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Open Continuum

D2.1 OpenContinuum Landscape v1 and preliminary recommendations

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Abstract	This document presents the work done within WP2 in order to start the common definition for a Continuum taxonomy as well as the methodology for defining a conceptual framework to analyse the European landscaping in

	order to provide recommendations for future work. It also introduces the graphical representation of results.
Keywords	Landscape, taxonomy, framework, recommendation, Continuum

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

DEM: Demonstrator, pilot, prototype, plan designs

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

DATA: Data sets, microdata, etc

DMP: Data management plan

ETHICS: Deliverables related to ethics issues.

SECURITY: Deliverables related to security issues

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

EXECUTIVE SUMMARY

The emergence of the continuum computing paradigm has raised the need of homogenising the existing work on cloud, edge and IoT initiatives. The jungle of standards within each of the three paradigms, the lack of a unified language and the existence of several solutions partially addressing the needs of this novel paradigm are fragmenting even more an already fragmented software market.

WP2 MAP & ACT, together with the activities performed within the EUCloudEdgeIoT initiative Task Force 3 Architecture, aims to develop a continuum landscape representing the existing software solutions. This work will produce several results:

- A homogenised taxonomy for the continuum, unifying common cloud, edge and IoT terminologies with the main aim of defining a common language to be used within the continuum paradigm, properly documented in written and online formats.
- A set of building blocks to easily understand the functionalities and technologies needed to operate an application across the continuum, available through the project website.
- A set of methodologies for developing a taxonomy or validating project results in the form of white papers and publish in public repositories.
- A reference architecture for the continuum, properly documented and supported by capabilities developed in European projects, to be promoted as a standard and further mapped with the solutions architectures of the funded research projects.
- A list of solutions implementing the reference architecture functionalities.
- A list of technology gaps and research challenges based on the lack of solutions implementing certain aspects of the continuum reference architecture.
- A set of recommendations to support the European digital autonomy in the continuum.

The work is performed in two iterations, according to the project schedule. This document presents the work done during the first iteration, presenting the basis for the development of the final landscape and the recommendations for ensuring the European digital autonomy.

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Abbreviations

MRL	Market Readiness Level
RIA	Research and Innovation Action
TF	Task Force
TRL	Technology Readiness Level
SRL	Service Readiness Level
UAV	Unmanned Autonomous Vehicle
WP	Work Package

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1 Introduction

1.1 Purpose of the document

OpenContinuum, focusing on the supply-side of the computing continuum landscape, aims to have a large-scale impact on strategic objectives for European technological, economic, and societal advancement. Within this context, it brings together actors from the continuum value chain engaging them in a broader community with a common language and understanding.

The objective of this document is to present the work during the first year of the project within the context of WP2 'MAP & ACT'. The objectives of this work package are as follows:

- To define a conceptual framework for the cloud-edge-IoT landscape.
- To map relevant actors in the cloud-edge-IoT landscape and engage them in the activities (looking for relevance, openness, diversity, representativeness of the community and its results).
- To support the analysis of the collected information.
- To provide strategic recommendations to support the EU digital autonomy in the computing continuum.
- To drive forward those actions by "acting/doing" beyond the pure analysis.

Furthermore, OpenContinuum, in collaboration with Unlock-CEI, focused on the demand-side of the computing continuum landscape funded the EUCloudEdgeIoT initiative [1]. The objective of this initiative is to bring together actors from both sides, supply and demand ones, to develop a community for the continuum where different actors may coexist and collaborate. The main objectives within this initiative about landscaping are:

- Enable the architectural discussions among projects in the area of IoT/Edge and Cloud to create a continuum.
- Identification of the thematic areas and building blocks.
- Understanding the contribution of each project to the thematic areas, allowing the identification of cross-project synergies.

1.2 Structure of the document

The document is structured into six main sections:

- **Section 1,** it is the document introduction of the overall objectives to be accomplished through the activities performed in the following subsections.
- **Section 2** presents the work done within the WP2 of OpenContinuum and how it was complemented with the activities of the EUCloudEdgeIoT initiative.
- **Section 3** introduces the work done for analysing the existing cloud, edge and IoT taxonomies and the methodology for defining one for the continuum.
- **Section 4** defines the conceptual framework for the continuum landscape and the methodology developed for evaluating the technical contributions from research projects.

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- Finally, **Section 5** presents the preliminary set of recommendations based on the work done and the next steps to be performed during the second year to complement the work already done and address these recommendations.

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2 Landscape definition

One of the main objectives of OpenContinuum is to draw the landscape of European cloud, edge and IoT solutions from the supply side. Bearing this in mind, different activities have been undertaken within the first year of the project in order to identify and provide feedback to WP1 to develop the European Open Source stack.

2.1 OpenContinuum Approach

In order to develop the European landscape, OpenContinuum must accomplish a series of objectives:

- To define a conceptual framework for the cloud-edge-IoT landscape.

Before developing the landscape, it is important to better understand how it can be constructed. For this reason, a conceptual framework has been developed to understand how different stakeholders are contributing to it. In a first iteration, OpenContinuum has worked with research projects and initiatives, which provided valuable feedback to define the main building blocks of the continuum. A second iteration is planned to gather feedback about how each of them are contributing with results to each of the building blocks. This will support the identification of synergies and gaps to identify future research challenges and further developments needed. Additionally, this work will be extended to other European software companies developing solutions for the continuum. And, in close collaboration with WP1, open source communities at European level.

- To map relevant actors in the cloud-edge-IoT landscape and engage them in the activities (looking for relevance, openness, diversity, representativeness of the community and its results).

Part of the work done within this WP consisted in a desktop analysis of the work that is being done in Europe, so different actors can be asked about their specific activities aiming to gather more useful feedback from the beginning. Thus, as it has been said before, a first round of interactions with research projects and initiatives have been performed.

Within this context, 46 projects and 6 initiatives have been reached and invited to participate in different activities. Some of them are more active than others, but all of them provide at least the minimum of information required.

More iterations are planned with them, but new actors are also expected to be involved to cover the whole continuum spectrum.

- To support the analysis of the collected information.

The first year of the project was dedicated to identifying the current context and interacting with different actors to gather feedback about how they understand the continuum. This activity was, indeed, the hardest one as each actor operates in different positions of the continuum value chain. Thus, all of them have different perspectives about what the continuum is, which technologies shall be considered or even what the value chain itself is.

Once an agreement was reached, the continuum building blocks were developed and the roadmap for the second year of the project was implemented. There are several activities already started that will finalise during the second year providing additional results, such as a homogenised taxonomy for the continuum that will be presented as a position paper; and a reference architecture for the continuum, that will be submitted as a standard, and can be

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mapped with the ones of the different projects highlighting their contributions to it. This reference architecture will be used as the basis of the landscape to identify synergies between projects, gaps in the European developments and future research challenges according to it.

- To provide strategic recommendations to support the EU digital autonomy in the computing continuum.

Based on the information gathered during the development of the landscape, a set of recommendations will be provided to reinforce the European positioning in the continuum arena. These recommendations will cover technical aspects, such as research challenges or technology gaps, to other more functional aspects, such as the creation of collaborative environments or the support for reaching external stakeholders (mainly from the demand side).

- To drive forward those actions by "acting/doing" beyond the pure analysis.

A set of actions will be identified and undertaken, as part of the EUCloudEdgeIoT initiative, including fostering the collaboration between different actors or support projects in their activities. This is something to be performed during the last year of the project.

2.2 Task Force (TF) 3: Architecture

OpenContinuum is collaborating with Unlock-CEI under the umbrella of the EUCloudEdgeIoT initiative [1]. The initiative launched 6 task forces [2] to perform different actions:

- Task Force 1: Strategic Liaisons
- Task Force 2: Open Source Engagement
- Task Force 3: Architecture
- Task Force 4: Ecosystem Engagement
- Task Force 5: Market & Sectors
- Task Force 6: Communications

WP2 is leading the activities of TF3 addressing the following topics:

- Taxonomy definitions: beyond the standards for cloud, edge and IoT definitions, find homogenised definitions for common terms applying to the continuum.
- Sharing of components between RIAs: identifying how each project is contributing with which results to the continuum so they can be further reused by current or future projects.
- Peer review and testing: of the continuum definition and the solutions proposed by RIAs.

Thus, accomplishing the following list of objectives:

- Enable the architectural discussion among projects in the area of IoT/Edge and Cloud to create a continuum: defining common terms and the continuum value chain.
- Identification of the thematic areas and building blocks: for developing software for the continuum and not only for a combination of, e.g., cloud and edge or edge and IoT.
- Understanding the contribution of each project to the thematic areas: supporting the definition of the European landscape and providing valuable feedback to WP1 in order to define the open source stack for the continuum.

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In order to do so, several actions have been performed, such as workshops or surveys, that are detailed in the Annexes of this document.

2.3 Collaboration with other task forces

As it has been explained before, WP2 activities within TF3 are related with the ones performed in other task forces so efforts will be focused on providing valuable feedback for all of them avoiding duplicating them and enriching results:

- TF1: this task force is in charge of establishing liaisons with other initiatives, thus, a strong collaboration has been established with it to reach them and gather feedback about their positioning in the continuum and how they foresee the future of the research in this area.
- TF2: as this task force aims to develop an open source stack with results from RIAs, both task forces are always in close collaboration being TF3 the one collecting feedback from the landscape and TF2 the one categorising the open source results.
- TF5: in order to provide feedback to them about the availability of software that can cover the demand side needs.
- TF6: for reaching all projects, even those not directly involved in TF3 to foster their participation in the TF activities, and to provide results in a nice way that can be reused by all RIAs.

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3 Definition of a taxonomy for the Continuum

In order to be able to define the continuum landscape, including architectural building blocks and terms to be used, it is of paramount importance to make sure that all actors within the continuum value chain speak the same language. Thus, the work during the first part of the project focused on homogenising the terminology used by all projects.

3.1 Methodology for defining a taxonomy

OpenContinuum has followed the Taxonomy Best Practice Framework [3], proposed by the Taxonomy Oversight Group, in order to define the structure of the continuum taxonomy so it can be further reused and extended in the future.
According to this framework, the methodology and actions performed are as follows:

Definition

A taxonomy is a group of terms, and their definitions, classified according to their similarities. WP2 is defining a taxonomy for the continuum, where the same terms can have different meanings according to the category they are related to. Thus, traditional hierarchical approaches cannot be applied, and it is necessary to follow a faceted approach, where different attributes can apply to the same term depending on their application domain.

Purpose

In order to provide a useful taxonomy that can be further reused by all actors it is important to state a clear purpose that fulfils the user requirements and allows the periodic update.
The main purpose of the continuum taxonomy is to go beyond existing cloud, edge and IoT taxonomies, even inheriting their results, providing common definitions for the continuum and periodically update whenever new concepts arise.

Complexity

Taxonomies are complex by their own nature. However, too complex taxonomies may have a significant negative impact on their adoption. Thus, the core of this taxonomy will be focused only on continuum terms definitions. Although linked with other commonly cloud, edge and IoT taxonomies, it will only define the continuum specific terms.

Balance

A taxonomy must be balanced, ensuring that all categories have at least one associated term. Taking into account that the continuum taxonomy is the results of a collaborative effort between different projects, the categories are related to the identified building blocks. While new potential categories and terms may arise by future research projects, then, the taxonomy will be updated accordingly.

Ownership and Governance

The initial taxonomy is owned by OpenContinuum and the contributions are open to all projects. However, in order to ensure that a project or any other actor is updating it according to their specific needs only, suggestions, contributions and updates will be managed by WP2 team. The governance model will be published together with the taxonomy and made available through the website.

Accessibility

To ensure its usefulness, the taxonomy must be accessible for all users. Initially, a downloadable document will be made available with all the information. But the possibility of having a wiki site is also being considered.

Interoperability

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All taxonomies should be able to be linked with other sources. In the specific case of this taxonomy, specific standardised terms for cloud, edge and IoT are excluded to avoid duplication and potential inconsistencies due to further updates on any of them.

Supported

As it has been said before, OpenContinuum will provide consultation material for explaining the taxonomy and its definition. As well as manage all the potential contributions to avoid misplacing and overlapping of terms definition.

Well-defined terms

It is important to properly classify the terms to avoid an unmanageable miscellaneous category with too many not-related terms. Thus, the continuum taxonomy starts with a limited number of agreed terms classified under different categories. In this way, the addition of terms and categories can be easily controlled.

Revision and Maintenance

To make sure that a taxonomy still covers user needs it is necessary to maintain and update it along the time. Even if the task work has ended, OpenContinuum will continue assigning resources to make new updates before the end of the project aiming to incorporate any request for new projects.

Metadata

Metadata must be provided for, at least, all versions of the taxonomy so it can be tracked. The continuum taxonomy contains a header stating the version, creation date (year), title and description, plus a short explanation of each category.

Methodology

How the taxonomy was developed should be made available to all users. OpenContinuum will provide the information contained in this section as a short introduction to the taxonomy itself, while the supporting documentation (taxonomy in a document format) will also contain the acknowledgement of the projects that were involved in its definition.

Engagement Strategy

It is necessary to attract users and contributors to develop a useful taxonomy. In this specific case, all of them were involved from the beginning and properly acknowledged.

Future Proof

A well-defined taxonomy is expected to be still usable after a long period of time. Thus, as it has been said before, OpenContinuum has established mechanisms to incorporate updates.

The results of this activity will be further documented and made available so all actors can make use of it.

Additionally, all terms presented within the continuum taxonomy will be used as tags to categorise projects and their results within the resulting landscape.

3.2 Analysis of existing taxonomies

The continuum is based on three main pillars: cloud, edge and IoT, all of them having their own standards or de-facto standards for associated terms definition.

This is the initial list of references for the taxonomy included in the analysis:

Cloud standard

Based on the taxonomy developed by NIST [4] in 2011, and further extended and updated, the continuum taxonomy uses its terms as the basis for the cloud-related classification.

According to it, there are four major categories:

1. Level 1: Role, to identify the actors of the cloud computing value chain:
2. Level 2: Activity, to define the behaviour of each of the previously identified roles.
3. Level 3: Component, to specify the actions to be undertaken to meet the goal of all the previously defined activities.

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4. Level 4: Sub-component, a modular representation of each of the abovementioned components.

Edge standard

Even if it is not a standardisation body, LF Edge is one of the biggest communities related to edge computing. Thus, initially its Open Glossary [5] was used as a reference for the continuum taxonomy.

Even if it is more a glossary rather than a proper taxonomy, it sets the basis for the ongoing work between LF Edge, OpenStack Foundation and TIA for developing an edge computing taxonomy and its corresponding landscape.

IoT standard

IoT is, indeed, the oldest and most mature pillar of the three ones. Thus, there is no single standard to define it but a set of different ones addressing each of its aspects, such as security or communication. Thus, only specific terms were incorporated for not overpopulating the taxonomy with only IoT-related terms.

Additionally, the list of common terms identified in D4.3 Towards a European Ecosystem for the Computing Continuum was incorporated.

A dedicated workshop was performed within the context of TF3 to identify which terms can be applied to more than one pillar. In this way, terms that can be applied to the continuum will be further incorporated in the taxonomy. The results of this workshop can be summarised as follows:

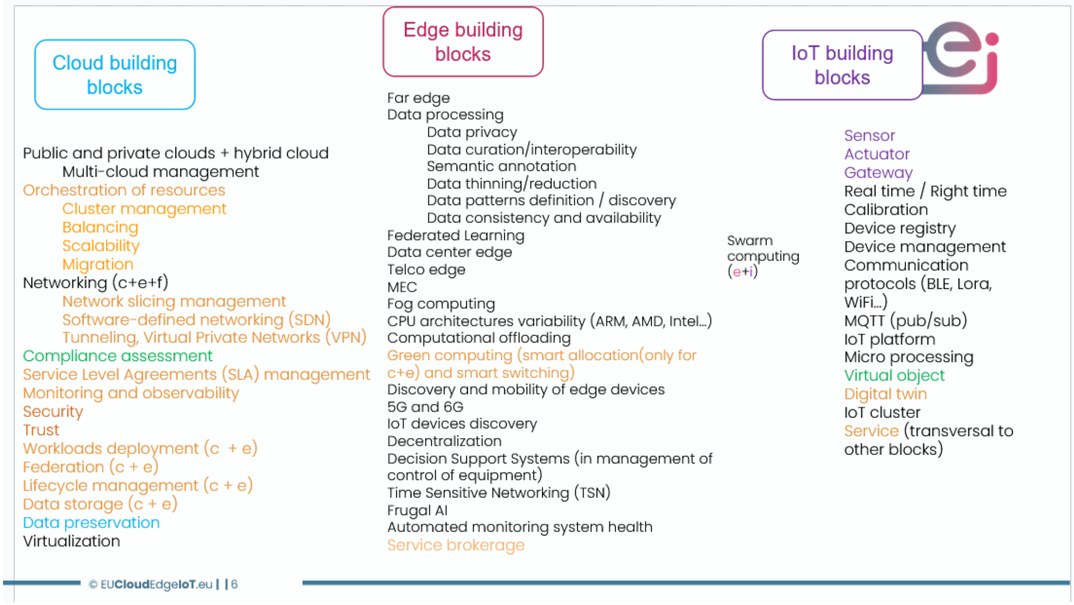

Figure 1 Results of the first taxonomy workshop

According to the colour scheme:

- Those terms in black are confirmed to be in the right category.
- Terms in green can be considered as general ones.
- Terms in orange belongs to the continuum as they can be applied in two or more of the pillars.

Further details about the workshop are provided in the corresponding Annex of this deliverable.

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3.3 Continuum Building Blocks

Taking into account the existing taxonomies, that usually relates to a reference architecture, an initial set of building blocks was identified to be used as the basis for further discussion with all the ongoing RIAs.

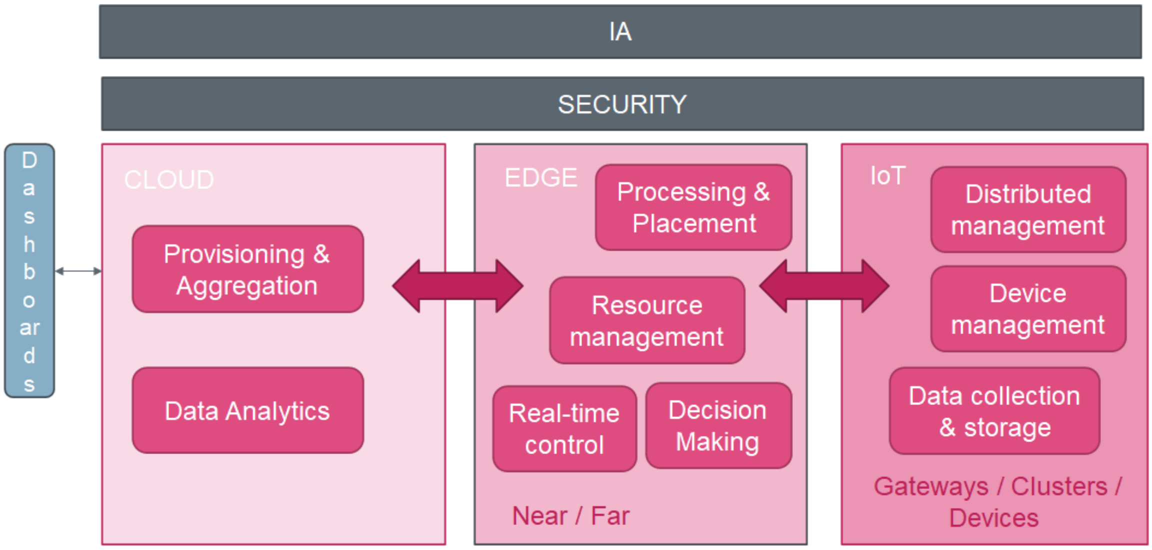

Figure 2 First version of the continuum building blocks

This initial version of the building blocks was performed taking into account that the continuum is built on top of the three main pillars (cloud, edge and IoT), and was mapped with the proposed building blocks for data spaces developed by FIWARE [6]. However, this proposal does not sufficiently address the needs of an architecture for the continuum, as it does not take into account the compute pipeline.
Then, Unlock-CEI proposed a new set of building blocks based on the requirements gathered from the demand side [7]:

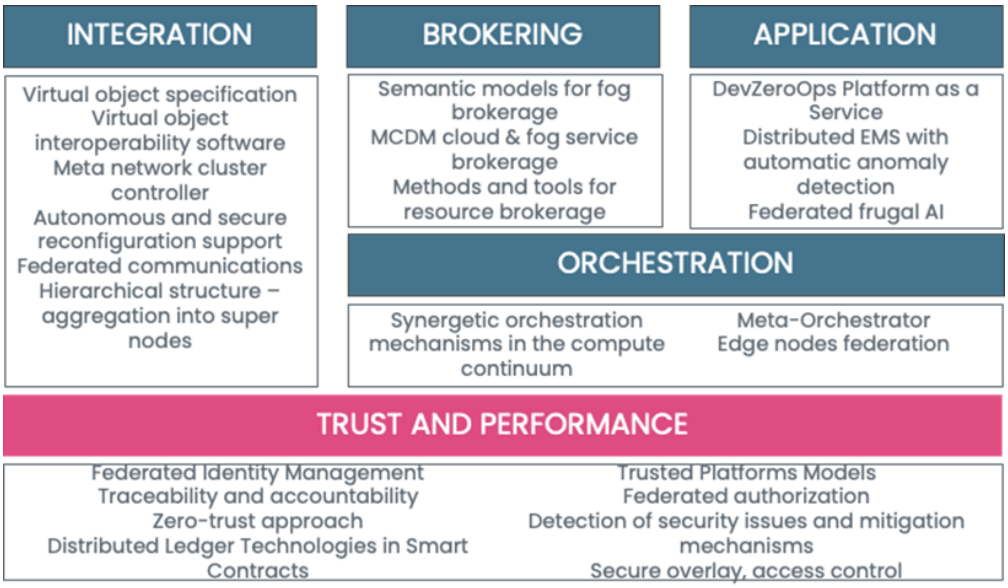

Figure 3 Building blocks proposed by Unlock-CEI [7]

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However, although this version was more focused on the compute pipeline functionalities, it lacked some of the major ones identified from the supply side. Thus, it was evolved to fit the continuum needs according to what RIAs have stated:

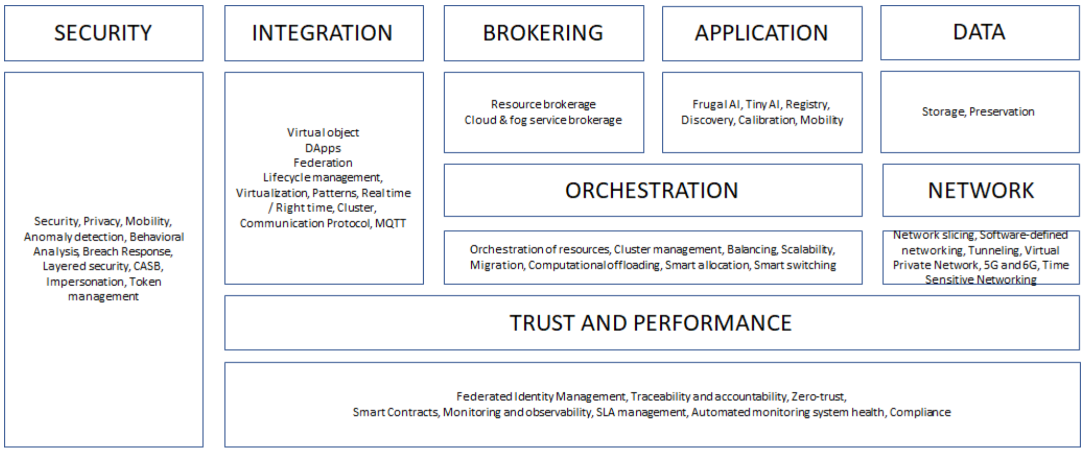

Figure 4 Second version of the continuum building blocks

However, these building blocks also do not cover the main functionalities and technologies involved in the development of solutions for the continuum. Thus, after further agreement with all involved RIAs in TF3, this is the final list of building blocks:

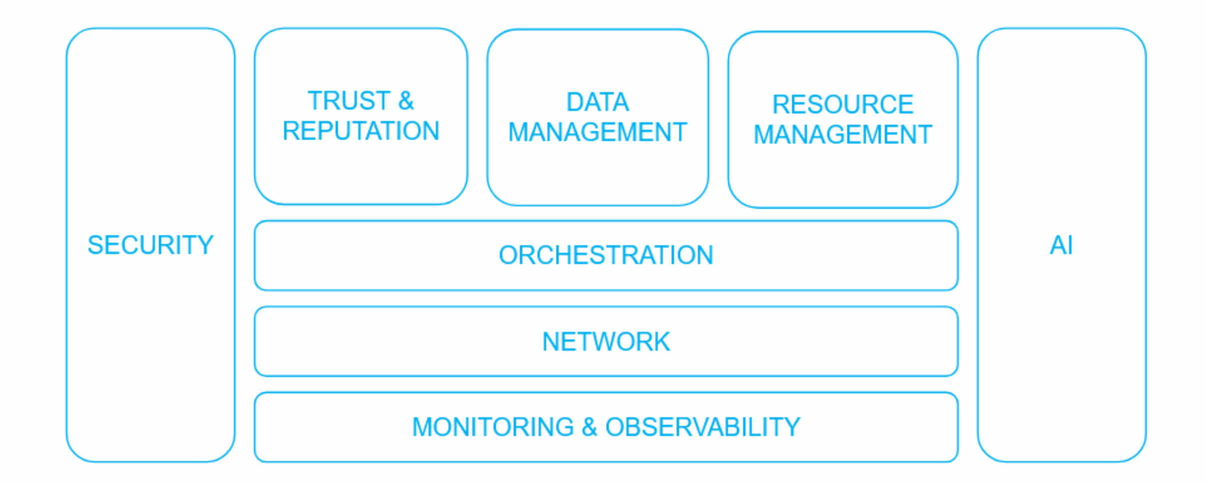

Figure 5 Final version of the continuum building blocks

This definition, also closer to the representation of a reference architecture, allows to incorporate as many functionalities as needed, split the blocks into components representing these functionalities and even incorporating new ones in the future if needed. In general lines, these building blocks refer to the following capabilities:

- **Security:** all mechanisms for secure data and transactions between the different components.
- **Trust & Reputation:** models for allowing users of a continuum platform to generate trust on providers or increase their reputation (mainly in federated models).
- **Data management:** including collection, storage and any other type of action performed over data.
- **Resource management:** of physical infrastructures and devices.

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- **Orchestration:** distributions of workloads, data or resources for executing a given action.
- **Network:** connectivity considerations, including private networks and activities such as network slicing.
- **Monitoring & Observability:** at infrastructure level, including telemetry, and service/application level.
- **Artificial Intelligence:** embedded in most of the activities performed.

4 Conceptual framework for the EUCEI landscape

Once the taxonomy and the building blocks are defined, the next activity within WP2 is to start with the landscape of existing research projects. For this reason, a conceptual framework was designed and a methodology for gathering feedback was developed.

4.1 Definition of the conceptual framework

OpenContinuum conceptual framework relies on the work previously done about the definition of the building blocks and the taxonomy related to it in order to graphically represent the European continuum landscape.
Thus, the steps followed were:

1. Analyse the existing taxonomies related to cloud, edge and IoT. Find the common terms that can apply to more than one of these pillars and identify those novel terms that can be applied to the continuum only.
2. Analyse the existing approaches to the continuum building blocks, especially from the compute pipeline perspective, and again identify common blocks and missing ones.
3. Develop the first version of the faceted taxonomy related to building blocks and pillars in order to use the terms as tags for categorising projects.
4. Categorise all projects according to it, so they can be easily associated to specific activities.
5. Develop the supporting material of the continuum taxonomy and promote it.
6. Develop the methodology for collecting information about project results and the recommendations that can be elicited from it.
7. Collect information about project results and map it with the list of building blocks, tagged with taxonomy terms.
8. Provide recommendations for further development, exploitation, promotion and policy making.
9. Develop the graphical representation of the continuum landscape.

During the first year of the project, the first five steps were performed. Being steps 1 and 2 documented in Section 3, step 3 documented in Appendix D, step 4 presented in Section 4.3, step 5 as available material on the website, step 6 introduced in Section 4.2, while steps from 7 to 8 will be performed during the last phase of the project.
The definition of the framework will be based on 1) a consensus-based discussion with all involved RIAs to ensure the building blocks they are developing are well represented in the taxonomy; and 2) references and papers from the state of the art suggested by these projects so that a common survey paper can be provided.

4.2 Methodology

Based on the IMAF methodology for maturity assessment in smart cities [8], OpenContinuum has developed a methodology for assessing and categorising project results within the continuum.
The IMAF framework aims to assess the ability of smart cities platforms to solve daily issues, identifying gaps and providing recommendations for replicating results in a standardised way.

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Following this approach, WP2 develops a methodology for collecting information and provide further recommendations based on five main pillars:

1. Basic information for categorising project results in the continuum landscape.
2. Identification of current technology gaps and future research challenges from the ongoing projects.
3. Develop a list of research results to build up the European continuum stack.

Additional benefits of this methodology are the possibility of identifying the dependency on non-European developed software, or how much software is open source or not.

4.2.1 Validation criteria

For implementing this methodology, a survey was created split into four main pillars that will help to understand the status of each of the project results.

Functional Capability

This pillar evaluates if a result is reusable and in which context it can be replicated. As one of the main objectives of the activity is to foster the reusability and replicability of project results to enhance the European software and avoid developing the same solutions again.

Technological Capability

The second pillar evaluates the maturity of project results. This means not only if a result can be further reused but how easy is, for example, to develop to functionalities to enhance it or even to directly adopt and integrate it with other solutions.

Operational Capability

Even if oriented to the marketability of a project result, it also evaluates if there is a clear plan behind the asset. The operational capability is of paramount importance in order to support the previous two pillars, as a result can have a good quality level from a technical perspective but will not be reused if there are no supporting mechanisms behind it.

Engagement Capability

This last pillar relates to the awareness created around a project result to engage different stakeholders. Positive answers to the related questions will mean that there is a plan for sustaining it, while negative ones may affect to the reusability of project results.

Full survey can be seen in Appendix C.

4.3 Initial landscape

The initial version of the continuum landscape contains information about ongoing projects in general, as the second version will focus more on their results. In this way it will be easier to identify gaps and commonalities in a lower level. It will be used to foster the reusability of results and to develop the European open source stack for the continuum.

In this initial classification, the list of projects is as follows (information available in CORDIS [9]):

Table 1 AI-SPRINT project

Name (Acronym)	Artificial Intelligence in Secure PRIvacy-preserving computing continuum (AI-SPRINT)
Tags	Cloud, edge, artificial intelligence, data management, security

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Short description	Tools for AI applications in computing continuum which allow a finely-tuned tradeoff between performance and AI model accuracy, putting security and privacy early in the design stage.

Table 2 CHARITY project

Name (Acronym)	Cloud for Holography and Cross Reality (CHARITY)
Tags	Cloud, network, orchestration
Short description	Framework that takes advantage of novel cloud architecture, a computing and network continuum autonomous orchestration, to overcome the challenges as well as meet the requirements of media applications.

Table 3 DataCloud project

Name (Acronym)	ENABLING THE BIG DATA PIPELINE LIFECYCLE ON THE COMPUTING CONTINUUM (DataCloud)
Tags	Data management, blockchain, edge
Short description	Paradigm with a complete life cycle managing Big Data pipelines through discovery, design, simulation, provisioning, deployment and adaptation across the computing continuum.

Table 4 PHYSICS project

Name (Acronym)	Optimized hybrid space-time service continuum in FAAS (PHYSICS)
Tags	Cloud, edge, FaaS, orchestration, data management
Short description	Cutting-edge, scalable and cost-effective cloud models operated across multiple hardware types, locations, edge computing nodes and multi-cloud resources.

Table 5 SERRANO project

Name (Acronym)	TRANSPARENT APPLICATION DEPLOYMENT IN A SECURE, ACCELERATED AND COGNITIVE CLOUD CONTINUUM (SERRANO)
Tags	Cloud, edge, security, orchestration, artificial intelligence
Short description	Novel ecosystem of cloud-based technologies, ranging from specialised hardware resources to software tool sets.

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Name (Acronym)	Architecture for Scalable, Self-*, human-centric, Intelligent, Secure, and Tactile next generation IoT (ASSIST-IoT)
Tags	IoT, edge, artificial intelligence
Short description	Reference architecture in which intelligence can be distributed among nodes by implementing artificial intelligence and machine learning close to data generation and actuation, and hyperconnecting nodes, in the edge-cloud continuum, over softwarised smart networks.

Table 6 iNGENIOUS project

Name (Acronym)	Next-Generation IoT sOlutions for the Universal Supply chain (iNGENIOUS)
Tags	IoT, edge, network, blockchain
Short description	Technical and business enablers to build a complete platform for supply chain management.

Table 7 IntellIoT project

Name (Acronym)	Intelligent, distributed, human-centered and trustworthy IoT environments (IntellIoT)
Tags	IoT, artificial intelligence
Short description	Framework for intelligent IoT environments that execute semi-autonomous IoT applications, enabling a suite of novel use cases in which a human expert plays a key role in controlling and teaching the AI-enabled systems.

Table 8 IoT-NGIN project

Name (Acronym)	Next Generation IoT as part of Next Generation Internet (IoT-NGIN)
Tags	IoT, edge, cloud, artificial intelligence, network, security
Short description	Pattern based meta-architecture and optimised IoT/machine-to-machine and 5G/machine-cloud-machine communications by extending the edge cloud paradigm.

Table 9 TERMINET project

Name (Acronym)	nexT Generation IoT as part of Next Generation Internet (TERMINET)
Tags	IoT, edge, network, blockchain

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Short description	Reference architecture to simplify the connection of a vast number of different devices through a flexible SDN-enabled middleware layer.

Table 10 VEDLIoT project

Name (Acronym)	Very Efficient Deep Learning in IOT (VEDLIoT)
Tags	IoT, data management, artificial intelligence
Short description	IoT platform that uses deep learning algorithms distribute throughout the IoT continuum.

Table 11 aerOS project

Name (Acronym)	Autonomous, scalablE, tRustworthy, intelligent European meta Operating System for the IoT edge-cloud continuum (aerOS)
Tags	IoT, edge, cloud, orchestration, network, artificial intelligence, trust, security, data management
Short description	Meta operating systems that follows a collaborative IoT-edge-cloud architecture supporting flexible deployments to achieve and optimal solution while satisfying the given constraings.

Table 12 FLUIDOS project

Name (Acronym)	Flexible, scalable and secUre decentralized OperationS (FLUIDOS)
Tags	Cloud, edge, artificial intelligence, security, resource management
Short description	Fluid, dynamic, scalable and trustable computing continuum that spans across devices, unifies edge and cloud in an energy-aware fashion, and possibly extends beyond administrative boundaries.

Table 13 ICOS project

Name (Acronym)	Towards a functional continuum operating system (ICOS)
Tags	Cloud, edge, resource management, orchestration, data management, artificial intelligence, security, trust
Short description	Meta operating system for a continuum, addressing challenges of devices volatility and heterogeneity, service execution and performance, trust, security and privacy, and costs reduction.

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Table 14 NebulOus project

Name (Acronym)	A META OPERATING SYSTEM FOR BROKERING HYPER-DISTRIBUTED APPLICATIONS ON CLOUD COMPUTING CONTINUUMS (NebulOus)
Tags	Cloud, edge, data management, artificial intelligence, security, blockchain, monitoring
Short description	Meta Operating System and platform for enabling transient fog brokerage ecosystems that seamlessly exploit edge and fog nodes, in conjunction with multi-cloud resources, to cope with the requirements posed by low latency applications.

Table 15 NEMO project

Name (Acronym)	Next Generation Meta Operating System (NEMO)
Tags	Edge, cloud, orchestration, artificial intelligence, security
Short description	Open source, flexible, adaptable, cybersecure and multi-technology meta-Operating System.

Table 16 NEPHELE project

Name (Acronym)	A LIGHTWEIGHT SOFTWARE STACK AND SYNERGETIC META-ORCHESTRATION FRAMEWORK FOR THE NEXT GENERATION COMPUTE CONTINUUM (NEPHELE)
Tags	Cloud, edge, IoT, network, artificial intelligence, orchestration
Short description	Efficient, reliable and secure end-to-end orchestration of hyper-distributed applications over programmable infrastructure that is spanning across the compute continuum from Cloud-to-Edge-to-IoT, removing existing openness and interoperability barriers in the convergence of IoT technologies against cloud and edge computing orchestration platforms, and introducing automation and decentralized intelligence mechanisms powered by 5G and distributed AI technologies.

Table 17 AC3 project

Name (Acronym)	Agile and Cognitive Cloud edge Continuum management (AC3)
Tags	Cloud, edge, data management, IoT, artificial intelligence

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Short description	Agile and cognitive cloud-edge continuum management framework providing scalability, agility, effectiveness, and dynamicity in service delivery over the cloud edge computing continuum infrastructure.

Table 18 ACES project

Name (Acronym)	Autopoietic Cognitive Edge-cloud Services (ACES)
Tags	Cloud, artificial intelligence, edge, resource management, monitoring, orchestration
Short description	Infused autopoiesis and cognition on different levels of cloud management to empower with AI different functionalities.

Table 19 CloudSkin project

Name (Acronym)	Adaptive virtualization for AI-enabled Cloud-edge Continuum (CloudSkin)
Tags	Cloud, edge, artificial intelligence, security
Short description	Cognitive cloud continuum platform leveraging AI/ML to optimize workloads, resources, energy, and network traffic for a rapid adaptation to changes in application behaviour and data variability.

Table 20 CODECO project

Name (Acronym)	Cognitive Decentralised Edge Cloud Orchestration (CODECO)
Tags	Cloud, edge, artificial intelligence, data management, orchestration, network
Short description	Cognitive, cross-layer and highly adaptive Edge-Cloud management framework with a unique orchestration approach that provides support for data management and governance decentralised data workflow; dynamic offloading of computation and computation status; and adaptive networking services.

Table 21 COGNIFOG project

Name (Acronym)	AI-empowered Edge Cloud Continuum for self-aware cognitive computing environments (COGNIFOG)
Tags	Cloud, edge, artificial intelligence, security, orchestration
Short description	Cognitive Fog Framework to reduce energy consumption and latency, reduce OPEX and ensure European leadership.

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Table 22 DECICE project

Name (Acronym)	Device-Edge-Cloud Intelligent Collaboration framework (DECICE)
Tags	Edge, artificial intelligence, monitoring
Short description	Open and portable cloud management framework for automatic and adaptive optimization of applications by mapping jobs to the most suitable resources in a heterogeneous system landscape.

Table 23 EDGELESS project

Name (Acronym)	Cognitive edge-cloud with serverless computing (EDGELESS)
Tags	Cloud, artificial intelligence, orchestration, edge, network
Short description	Orchestration system that provides a flexible horizontally scalable compute solution able to fully use heterogeneous edge resources, while preserving vertical integration with the cloud and the benefits of serverless.

Table 24 MLSysOps project

Name (Acronym)	Machine Learning for Autonomic System Operation in the Heterogeneous Edge-Cloud Continuum (MLSysOps)
Tags	Cloud, edge, resource management, orchestration, artificial intelligence, security
Short description	Framework for autonomic end-to-end system management across the full cloud-edge continuum.

Table 25 SovereignEdge.Cognit project

Name (Acronym)	A Cognitive Serverless Framework for the Cloud-Edge Continuum (SovereignEdge.Cognit)
Tags	Cloud, edge, artificial intelligence
Short description	Distributed FaaS paradigm for edge application management and smart orchestration, which will change how applications and services are deployed and executed in the cloud-edge continuum.

Table 26 INCODE project

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Name (Acronym)	Programming Platform for Intelligent Collaborative Deployments over Heterogeneous Edge-IoT Environments (INCODE)
Tags	Cloud, edge, IoT, network, orchestration
Short description	Open platform for the deployment and dynamic management of end user applications, over distributed, heterogeneous and trusted IoT-Edge node infrastructures, with enhanced programmability features and tools at both the network infrastructure level and the service design and operational level.

Table 27 OASEES project

Name (Acronym)	Open Autonomous programmable cloud appS & smart EdgE Sensors (OASEES)
Tags	Edge, data management, artificial intelligence
Short description	Open, decentralized, intelligent, programmable edge framework for Swarm architectures and applications, leveraging the Decentralized Autonomous Organization paradigm and integrating Human-in-the-Loop processes for efficient decision making.

Table 28 OpenSwarm project

Name (Acronym)	Orchestration and Programming Energy-aware and collaborative Swarms With AI-powered Reliable Methods (OpenSwarm)
Tags	Data management, network, artificial intelligence
Short description	True collaborative and distributed smart nodes.

Table 29 SMARTEDGE project

Name (Acronym)	Semantic Low-code Programming Tools for Edge Intelligence (SMARTEDGE)
Tags	Cloud, edge, network, orchestration
Short description	Cross-layer toolchain that facilitates the seamless and real-time discoverability and composability of autonomous intelligence swarm.

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Table 30 TaRDIS project

Name (Acronym)	Trustworthy and Resilient Decentralised Intelligence for Edge Systems (TaRDIS)
Tags	Data management, artificial intelligence
Short description	Novel programming paradigm with a toolbox for supporting the development and execution of applications.

Table 31 AERO project

Name (Acronym)	Accelerated EuRopean clOud (AERO)
Tags	Cloud, security
Short description	Open-source software ecosystem that encompasses a wide range of software components ranging from operating systems to compilers, runtimes, system software and auxiliary software deployment services for cloud computing.

Table 32 OpenCUBE project

Name (Acronym)	Open-Source Cloud-Based Services on EPI Systems (OpenCUBE)
Tags	Cloud
Short description	Full-stack solution of a validated European Cloud computing blueprint to be deployed on European hardware infrastructure.

Table 33 RISER project

Name (Acronym)	RSC-V for Cloud Services (RISER)
Tags	Cloud
Short description	All-European RISC-V cloud server infrastructure, significantly enhancing Europe's open strategic autonomy.

Table 34 Vitamin-V project

Name (Acronym)	Virtual Environment and Tool-boxing for Trustworthy Development of RISC-V based cloud Services (Vitamin-V)
Tags	Cloud, artificial intelligence, data management

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Short description	RISC-V open-source software stack for cloud services with iso-performance to the cloud-dominant x86 counterpart and a powerful virtual execution environment for software development, validation, verification, and test that considers the relevant RISC-V ISA extensions for cloud deployment.

Table 35 COSMOS project

Name (Acronym)	DevOps for Complex Cyber-physical Systems (COSMOS)
Tags	Artificial intelligence
Short description	Validation and verification, which will comprise a mix of static code analysis correlated with issues and bug reports, automated test-case generation, runtime verification, hardware in the loop testing and feedback from field devices.

Table 36 ELEGANT project

Name (Acronym)	Secure and Seamless Edge-to-Cloud Analytics (ELEGANT)
Tags	IoT, data management, artificial intelligence, security
Short description	Software solution that addresses key challenges facing IoT and Big Data: interoperability, reliability, safety and security.

Table 37 FOCETA project

Name (Acronym)	FOUNDATIONS FOR CONTINUOUS ENGINEERING OF TRUSTWORTHY AUTONOMY (FOCETA)
Tags	Artificial intelligence, data management, trust
Short description	Foundation for continuous engineering of trustworthy learning-enabled autonomous systems integrating data-driven and model-based engineering.

Table 38 PIACERE project

Name (Acronym)	Programming trustworthy Infrastructure As Code in a sEcuRe framework (PIACERE)
Tags	Cloud, network
Short description	Tools, techniques and methods to allow organisations to develop and operate IaC through DevSecOps practices as they would do with traditional code.

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Table 39 VeriDevOps project

Name (Acronym)	VeriDevOps (VeriDevOps)
Tags	Security
Short description	Methods and tools that provide a faster feedback loop for verifying the security requirements in large-scale cyber-physical systems.

Table 40 XANDAR project

Name (Acronym)	X-by-Construction Design framework for Engineering Autonomous & Distributed Real-time Embedded Software Systems (XANDAR)
Tags	Security, artificial intelligence
Short description	Software toolchain that fulfils the industrial requirements for rapid prototyping of interoperable and autonomous ES.

Table 41 SPADE project

Name (Acronym)	Multi-purpoSe Physical-cyber Agri-forest Drones Ecosystem for governance and environmental observation (SPADE)
Tags	Cloud, edge, data management, artificial intelligence
Short description	Ecosystem based on UAVs (drones) to promote sustainable digital services. This includes individual UAV usability, type applicability, governance models availability and trustworthiness.

Table 42 TEADAL project

Name (Acronym)	Trustworthy, Energy-Aware Federated Data Lakes Along the Computing Continuum (TEADAL)
Tags	Cloud, edge, data management, trust
Short description	Cloud and edge data management system that shares data sets in a traceable, trustworthy and confidential manner.

Table 43 TRUSTEE project

Name (Acronym)	TRUST AND PRIVACY PRESERVING COMPUTING PLATFORM FOR CROSS-BORDER FEDERATION OF DATA (TRUSTEE)
Tags	Data management, security, trust

Short description	Green, secure, trustworthy and privacy-aware framework that aggregates multiple interdisciplinary data repositories and also takes into account other European data federation spaces and transnational initiatives.

Table 44 TRANSACT project

Name (Acronym)	Transform safety-critical cyber-physical systems into distributed solutions for end-users and partners (TRANSACT)
Tags	Edge, cloud, security, data management, artificial intelligence
Short description	Universal distributed solution architecture for the transformation of safety-critical CPS from local, stand-alone systems into safe and secure distributed solutions.

Table 45 CROSSCON project

Name (Acronym)	Cross-platform Open Security Stack for Connected Devices (CROSSCON)
Tags	Security, edge, IoT
Short description	Open, flexible, highly portable and vendor-independent IoT security stack that can run across different edge devices and multiple HW platforms.

4.4 Graphical representation

This is the last task of WP2, with the objective of presenting in a web form the knowledge and findings of the previous tasks. As such, the graphic design is nurtured by the results of the previous tasks in order to provide an easy way of understanding them.
The initial idea for the graphical representation of the continuum landscape is the development of an actionable map where all projects will be represented according to the part of the continuum they are related to: cloud, edge or IoT. Clicking on each of them will open a pop-up with a short description, the information about the building blocks it is related to and the link to its website. Additionally, the information about the taxonomy will be made available through this map. The first iteration of the actionable map was developed starting from the CNCF Cloud Native Interactive Landscape (https://landscape.cnf.io/) and evolved both graphically and functionally to support the needs of the continuum stakeholders.

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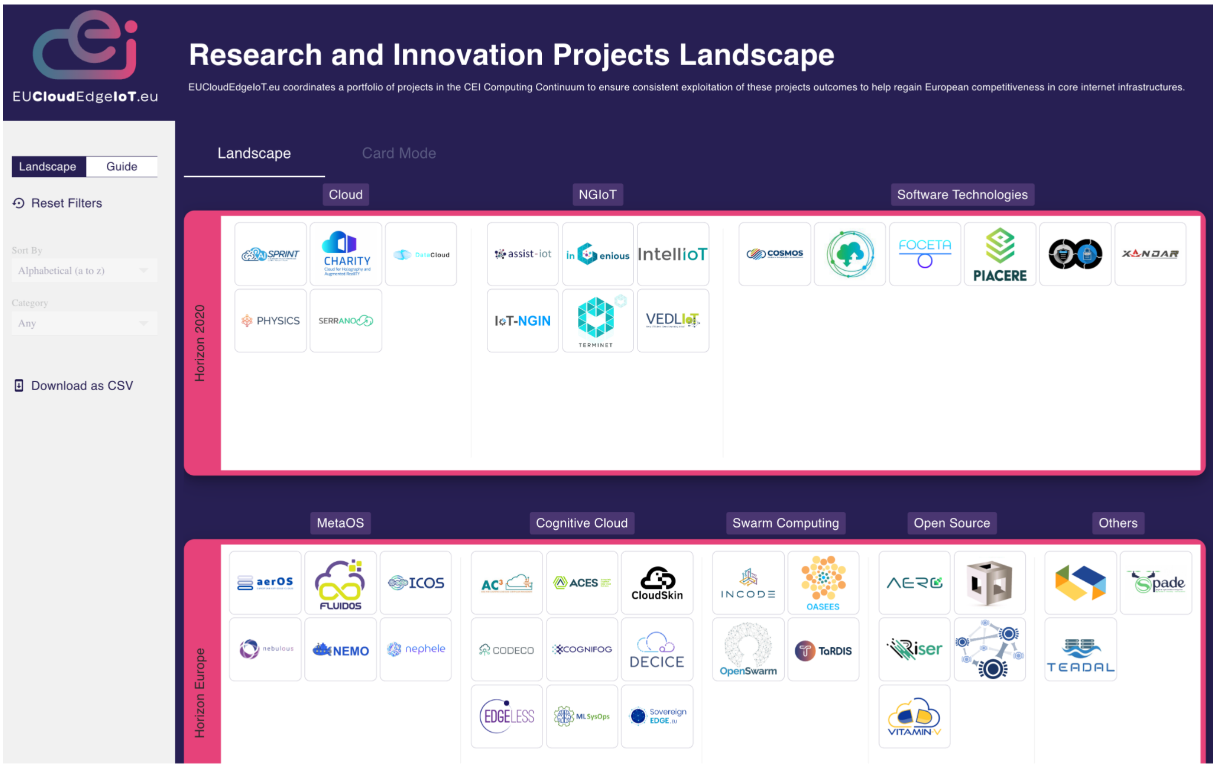

Figure 6 First iteration of the actionable map

Figure 7 Detail card

A second iteration will be more focused on the solutions developed by each project and how they are contributing to the implementation of the continuum reference architecture.

5 Recommendations and Next steps

This document presented the work done during the first period of the project for developing the European continuum landscape.
Several activities, such as the identification and analysis of the most commonly used standardised definitions for cloud, edge and IoT terms and the development of the methodologies to be applied, have been already performed during this period. While other activities have been identified and will be performed during the last period of the project.
According to the work already done, there are some recommendations to be taken into account during the second period of the project:

- There are many projects addressing the same research challenges from different perspectives. However, there is a lack of communication between them. Workshops have demonstrated to be a useful tool to put in common the work done by each of them and share the knowledge gained during the research and development phase. Thus, more workshops are needed to collect and share this information.
- The different levels of maturity of the projects make it difficult to assess their results or to identify in which aspect of the reference architecture they might contribute. Thus, actions for the development of the reference architecture will be undertaken during the second period of OpenContinuum matching with the first version of the architectures developed by the projects starting later.
- Most of the projects have different naming conventions for common terms, mainly due to the background of the participants. Thus, the taxonomy has highlighted its important so it can be mapped with their own glossaries.
- It is not easy to categorise project results in the continuum according to the available information. Also taking into account that not all projects are on the same stage. Thus, two or more iterations of the survey for assessing results are needed. The first one to be performed with projects ending in 2023, also to validate the conceptual framework.
- There is a gap between cloud-edge and IoT projects for interconnecting their architectures due to the different definitions of the continuum. The harmonisation of this concept is a crucial step for developing a continuum approach.
- There are several initiatives working on the continuum, each of them from their own perspective. What ends, again in a gap in the definition of the continuum itself.
- Different projects are developing their own architectures for the continuum, mainly based on their specific use cases' needs. Thus, there is a need for developing the reference one that can be mapped with each of these solution ones highlighting which specific aspects each project is addressing.
- Market fragmentation and the dependency of third-party software is preventing Europe from reaching a total autonomy in the continuum arena. More efforts should be invested in analysing the available software and the current gaps.
- Overall, there is a lack of homogenisation in the continuum itself, starting from its definition. Thus, the work done in OpenContinuum must reinforce the agreements between different actors to interact under a common umbrella.

As for the next steps, although they are mentioned along the document, the following list summarises them:

- Properly document the taxonomy and make it available.

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- Conduct the survey for research projects within the projects ending in 2023 to start the landscape.
- Conduct a research analysis on the state of the art to be included in a common survey paper.
- Start with the definition of the reference architecture based on the identified building blocks so it can be submitted to a standardisation body before the end of the project.
- Organise more workshops with the ongoing projects to include new results from those already started and initial feedback from those starting this year.
- Further develop the graphical representation of the European research landscape and validate it within different stakeholders.
- Present the results of this WP to different actors, not only from research, to gather their feedback and update them when needed.

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1. Appendix A: Workshops

Two main workshops were organised during this year and, although properly documented in the dissemination deliverable, a summary is also included here to make the document self-contained and provide the needed information to ensure its readability.

Name: Common Taxonomy for EU MetaOS: First Workshop

Date: 3rd April 2023

Number of attendees: 30

Projects involved:

- aerOS – Autonomous, scalablE, tRustworthy, intelligent European meta–Operating System for the IoT edge-cloud continuum
- FLUIDOS – Flexible, scaLable and secUre decentralizeD Operation
- ICOS – Towards a functional continuum operating system
- NebulOus – A meta operating system for brokering hyper-distributed applications on Cloud computing continuums.
- NEMO – Next Generation Meta Operating System
- NEPHELE – A lightweight software stack and synergetic meta-orchestration framework for the next generation compute continuum
- TRANSACT – Towards safe and secure distributed cyber-physical systems.

Objectives: The aim of this workshop was to gather all EU MetaOS projects to work collaboratively on the development of a common standardised taxonomy for the continuum as well as the minimum expected functionalities for each of the Continuum layers.

Results: This first workshop of the series brought together MetaOS cluster representatives, and an ECSEL one, to discuss a common terminology as well as the minimum expected functionalities for each of the Continuum layers. Participants in this initial discussion included project coordinators and technical managers, aiming to find a common understanding on the definition of the Continuum from a compute pipeline perspective. Results collected from this interaction are under consolidation for refining the initial proposal of the Continuum architecture building blocks and terms to be added to the taxonomy.

Name: Common taxonomy for the EuCloudEdgeIoT Continuum (2nd workshop)

Date: 21st July 2023

Number of attendees: +60

Projects involved: 29

6GSMART; AC3; ACES; aerOS; AIDOaRt; ASSIST-IoT; CODECO; Cognifog; Cognit; SovereignEdge; Edgeless; Extract; FLUIDOS; ICOS; IoT-NGIN; MLSysOps; MLSysOps; NebulOuS; NEMO; Nephele; OpenContinuum; PHYSICS; PIACERE; RISER; SERRANO; SmartEdge; Teadal; TERMINET; TRANSACT; Unlock CEI.

Objectives: to find a common understanding on the definition of the Continuum from a compute pipeline perspective and the essential building blocks for the Architecture.

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Results: More than 60 people participated in this discussion, including project coordinators and technical managers, Results collected from this interaction were used to consolidate the proposed building blocks for the continuum and additional terms to be added to the taxonomy.

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2. Appendix B: Survey for initiatives

This section contains the questions shared with other initiatives working within the Continuum context. This information, combined with OpenContinuum point of view, was used to identify technical gaps and synergies when operating in the Continuum.

CEI Survey – TF3

The purpose of this survey is to collect inputs from other initiatives addressing the challenge of understanding and developing the Cloud, Edge and IoT (CEI) Continuum.

1. *What initiative do you represent?*

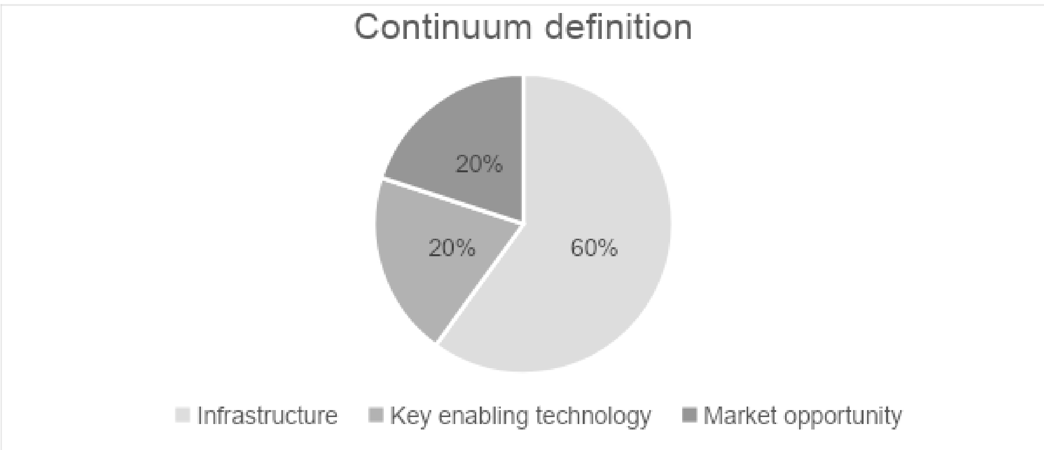
All the initiatives presenting their roadmap in the Concertation and Consultation event[1] were invited to participate. From them, this is the final list of participants in the survey:

- NESSI
- Inside
- FiWARE
- HiPEAC
- European Alliance for Industrial Data, Edge and Cloud

All of them provided feedback to all the questions listed below, and the analysis of results is included in each of them.

2. *Can you provide a brief description on what is the CEI under your point of view?*

This was probably the most difficult question to answer as there is not a harmonised definition of the Continuum.



Full answers (not edited) are as follows:

- A connected compute infrastructure (including management facilities) covering the whole continuum of compute nodes from end-user devices (smartphones, etc.), IoT devices, edge, and cloud.

[1] https://eucloudedgeiot.eu/concentration-and-consultation-meeting-on-computing-continuum-uniting-the-european-ict-community-for-a-digital-future/

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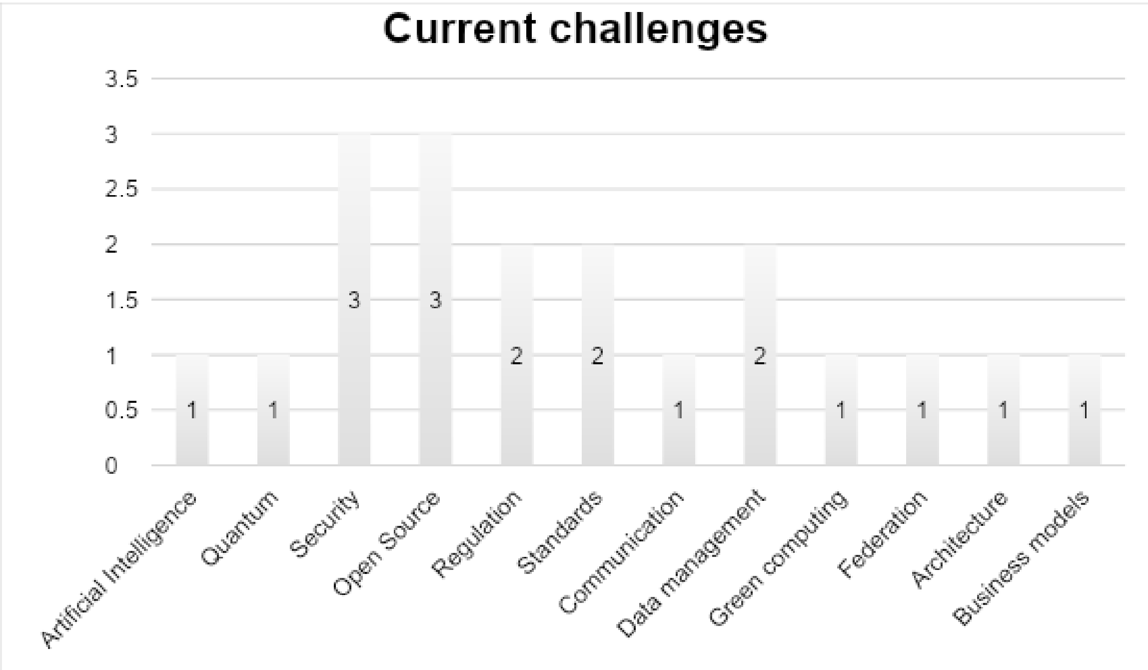
- CEI is the dynamic secured compute infrastructure that supports data capture, processing and sharing from end point to cloud and all infrastructure layers in between. The dynamism comes from the OS that supports increase/decrease of compute demand by sharing resources across the defined continuum.
- The continuum digital infrastructure to deploy data, services and digital solutions.
- It is a key enabling technology for the further digitalisation of society.
- An opportunity to reverse the cloud market and increase Europe's leadership position on industrial data.

At this stage it is needed to clarify that OpenContinuum considers it as a paradigm integrating cloud, edge and IoT ones. Thus, something beyond software and/or hardware, able to generate research challenges and business opportunities. So OpenContinuum vision is not only a little bit wider but also a compendium of others.

3. *From your point of view, what are the most pressing research challenges in this field right now?*

As expected, different initiatives have different points of view. However, there are some commonalities between their perspective about current research challenges.



All of these challenges also affect cloud, edge and IoT research thus, it makes sense that affects the integration of the three paradigms.

Full answers (not edited) are as follows:

- 1) Leveraging Generative AI for SE on the CEI; 2) Anticipating how to integrate Quantum Software into the CEI; 3) Stringent Software security and cybersecurity of the CEI; 4) Balanced approach to OSS (closed, open and AI generated code).
- EU rule on Cloud. Clear definition of EDGE. Secured comms (5G/6G with edge nodes in the networks). Trusted MetaOS on the continuum.
- Transparency from the user perspective, smooth and efficient transition from one infrastructure to another one, decentralized management of data across the continuum.
- Reliability, security, safety, privacy, ecological impact.

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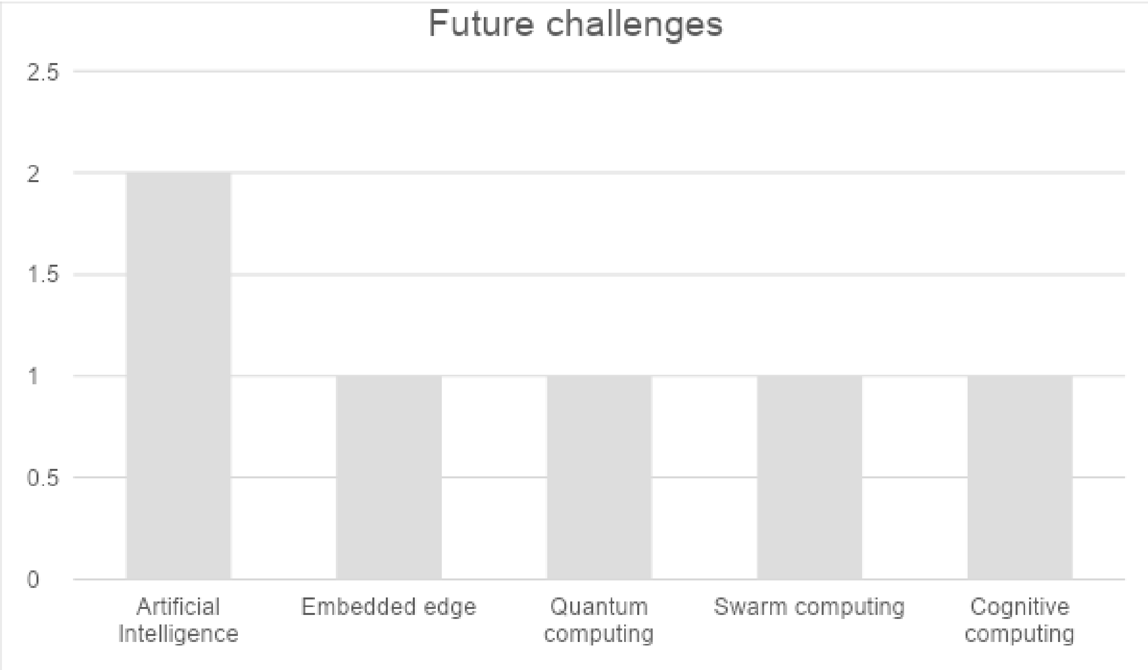
- 1) Representation in Open Standards, Relation to Norms & Standards, Industrial Data; 2) Multi-Provider Edge-Cloud Federation; 3) Support Distributed & Interoperable Architectures; 4) Make EU Regulations Fit for a Digital Sovereign Europe; 5) EU Standards on Pre-procurement of EU Products, Systems & Services; 6) Data-sharing Business Models.

OpenContinuum is also taking all of them into account, especially in the work done within TF3, in order to identify not only current but also future research challenges as the result of the continuum paradigm evolution.

4. *Which technologies are the most disruptive and which ones do you foresee coming into common use?*

According to the answers provided, those technologies that will come into common use can be considered as disruptive, as there is still room enough for more research (applied or not).



The identified future challenges by the initiatives are fully aligned with current research initiatives. So, according to this, the evolution of these technologies will set the basis for future research.

Full answers (not edited) are as follows:

- GenerativeAI (large language models, AI chatbots).
- Edge embedded in the 5G/G networks allowing alternative data processing capacity to join a continuum for the duration of data collection / sharing. e.g., smartphone connects to network, joins a continuum where data on local mobility is shared, reads the data and disconnects.
- I am not an expert in the domain, but looking at what experts say, the disruptive technologies will be: cognitive/swarm/quantum computing; and the ones entering into use: multi-cloud, containers, edge computing...
- Artificial intelligence is the most disruptive technology of today, and it will pop up everywhere around us in smart interconnected devices.
- The technology and deployment priorities can be grouped in three main domains: * Becoming the leader in the transversal technology domains that will shape the

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European cloud and edge offerings on the global market. The future cloud-edge continuum will require new innovative cross-layer and cross-domain services and technologies for carbon neutrality, cybersecurity, trustworthy data exchange, portability, and interoperability that will shape worldwide standards. * Renewing and expanding infrastructure foundations across Europe. The deployment of the cloud-edge continuum requires an increased density of edge and cloud computing facilities backed by ubiquitous connectivity and local 5G networks to deliver the right performance in terms of bandwidth and latency and managed with advanced orchestration technologies to guarantee efficient infrastructure utilisation. * Enabling sovereign and sector-specific services to end users. Existing infrastructure and platform cloud service offerings must be strengthened, with a focus on providing businesses with open-source sovereign software solutions for telecommunications, edge, HPC, and quantum computing services; and an open ecosystem of data services and advanced applications.

5. *What role do you see public-private partnerships playing in the development of the CEI continuum?*

One of the main goals of OpenContinuum is the development of the continuum landscape, this will let to know not only what projects have developed, or are developing, but to find the common points and the existing technological gaps. In this way, it will be easier to share or reuse them, to nurture project results through cross-fertilisation and to avoid the duplication of efforts. This will be done based on projects feedback and validated within other actors who can provide valuable feedback.

This also seemed to be the goal of the different initiatives working in the same topic.

Full answers (not edited) are as follows:

- Ensuring alignment of R&I activities (avoiding redundant work and funding on common elements, delivering innovation in specific, possibly domain-specific, features, standardisation).
- Network operators need to participate in this, supported by the EU tech providers.
- Further research on emerging topics and joint deployments in consolidated topics.
- This will depend on the sector. In sectors like mobility and energy, PPPs seems to be useful to build the infrastructure.
- They are needed to develop the technologies to operate the CEI continuum.

6. *How can those partnerships be leveraged effectively to foster innovation?*

As reflected by the initiatives the work done in WP2 and TF3 defining the reference architecture, and in WP1 and TF2 developing the open source stack seems to be a key activity to support the European digital autonomy in the continuum.

Full answers (not edited) are as follows:

- Provide an architectural approach to defining the participating projects in the partnership, i.e., starting from a concise (even if high-level) reference architecture, to assure alignment of the various outcomes.
- Research might not be what they want to share but on OpenCalls they should participate in Tech Extension and in Verification of results.
- By leveraging on open standards and open source.
- The funding agencies could, e.g., subsidize low TRL research, pilot systems...

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- In the context of open-source communities and organizations that define open specifications and standards.

7. *What are the most significant challenges in building an open ecosystem for the CEI continuum in Europe?*

According to the initiatives, the most significant challenges are the development of open source software itself and the involvement of different actors. This is also a common pain point for all research projects. The different activities within OpenContinuum aim to address these challenges, but further support will be needed when the project ends.

Full answers (not edited) are as follows:

- Bringing together all relevant stakeholders (from R&I) to deployment and uptake and doing it in an efficient and fast manner adequate for innovation in ICT.
- Too much dependency on non-EU actors. Open means sharing and that might be conflicting with economic models, although an Open Source approach (not just SW) as in joint research will help speed up EU innovations to align with chips and data act.
- Do not reinvent the wheel and duplicate what is already done.
- Standards, adoption.
- See Section 11 in https://digital-strategy.ec.europa.eu/en/news/european-alliance-industrial-data-edge-and-cloud-presents-its-first-deliverables.

8. *How can those challenges be addressed?*

All initiatives seem to be aligned with the approach followed by OpenContinuum to foster collaboration and knowledge share between projects and other stakeholders.

Full answers (not edited) are as follows:

- Speeding up the time from idea to result (shorter periods of WPs, faster time from proposal to execution, involving industry players...)
- C&C meeting like on 10-11 May on more defined technical issues to conclude on how tech partners can contribute supported by EC.
- Open exchange of knowledge, wider communication across communities/initiatives, kind of events like the concertation meeting.
- Bringing the relevant stakeholders together.
- See Section 11 in https://digital-strategy.ec.europa.eu/en/news/european-alliance-industrial-data-edge-and-cloud-presents-its-first-deliverables.

9. *What are the main barriers for the adoption of CEI technologies and solutions?*

Europe is providing plenty of novel software, mainly open source, but it seems that it is not reaching the appropriate channels so customers can adopt it. As OpenContinuum focuses on the supply side, it is necessary to strength the collaboration with Unlock-CEI to reach targeted stakeholders within the demand side.

Full answers (not edited) are as follows:

- Gap between invention and innovation / adaption. What happens with all the outcomes of CEI projects? There may be organisation specific exploitation, but could there be a bigger picture?

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- Understanding of concept, trust from consumer part. reliability and availability from provider side. from EC continuation of R&I but stronger support for IA to speed up realisation.
- Sense of lack of privacy.
- Investments, total cost of ownership, change management.
- See Section 11 in https://digital-strategy.ec.europa.eu/en/news/european-alliance-industrial-data-edge-and-cloud-presents-its-first-deliverables.

10. *In your opinion, how can those barriers be overcome?*

This question is directly related with number 7 and the pain adoption points identified. However, the main issue is directly related to the implementation of the exploitation plans thus, out of the scope of OpenContinuum.

Full answers (not edited) are as follows:

- (1) Offering a clear path from HE funding to DEP or other higher TRL paths. (2) Considering a 1-2 year extension of projects (after successful final review) without additional proposal to facilitate exploitation and uptake.
- CSA's to support IA with higher funding rate if EU proven development, etc.
- Education of users, regulation compliance by all providers.
- Prove that the technology reduces cost.
- See Section 11 in https://digital-strategy.ec.europa.eu/en/news/european-alliance-industrial-data-edge-and-cloud-presents-its-first-deliverables.

11. *What are some of the most promising use cases for CEI technologies and solutions in Europe?*

The information provided by the initiatives can be used for the selection of use cases in new proposals and to look for stakeholders to validate the results of OpenContinuum.

Full answers (not edited) are as follows:

- AR, VR, XR, which requires immense power at the edge in alignment with end-user devices.
- Manufacturing, Mobility, Environmental monitoring, Smart City.
- Data Spaces.
- Almost any sector: mobility, energy, health, cities, agriculture...
- Please see Use Cases and Enablers in https://digital-strategy.ec.europa.eu/en/news/european-alliance-industrial-data-edge-and-cloud-presents-its-first-deliverables.

12. *How can your initiative help to promote these use cases?*

As all initiatives are also on the supply side, the collaborations with initiatives from the demand side, such as Unlock-CEI, may benefit both sides.

Full answers (not edited) are as follows:

- NESSI is not domain-specific.
- In the MetaOS's these UC are represented, but the Open Calls should provide support needed.

- Bringing liasion with data spaces and all the upcoming emerging pilots that will arise in following deployment projects.
- HiPEAC is working on the underlying computing technologies (not the applications). We will keep doing this.
- Please see Use Cases and Enablers in https://digital-strategy.ec.europa.eu/en/news/european-alliance-industrial-data-edge-and-cloud-presents-its-first-deliverables.

13. *How can your initiative encourage greater adoption of CEI across different industries and sectors?*

Full answers (not edited) are as follows:

- We are doing so by creating awareness of the opportunities but also challenges entailed.
- Publications, dissemination events, open call support.
- Use of FIWARE network of members and Innovation Hubs worldide to expand the word.
- This falls a bit out of the scope of HiPEAC, we are not focussing on application domains and sectors, but on the underlying technology.
- Development of technology roadmaps to meet the needs of emerging, highly innovative use cases and enablers that are critical for strengthening the position of the EU industry regarding next-generation cloud and edge technologies, and industrial data.

14. *How can we ensure that there is real coordination and alignment between different CEI initiatives across Europe?*

Full answers (not edited) are as follows:

- There need to be less initiatives; the current landscape is overly convoluted and complex, really difficult to navigate (e.g., GAIA-X, IPCEI, Alliance on..., FIWARE, IDSA/EDIH...).
- jTF's as currently in place supported by OpenContinuum and UNLOCK-CEI should be active on a continuous basis not just as long as CSA's are operational.
- Coordination teams/projects endorsed by the European Commission.
- Regular coordination meetings.
- Open specifications and open source software. They minimise vendor lock-in and gives Europe a chance to create and maintain its own, independent digital approach and to stay in control of its processes, information, and technology, fostering an open ecosystem around sustainable joint innovation. Following the approach defined by the new Standardisation Strategy presented by the European Commission in early February 2022, the new developments should make use of and produce open source implementations of open standards.

15. *Is there anything else you would like to add?*

Full answers (not edited) are as follows:

- No.
- Look forward to the results.
- Thanks!
- We are happy to help where we can.
- No.

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3. Appendix C: Survey for research projects

This section contains the questions for European projects in order to 1) determine the domains where the apply, information needed for the initial landscape; 2) identify current gaps and future challenges; and 3) list all the available results so any external stakeholder having a look to the research project can also easily identify the available research results. This information will be included in the second iteration of the project landscape. However, it does not want to substitute the EC Innovation Radar, but to be use as a knowledge base of technical assets and open source/standards contributions.

All projects are invited to contribute with their results, independently of the TRL, answering the questionnaire once per asset. The survey was tested with one project, ASSIST-IoT, to double check if any update is needed.

Landscape Framework for Research Assets Evaluation

The framework is built up on four main pillars for categorizing research results into the overall European Cloud-Edge-IoT Continuum landscape.

Basic Information

Public information to be published in the online landscape

4. *Name of the asset*
5. *Project*
6. *Short description*
7. *TRL and MRL*
8. *License*
9. *Owner – organisation*
10. *Contact*
11. *Link to the source code (if any)*
12. *Link to the documentation (if any)*
13. *Link to a demo video (if any)*
14. *Tags for categorising the asset (separated by commas)*
15. *Domain(s) where the asset has been tested: Smart City, Smart Building, Smart Vehicle, Smart Grid, Smart Living, Smart Factory, Other*
16. *Main functionalities*

Functional Capability

To measure the applicability of the identified solution in terms of reusability and replicability

1. *Is the asset available for external stakeholders (e.g., in a public repository)? Yes/No/NA*
2. *Does the asset have any supporting documentation (installation, configuration and user manual)? Yes/No/NA*
3. *Has the asset been tested in more than one applicability scenario? Yes/No/NA*
4. *Is there any replicability plan that can be followed? Yes/No/NA*
5. *Are there any recommendations about how to better use the asset? Yes/No/NA*
6. *Is there any demo scenario that can be reused? Yes/No/NA*
7. *Is the asset management following a standardised procedure? Yes/No/NA*
8. *Does the asset have any support mechanism? Yes/No/NA*
9. *Does the asset follow an open source licensing scheme?*

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10. Is there any information about how costly (in terms of efforts) is to use the asset in a given context? Yes/No/NA

Technological Capability

To measure the maturity itself of the solution in terms of TRL and dependencies

1. *Does the asset need other technology solutions to work? Yes/No/NA*
2. *Is the TRL high enough to be market-ready in short-medium term? Yes/No/NA*
3. *Can the asset be easily integrated within other existing solutions? Yes/No/NA*
4. *Does the asset have any dependency of external data? Yes/No/NA*
5. *Does the asset have any dependency of the use cases developed within the project? Yes/No/NA*
6. *Is the impact of the asset measured? Yes/No/NA*
7. *Does the asset have a clear development roadmap (after the end of the project)? Yes/No/NA*
8. *Is there any knowledge/technology transfer needed? Yes/No/NA*
9. *Does the asset have more than one owner? Yes/No/NA*

Operational Capability

To measure the organisation capability to put a new service/product in the market in terms of SRL and MRL

1. *Does the asset have a supporting team or any other type of supporting mechanism (in terms of assigned people)? Yes/No/NA*
2. *Does the asset have a clear roadmap for exploitation (commercial, research, etc.)? Yes/No/NA*
3. *Does the asset count with the required infrastructure? Yes/No/NA*
4. *Is there any long-term strategy for ensuring the sustainability of the asset? Yes/No/NA*
5. *Is the asset aligned with the organisation strategy? Yes/No/NA*
6. *Is there any market analysis performed for the asset? Yes/No/NA*
7. *Is the IP of the asset protected? Yes/No/NA*
8. *Does the asset have a clear value proposition? Yes/No/NA*
9. *Have the competitors been identified and positioned against the asset? Yes/No/NA*
10. *Is the market segment for the asset properly identified? Yes/No/NA*

Engagement Capability

To measure the market potential based on the ability of engaging customers/adopters

1. *Has the asset been validated with any external stakeholder (beyond the project use cases)? Yes/No/NA*
2. *Have the channels for exploiting the asset been identified? Yes/No/NA*
3. *Is there any go-to-market strategy in place? Yes/No/NA*
4. *Is there any SDO involved within the asset? Yes/No/NA*
5. *Is there any open source community involved within the asset? Yes/No/NA*
6. *Has any external stakeholder expressed interest in the asset? Yes/No/NA*
7. *Has the asset been presented to external stakeholders? Yes/No/NA*

Other Information

Any other additional information that you consider useful for external readers to better understand the asset

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1. Additional information

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17. Appendix D: Taxonomy for the Continuum

According to the faceted taxonomy definition, there are three main pillars: Cloud, Edge and IoT and a miscellaneous category for those terms that are not related to any of them. At the same time, there are 8 building blocks: Security, Trust & Reputation, Data management, Resource management, Orchestration, Network, Monitoring & Observability and AI.

Name	Taxonomy for the Continuum
Version	0.1
Year	2023

Terms belonging to the main pillars are not included in this list, although they will be included in the online material, properly referenced, to avoid the need of consulting different sources. Thus, only common terms for the continuum, related to the building blocks and not included in any of the consulted taxonomies are defined as follows[2]:

Term	Definition	Building block
Security	Strategy that prevents unauthorized access, and activities, to software and hardware.	Security
Privacy	Strategy that prevents unauthorized access, and activities, to data.	
Anomaly detection	Identification of rare activities that are different of the behavioural patterns.	
Authorization	Determination of access rights.	
Authentication	Verification of the identify.	
Threat[3]	Any circumstance or event with the potential to adversely impact organisational operations.	
Encryption	Process of converting information to ciphertext.	
Anonymisation[4]	Process of removing personal identifiers, both direct and indirect, that may lead to an individual being identified.	
Trust[5]	The confidence one element has in another, that the second element will behave as expected.	Trust & Reputation
Reputation	Security mechanism to determine the legitimacy or safety of any given source.	
Traceability	Capacity to trace (follow history) data.	

[2] If any of the terms is already defined by another standard, or de facto standard, that is the used definition.

[3] https://csrc.nist.gov/glossary/term/threat

[4] https://www.ucl.ac.uk/data-protection/guidance-staff-students-and-researchers/practical-data-protection-guidance-notices/anonymisation-and

[5] https://csrc.nist.gov/glossary/term/trust

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Accountability[6]	A property that ensures that the actions of an entity may be traced uniquely to that entity.	
Smart contract	Type of blockchain application execute according to predefined conditions.	
Confidentiality[7]	Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information.	
Governance	Set of standardised policies and processes to ensure the efficient and effective use of information.	Data management
Interoperability	Ability of data of being accessible and consumed.	
Thinning	Act of reducing data in a dataset.	
Pattern	Data repeated in the same recognisable way.	
Discovery	Process of collecting information from different sources.	
Consistency	Ability of data for remain the same across different locations.	
Availability	Timeless and reliable access to data.	
Storage	Information registry using certain technology.	
Federation	Independent resources grouped by a previous agreement.	Resource management
Registry	Directory of resources.	
Ad-hoc clustering	Automatic grouping of independent resources for executing a given action.	
Resource	Hardware or software system needed to perform an action.	
Communication	Data model that allows the interaction between different resources.	
Orchestration	Coordination and management of resources.	Orchestration
Balancing	Task distribution over a set of resources.	
Adaptation	Process of adapting behaviour to environmental conditions.	
Scalability	Ability to continue working properly when there are changes in size and/or volume.	
Autoscaling	Automatically increase or decrease of the number of resources.	
Offloading	Transfer from a resource to another resource.	
Migration	Shifting from one resource to another resource.	
Deployment	Action of making a system ready to use.	
Lifecycle	Stages followed since the creation of a service/application.	

[6] https://csrc.nist.gov/glossary/term/accountability
[7] https://csrc.nist.gov/glossary/term/confidentiality

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Brokerage	Facilitates transactions.	
Choreography	Technique of using algorithms to define the lifecycle.	
Slicing	Action of creating independent and secured parts of a network.	Network
Tunnelling	Technique for implementing private network communications over a public network.	
Mobility	Ability to provide communications between nodes even if they change their position.	
Observability	Ability to measure the system health based on collected data.	Monitoring & Observability
Telemetry	Data collection and transmission from remote sources.	
Frugal AI	Action of training systems with little resources.	AI
Tiny AI	Action of minimising the usage of data and computing power by using compressed algorithms.	
Federated learning	Technique to decentralised train algorithms.	
Swarm learning	Decentralised technique that allows resource collaboration using edge and blockchain.	

This version is not the last one, as according to the methodology for developing a taxonomy, it must be supported and updated when needed.

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