driving the adoption of open standards and protocols. For this purpose, it collaborates with other organizations and industry consortia to align efforts and develop common frameworks that enable seamless integration and communication between different IoT components,

[28] https://iot.eclipse.org/

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contributing to reduce vendor lock-in and foster a more diverse and interoperable IoT ecosystem.

From the liaison perspective, the background of the IoT WG in terms of concrete projects oriented to the industry domain and to key applications represents a solid European asset that should be integrated and complemented by the European funded research, and which should actively contribute to the strategic research agendas. From this perspective, Eclipse is already actively contributing to the KDT and Chips JU ECS-SRIA, which plays an important role in Europe as a reference funding-programme agnostic document driving and inspiring research and innovation. An alignment with the IoT WG is also important because it coordinates different organisations in the definition of specifications, development of reference architectures, and addressing common challenges: the presence of Eclipse in the OpenContinuum project facilitates this alignment. Finally, an important value of the IoT WG is represented by the attention to the adoption of IoT technologies in several industrial and application domains, including manufacturing, transportation, healthcare, and smart cities, etc.

4.3 **AIOTI**

The Alliance for Internet of Things Innovation[29] (AIOTI - is a European initiative that brings together industry stakeholders, research institutions, and government bodies to foster the development and deployment of Internet of Things (IoT) technologies and, recently, of edge computing. It positions in a key part of the edge-to-cloud continuum and addresses technical, societal, and policy challenges related to IoT adoption and deployment. AIOTI is not directly involved in funded programmes management, directly contributing to the development of research projects, or involved like Eclipse in concrete open-source projects, but the members of AIOTI initiative are involved in these activities, therefore there is an indirect connection. The members include a wide range of stakeholders, such as industry representatives, research organisations, standardisation bodies, and public sector entities: the intention of the initiative is to provide a platform for these stakeholders to collaborate, share knowledge, and work towards common goals in the IoT domain and in various industry verticals.

AIOTI's primary purpose is to accelerate the adoption of IoT technologies and foster innovation in Europe by creating a collaborative ecosystem, addressing the technical challenges in the IoT domain, including interoperability, security, privacy, and scalability. The initiative focuses also on societal and policy aspects of IoT, including ethical considerations, social acceptance, and standardisation/regulatory frameworks.

AIOTI is structured in working groups and task forces focused on specific IoT-related topics and domains: IoT architectures, interoperability, standardisation, security, privacy, and applications in sectors like smart cities, agriculture, energy, and healthcare. The activities and outcomes of the working groups drive R&D&I projects in European Research Programmes, develop best practices, and provide recommendations to stakeholders. AIOTI also provides inputs and recommendations to the EC on policy development, regulatory frameworks, funding programs, and initiatives related to IoT.

An important asset for the edge-to-cloud continuum is represented by the focus AIOTI gives on policies and regulations' support that influence the growth and adoption of IoT technologies. The alliance engages with policymakers, regulators, and standardisation

[29] https://aioti.eu/

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bodies to provide expertise, guidance, and recommendations on IoT-related policies. AIOTI aims to create an environment that encourages innovation, safeguards privacy and security, and promotes the responsible and ethical use of IoT technologies.

Regarding the liaison activities, policies and regulations represent an important area because they are not generally covered by the other European initiatives. AIOTI also publishes reports, white papers, and other resources to disseminate knowledge, best practices, and research findings: it is important that the vision, challenges, and roadmaps presented in these documents remain aligned with the other European strategic agendas. An AIOTI representative is already involved in the INSIDE, KDT JU, EPOSS and FIWARE, therefore good synergies and alignment could be created.

4.4 TransContinuum Initiative

The TransContinuum Initiative[30] (TCI) is a European initiative trying to cover the entire edge-to-cloud continuum, promoted by the ETP4HPC and intended to elaborate a vision of the characteristics of the infrastructure required for the convergence of data and compute capabilities in many leading edge industrial and scientific use case scenarios. The initiative builds on the concept that, to address the challenges of the continuum, it is necessary to design systems encompassing millions of computing devices, hyperconnected, distributed in heterogeneous domains, adopting IoT technologies, supercomputers, and cloud systems. The TransContinuum aims at achieving five objectives:

1. Elaborate joint recommendations for R&D to be carried out in EU- or JU-funded work programmes addressing challenges in the digital continuum.
2. Engage with EU Research & Innovation funding entities to promote their recommendations.
3. Generate and foster an interdisciplinary network of experts in science and industry.
4. Contribute to Strategic Research (and Innovation) Agendas or any other road mapping documents issued by participating partners, specifically on interdisciplinary technical aspects, with a view to extend the concept of co-design to cover the entire continuum.
5. Contribute to the 5 Horizon Europe missions (adaptation to climate change including societal transformation, cancer, healthy oceans, seas coastal and inland waters, climate-neutral and smart cities, soil health and food.)

TCI covers a wide spectrum of activities and objectives in the edge-to-cloud continuum but, currently, seems to be in an early stage of assessment and activity planning. The centrality of high-performance computing doesn't reflect the structure of the architectures on which the continuum is currently based, but this frequently depends on the perspective from which the continuum is observed. Regarding the liaison activities, it is important to align TCI contribution to Strategic Research and Innovation Agendas, roadmaps and contribution to the 5 Horizon Europe missions.

[30] https://www.etp4hpc.eu/transcontinuum-initiative.html

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4.5 KDT Joint Undertaking

The Key Digital Technologies (KDT) Joint Undertaking[31] is a European initiative that aims to accelerate the development and deployment of key digital technologies in Europe. In 2023, it will be extended and evolved in the Chips JU, as part of the European Chips Act. This initiative provides all the basic and advanced building blocks, i.e. electronic components and systems (ECS), enabling the edge-to-cloud continuum, from the edge, to the IoT, to the cloud interfacing, and providing enabling technologies for connectivity. It is an industry-driven public-private partnership that brings together industry, research institutions, and EU member states (including Israel and Norway) to collaborate on research and innovation projects in the field of digital technologies. The KDT Joint Undertaking operates under the framework of Horizon Europe. The KDT JU seeks to enhance Europe's competitiveness in digital technologies by fostering innovation, driving technological advancements, and supporting the digital transformation of various sectors. It aims to strengthen Europe's digital strategic autonomy and ensure that European businesses and industries can benefit from the latest digital technologies. The KDT Joint Undertaking supports collaborative research and innovation projects in key digital technologies, including but not limited to semiconductor manufacturing, nano and microelectronics, chips, embedded software, edge AI, high-performance embedded computing, connectivity, cybersecurity, etc. These projects bring together various stakeholders from industry, academia, and research organizations to address common challenges and develop cutting-edge solutions inspired and supporting key application domains for Europe: mobility, energy, digital industry, healthcare, agrifood and natural resources, digital society.

The KDT Joint Undertaking provides financial support through a combination of public and private funding. It allocates funding to selected projects through competitive calls for proposals, based on their alignment with the strategic objectives and priorities of the initiative. The funding enables the development of innovative technologies, prototypes, and demonstrators. The KDT Joint Undertaking aims to facilitate the transfer of technology and knowledge from research to industry. It supports activities that promote the commercialization of research outcomes, including technology transfer initiatives, start-up incubation, and collaboration with industry partners. The goal is to accelerate the adoption and deployment of key digital technologies in various sectors of the European economy.

Although being industry-driven, the initiative aims to have a positive impact on various societal challenges, such as sustainable development, green deal, healthcare, mobility, and digital inclusion. It seeks to leverage digital technologies to address societal needs, improve quality of life, and contribute to the United Nations Sustainable Development Goals.

INSIDE and EPOSS, respectively partners of OpenContinuum and UnlockCEI, represent the liaison link. INSIDE and EPOSS, together with AENEAS, are the three industry associations representing the private party of the tripartite KDT JU and of the future Chips JU. The three industry associations coordinate a community of more than 300 experts that prepare every year the ECS Strategic Research and Innovation Agenda (ECS-SRIA), a funding-programme agnostic, open and living document that represents the reference point for the KDT JU work programme. The ECS-SRIA covers the entire edge-to-cloud continuum, including the interfaces to the cloud but excluding cloud platforms, and including edge-to-cloud connectivity. The ECS-SRIA identifies the challenges in the edge-to-cloud continuum and the actions to tackle them for the next decade. It is the document to consider for the alignment and coordination actions.

[31] https://www.kdt-ju.europa.eu/

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4.6 GAIA-X

Gaia-X[32] is a European initiative aimed at developing a secure, controlled, federated, privacy-preserving and transparent data infrastructure to foster data sovereignty and promote the exchange and sharing of data in a trusted manner. Gaia-X promotes the principles of data sovereignty, giving individuals and organisations control over their data and determining with whom and how it is shared. The initiative and associated projects involve a broad range of stakeholders, including companies, research institutions, and public entities, with the goal of establishing a European data ecosystem that adheres to European values and regulations, and shape the future development of the European data ecosystem. Gaia-X aims to strengthen Europe's position in the digital economy by fostering innovation, supporting cross-sector data exchange, and addressing concerns related to data sovereignty, privacy, and security. The initiative seeks to establish a common set of rules, standards, and certifications to ensure transparency, trustworthiness, and interoperability within the European data ecosystem.

The Federated Data Infrastructure is at the core of the initiative, representing a decentralized data approach that connects various data spaces, allowing data to be shared, accessed, and processed securely across different domains and sectors. The infrastructure has been conceived to be scalable, flexible, and based on open standards, enabling seamless integration and interoperability across systems and data sources. The proposed solution is strongly based on security and trust, with the intention of providing privacy-preserving mechanisms to protect data and ensure compliance with relevant regulations, such as the General Data Protection Regulation (GDPR). From a technical perspective, the solution relies on the use of encryption, access control mechanisms, secure data exchange protocols to safeguard data throughout its lifecycle, and the development of trustworthy certification processes and standards for service providers, ensuring transparency and accountability in data handling.

The solution relies also on interoperability and adoption of open standards to enable seamless data exchange and collaboration between different systems and platforms: GAIA-X promotes the use of common APIs, data models, and technical interfaces, allowing data and services to be easily discovered, accessed, and integrated. Gaia-X actively engages with standardisation organisations and other relevant initiatives to align efforts and establish a common framework for data interoperability.

Gaia-X intends to establish trust marks and certification mechanisms to verify the compliance of services and solutions with the defined criteria, thereby facilitating the adoption of Gaia-X across various sectors.

The initiative promotes the adoption of Gaia-X-compatible solutions, encouraging organisations to build and offer services that align with Gaia-X principles: the most important asset for the liaison activities is the cloud platform itself, being this initiative the only one covering the cloud segment of the continuum and having an adequate critical mass. Although a concrete implementation of the platform is not available yet, some projects in specific vertical domains (e.g. EUPRO Gigant, ag data hub, Mobility Data Space, Elinor-X, Catena-X, etc.) have implemented the specifications and could be interesting entities for the liaison activities.

[32] https://gaia-x-hub.de/

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4.7 CATENA-X

Catena-X[33] is a European automotive industry initiative that aims to establish a secure, trusted, and transparent data ecosystem for the automotive value chain of the future. It brings together various stakeholders, including automotive manufacturers, suppliers, and technology providers, with the goal of enabling efficient data exchange and collaboration within the industry. Catena-X aims to create a digital ecosystem that facilitates data sharing, collaboration, and innovation in the automotive industry, trying to improve the efficiency and transparency of data exchange, security and control of data access, and compliance with data protection regulations and standards across the entire automotive value chain, including manufacturers, suppliers, logistics providers, and other relevant stakeholders in the value chain. CATENA-X aims to build a scalable and future-proof data ecosystem that can adapt to emerging technologies and evolving requirements of the automotive industry. It also focuses on long-term sustainability and the continuous evolution of this ecosystem, ensuring that it remains relevant and valuable for the automotive industry.

CATENA-X builds the solution on the concept of interconnected digital data spaces connecting various stakeholders within the automotive value chain. Data spaces allow the involved stakeholders to share and exchange data securely and efficiently, fostering collaboration, streamlining processes, and enabling new business models. The initiative promotes the use of open standards, APIs, and secure communication protocols to ensure interoperability and seamless integration of systems, data spaces and their sources. The initiative also considers the integration of advanced technologies such as blockchain, artificial intelligence, and machine learning to enhance data security, traceability, and analytics capabilities.

Data is crucial also from the perspective of sovereignty and trust, allowing each stakeholder to control its data and its sharing within the value chain. This approach is based on establishing trust and transparency by implementing robust security measures, data protection mechanisms, and privacy-preserving technologies. To ensure data monitoring and control, Catena-X addresses data governance, access control, and consent management to ensure that data is handled in a secure and privacy-compliant manner.

The third centre of gravity is represented by interoperability, which relies on common data models, standards, and protocols to enable seamless data exchange and integration between different systems and organisations: the initiative works closely with standardisation bodies and industry partners to define and adopt standardized interfaces and data formats. Interoperability becomes the means to simplify integration of different IT systems, enabling efficient data communication and reducing barriers to collaboration.

CATENA-X and Gaia-X are two separate initiatives, but they share a common vision and objective of establishing secure and trusted data ecosystems in their respective domains: CATENA-X focuses specifically on the automotive industry, while Gaia-X is a broader European initiative that aims to create a federated data infrastructure for various sectors and application domains, including automotive.

Following the considerations made for Gaia-X, from the liaison perspective the important assets are represented in this case by both the data spaces and the underlying cloud platform. Moreover, CATENA-X focuses specifically on the automotive domain which presents one of the most complex, challenging, and relevant examples of edge-to-cloud continuum. Liaison with this initiative is very important, also because the implementation of

[33] https://catena-x.net/en/

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the proposed solution is in an advanced stage of development. Many OEMs and Tier1s participating in CATENA-X are members of INSIDE and this could represent a good starting point for the creation of coordination activities and synergies.

4.8 Other initiatives

The liaison activities are currently focused on the alliances, partnerships, and initiatives addressing the edge-to-cloud continuum described in the previous sections. These activities require a significant amount of resources which are limited in the project also from a temporal perspective. For this motivation we tried to identify the most relevant alliances, partnerships, and initiatives, trying to maximise the final result in terms of coordination, alignment and synergies. Nevertheless, the analysis of the European ecosystem will continue in an attempt to also include other important initiatives such as SNS, NESSI, ETSI, IIC, EDI, etc.

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5 Conclusions

This document is aimed to start explaining the elaborate strategy for European digital autonomy through Open Source, Standard and Alliances This document is aimed to start explaining the elaborate strategy for European digital autonomy through Open Source, Standard and Alliances. The final aim is to arrive at a common definition understanding of open source, standard and alliances and how these can be a real deal and help for the computing continuum.

In order to do so, first steps have been made in the direction of creating a community: a suite of seminars has been planned and organised with the aim of presenting the Open Source activities with different points of view as well as give to them information of important and well-known open source tools. On this matter, these seminars will bring to light Open Source Foundation activities and components and some open source best practices applied by the members (individuals or organisations) of these foundations. In parallel with the seminars, and with the same aim, relevant events are identified or organised or co-organised for the stakeholders. Furthermore, the initial results presented here, and the face-to-face discussion with the projects, reinforce the idea of 'breaking the silos' among projects.

The development of the computing continuum ecosystem will require standardisation support. In this document has presented and identified several approaches, based on the main level addressed by projects: architecture level, trustworthiness level, interoperability level, and open-source level.

A landscape of existing standardisation activities and possible routes for projects to take have been provided.

European alliances, partnerships, and initiatives in the edge-to-cloud continuum are an important aspect of the strategy and they have been presented in this document along with their description and relation to the work.

The main achievement will be to have a wide vision and liaison with the heterogeneous perspective in order to lead to a common open vision for the computing continuum.

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7 Annex A: Guidance for Reference Architectures (RA)

This section provides guidance for reference architecture deliverables that will subsequently be promoted at standardisation level.

7.1 Structure of Architecture Standards

Figure 20 shows the topics that must be described:

- The entity of interest,
- The environment of the entity of interest,
- Stakeholders,
- Their concerns,
- Architecture viewpoints, which represent the expectations of stakeholders,
- Architecture views, which represent the proposed architecture description.

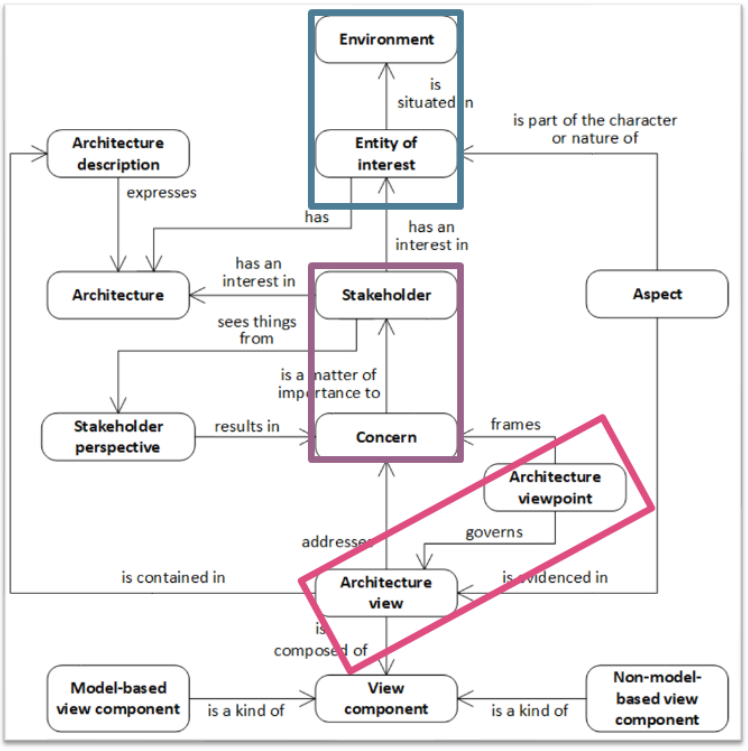

Figure 20 - Conceptual model of an Architecture (ISO.IEC/IEEE 42010)

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Table 6 is the proposed structure for a reference architecture standard.

TABLE 6 -STRUCTURE OF AN RA STANDARD

Introduction			Per ISO/IEC directives part 2
1 Scope			Per ISO/IEC directives part 2
2 Normative references			Per ISO/IEC directives part 2
3 Terms and definitions			Per ISO/IEC directives part 2
4 RA context	4.1 RA overview [42010, 6.1]		Per ISO/IEC/IEEE 42010: Identify the entity of interest and the expected environment of that entity of interest. Include a statement of its intended purpose. Identify information and supplementary information
	4.2 RA stakeholders and concerns [42010, 6.2, 6.4]		Who are the stakeholders for this RA standard? What are the concerns addressed by this RA standard?
	4.3 RA stakeholder perspectives [42010, 6.3]		Identify any perspectives used in this RA standard Identify the stakeholders associated with this perspective
	4.4 Domain sources of information		Are any discipline or domain ontologies needed to understand this RA standard?
5 RA viewpoints and views	5.1 Overview		Provide an overview of the viewpoints and views
	5.2 RA viewpoint and views	5.2.1 Viewpoint [42010, 6.6]	Provide or reference the viewpoints covering the concerns from the *Reference architecture stakeholders and concerns* clause. Provide the correspondences Include viewpoint specifications (per 5.2.1) for each identified viewpoint.
		5.2.2 View(s) [42010, 6.7]	Provide the views covering the identified concerns and perspectives. For each identified viewpoint, include one or more views governed by that viewpoint. For each view, include identifying information,
	5.3 RA view 2 …		…
Annex A Optional model kinds			Specify model kinds that are optional, as well as the criteria for using them
Annex B Reference architecture requirements [Optional]			Specify requirements on the application of this RA standard (such as for claims of conformance, branding, interoperability)

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7.2 TEMPLATES

7.2.1 Viewpoint Template

Table 7 provides a template for viewpoint description.

TABLE 7 - VIEWPOINT TEMPLATE

Viewpoint name		Provide a name for the viewpoint
Overview		Framing of the concerns to be addressed by the views Indicate if the viewpoint is essential to the domain
Viewpoint specification [42010, 8.1]	Known typical stakeholders	Identify typical stakeholders for views using this viewpoint.
	Concerns	Identify concerns which are framed by this viewpoint.
	Model kinds/Legends	Identify and specify one or more model kind. Include any legends for use with views of this viewpoint.
	View methods	Provide any associated methods and patterns that guide creation, use, analysis of models (view components) governed by this viewpoint.
	Correspondence methods	Provide any correspondence methods linking view elements to other architecture description elements.
	References	References to any source of information about this viewpoint. Can include references to essential ontologies

7.2.2 Model Kind Template

Table 8 is a template for model kinds.

TABLE 8 - MODEL KIND TEMPLATE

Model kind name [42010, 8.2]	Provide a name for this model kind.
Overview	Provide a short description of the types of modelling this model kind is useful for.
Version	Provide version info
Conventions	Can include a meta model, template, grammar or other means of documenting the conventions for architects, stakeholders and other readers.
View methods and correspondence methods	Provide any associated methods and patterns that guide creation, use, analysis of models (view components) governed by this model kind. Provide any correspondence methods linking to other architecture description elements.
References	Provide useful references to this model kind.

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7.2.3 Pattern Template

Patterns can be understood as a solution to a particular system development problem. Table 9 provides a pattern template. For instance, an implementation architecture for industrial IoT can use the patterns library in [17].

TABLE 9 - PATTERN TEMPLATE

Information	Name	Name of pattern *The pattern's name should convey the essence of the pattern succinctly. A good name is vital, because it will become part of your working vocabulary.*
	Related patterns	Similar patterns, depending patterns *There could be similar patterns. The pattern can extend other patterns*
Problem		Description of problem which the pattern attempts to solve *A short statement that answers the question: What particular issue or problem does it address?*
Known Context	Specific context	The particular context in which the pattern solves a problem *Where does the pattern apply? For example, the use of an enterprise-wide data model frequently makes sense in a* *problem context where distributed data management is a concern - the architecture for an air-to-air missile may not be an appropriate context for this pattern.)*
	Related context	Other related context
Solution	Architecture models	Architecture models for the pattern *Text and diagrams necessary to understand the essential concepts and relationships for the pattern*
	Examples	Scenarios/use cases where the pattern has been applied *Useful patterns are motivated by known, previous usages.* *Examples (and Visual Analogies) help explain the pattern*
	Rationale for the pattern	The rationale can be theoretical (e.g., the mathematical theory of rate monotonic scheduling), or practical (e.g., prior case studies in which the pattern was successfully employed
	Guidance	Provide useful information that assists an architect in using the pattern. Guidance can include Description of characteristics References to other documents (e.g. standards, regulations, white papers, ontologies) Discussion on pain points, critical decisions, underlying requirements, trade-offs

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