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D1.2 A STRATEGY FOR EUROPEAN DIGITAL AUTONOMY THROUGH OPEN SOURCE, STANDARD AND ALLIANCES

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Abstract	This document reports the community building and communication strategy and describes the activities OpenContinuum pursues to guarantee broad visibility, promotion and uptake of the European Cloud, Edge & IoT Continuum, but also of Cloud Computing projects and other relevant initiatives at European and international level.
Keywords	Open Source, Standardisation, Liaison, Continuum

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

DEM: Demonstrator, pilot, prototype, plan designs

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DATA: Data sets, microdata, etc

DMP: Data management plan

ETHICS: Deliverables related to ethics issues.

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

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EXECUTIVE SUMMARY

This deliverable describes the results of the OpenContinuum work about 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 the main topic, three important aspects in the lifetime of a European project: 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 practices 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.

Upon these objectives, the document presents the results under three different views:

- Open source strategy and role, including the main objectives, the description of the target audiences and the strategic actions performed during this period. 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.
- Open standard overview providing the study of several approaches and activities that have been used to support the project's work.
- EU Alliances and Open Ecosystem explaining the relation and the activities organised to facilitate this collaboration.

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ABBREVIATIONS

ECC	European Cloud Computing
CC	Cloud Computing
MetaOS	Meta Operating System
EC	European Commission
CEI	Cloud, Edge, and IOT
OSS	Open Source Stack

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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 final work of the Work Package 1 (WP1) 'OpenContinuum IMPACT' and describes the results of the actions and the studies carried out during the last period.

In particular, it describes OpenContinuum works on European open source (initiatives, communities and standardisation) as well as the liaison between EU Alliances and Ecosystems based on an open collaboration approach. It promoted 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 reinforced this commitment. In this respect, through the European Cloud, Edge & IoT Continuum initiative, together with Unlock CEI, the main activities of this WP were 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 strategies and governance models (?).
- 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.
- Train research projects on successful processes to standardise open source outcomes.
- Support computing continuum research projects on pre-standardisation initiatives.

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- 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 the stakeholders and the ecosystem engaged in during the project period 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 actions performed during this period. 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 study of several approaches and activities that have been used 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.

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2 OUR STAKEHOLDERS & COLLABORATION

This section provides a high-level overview of the projects involved in the work. Figure below shows a graphic overview of the logos and the main topics of the Research Innovation Action (RIA) projects involved. An exhaustive detailed description can be found in the document D4.3 named 'Toward an European ecosystem for the computing continuum Working version'.

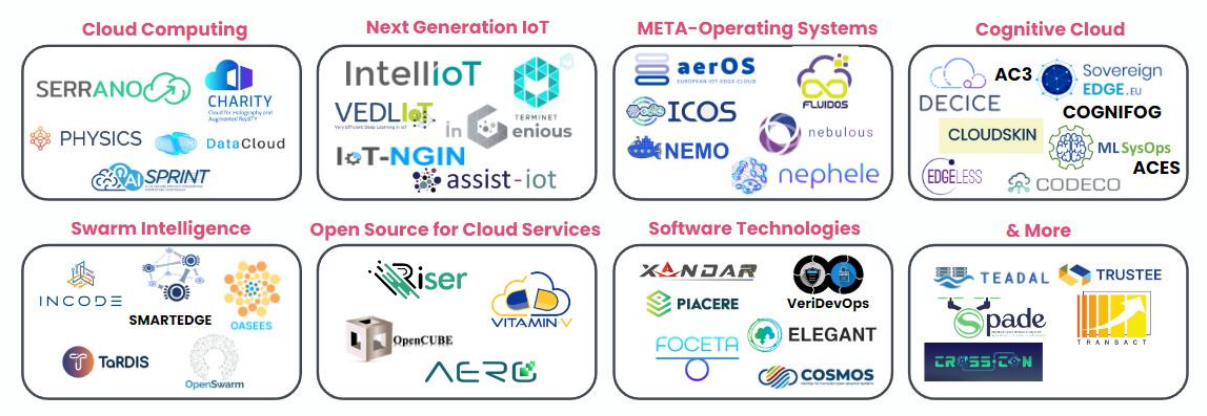

FIGURE 1 - EUCLOUDEDGEIOT ECOSYSTEM

Furthermore, the strong collaboration with UnlockCEI has been carried on with success under the umbrella initiative called European Cloud Edge IoT Continuum Initiative[1]

The European Cloud, Edge & IoT Continuum Initiative goal is to unlock the potential of these transformative technologies by understanding the supply and demand value chains in Europe. OpenContinuum aims to foster an open ecosystem for European strategic autonomy and interoperability across the computing continuum on the supply side. UnlockCEI aims to help accelerate the deployment of the Cloud-to-Edge-IoT (CEI) computing continuum on the demand side. Together, the joint initiative is set to regain European competitiveness and create a seamless, secure, sovereign, and sustainable internet infrastructure.

From this collaboration six Task Forces have been created, and two of them enriched the work of this WP:

- TF1 - Strategic Liaisons
- TF2 - Open Source Management mainly

The resulting work will be described along this document.

[1] https://eucloudedgeiot.eu

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FIGURE 2 - EUCLOUDEDGEIOT.EU

2.1 LIAISON WITH RELEVANT EUROPEAN CLOUD AND IOT COMPUTING INITIATIVES

OpenContinuum project directly expresses the core ambition of fostering European strategic autonomy and interoperability through an open ecosystem for the computing continuum, using a blend of evolutionary and transformative measures with respect to past and current practices of coordination and support work.

The current Computing Continuum context is the joint evolution of the Cloud Computing and Internet of Things domains. OpenContinuum is related to various ECC and IoT initiatives that are on-going. The most relevant ones are:

- MetaOS Projects
- H-CLOUD
- HUB4CLOUD
- SWForum
- OPEN DEI
- EU-IoT
- NGIOT
- 5G PPP
- GAIA-X
- KDT-JU & Chips JU
- IDSA
- 6G-IA
- AIOTI
- ARTEMIS-IA
- Data Spaces Business Alliance
- European Alliance for Processors and Semiconductor Technologies
- TransContinuum Initiative
- EUROHPC
- Etc. (see the next Figure 1).

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FIGURE 3 - OVERVIEW OF VARIOUS ECC AND IOT INITIATIVES

This rich and heterogeneous ecosystem covers the entire edge-to-cloud computing continuum, with initiatives and alliances addressing enabling technologies, architectures, critical building blocks and structural solutions, as well as vertical application domains that are key for Europe (see e.g. health care, manufacturing and automotive).

The OpenContinuum consortium is ideally positioned as its partners are directly involved in these projects and initiatives and will therefore guarantee to maximise the impact of the planned activities, while leveraging on recent achievements in close coordination with the IoT and Cloud EC Units at DG CONNECT.

2.1.1 The liaison activities

Liaison activities are the part of the core nature of INSIDE association. They are a continuous, multifaceted effort involving daily interactions, project-specific collaborations, and event-driven engagements. By aligning research agendas, fostering strong connections within the ECS community, and actively involving and promoting RIA projects, we weave a rich set of relationships that drive the entire community forward. In the specific context of the OpenContinuum, an important role for the liaison activities is played by Task Force 1 and its close cooperation with Task Force 6, which is directly connected with the RIA projects and carried on several activities including:

- Regular monthly calls
- Sharing updates
- Presenting event/networking opportunities
- Event participation
- Represent TF members
- Represent Compute Continuum efforts
- Organise event / publications
- Projects interviews
- Showcase projects

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The RIA projects that regularly and actively participated to the task forces activities include: HE-CODECO, INTEND, TEADAL, NEPHELE, MYRTUS, NebulOuS, ICOS, INCODE, EDGELESS, FLUIDOS, aerOS, VEDLIoT, ASSIST-IoT, INTELLIOT, VEDLIOT, COGNIFOG, DECICE, MLSysOps, SovereignEdge.Cognit, Vitamin-V.

2.1.2 KDT and Chips JU

INSIDE is a member of the KDT JU and of its successor the Chips JU, which started the operation in September 2023 continuing the activities of the KDT and extending them with the new objectives introduced by the Chips Act. In this industry-driven ecosystem, INSIDE role already includes the community building, the liaison activities, network creation, roadmaps and strategic research and innovation agenda definition, calls preparation: these activities represent a daily routine for the association, which builds strengths and value propositions on them.

The KDT and Chips JU projects address the technology domain of the electronic components and systems, which represent technology enablers for the edge-to-cloud continuum. In principle, any ECSEL/KDT/Chips JU project is directly or indirectly connected to it. For the liaison activities, we considered the projects that are directly investing the topic of the edge-to-cloud continuum and that provide architectures, building blocks and entire solutions for the continuum: AIMS5.0 and Arrowhead fPVN - Chips-JU IA projects (both projects are based on the Eclipse Arrowhead, therefore we have included in the liaison the Eclipse Arrowhead bi-weekly meeting and a session at the EclipseCon 2024 about edge-to-cloud data model interoperability), CPS4EU, AFARCLOUD, InSecTT, EDGE AI, FEDERATE, HAL4SDV, CONNECTS, TRISTAN, A-IQ READY, Newlife, REBECCA, CLEVER, H2TRAIN, AGRARSENSE, ISOLDE, Lollipop-IoT, ARCHIMEDES. Resilient-Trust, MLBuffet, AIDOaRT, and others.

The liaison activity included also events in the KDT/Chips JU ecosystem, where we covered the edge-to-cloud continuum promoting cooperation, coordination of projects, and initiatives alignment (see also the “Events” section):

- European Conference on Edge AI 17-19/10/23
- National mirror groups events such as ChipsIT (Rome, 6/3/2024) or ESBS Austria (Vienna, 14/05/2024).
- ESI Conference organised by TNO, Eindhoven, 15/04/2024.
- ECS Brokerage Event
- Liaison with SNS 6G April 14, 2024, in Brussels.
- INSIDE Thematic Workshops, Budapest, 13/06/2024.
- Software Defined Vehicle Governance Meeting.

Finally, a key contribution to the liaison activities is related to the alignment and synchronisation of the EU research agendas with a specific focus on the ECS-SRIA 2024 and 2025: INSIDE is leading the ECS-SRIA and the yearly update has extended the coverage of the edge-to-cloud continuum from an architectural and system of systems point of view. The ECS-SRIA already addresses in an extensive way the technologies and building blocks enabling the continuum, but we wanted to increase the coverage of the AI shift on the edge, cover the connectivity aspects and better highlight the role and importance of the continuum in vertical domains that are key for Europe (see Figure 1 and Figure 2).

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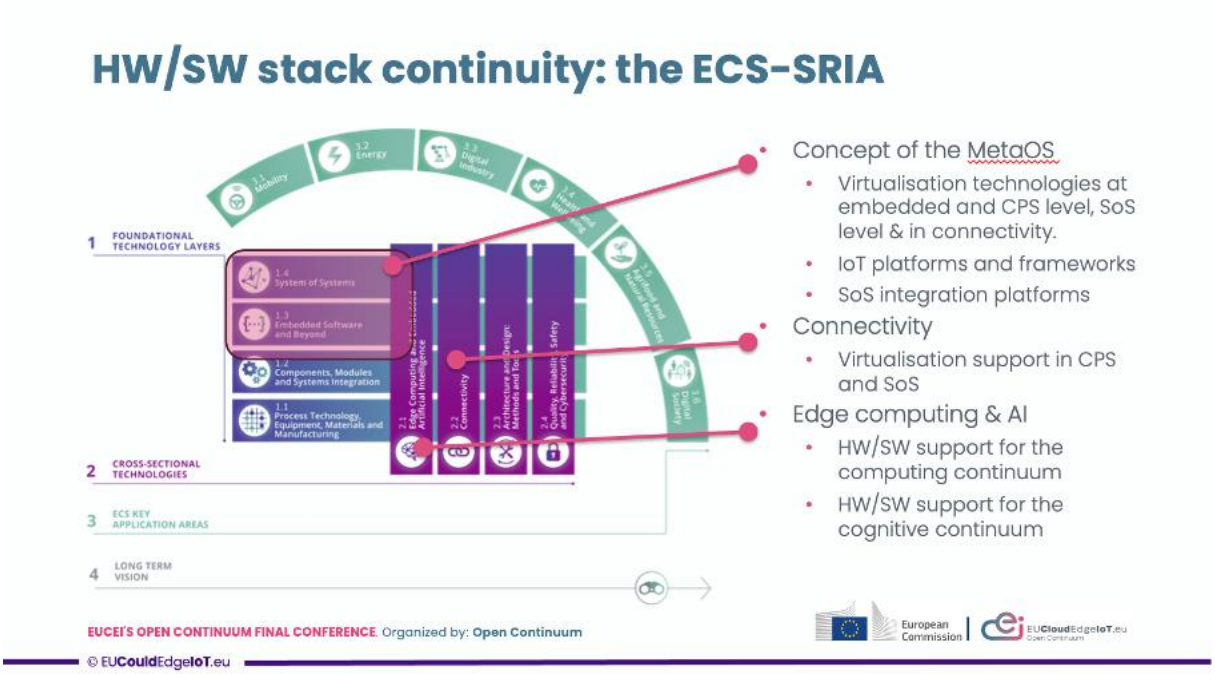

FIGURE 4 - THE ECS-SRIA OVERVIEW

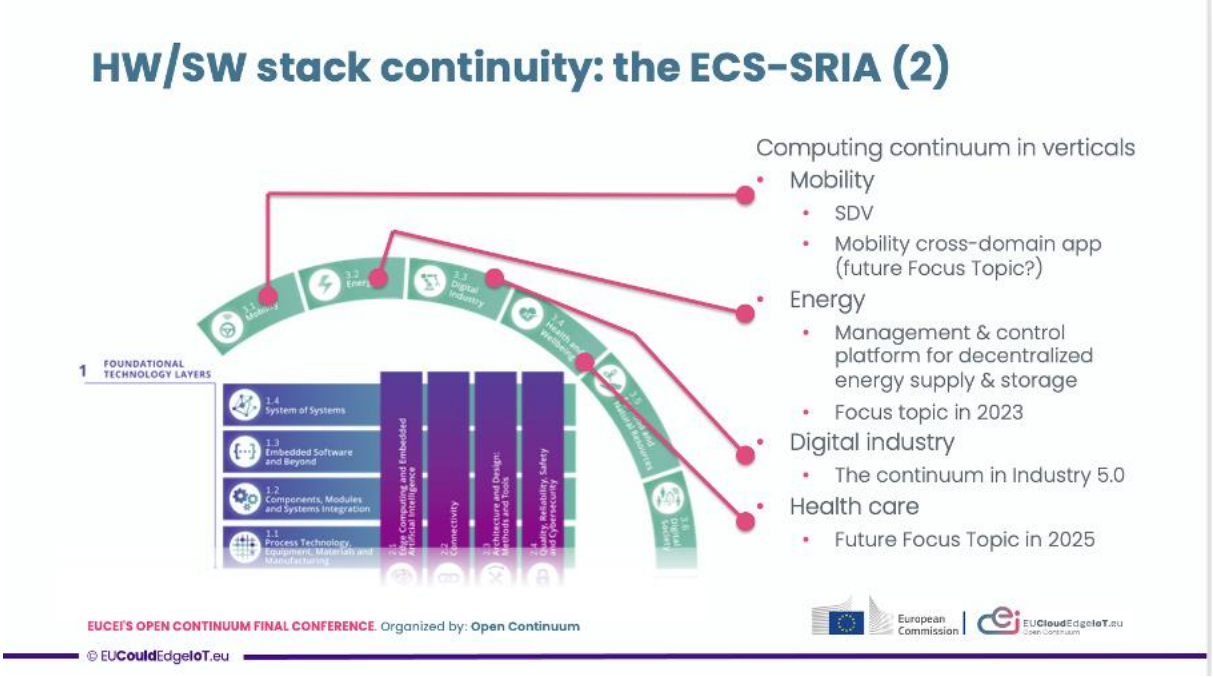

FIGURE 5 - THE ECS-SRIA OVERVIEW

2.1.3 Liaison with HiPEAC

INSIDE is a member of the HiPEAC CSA and we reserved a specific attention to the liaison with this initiative because of its long experience in the area of computing. In the context of HiPEAC, we established a Computing Continuum working group, which acts as a bridge between OpenContinuum and other key EU initiatives, enhancing collaboration within the Edge-to-Cloud continuum. The working group has been involved in the following activities:

- Identification of shared actors.

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- Common ground for computing continuum.
- Create a common glossary for the Strategic Research and Innovation Agendas (SRIAs).
- Sharing analysis results.
- Alignment on the priorities of various initiatives.
- Dissemination of liaison activities.

2.2 EVENTS

The liaison activities included several events:

- European Conference on EDGE AI technologies and applications
    - Conference + Workshop
    - Athens, 17-19/10/2023
    - In the context of the EDGE AI Conference promoted by the KDT project "Edge AI", INSIDE and EPOSS organised a workshop focused on a strategy for the development of Edge AI ecosystem in Europe. Edge AI represents a key asset for the continuum, and we decided to start the definition of a future R&D&I roadmap for Edge AI, including a series of Focus Topics calls in the Chips JU, for an open ecosystem fostering fast adoption of R&I, strengthening the role of European ECS in the emerging Digital Continuum and AI-based applications. The event included an open consultation to collect feedback from the entire community, a session to inform the community about Chips JU activities and an open discussion. The workshop addressed the following topics:
        - Technological milestones
        - Technological challenges
        - The continuum and the value chain
        - Major business drivers
        - Major use cases

FIGURE 6 - EUROPEAN CONFERENCE ON EDGE AI TECHNOLOGIES AND APPLICATIONS

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- Vehicle of the future governance meeting

Automotive Intelligence Center
Bilbao, Spain, 12/12/2023
The automotive domain represents one of the most important verticals for the edge-to-cloud continuum, constituting one of the enabling technologies of the vehicle of the future. The event was included in the timeline of the Software Defined Vehicle Governance Group and organised by INSIDE. In this context, we took the opportunity to present the role and activities of the Open Continuum and Unlock CEI, and we illustrated the EDGE AI roadmap and discussed the role of edge AI in the automotive edge-to-cloud continuum. Several executives from the EC, Spanish Government and EU Industrial stakeholders participated to the meeting (EC, Continental, Renault, BMW, Gestamp, Valeo, Forvia, VDA, PFA, FEV, ST, NXP, Infineon, etc.) and we had the opportunity to liaison with Catena-X, Gaia-x, EPOSS, CCAM, 2Zero.

FIGURE 7 - VEHICLE OF THE FUTURE GOVERNANCE MEETING

- Elevating Innovation: 2024 RIAs Challenge

ECS brokerage event
Brussels, 20-21/02/2024
https://ecs-brokerage-event.eu/
The RIAs Challenge has been organised to highlight Research and Innovation Action projects (RIAs) within the "Edge to Cloud Continuum" domain which has achieved relevant results and encouraging exploitation opportunities. The winner RIAs have been presented at the ECS Brokerage Event 2024, a networking event organised by AENEAS, EPoSS and INSIDE, and dedicated to KDT/Chips JU calls and future project proposals. The event attracted significant attention and gathered more than 500 attendees, exceeding the capacity of the venue. The 2024 RIAs Challenge has been organised to showcase Research and Innovation Action projects (RIAs) within the "Edge to Cloud Continuum" which has achieved relevant results and encouraging exploitation opportunities. The following projects submitted their candidature through a specific questionnaire intended to highlight the project's added value, impact, innovation, and key results: Vitamin-V, HE-CODECO, INTEND, TEADAL, NEPHELE, MYRTUS, NebulOuS, ICOS, INCODE, EDGELESS, FLUIDOS, aerOS, VEDLIoT. Among them, we selected four projects, which reached significant milestones in the domain of the continuum and that hold promising avenues for further exploitation and industrial impact: NEPHELE, MYRTUS, ICOS, and FLUIDOS. We decided to organise the 2024 RIAs Challenge in conjunction with the ECS Brokerage Event 2024 to allow the selected projects to showcase their added value, potential impact and innovation, and to build a bridge with the industry to encourage the exploitation of their significant results and the creation of new project proposals.

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FIGURE 8 - ELEVATING INNOVATION: 2024 RIAS CHALLENGE

- Decentralised Edge-to-Cloud Computing with ColonyOS

Workshop
RISE – Sweden + online, 15/03/2024
ColonyOS is a Meta-Operating System developed by RISE, designed to simplify and streamline utilisation of heterogeneous computing infrastructures, including IoT, edge, cloud, and HPC. It is designed to operate as an overlay to interface with a wide variety of computing environments, enabling seamless integration and operation across different platforms. In ColonyOS, each service runs independently within its designated environment or grid, known as a colony. These colonies are provisioned with precisely the resources they need, and communication is confined within the colony, adhering to a strict zero-trust security protocol. Services in ColonyOS are composed of so-called executors that integrate with various underlying platforms based on a distributed microservice architecture. This enables creation of so-called compute continuums. Self-sovereignty and decentralisation are foundational principles of ColonyOS. In self-sovereign systems, trust is established through transparent and secure mechanisms rather than through a centralised entity. This ensures that control and autonomy are in the hands of the users. ColonyOS supports standard HTTP, but also P2P communication to establish a decentralised network of colonies accessible anywhere on the Internet, forming a pervasive cloud. Today, ColonyOS is used commercially by RockSigma AB in a processing engine running on Kubernetes to analyse seismic events in one of the world's largest underground mines. Plans are underway to integrate with Eclipse Arrowhead, which will further enhance Arrowhead's functionality throughout the Edge2Cloud continuum. ColonyOS is also used by ENCCS to make it easier to use EuroHPC systems. The workshop showcased how to run a cross-platform workflow and how easily ML training can be performed with this solution.

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FIGURE 9 - DECENTRALISED EDGE-TO-CLOUD COMPUTING WITH COLONYOS

- INSIDE Thematic Workshops

Workshop
Budapest, Hungary, 13/06/2024
The workshop provided a unique opportunity to envision tomorrow's innovation projects and network with leaders and experts in the fields of the Electronic Components and Systems and Edge-to-Cloud continuum. It gave the community the possibility to engage with experts, diving into discussions about complex CPS and SoS engineering automation, about the Edge2Cloud cognitive computing continuum, and about safety and security critical system of systems. The workshop brought together 60 attendants and included collaborative sessions, allowing them to participate in group breakouts to develop proposal headlines and forge partnerships. The discussions in the breakout sessions were preceded, steered and inspired by visionary keynote speeches prepared by experts in the mentioned fields to shape the future of software and systems engineering. This initiative will have a follow-up workshop in autumn 2024.

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FIGURE 10 - INSIDE THEMATIC WORKSHOPS

2.3 INSIDE MAGAZINE

The INSIDE Magazine[2] is the quarterly magazine of INSIDE Industry Association. The magazine has an excellent track record of more than 10 years, reaching more than 9000 experts, C-levels, decision makers and public authorities. The magazine is oriented to the ECS community but doesn't limit to it and is oriented to:

- Provide a continuous update on the state of art of electronic components and systems (ECS) and about frontier technologies.
- Present the members of the ECS community and their activities.
- Present leading figures in the ECS domain.
- Present projects achievements.
- Inspiration for new project proposals.

In this context we published several articles illustrating the role and mission of EUCEI and OpenContinuum, presenting RIAs and increasing their visibility and achievements in the industry domain, creating a link with the ECS community, inspiring new projects and initiatives (see the next figure).

[2] https://www.inside-association.eu/publications

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FIGURE 11 - INSIDE MAGAZINE

We have planned to include an article about the OpenContinuum final event in the magazine issue that will be published at the end of September 2024.

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3 STRATEGY AND ACTIONS FOR DRIVING OPEN SOURCE INITIATIVES IN EUROPE

The aim to elaborate strategy for European digital autonomy through Open Source is a long run work to arrive at a common definition understanding of open source and future vision.

In the previous deliverable D1.1 - Toward a strategy for European Digital autonomy through Open Source, Standard and alliances - the initial investigation and activities have been described and will be briefly reported here in the related subsections.

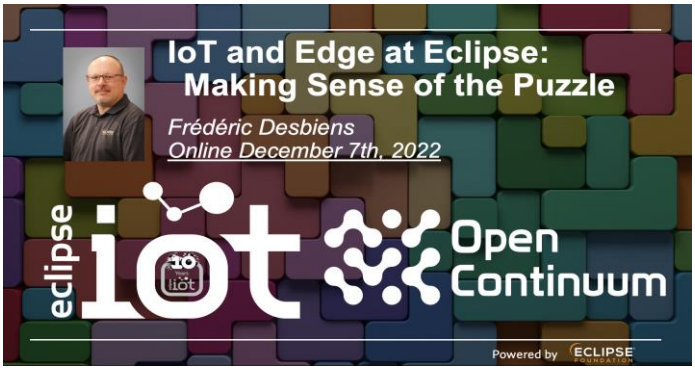
In order to achieve the maximum result in the project period the approach that has been applied is twofold and carried on in parallel: on one hand there is the need to disseminate and communicate all the information about Open Source and Open Continuum as well as starting engaging projects; on the other hand, the needs is to collect information from the engaged project cluster.

3.1 TRAINING AND DISSEMINATION OF OPEN SOURCE

Dissemination activities can be organised into two big actions: preparing and addressing strategic events as well as organised events for the entire EUCloudEdgeIoT Community. As an ultimate goal, a white paper has been released with all the work and investigation conducted during the project with respect to Open Source.

In the following table are reported all the main activities conducted in this task in this respect, during all the project lifespan. A more detailed description of the events is available online in the EUCloudEdgeIoT website[3] as well as in the D3.3 Community Building and Community Strategy Report.

TABLE 1 – OVERVIEW OF THE T1.1 DISSEMINATION. COMMUNICATIONS AND COMMUNITY BUILDING ACTIVITIES

	• Webinar • Online, December 7th, 2022 • Video

[3] https://eucloudedgeiot.eu/task-forces/open-source-management-tf2/

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	• Workshop • Toulouse, France • MetaOS open source stack • January 18th, 2023
	• Online, June 8th, 2023 • Information
	• Webinar, • Online, July 4th, 2023 • Information
	• Webinar • Online, December 13th, 2023 • Information

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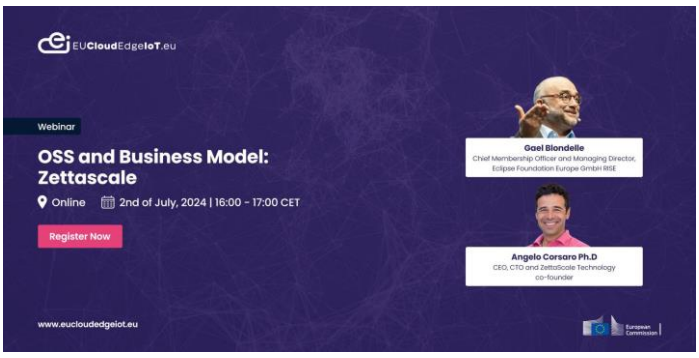
	• Webinar • Online, March 7th, 2024 • Information
	• Webinar • Online, May 17th ,2024 • Information
	• Webinar • Online, June 4th, 2024 • Information
	• Webinar • Online, July 2nd, 2024 • Information

Deliverable D3.3 and the final report contains an overview of all the main strategic events attended in the project period under the work of task 1.1. It is worth to mention here that a paper:

"Towards a European Open Continuum Reference Stack and Architecture", Rossini R. & Lopez L. has been accepted and presented in Splitech2024 Conference[4].

The paper is a joint work with WP2 and TF3 and presents the intermediate results on architecture and open source stack.

3.2 COLLECTION OF INFORMATION

As mentioned above, an important parallel activity conducted during the project is the collection of information from the engaged projects.

The main objective of this activity is to understand the open source situation in the referred EU projects and define a common vision on an Open Source Stack.

In order to do so, two investigations have been conducted. The first investigation was dedicated to the creation of a baseline architecture stack and started collecting and organising the first information. With this goal in mind, the first investigation has been conducted on the MetaOS projects cluster during the first period of the OpenContinuum project. In this regard, all information can be found in the previous version of this document D1.1 - Toward a strategy for European digital autonomy through Open Source, Standard and Alliances. It is reported here in Figure 11 the final Open Source Stack derived from the first investigation and confirmed with the second investigation carried out in this period.

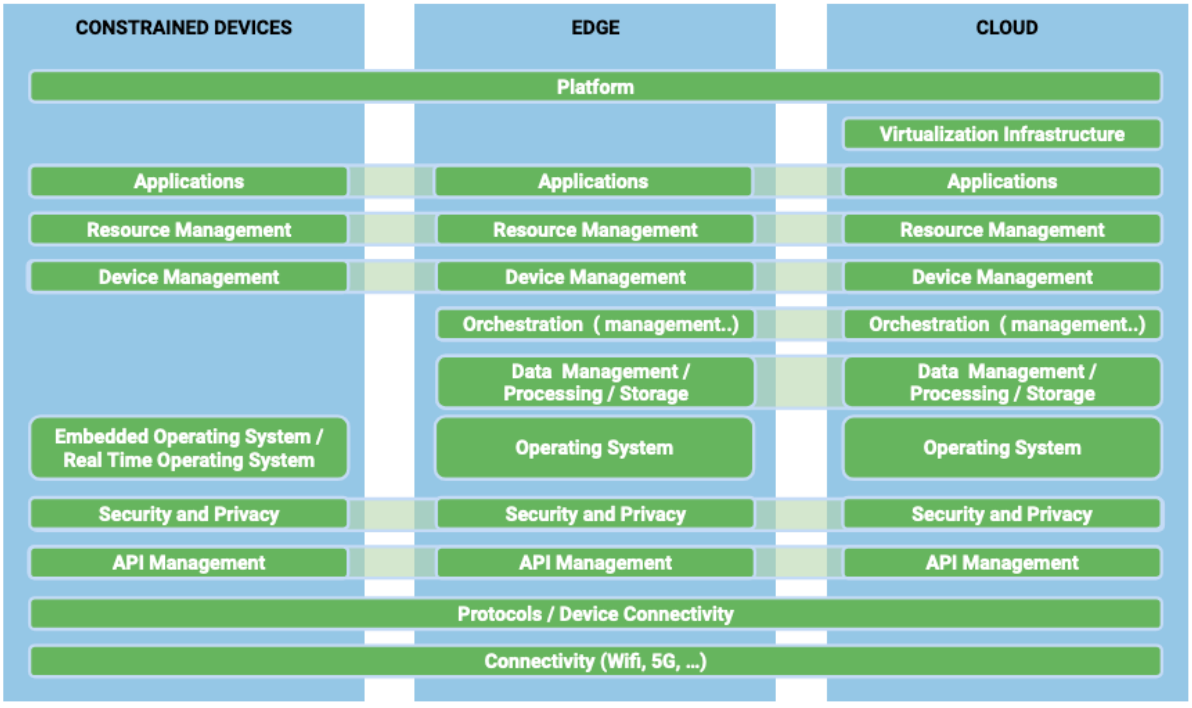


FIGURE 12 - OPEN SOURCE STACK

The second investigation was meant to consolidate the vision on the open source stack (Figure 12 - OPEN SOURCE STACK) and architecture and potentially identify missing open source parts

[4] https://splitech.org/Home

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as well as validate all the layers; this investigation has been conducted on all the RIA's projects cluster (46 projects) shown in Figure 12.

The survey form is shown in Figure 13 and it is based on the domains and layers identified in the Open Source Stack.

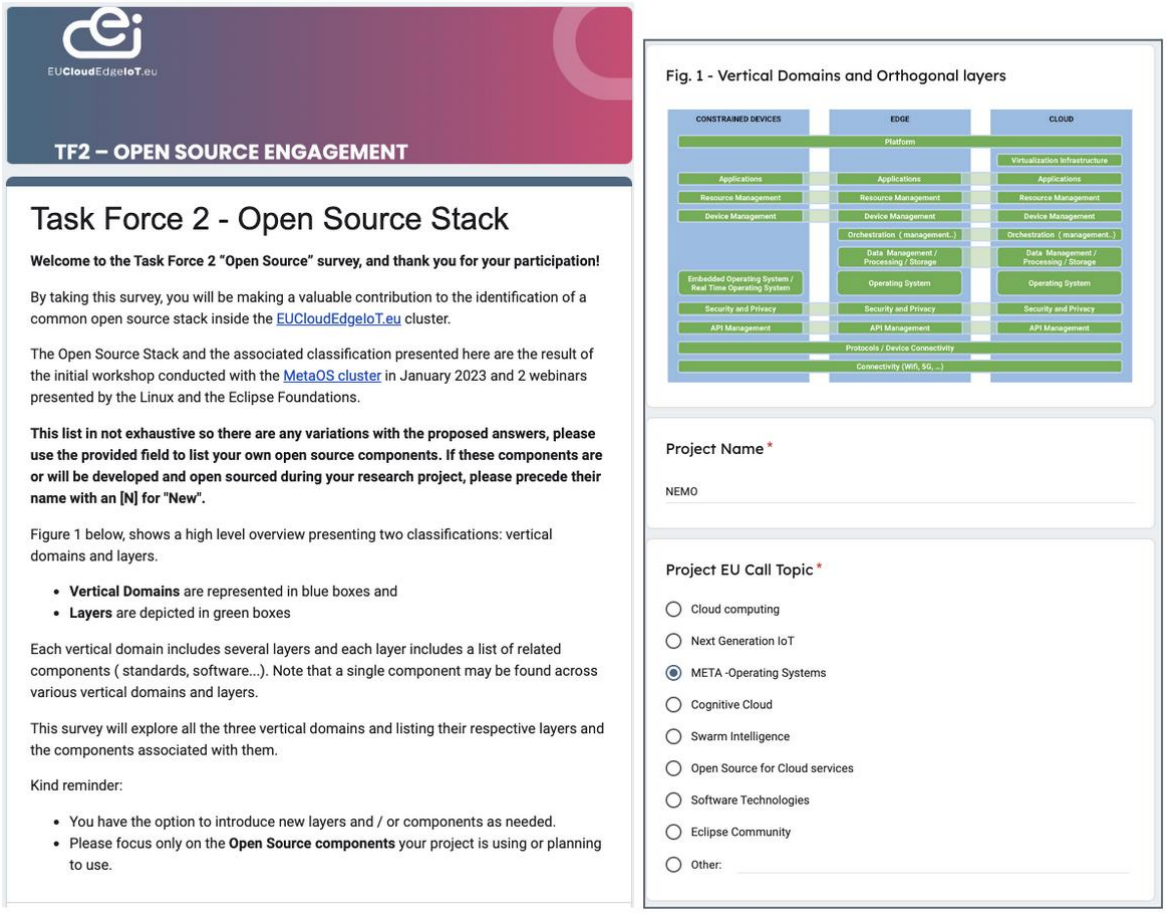

FIGURE 13 - SURVEY

Over the three domains, 35 questions have been formulated, note that an additional domain has been added in order to capture the cross domain layers present and visible in the Open Source Stack. The name of this additional level is 'A-Cross Domains' and it contains the three layers that in Figure 12 'cross' the three domains.

An overview of the questions is listed below:

- Project Name
- Project EU Call Topic
- A-Cross Domains

A.1-"Connectivity" layer
A.2-"Protocols" layer
A.3-"Platform" layer

- B-Constrained Devices

B.1-"API Management" layer
B.2-"Security and Privacy" layer
B.3-"Embedded OS / RTOS" layer
B.4-"Device Management" layer
B.5-"Resource Management" layer
B.6-"Application" layer
B.7-Do you have different layers? If yes, please describe them and their components.

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- C-Edge

C.1-"API Management" layer
C.2-"Security and Privacy" layer
C.3-"Operating System" layer
C.4-"Data Management" layer
C.5-"Orchestration Management" layer
C.6-"Device Management" layer
C.7-"Resource Management" layer
C.8-"Applications" layer
C.9- Do you have different layers? If yes, please describe them and their components.

- D-Cloud

D.1-"API Management" layer
D.2-"Security and Privacy" layer
D.3-"Operating System" layer
D.4-"Data Management" layer
D.5-"Orchestration Management" layer
D.6-"Device Management" layer
D.7-"Resource Management" layer
D.8-"Applications" layer
D.9-"Virtualization Infrastructure" layer
D.10- Do you have different layers? If yes, please describe them and their components.

As it is clear from the list, the survey contains four main domains: one related to a cross domain, A- Cross Domains, and three associated to the Open Source Stack, B-Constrained Devices, C-Edge, D-Cloud.

The questions, in the form of a survey, have been distributed among the whole cluster of European projects involved in the EUCEI community, for a total of 46 projects. As a recap, over 46 projects 30 answered the survey with a total of 1635 answers with a total of 981 components collected.

An important information that derives from the data is the distribution of the answers on the different calls: in this case we can say that even if we did not receive all the 46 answers, we have at least a sample for each call/topic presented in the cluster. It also means that we can say that our overview can be considered as a reference and representative of the 46 projects at this moment. A detailed overview of the number of projects that answered per call is shown in Figure 13 below.

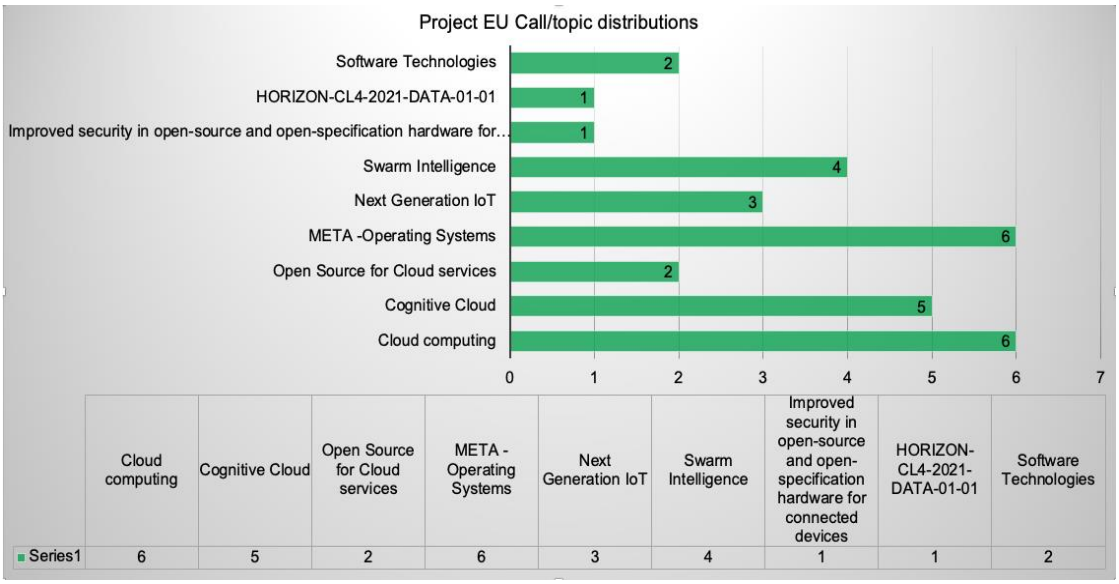

FIGURE 14 - PROJECTS EU CALL/TOPICS DISTRIBUTIONS OF THE ANSWERS

In order to analyse the data collected, two different databases have been extracted and considered. As a baseline, the data has been cleaned from the metadata inserted by the system. At this point, as a second step the data has been prepared and an inconsistency check has been

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performed to identify and count duplicates and eliminate incoherences, as an example: in the same answer could be present more than one component, in such case the record has been split and reconsidered as more answers for the same project. The database after the cleaning counts 981 correct answers with duplicates and 611 answers without duplicates. Figure 15recap the total overview per call and per layer with duplicates.

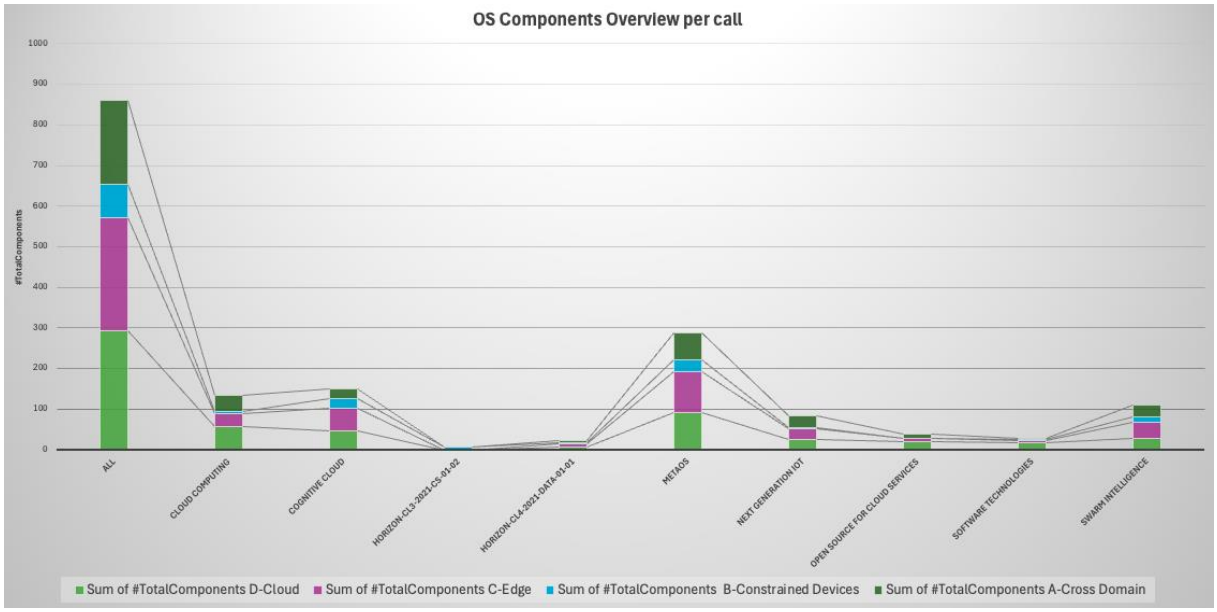

FIGURE 15 - OPEN SOURCE COMPONENTS PER CALL/TOPICS

All the bars in the chart contain aggregated results with respect to the four topics of the survey, and starting from the bottom:

- light green D-Cloud,
- purple C-Edge,
- light-blue B-Constrained Devices,
- dark green A-Cross Domains.

The first bar on the left of the figure shows the total number of components for each layer of the OSS, the other bars show the aggregated results for each call. In a first look, it is immediately clear the difference in terms of numbers between the Cloud and Edge layers over the other layers. This behaviour has been already observed in the restricted investigation conducted among the MetaOS cluster.

An important observation derives from the A-Cross Domains layer: all the calls, but one, consider it and use it, as it is expected since almost all the calls are concentrated on the continuum. This observation ties the call topic to the components extracted from the survey, and the coherence and alignment with the topic give us confidence in the quality of the answers. It could also be visible in further visualisations that are presented in this document. Looking to a different perspective in Figure 16 we can see an overview of the total number of components per call.

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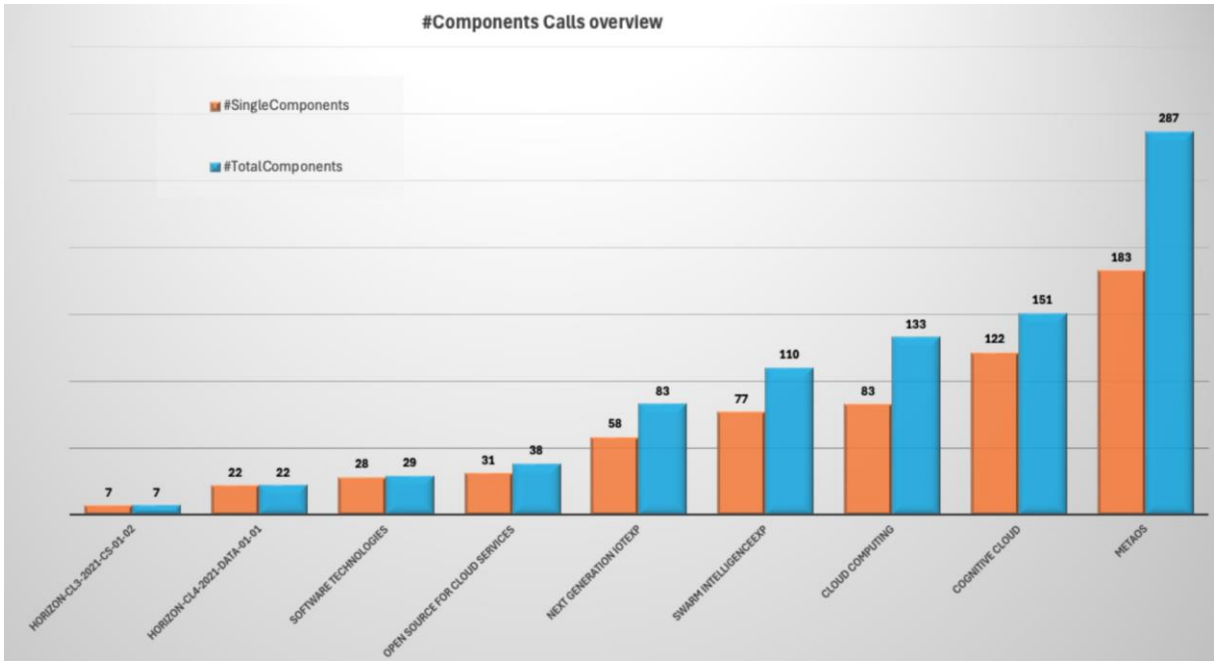
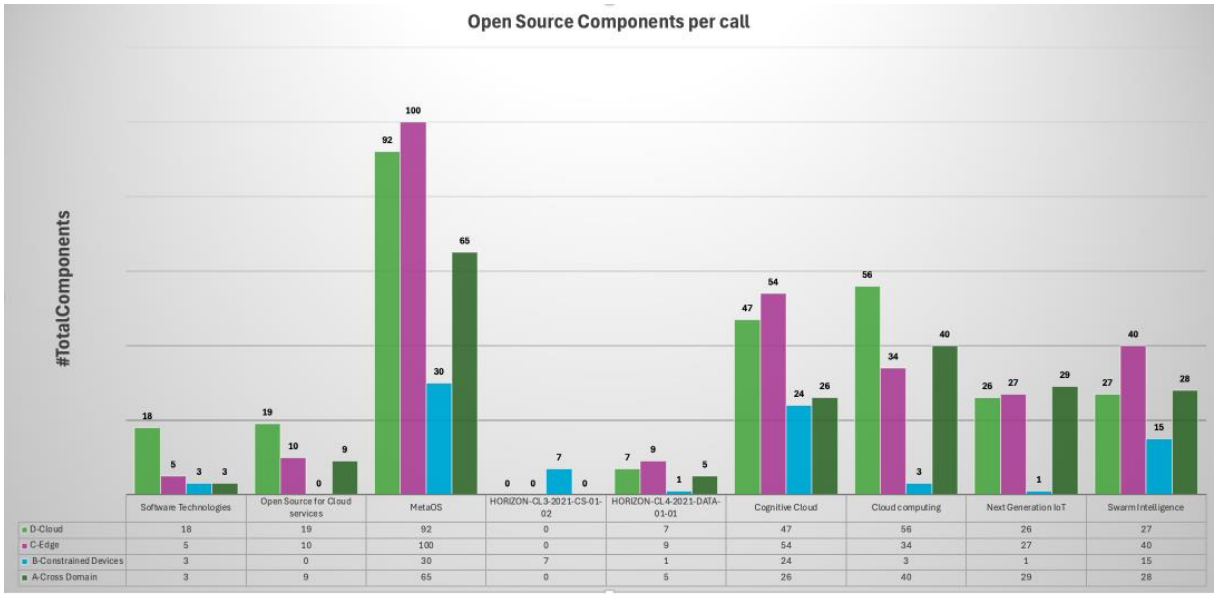


FIGURE 16 - OVERVIEW OF THE TOTAL NUMBER OF COMPONENTS PER CALL

Note that for each layer we are considering two dimensions: #SingleComponents and #TotalComponents. The first indicates the unique components in the counting without duplicates, in other words, the unique software components declared by the projects of that specific call. The second, #TotalComponents, represent the total number of answers related to the specific call that means the number of all components including duplicates between the projects in that call.

Another important mention is dedicated to the free answers given in the survey and that are covered later in the chapter.

In this cleaned database we can extract information that gives us the following vision on the different Calls considering first the Total Components, with duplicates:



	Software Technologies	Open Source for Cloud services	MetaOS	HORIZON-CL3-2021-CS-01-02	HORIZON-CL4-2021-DATA-01-01	Cognitive Cloud	Cloud computing	Next Generation IoT	Swarm Intelligence
D-Cloud	18	19	92	0	7	47	56	26	27
C-Edge	5	10	100	0	9	54	34	27	40
B-Constrained Devices	3	0	30	7	1	24	3	1	15
A-Cross Domain	3	9	65	0	5	26	40	29	28

FIGURE 17 - OPEN SOURCE COMPONENTS PER CALL #TOTALCOMPONENTS

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And then the Single Components without duplicates that confirms the trend of each call:

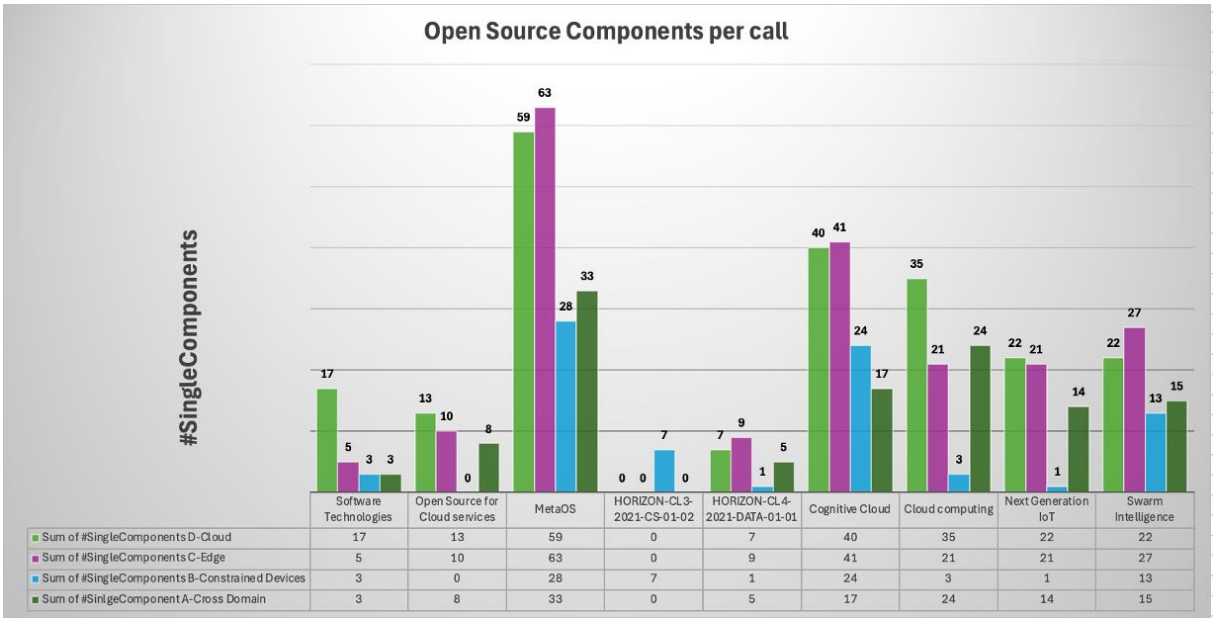

FIGURE 18 - OPEN SOURCE COMPONENTS PER CALL #SINGLECOMPONENTS

For each call the data related to each layer and the components are reported in the next subchapter. Moreover, it is possible to make some observations before going into the data. Looking at the number, we cannot really compare all the calls since we have different numbers of projects participating in each of them. However, it is clear that some calls used a very few open source components. In some cases, we can assume that they already have some assets but one important factor that can help us to view these data is that the calls have different periods of activity, i.e., the projects are not all aligned in time. This implies that some of them have different maturity and technological awareness, and it makes it difficult to make strong assumptions. However, our goal is to consolidate our vision on the Open Source Stack and, so it is. These observations are confirmed by the perspective views described listed in the appendix:

- 7.1Data Overview per Call
- 7.2 Data Overview per Layer

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4 STANDARDISATION TOWARDS A COMPUTING CONTINUUM ECOSYSTEM

This section is an update of D1.1 which was prepared in May 2023. This update reflects the landscape as of June 2024. To help the reading of this section and of tables, each paragraph or entry has been assigned one of the following tags: unchanged, updated, and new.

The work carried out during the second half of OpenContinuum continued on approaches identified for the development of a computing continuum ecosystem where standardisation support is needed. We remind the 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.

new

This section is an update on the landscape of existing standardisation activities and provide possible routes for projects to take. It is important to note that it is important for the survey includes standards under development as (1) they could influence research projects, or (2) projects could decide to contribute to them or even submit new standards.

Access to standards under development or contributions can take place as follows:

- through national body membership,
- through participation to an organisation that has a liaison. For instance, AIOTI or ECLIPSE have a liaison with ISO/IEC JTC 1/SC 41
- through a liaison request by a research project. For instance, Trialog has established one liaison from PRIPARE (Framework 7) to ISO/IEC JTC 1/SC 27/WG5 in 2014 or from PDP4E (H2020) to ISO PC 317/WG1 in 2018.

This section further includes a survey of harmonised standards developed by CEN-CENELEC as a response to the commission standardisation requests from the European Commission. These standards are especially important since they will allow for presumption of conformity with the associated legislation.

4.1 ARCHITECTURE LEVEL

4.1.1 Approach

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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 - STANDARDS TO DESCRIBE REFERENCE ARCHITECTURES

Standard or related document	Scope	OpenContinuum work	Recommendation and support beyond OpenContinuum
unchanged 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 [16]. Note that this document is not published externally[5]. Annex 1 provides a summary.	This document has been used as a reference in the EUCloudEdgeIoT task force on architecture It provides a document structure which can be applied to continuum architecture building blocks. Has been used in several projects, e.g. NEPHELE, ENERSHARE, SPADE, CONNECT	See item below
new ISO/IEC 40141 IoT guidance on reference architecture [13]	This document provides guidance on using the ISO/IEC 30141 - IoT Reference Architecture Edition 2. It provides background on the changing context IoT systems are being developed in, an overview of the different sections of the IoT Reference Architecture. It also provides some rationales on why to use the IoT Reference Architecture and information about how to use it to architect an IoT system, and an explanation of construction patterns.	Replaces above reference	Use this reference which is under development (planned publication early 2025) Future building blocks in the ecosystem should use this type of guidance
unchanged Architecture description ISO/IEC/IEEE 42010 [16]	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 Appendix 7.3 provides templates
new ISO/IEC/IEEE 42024 Enterprise, systems and software — Architecture fundamentals [14]	This document specifies the foundational vocabulary, concepts and principles associated with an architecture and used within the architecting practice for various entities, including software, systems, enterprises, missions, systems of systems, families of systems, infrastructures, products (goods or services), product lines, service lines, technologies and business domains. The application areas of this document include, but are not limited to, the following: artificial intelligence (AI), machine learning (ML), Internet of Things (IoT), cloud computing, big data, smart cities, smart manufacturing, cybersecurity, digital	Provide description concepts which can be applied to continuum architecture building blocks.	Use this reference which is under development (planned publication end of 2026)

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

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	twin, telecommunications, aerospace, defense, banking, finance, insurance, energy, automotive, hospitality, healthcare, supply chain, transportation, manufacturing, agriculture, production, and infrastructure.		
new ISO/IEC/IEEE 42042 Enterprise, systems and software — Reference architectures [15]	This standard describes the requirements to be satisfied by domain-specific reference architectures that address entities of interest such as software, systems, enterprises, missions, 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 which is under development (planned publication end of 2026)

updated

Figure 19 shows the guidance provided by ISO/IEC 40141 [13] on how implementations can conform to a reference architecture supporting the computing continuum (note that the figure is slightly different from the one used in D1.1):

- At the reference architecture level, reference architecture standards are supported by the ISO/IEC 40141 standard and extended by construction patterns.
- At the implementation architecture level, the use of reference architecture standards leads to a set of derived requirements, of construction patterns and of further guidance, which in turn guides the implementation architecture, which finally guides implementation.

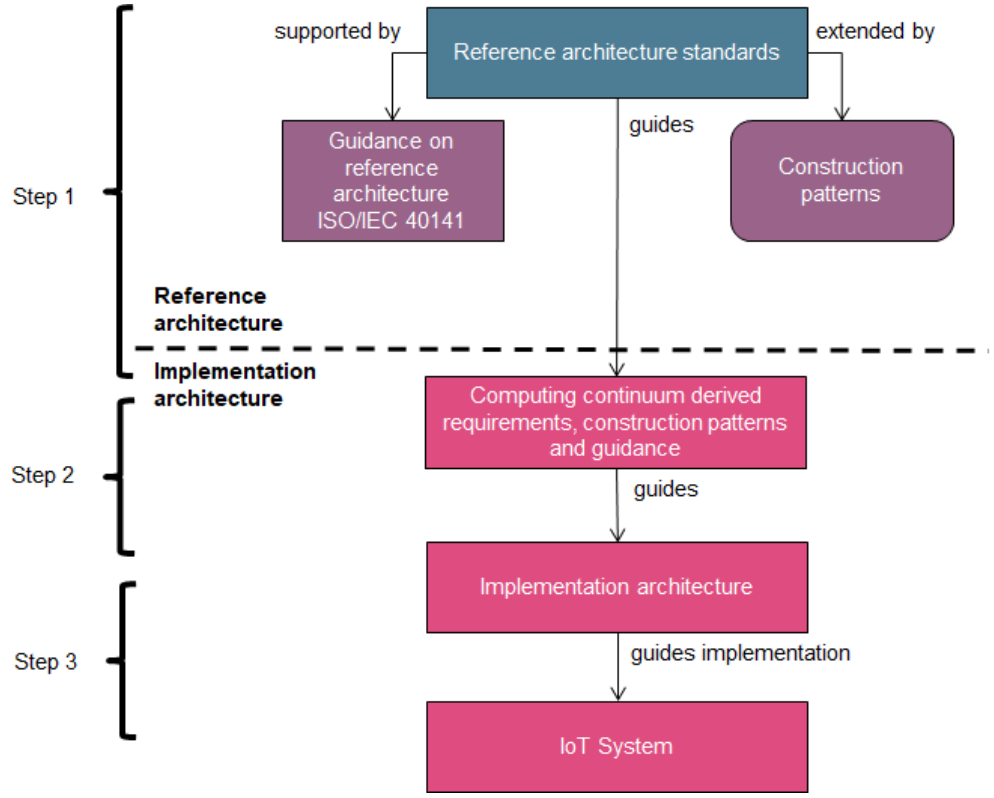

FIGURE 19 – CONSTRUCTING A COMPUTING CONTINUUM REFERENCE ARCHITECTURES AND USING IT IN IMPLEMENTATIONS

4.1.2 Existing Standards

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unchanged

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 which should also be freely available),
- Digital twin reference architecture (underway),
- Edge computing technical report,
- Cloud computing reference architecture (second edition freely available)
- Cloud computing vocabulary (second edition freely available),
- Cloud computing data spaces (underway),
- Integration of IoT and digital twins in data spaces (underway), and
- 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 beyond OpenContinuum
new PWI TR JTC1-SC41-22 Internet of Things (IoT) – Architecture considerations for IoT, edge and cloud. [19]	This is resolution 518 of the SC41 resolution document from the Helsinki plenary of May 2024. Based on the AIOTI contribution (SC41N2657), JTC 1/SC 41 decides to register the following PWI for a TR: Title: Internet of Things (IoT) – Architecture considerations for IoT, edge and cloud Scope: Provide a technical report on the architecture in the IoT, edge and cloud with the goal to contribute to the reference architecture in the form of construction patterns. JTC 1/SC 41 assigns this PWI to WG 3 and appoints Antonio Kung (FR) as a PWI Editor and Lara Lopez (AIOTI) as a PWI Co-Editor.	This is the direct result of OpenContinuum effort to promote EuCloudEdgeIoT task force 3 architecture work.	MetaOS and other computing continuum projects will be invited to participate through AIOTI.
updated ISO/IEC 30141 IoT Reference Architecture Edition 2 (underway [19]) Note that Edition 1 is freely available[6]	This document specifies an Internet of Things (IoT) reference architecture (IoT RA). The IoT RA is a generalization 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	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	Use this reference which is under development (planned publication end of 2024)

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

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support beyond OpenContinuum
It is planned that Edition 2 will also be freely available.	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.	consistent with ISO/IEC 40141 [13]	
unchanged ISO/IEC 30188 Digital Twin Reference Architecture [21]	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.	Use this reference which is under development (planned publication early 2025)
unchanged ISO/IEC TR 30184:2020 Edge Computing [24]	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 standardization in edge computing for IoT.	The description of a computing continuum reference architecture should take into account this standard	Use this reference.
updated ISO/IEC 22123-3 Cloud computing - Part 3: Reference architecture [25]	This document specifies the cloud computing reference architecture (CCRA).	The description of a computing continuum reference architecture should allow for a composition with ISO/IEC 22123-3 to create an architecture profile integrating the continuum	Use this reference Note that this standard is not based on [12], nor [13]
unchanged ISO/IEC 22123-1:2023, Cloud computing - Part 1: Vocabulary [26] Note that the document is freely available[7]	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
updated ISO/IEC 20151, Cloud computing – Data spaces [27]	This document provides the foundational concepts and essential characteristics of dataspaces. This document is applicable to all organizations.	The description of a computing continuum reference architecture should allow for a composition with data space reference architecture	Contribution to these standards is recommended. 20151 is under development (planned publication end 2026) 30152 and 30151 are under ballot. Results
updated ISO/IEC 30152 IoT and digital twins – Guidance	This document provides guidance on the connection of IoT systems and digital twins in data spaces, including principles, architecture and lifecycle considerations. It is based upon		

[7] https://standards.iso.org/ittf/PubliclyAvailableStandards/ISO_IEC_22123-3_2023_ed_1_-_id_82759_Publication_PDF_(en).zip

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support beyond OpenContinuum
on the connection to data spaces[8]	• concepts and characteristics described in ISO/IEC 20151 (Dataspace concepts and characteristics), • architecture considerations described in ISO/IEC 30141 Ed2 (IoT reference architecture) and ISO/IEC 30188 (Digital twin reference architecture), and interoperability aspects described in the ISO/IEC 21823 series (Interoperability for IoT systems).		will be known in September 2024)
updated ISO/IEC 30151 Digital Twin — Extraction and transactions of data products[9]	This document provides a framework enabling the integration of digital twins in data spaces, consisting of • an underlying digital twin supporting the management of models, • a process for data product extraction from the digital twin supported models, • a connector pattern that enables publication of data products in data spaces. • a methodology to evaluate the value of publishing data products in data spaces. This document further provides an implementation example to publish 3D data products using IDSA connectors.		
unchanged ISO/IEC 20547-3:2020, Big data reference architecture — Part 3: Reference architecture [28]	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; • 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	The description of a computing continuum reference architecture should allow for a composition with big data reference architecture	Use this reference Note that this standard is not based on [12], nor [13]

[8] ISO/IEC JTC1/SC41 proposal currently under ballot until sept 2024 (ref SC41 JTC1-SC41/440/NP)

[9] ISO/IEC JTC1/SC41 proposal currently under ballot until sept 2024 (ref SC41 JTC1-SC41/444/NP)

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support beyond OpenContinuum
	other consumers to understand, discuss, categorize and compare big data solutions; and • facilitate the analysis of candidate standards for interoperability, portability, reusability, and extendibility.		

4.1.3 Opportunities

unchanged

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.

4.2 TRUSTWORTHINESS LEVEL

4.2.1 Approach

unchanged

Trustworthiness is defined as the ability to meet stakeholders' expectations in a verifiable way[10]. 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,
- expressing the relationships between key characteristics.

4.2.2 Existing Standards

Table 3 describes standards related to trustworthiness.

TABLE 3 - STANDARDS FOR TRUSTWORTHINESS

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

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support beyond OpenContinuum
unchanged ISO/IEC TS 5723 Trustworthiness – Vocabulary [29]	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
updated ISO/IEC 31303 Trustworthiness - Overview and concepts [30]	This document provides an overview of trustworthiness and related concepts and describes trustworthiness applicable to information technology (IT)..	The description of a computing continuum trustworthiness could be based on these future standards.	Contribution to these standards is recommended 31303 is under development (planned publication early 2027) 18149 may lead to proposal for a new standard development
unchanged 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 [31][32].		
updated ISO/IEC 30149 IoT trustworthiness principles [33]	ISO/IEC TS 30149:2024 provides principles for IoT trustworthiness based on ISO/IEC 30141 - IoT Reference Architecture.		Use this reference
unchanged ISO/IEC TR 24028:2020 Overview of trustworthiness in AI [34]	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
unchanged ISO/IEC 27090, Guidance for addressing security threats and failures in artificial intelligence systems [37]	This document provides guidance for organizations to address security threats and failures in artificial intelligence (AI) systems. The guidance in this document aims to provide information to organizations 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.	The description of a computing continuum trustworthiness involving AI should take into account these standards.	Contribution to these standards is possible 27090 publication is planned for the end of 2025 27091 publication is planned for 2026
unchanged ISO/IEC 27091	This document provides guidance for organizations to address privacy risks in artificial intelligence (AI) systems and machine		

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support beyond OpenContinuum
Artificial Intelligence — Privacy protection [40]	learning (ML) models. The guidance in this document helps organizations 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 organizations, including public and private companies, government entities, and not-for-profit organizations that develop or use AI systems.		
updated ISO/IEC 11034 Information technology — Cloud computing — Trustworthiness in cloud computing [38]	This document provides an overview, frameworks, and concepts for Trustworthiness in cloud computing.	The description of a computing continuum trustworthiness could be based on these future standards.	Contribution to these standards is possible 11034 publication is planned for 2026
updated ISO/IEC 27115, Cybersecurity evaluation of complex systems – Introduction and framework overview [39]	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 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.	The evaluation of computing continuum trustworthiness could be based on these future standards.	Contribution to these standard is possible 27115 publication is planned for the end of 2026 27116 and 25240 may lead to proposal for new standard developments
new ISO/IEC PWI 27116, Support for customized or multipurpose evaluation[11]	The PWI will undertake a review and study how to support customized and/or multipurpose evaluation. • The customization view takes into account the support of specific domains and jurisdictions • The multi-purpose view takes into account reuse for different purpose (e.g. AI evaluation, Cybersecurity evaluation) The PWI will include • A review of cybersecurity requirements and related evaluation methodologies with a view to provide recommendations on the following actions		

[11] Described in ISO-IEC_JTC_1-SC_27-WG_3_N2680

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support beyond OpenContinuum
	• A review of cybersecurity evaluation and certification process • An analysis of reusability		
new ISO/IEC PWI 25240, Evaluation of AI-based Technology[12]	To examine and propose AI-specific Threats, Organization Security Policies, Assumptions, and Security Objectives for various types of AI attack types and techniques. NIST publication AI 100-2 E2023 can be used as a starting reference. Other items from SC42 Artificial Intelligence (not yet reviewed) could also be useful. To develop extended AI-specific Security Functional Requirements (AI-SFRs) and AI-specific Security Assurance Requirements (AI-SARs) to counter the identified AI attack types and techniques. To develop evaluation methodology to verify the efficiency and sufficiency of the AI-SFRs and AI-SARs.		
unchanged ISO 31700-1:2023, Consumer protection — Privacy by design for consumer goods and services — Part 1: High-level requirements [44]	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
unchanged ISO/IEC PWI 27568 Security and privacy of digital twins[13]	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
new Standardisation request related to the RED directive [41]	RED establishes a regulatory framework for placing radio equipment on the market. The 2014 directive has been extended to cover cybersecurity with a standardisation request for common security requirements for radio equipment that is underway. It includes 3 standards, EN 18031-1:2024, EN 18031-2:2024, EN 18031-3:2024 which are under approval	These standards will be used for compliance presumption with the RED directive. Note that that as of today, it is not clear whether the commission will approve those standards as harmonized standards	Use these references for compliance.

[12] Described in ISO-IEC JTC 1-SC 27-WG 3_N2646

[13] Underway in ISO/IEC JTC1/SC27.

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support beyond OpenContinuum
new Standardisation request related to the AI Act [42]	The AI Act establishes obligations for providers and users depending on the level of risk from artificial intelligence • applications with unacceptable risks are forbidden • high-risk applications must comply with security and transparency • limited-risk application and gen AI have transparency obligations.	These standards will be used for compliance presumption with the AI act. Several standards are under development or being discussed for development: AI risk management, AI trustworthiness framework, AI quality management framework, AI conformity assessment	Use these references for compliance. Contribution to these standards is possible
new Standardisation request related to the Cyber Resilience Act [43]	The Cyber Resilience Act will guarantee: • harmonised rules when bringing to market products or software with a digital component; • a framework of cybersecurity requirements governing the planning, design, development and maintenance of such products, with obligations to be met at every stage of the value chain; and • an obligation to provide duty of care for the entire lifecycle of such products.	These standards will be used for compliance presumption with the CRA The list of standards to be developed is under discussion	Use these references for compliance. Contribution to these standards is possible
new Standardisation request related to the European Trusted Data Framework	A comprehensive set of standards, practices, and rules to ensure trusted, legally compliant data sharing across parties, including data intermediaries and altruism organizations. This encompasses data catalogue standards for publication and discovery of data assets, ontology standards for integration and use of shared data, and common KPIs to guide European data spaces towards cross-domain interoperability, enhancing transparency and usage. All actions will be coordinated closely with the European Data Innovation Board and, where relevant, the Data Spaces Support Centre.	The computing continuum will either contribute to	

4.2.3 Opportunities

updated

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. This can include use cases.

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4.3 INTEROPERABILITY LEVEL

4.3.1 Approach

unchanged

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 [46][47][14]. Interoperability is critical in increasingly complex system infrastructure where multiple 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.

4.3.2 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 beyond OpenContinuum
unchanged ISO/IEC 21823 Interoperability for IoT systems — Part 1: Framework [46]	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 of 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
unchanged ISO/IEC 21823-3 Interoperability for IoT systems — Part	This document provides the basic concepts for IoT systems semantic interoperability, as described in the facet model of ISO/IEC 21823-1, including:	The description of a computing continuum interoperability could be based on this standard	Can be used as a reference

[14] Definition proposed by the cloud computing community (SC38) and reused by the IoT community (SC41)

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Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support beyond OpenContinuum
3: Semantic interoperability [48]	• 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; • 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.		
updated ISO/IEC 21823-5 Interoperability for IoT systems – Part 5: Behavioural and policy interoperability [49]	This part of ISO/IEC 21823 specifies interoperability from a behavioural and policy viewpoint. In this document, the following specifications for interoperability from a policy and behavioural point of view are included: • a principle of how to achieve behavioural and policy interoperability. • requirements on information related to behavioural and policy interoperability, and • a framework for processes on developing information exchange rules from a behavioural and policy viewpoint	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
unchanged SAREF public portal [50]	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
unchanged ETSI TS 103 673. SAREF Development Framework [51]	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 [53].		

4.3.3 Opportunities

unchanged

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.

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4.4 OPEN-SOURCE APPROACH

4.4.1 Approach

unchanged

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)

4.4.2 Existing standards

Table 5 describes standards related to open source.

TABLE 5 - STANDARDS FOR OPEN SOURCE

Standard or related document	Scope	Relationship with Computing continuum	Recommendation and support beyond OpenContinuum
updated ISO/IEC 5230 OpenChain Specification [54] This document is freely available	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 Honda recently made an announcement on an ISO/IEC 5230 implementation program. See https://www.youtube.com/watch?v=9Fek6fSfBew Other interesting webinars can be found in https://openchainproject.org/webinars	Can be used in open-source development related to the computing continuum	Can be used by computing continuum projects
updated ISO/IEC 18974 OpenChain security assurance specification [55] This document is freely available	This specification contains 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.		
unchanged ISO/IEC TR 6114 Cybersecurity – Security	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	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 beyond OpenContinuum
considerations throughout the product life cycle	greater transparency to customers at every point on the ICT product life cycle. This document describes the 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, • 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 organization shape their plans, procedures and policies.		

4.4.3 Opportunities

unchanged

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

4.5 WORK ACHIEVED AND FUTURE WORK

updated

This section is taken from OpenContinuum deliverable D4.4 Towards a European Ecosystem for the Computing Continuum [36]. Figure 20 shows the intended approach to foster the creation of a computing continuum ecosystem:

- The layer above describes the work achieved: OpenContinuum has engaged projects with two objectives in the frame of the EUCloudEdgeIoT task force 3 (architecture):

Create a taxonomy of computing continuum reference building blocks what will serve for the construction of a computing continuum architecture.
Present the taxonomy to ISO/IEC JTC 1/SC 41 and propose the development of a work item. This was achieved by producing a report within the AIOTI association and submitting it through the liaison category A which AIOTI has with SC41/
The creation of the work item (Architecture considerations for IoT, edge and cloud) [19] was accepted during the SC41 plenary in Helsinki in May 2024 with Antonio Kung (Trialog), and Lara Lopez (Eviden) being the editors.
Note that a liaison category A between the European Commission and ISO/IEC JTC 1/SC41 was also created and accepted. Svet Mihaylov from the commission attended the plenary.

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- The layer below describes the future work that will take place beyond OpenContinuum.

Participants in the Computing continuum will be invited to contribute architecture patterns, and a first report will be presented at the next plenary in Wuxi (China) in November 2024.

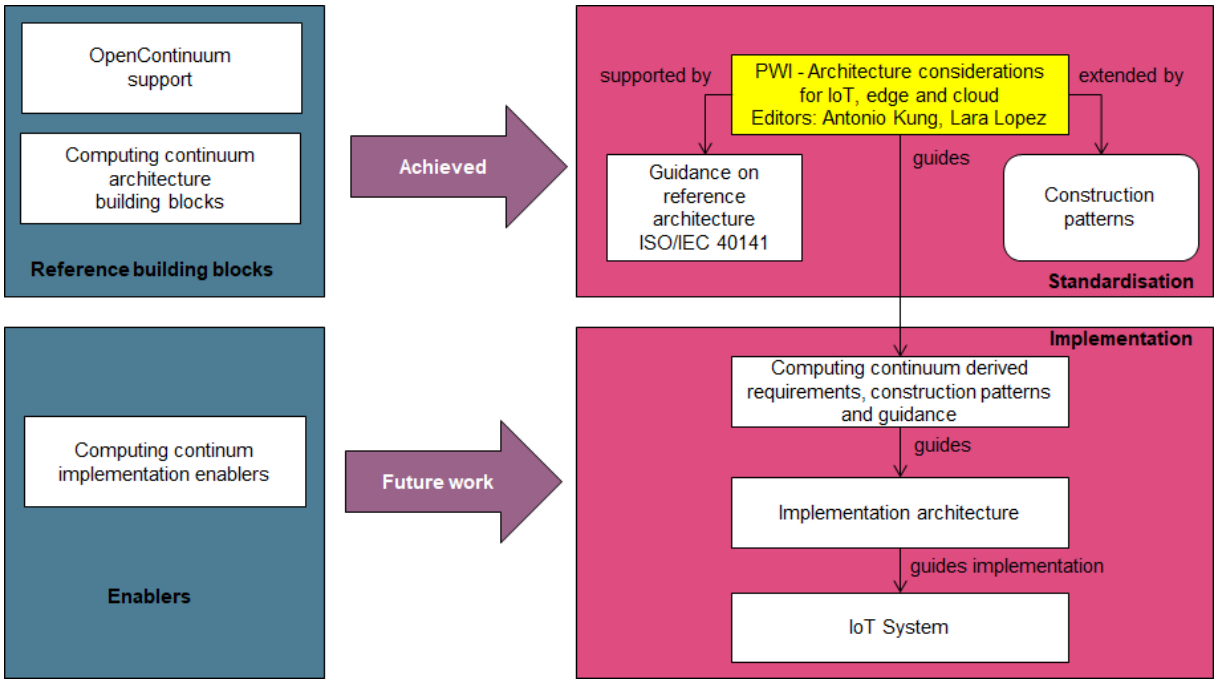

FIGURE 20 - OPENCONTINUUM STRATEGIC APPROACH FOR ECOSYSTEM IMPACT

The proposed approach leverages the following references:

- An interoperability approach as envisioned by [17], [18].
- Alignment with the future IoT reference architecture standard, [19], and an approach based on patterns (as in [20])
- Alignment with the future Digital Twin reference architecture [21], and
- Support for domain specific standards such as RAMI for smart manufacturing [22] or SGAM for energy [23].

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5 ALLIANCES

In the previous deliverable (D1.1) we identified several European alliances and partnerships that are focused on the edge to cloud continuum and that we considered for the liaison activities. These initiatives cover different parts of the value chain associated with the edge to cloud continuum, adopting heterogeneous and multidisciplinary technologies and aiming at different objectives. During the last year of the project, we extended the liaison activities to cover more widely the edge-to-cloud ecosystem and also initiatives focused on its adoption in vertical domains that are key for Europe. The following figure has been updated to include these initiatives, providing their positioning in the edge-to-cloud continuum. The existence of consolidated relationships between them is confirmed and concretises in synergies based on sharing the same experts, participating in joint events, cooperating in the definition of strategic agendas and their adoption, etc. The liaison activities aimed at further consolidating and extending the coordination and alignment between these initiatives, to reduce unnecessary overlapping and make it constructive and productive, optimise the use of resources and avoid fragmentation.

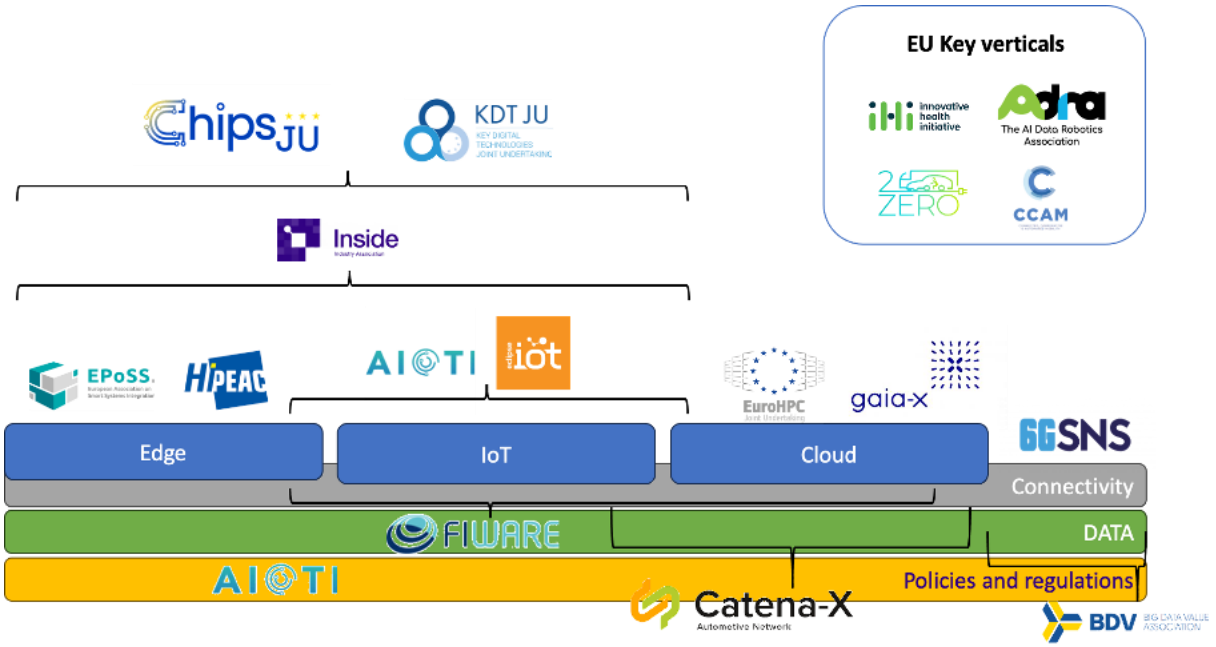

FIGURE 21 - INITIATIVES IN THE CLOUD CONTINUUM

5.1 SUMMARY OF EUROPEAN INITIATIVES IN THE EDGE-TO-CLOUD CONTINUUM

In this section we provide a summary of the European initiatives relevant to the edge-to-cloud computing continuum presented in D1.1 and a description of the new initiatives included during the last year of the project:

5.1.1 HiPEAC (High-Performance and Embedded Architecture and Compilation)

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- Focus: Scientific research and training on high-performance computing, embedded systems, and related technologies.
- Key Activities:

Organises conferences, workshops, and summer schools.
Promotes collaboration between academia and industry.

- Liaison:

Collaboration on research projects and training initiatives related to edge computing and embedded systems.

5.1.2 FIWARE

- Focus: Open-source platform for building and deploying smart applications in various domains (smart cities, agriculture, etc.).
- Key Assets:

Standardised APIs (NGSI) for interoperable context data management.
Open architecture with modular components (context management, data processing, etc.).
Large community of developers, startups, and research institutions.

- Liaison:

Collaboration on standardisation efforts and interoperability with edge-to-cloud solutions.
Integration of FIWARE components into edge and cloud applications.

5.1.3 Eclipse IoT Working Group

- Focus: Fostering an open ecosystem for IoT development by promoting open-source software, defining standards, and facilitating collaboration.
- Key Strengths:

Experience in hosting and supporting various open-source IoT projects (MQTT broker, IoT gateway framework, etc.).
Collaboration with other organisations and industry consortia on interoperability and open standards.

- Liaison:

Alignment on open-source software development and standards for edge-to-cloud communication.
Leveraging Eclipse IoT projects for edge device management and data collection.

5.1.4 AIOTI (Alliance for Internet of Things Innovation)

- Focus: Accelerating IoT adoption in Europe by creating a collaborative ecosystem, addressing technical and policy challenges.
- Key Activities:

Working groups on IoT architectures, interoperability, security, privacy, and applications in various sectors.
Provides input and recommendations to the European Commission (EC) on policy development related to IoT.

- Liaison:

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Collaboration on policy and regulatory frameworks for responsible and secure IoT deployment.
Sharing best practices and recommendations for addressing technical challenges in the edge-to-cloud continuum.

5.1.5 Trans Continuum Initiative (TCI)

- Focus: Establishing a vision for the infrastructure required to support data and compute convergence across edge, cloud, and IoT. This initiative is not currently active.
- Objectives:

Develop joint recommendations for R&D in the edge-to-cloud continuum.
Engage with EU funding entities to promote research in this area.
Contribute to Strategic Research Agendas and roadmaps for the continuum.

- Liaison:

Collaboration on defining research priorities and roadmaps for the edge-to-cloud continuum.
Input on technical requirements for infrastructure supporting edge, cloud, and IoT integration.

5.1.6 KDT Joint Undertaking (Key Digital Technologies)

- Focus: Accelerating the development and deployment of key digital technologies in Europe, including semiconductors, embedded systems, and high-performance computing.
- Key Activities:

Supports collaborative R&D projects in key digital technologies.
Facilitates technology transfer from research to industry.
ECS Strategic Research and Innovation Agenda (ECS-SRIA) sets priorities for KDT JU funding.

- Liaison:

Collaboration on R&D projects focusing on key technologies for the edge-to-cloud continuum.
Leveraging ECS-SRIA as a reference for aligning research efforts in the domain.

5.1.7 Gaia-X

- Focus: Developing a secure, federated data infrastructure for fostering data sovereignty, exchange, and sharing across Europe.
- Key Features:

Federated data infrastructure for secure data exchange across different domains.
Emphasis on privacy-preserving mechanisms and compliance with data protection regulations.
Common set of rules, standards, and certifications for the European data ecosystem.

- Liaison:

Collaboration on secure data management and exchange solutions for the edge-to-cloud continuum.
Contributing to the development of Gaia-X cloud services and data spaces relevant to edge applications.

5.1.8 CATENA-X

- Focus: Establishing a secure, trusted data ecosystem specifically for the automotive industry value chain.

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- Key Aspects:

Interconnected data spaces for secure data exchange between stakeholders.
Open standards, APIs, and secure communication protocols for interoperability.
Focus on data sovereignty, trust, and compliance with data protection regulations.

- Liaison:

Collaboration on interoperable data exchange solutions between edge devices

5.2 NEW INITIATIVES COVERED BY LIAISON ACTIVITIES: HORIZONTAL TECHNOLOGIES

The European initiatives focused horizontal technologies for the edge-to-cloud continuum that have been included in the liaison activities during the last year are the following:

5.2.1 Chips JU

The Chips JU[15] operates in the context of the European Chips Act[16], conceived to reduce Europe's reliance on chip imports and strengthen its position in the global semiconductor market. It is a European partnership that extends the previous KDT JU and aims at boosting the development and production of advanced semiconductor and their applications within the EU, with a budget of around 11 billion for the period 2021-2027. The key goals of the Chips JU include:

- The development of pilot lines for testing and validating new chip technologies, including quantum and photonics.
- The creation of a cloud-based design platform for chip designers.
- The support for research and innovation in electronic components and systems and their applications.
- Attracting investments in the European electronic components and systems and their applications.

Essentially, the Chips JU is working to establish a robust semiconductor ecosystem in Europe, capable of competing on a global scale and to support the electronic components and systems value chain and their applications: like the former KDT JU, it represents a key enabler for all the technologies adopted in the edge-to-cloud continuum.

The Chips JU is a tripartite initiative composed by the European Commission, by the participant states (EU member states and other associated countries including Norway, Israel, Canada, etc.) and by European private entities (companies, academic institutes and research and technology organisations) represented by three industry associations (AENEAS, EPOSS and INSIDE).

[15] https://www.chips-ju.europa.eu/

[16] https://digital-strategy.ec.europa.eu/en/factpages/european-chips-act-chips-europe-initiative#:~:text=The%20Chips%20for%20Europe%20Initiative%20includes%20a%20number%20of%20pilot,as%20well%20as%20small%2Dscale

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INSIDE actively participates in the Chips JU leading the Electronic Components and Systems Strategic Research and Innovation Agenda (ECS-SRIA), the reference document for the Chips JU calls, and strives for a leading position of Europe in Intelligent Digital Systems and their applications. The Association is a membership organisation for the European R&I actors with more than 265 members from 28 European and associated countries, spanning the entire Electronic Components, Software and Systems value chain, from semiconductors to applications.

5.2.2 EuroHPC

The EuroHPC[17] JU represents a strategic move to position Europe as a global leader in the high-performance computing (HPC) market. It provides financial support with a budget of around €7 billion for the period 2021-2027. The JU is a tripartite entity based on the collaboration between the European Commission, member states, and private industry, ensuring a strong foundation and diverse expertise. It focuses on pre-exascale and exascale systems, prioritising the development and deployment of these powerful supercomputers to drive innovation. It also addresses quantum computing integration into HPC systems. The JU provides support for accessibility and skills development, to make HPC accessible to a wider range of users and to build a skilled workforce in this field. EuroHPC has already deployed some supercomputers like Leonardo, a pre-exascale system located in Italy, known for its capabilities in AI and data-intensive applications, Vega, a pre-exascale system in Spain focusing on weather forecasting and climate modelling, and Meltemi, a pre-exascale system in Greece, targeting applications in the energy sector.

EuroHPC JU aims to accelerate innovation, addressing complex challenges in areas like climate change, medicine, and materials science. It also aims to boost industrial competitiveness, enabling industries to develop new products and services through advanced simulations and data analysis, and strengthen European digital sovereignty, reducing reliance on external computing resources and protecting sensitive data.

HPC technologies are crucial to support the cloud segment of the continuum, but also the high-performance devices on the edge.

5.2.3 6GSNS

Smart Networks and Services Joint Undertaking (SNS JU)18 is a public-private partnership established to accelerate Europe's leadership in 5G and 6G technologies, supporting research projects and pilots to develop new 5G and 6G technologies and applications. The JU actively participates in international standardisation efforts to shape the future of mobile networks and fosters collaboration between industry, academia, and policymakers to create a thriving 5G and 6G ecosystem. The SNS JU combines funding from the EU and private industry, leveraging their combined resources. It is a key component of the EU's strategy to drive digital transformation and economic growth and represents a key initiative for the edge-to-cloud continuum because connectivity is fundamental for its existence. Key objectives of the SNS JU are:

[17] https://eurohpc-ju.europa.eu/index_en

[18] https://smart-networks.europa.eu/

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- 5G deployment acceleration, promoting the widespread adoption of 5G networks across Europe.
- Drive 6G research and innovation, investing in research and development to secure Europe's leading position in 6G technology.
- Foster a strong industrial ecosystem, supporting European companies in developing and deploying 5G and 6G products and services.
- Address societal challenges, using 5G and 6G to tackle issues like climate change, healthcare, and agriculture.

By pooling resources and expertise, the SNS JU aims to position Europe as a global leader in the development and deployment of advanced wireless networks.

5.2.4 BDVA

The Big Data Value Association (BDVA)[19] is an industry-led non-profit organisation dedicated to fostering a thriving data-driven ecosystem in Europe. Its primary goal is to accelerate the digital transformation of the economy and society through the effective utilisation of big data and artificial intelligence (AI). Key objectives of BDVA include the development of an innovation ecosystem with industry, academia, and research institutions to collaborate on big data and AI projects, the maximisation of the potential of big data to drive growth and improve people's lives, and the positioning of Europe as a global leader in the big data and AI landscape.

BDVA plays a crucial role in shaping the European data economy because it coordinates research and innovation, overseeing large-scale projects and initiatives. It also promotes standardisation and interoperability, ensuring data can be effectively shared and utilised, and is active in policymaking to create a favourable environment for data-driven businesses. BDVA addresses the issue of the "lack of skills", supporting the creation of a skilled workforce, developing the talent needed to harness the power of big data and AI.

By fostering collaboration and driving innovation, BDVA is instrumental in unlocking the full potential of big data for Europe and represents a key initiative for the edge-to-cloud continuum from the data perspective.

5.3 NEW INITIATIVES COVERED BY LIAISON ACTIVITIES: VERTICAL DOMAINS

The initiatives focused on key vertical domains for Europe that have been included in the liaison activities during the last year are the following:

5.3.1 CCAM

CCAM (Connected, Cooperative, and Automated Mobility)[20] is a European public private partnership focused on mobility and on developing a paradigm shift in transportation, aiming to

[19] https://bdva.eu/

[20] https://www.ccam.eu/

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enhance road safety, efficiency, and sustainability through the integration of advanced technologies. CCAM covers the main components required by this shift:

- Connectivity: Vehicles communicate with each other, with the mobility infrastructure, and other road users, sharing real-time information.
- Cooperativity: Vehicles and infrastructure collaborate to optimise traffic flow, improve safety, and enhance the overall transportation experience.
- Automation: Vehicles can perform driving tasks with minimal or no human intervention, increasing safety and reducing traffic congestion.

CCAM aims at improving safety through systems that can significantly reduce accidents, anticipating potential hazards and reacting quickly. It also aims at increasing the efficiency of mobility, optimising traffic flow and reducing congestion to lead to reduced travel times and lower fuel consumption. This extends to sustainability, where CCAM can contribute to reducing environmental impact by promoting shared mobility and electric vehicles. CCAM also tries to create an improved level of accessibility to mobility, with technologies that can benefit people with disabilities by providing more independent mobility options.

The vertical domain of mobility represents a key market for the edge-to-cloud continuum and presents significant challenges, including cybersecurity, legal and ethical considerations, and infrastructures development. In the future, specifically with automated driving and smart mobility infrastructures, this domain will offer immense opportunities for innovation and economic growth, which will be largely unleashed by the adoption of the edge-to-cloud continuum paradigm.

5.3.2 2ZERO

2ZERO (Accelerating Zero-Emission Mobility)[21] is a partnership between the European Commission and the private sector, specifically EGVIA, aimed at promoting green vehicles and mobility solutions in Europe. The initiative focuses on accelerating the transition to zero-emission transportation. 2ZERO aims at promoting green mobility, encouraging the development and adoption of electric and other zero-emission vehicles. To support this, it promotes the development of the charging infrastructure, investing in innovation that contributes to the expansion of charging networks across Europe. Innovation is indeed a key objective for 2ZERO, which promotes research and development in battery technology, charging solutions, and other related technologies. 2ZERO is also active in policy making, advocating for policies that promote the uptake of zero-emission vehicles.

By bringing together public and private sector stakeholders, 2ZERO aims to create a thriving ecosystem for zero-emission mobility in Europe. Like CCAM, it is active in a vertical domain that widely rely on the edge-to-cloud continuum, because the zero-emission transportation goal can be certainly reached starting from the vehicle but more widely addressing mobility as an integrated system of systems, where the continuum is a key enabler.

5.3.3 IHI

21 https://www.2zeroemission.eu/

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The Innovative Health Initiative Joint Undertaking (IHI JU)[22] is a public-private partnership (European Commission, industry associations, and research organisations) aimed at accelerating the translation of research and innovation in the healthcare sector into tangible benefits for patients and society. By bringing together diverse stakeholders, the IHI JU aims to accelerate the development and adoption of innovative healthcare solutions that improve the lives of patients and strengthen Europe's position as a global leader in health research and innovation.

IHI seeks to ensure Europe remains at the forefront of interdisciplinary, sustainable, and patient-centric health research. IHI JU aims at transforming healthcare research into real-world impact, bridging the gap between research and clinical practice. This will create a concrete possibility to deliver innovative healthcare solutions, addressing unmet medical needs through groundbreaking therapies and technologies.

The edge-to-cloud continuum plays a key role from this perspective, because healthcare is and will be evolving towards connected, AI-based, P4 oriented solutions where the continuum is fundamental to guarantee the predictive, preventive, personalised, and participatory healthcare of the future. To reach this goal, IHI focuses also on strengthening Europe's health industry, fostering a competitive and sustainable healthcare ecosystem.

IHI provides financial support for promising projects with high potential impact, builds networks of experts, fosters collaboration among researchers, industry, and healthcare providers, and drives policy development, to influence healthcare policies to support innovation and patient care.

5.3.4 ADRA

The Adra Association[23] is a non-profit organisation that jointly promotes AI, data, and robotics research and innovation in Europe, with more than 180 members from academia and industry, including some of the leading experts in the field. Adra's mission is to make Europe a global leader in AI, data, and robotics. The association provides a platform for members to network and collaborate, organises events and conferences, provides funding for research projects and is active in lobbying for policies that support AI, data, and robotics.

Robotics is a critical element to consolidate and strengthen European manufacturing and industry competitiveness, which are widely based on the edge to cloud continuum, both in terms of technologies and data.

22 https://www.ihi.europa.eu/

23 https://www.adr-association.eu/

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6 CONCLUSIONS

During this last period, the work of WP1 focused on finalising all the activities started in the first period to put solid basis on the future and final work. OpenContinuum works on European Open Source initiatives, open source communities and Standardization as well as the liaison between EU Alliances and Open Ecosystem have been initiated and how these can be a real deal and help for the computing continuum.

In order to do so, strategic events and activities (e.g. workshops, training) have been organised 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 giving them information on important and well-known open source tools. In parallel with the seminars, and with the same aim, relevant events have been identified, organised or co-organised for the stakeholders.

The results further show the importance and necessity of having an open source stack that can be used as the basis for all future development as well as a common understanding on standards in the continuum. With the "breaking the silos" idea in mind, it is possible to see also in these results how it is so important to create a community in which projects can communicate and collaborate on common aspects. With the investigation conducted in this period, we are able to confirm and consolidate the Open Source Stack.

The development of the computing continuum ecosystem requires standardisation support. In this project several approaches have been identified, 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 defined.

As already mentioned in the previous report, The European Cloud Edge & IoT initiative launched 6 task forces dedicated to the different focus topics. In this context, the work carried on by the Open Source Engagement Task Force 2 (TF2) and Task Force 1 (TF1) is managed by Work Package 1.

The TF2 mission is complementing on overlapping the work of task 1.1 and focus, on the one hand, 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.

Moreover, the work package activity has identified and participated in a number of events highly relevant to the European Cloud, Edge and IoT Continuum and for the scope of the work. These events have been targeted for organising workshop sessions, presenting in, or participating in; full details and overview of all the events have been reported in D3.3.

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7 APPENDIX

7.1 DATA OVERVIEW PER CALL

In this subchapter the overview of each call is presented considering each layer in the survey. Every chart presents the labels on the left and the data on the right. The labels in each layer are separated by the main questions raised in the survey and refer to the list of questions mentioned at 3.2.

7.1.1 Cloud Computing

In this call 6 projects participated in the survey.

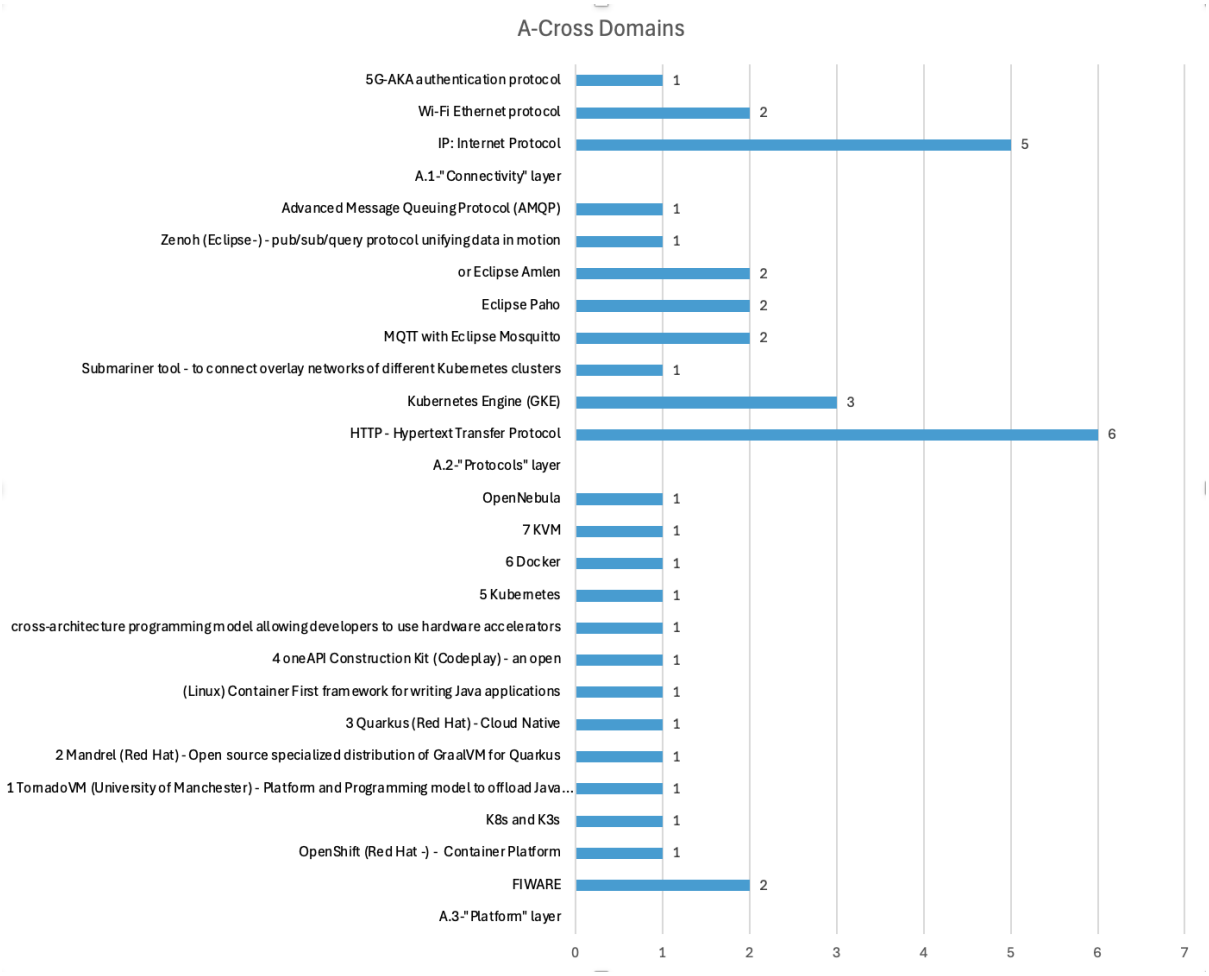

FIGURE 22 - CLOUD COMPUTING A-CROSS DOMAINS OVERVIEW

Funded by Horizon Europe Framework Programme of the European Union

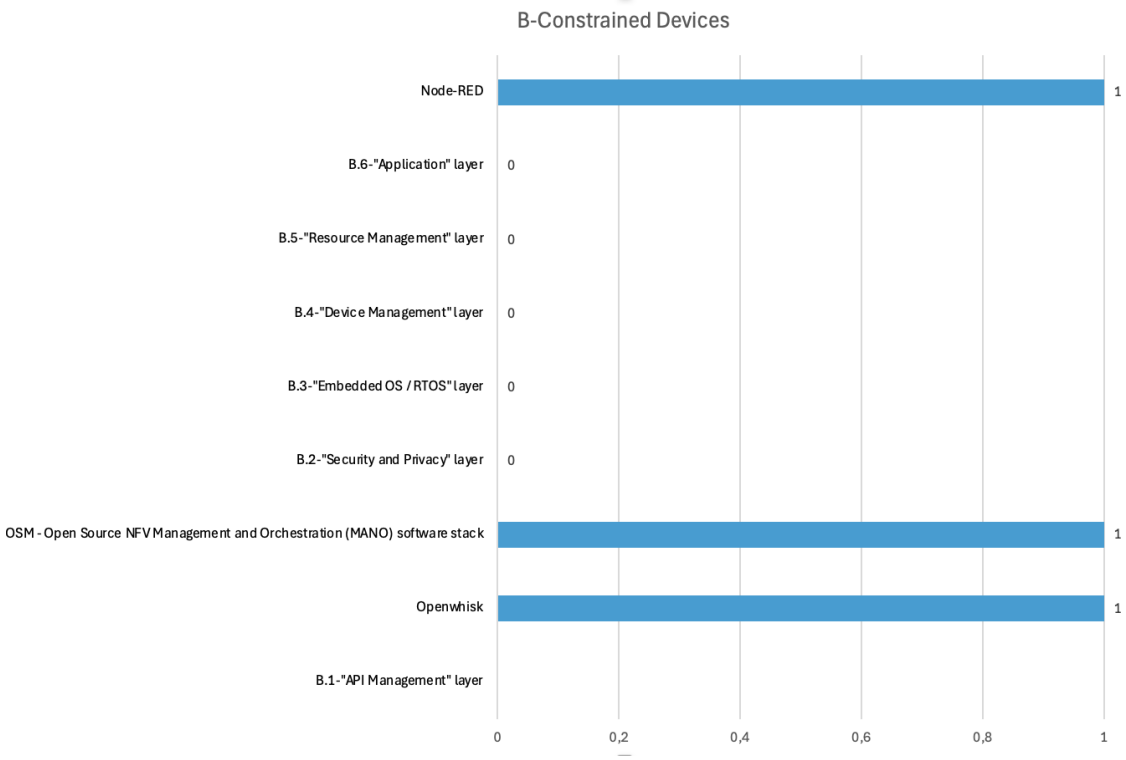

FIGURE 23 - CLOUD COMPUTING B- CONSTRAINED DEVICES

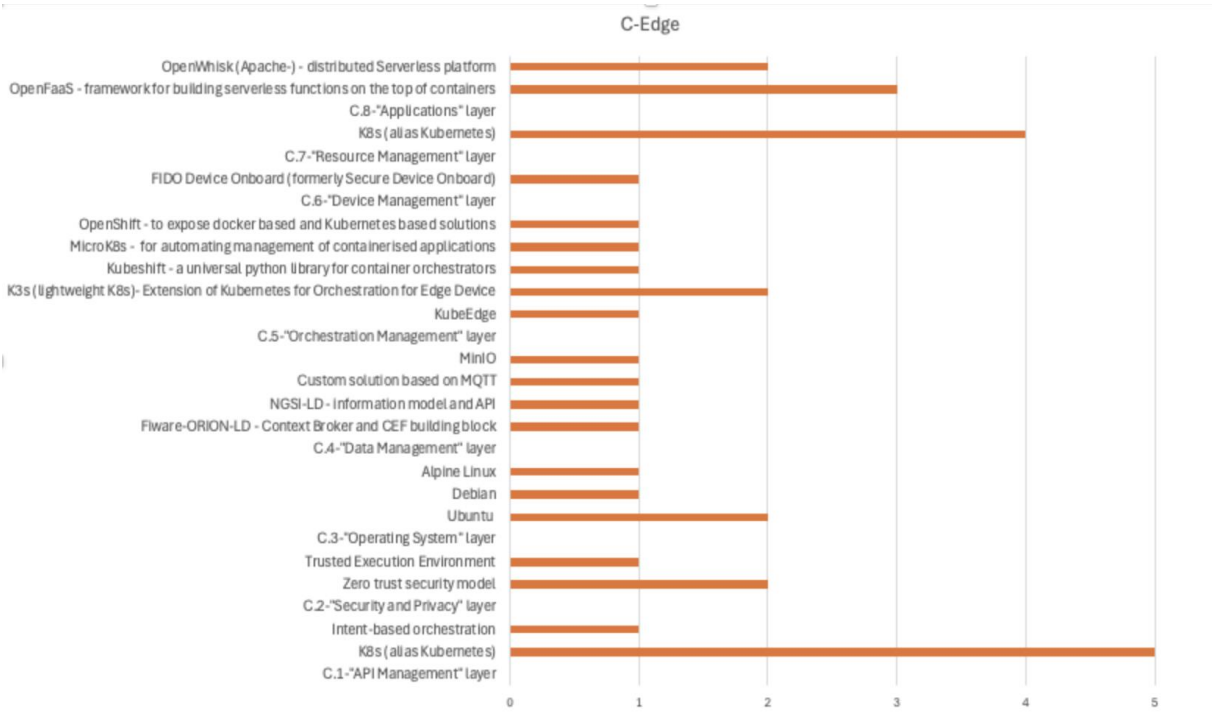

FIGURE 24 - CLOUD COMPUTING C-EDGE

Funded by Horizon Europe Framework Programme of the European Union

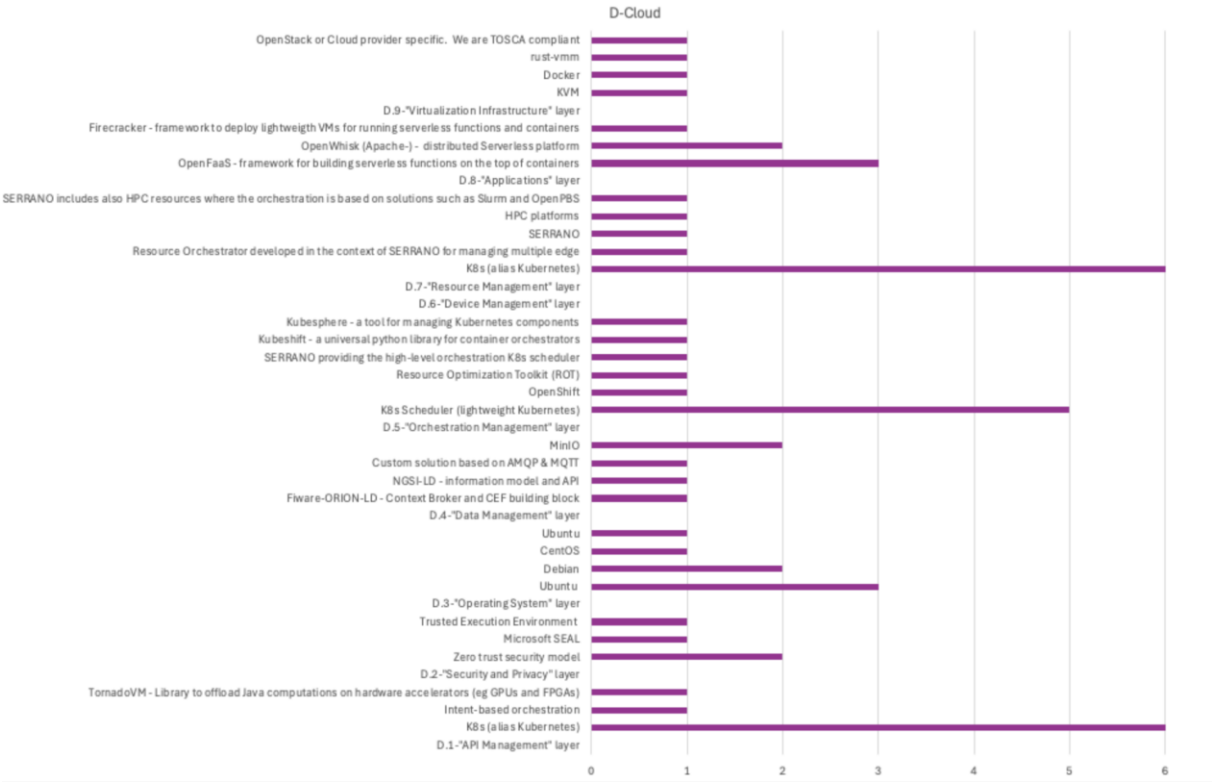

FIGURE 25 - CLOUD COMPUTING D-CLOUD

7.1.2 Cognitive Cloud

In this call 5 projects participated in the survey.

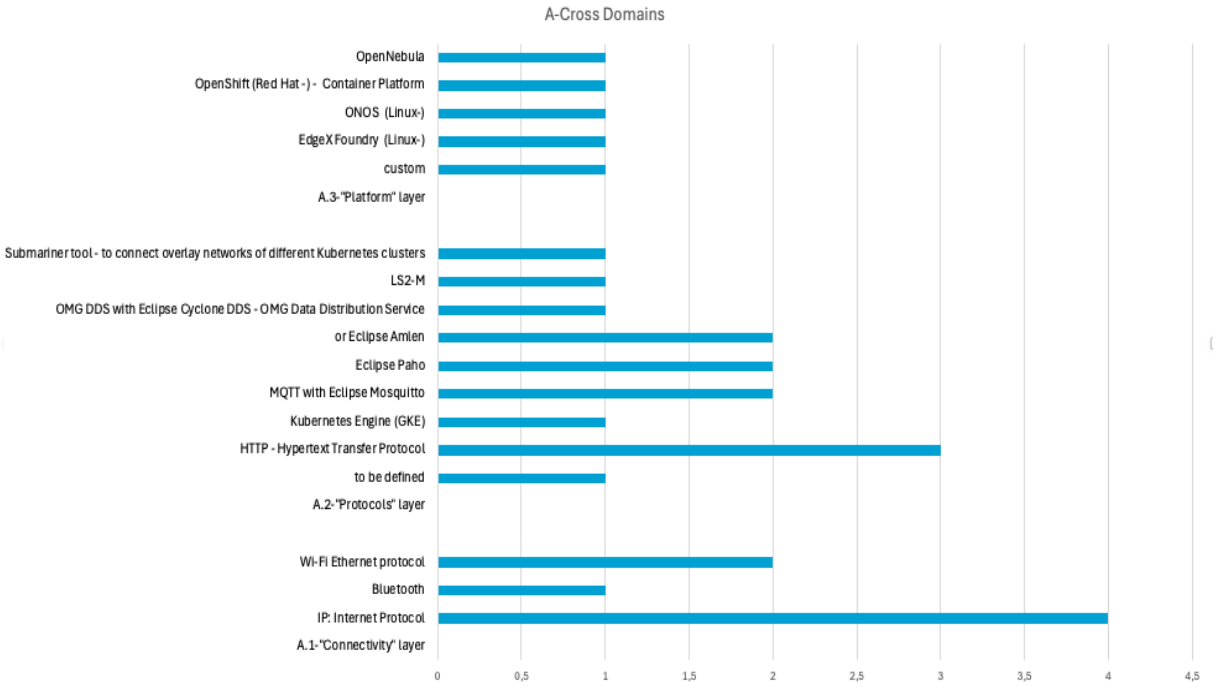

FIGURE 26 - COGNITIVE CLOUD -A-CROSS DOMAIN

Funded by Horizon Europe Framework Programme of the European Union

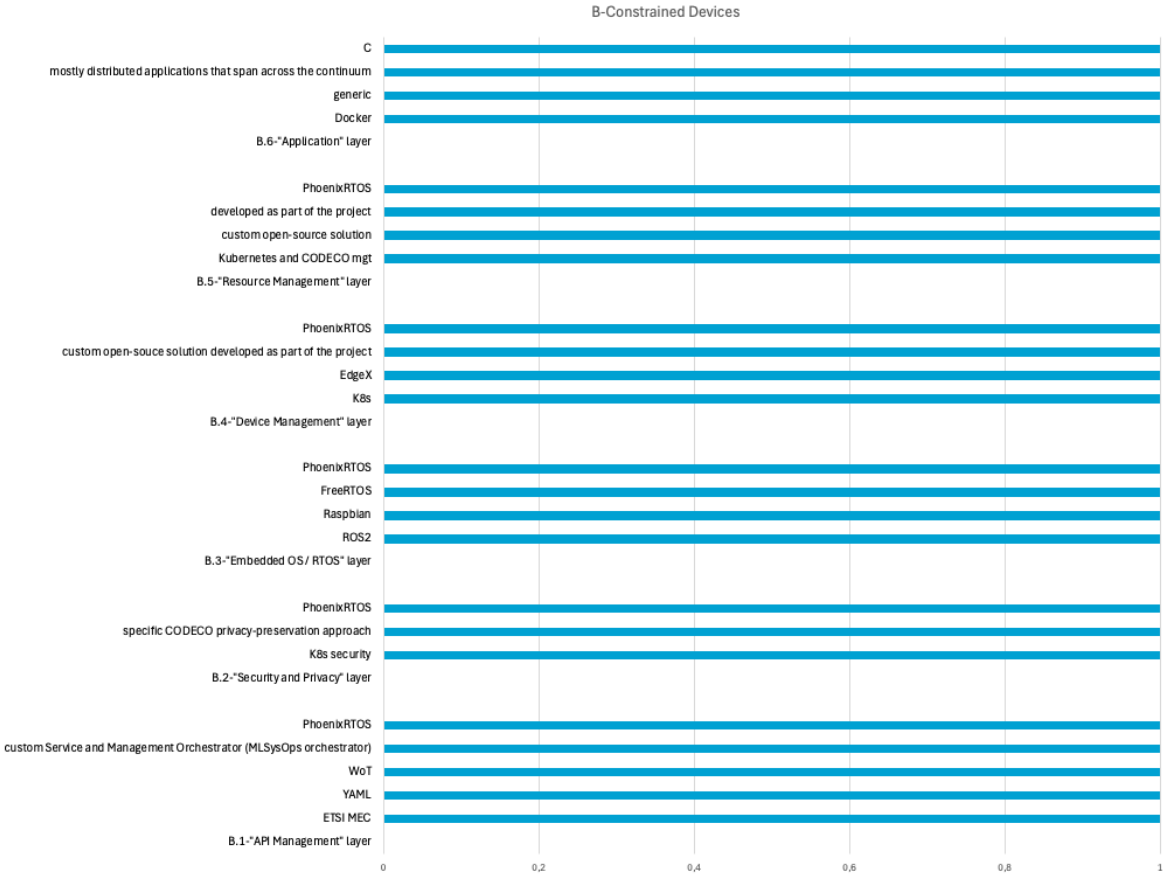

FIGURE 27 - COGNITIVE CLOUD B-CONSTRAINED DEVICES

Funded by Horizon Europe Framework Programme of the European Union

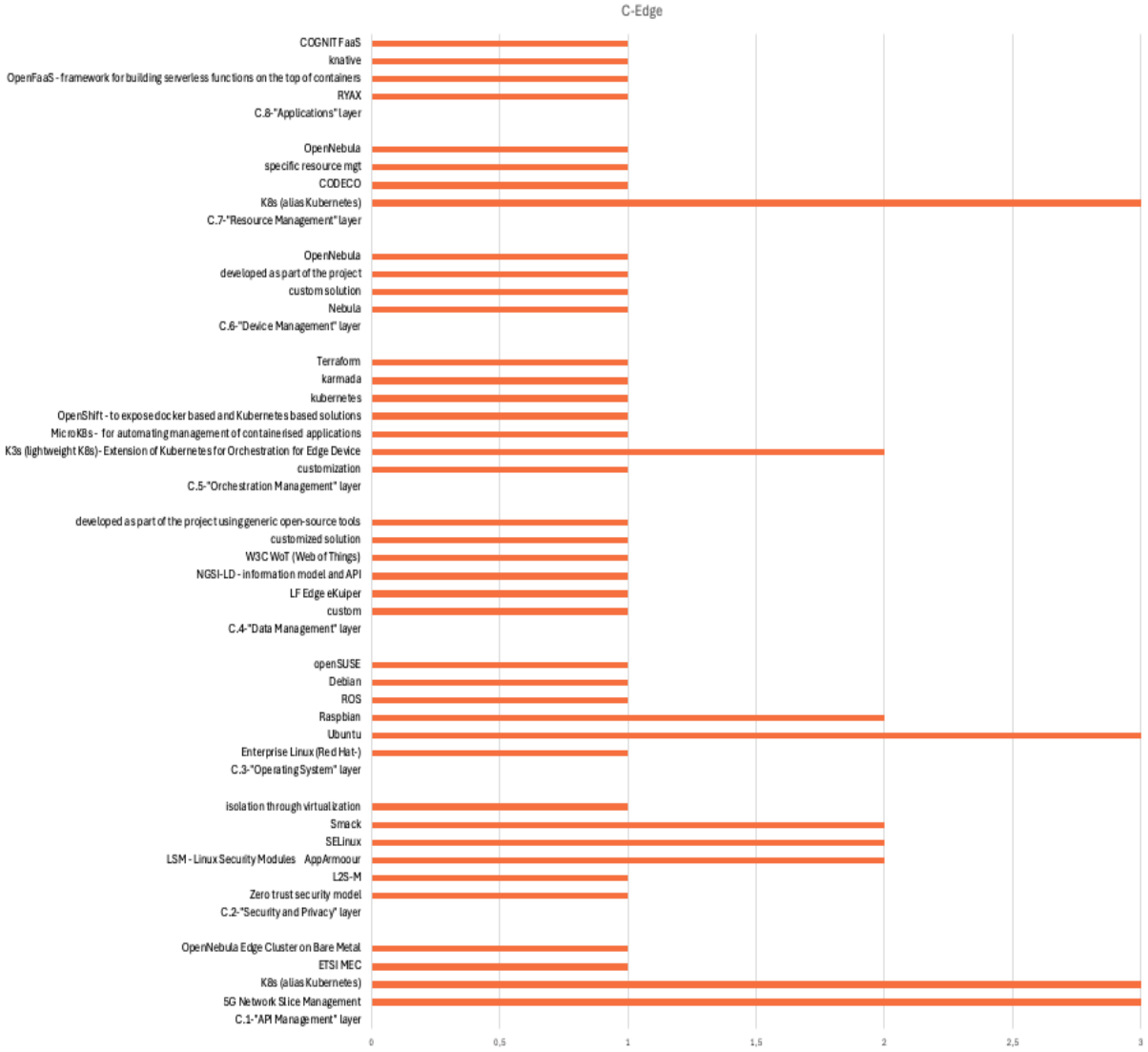

FIGURE 28 - COGNITIVE CLOUD C-EDGE

Funded by Horizon Europe Framework Programme of the European Union

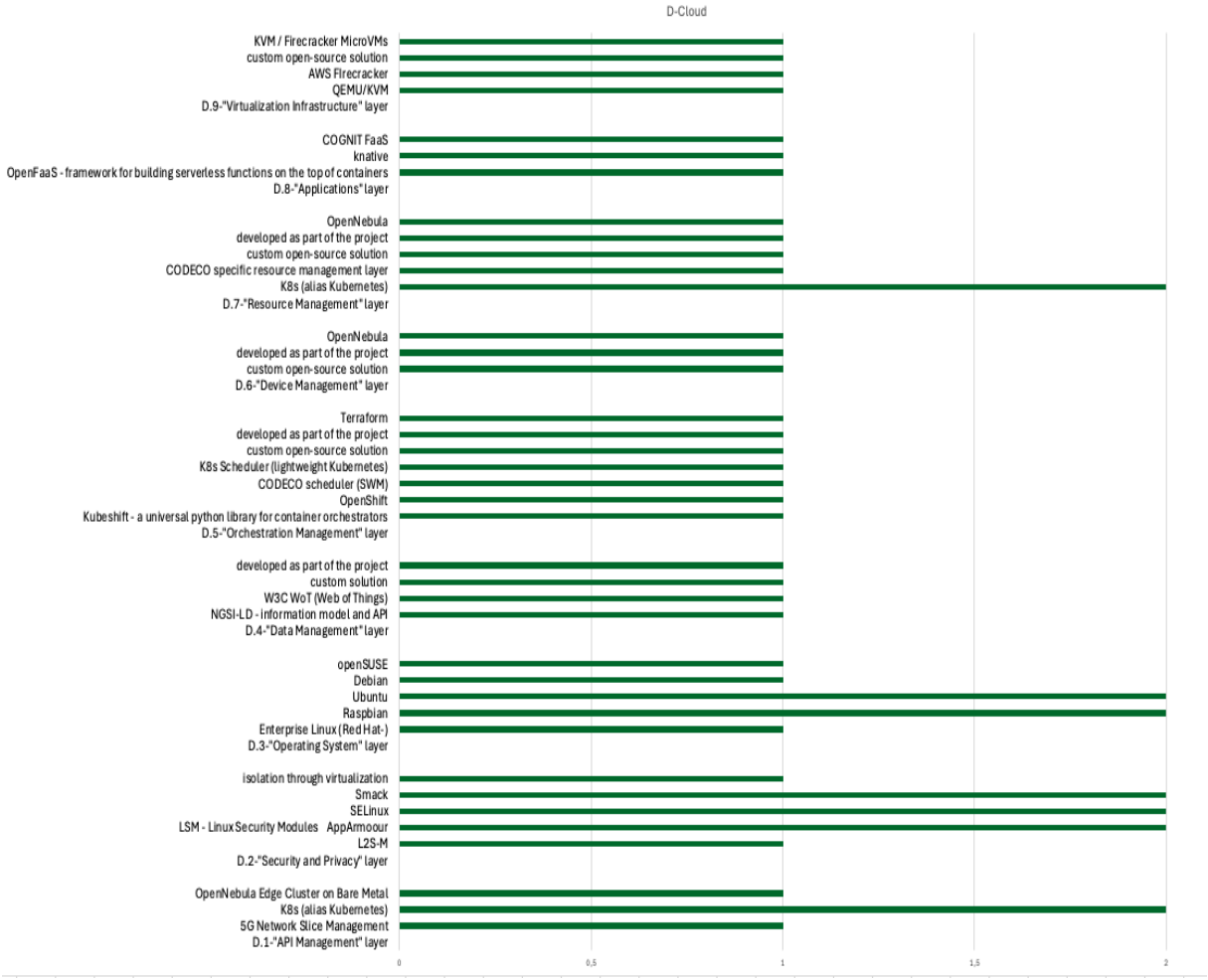

FIGURE 29 - - COGNITIVE CLOUD D-CLOUD

7.1.3 HORIZON-CL3-2021-CS-01-02 (Improved security in open-source and open-specification hardware for connected devices)

In this call 1 project participated in the survey.

The project has no components in the A-Cross Domains layers nor in the C-Edge and D-Cloud Layers. The only layer considered is the B-Constrained Devices reported in the figure below.

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FIGURE 30 - HORIZON-CL3-2021-CS-01-02 B-CONSTRAINED DEVICES

7.1.4 MetaOS

In this call 6 projects over the 6 projects funded under this call participated in the survey.

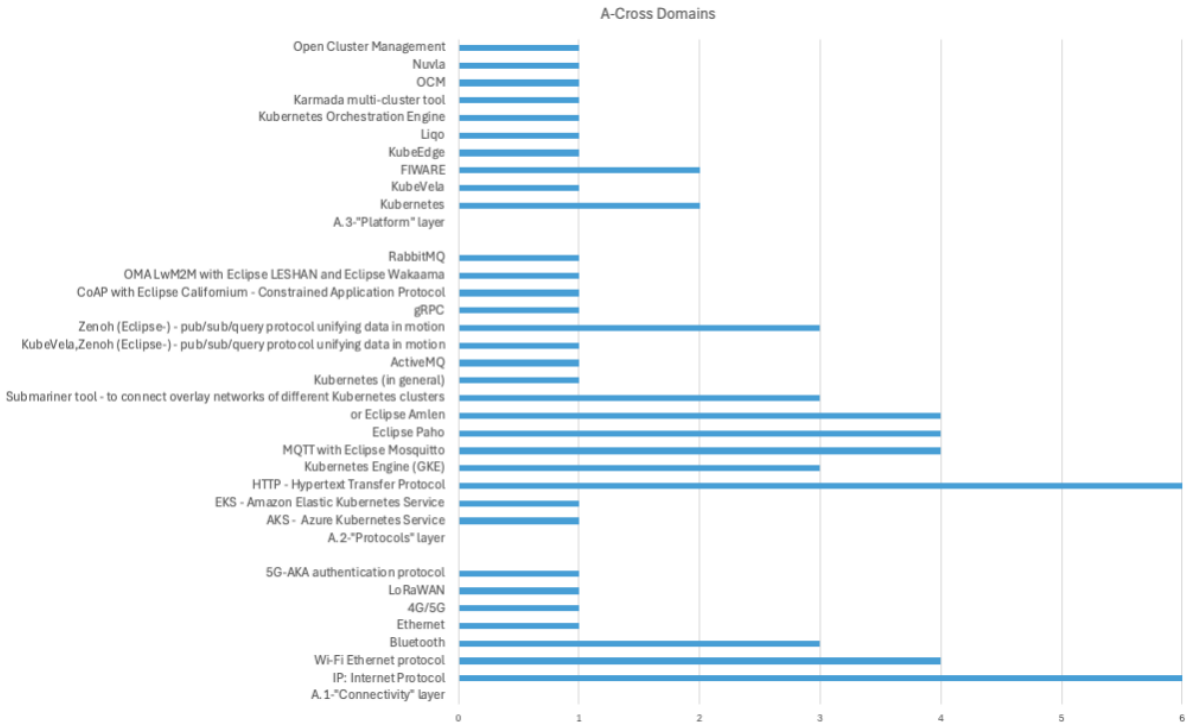

FIGURE 31 - METAOS A-CROSS DOMAINS

Funded by Horizon Europe Framework Programme of the European Union

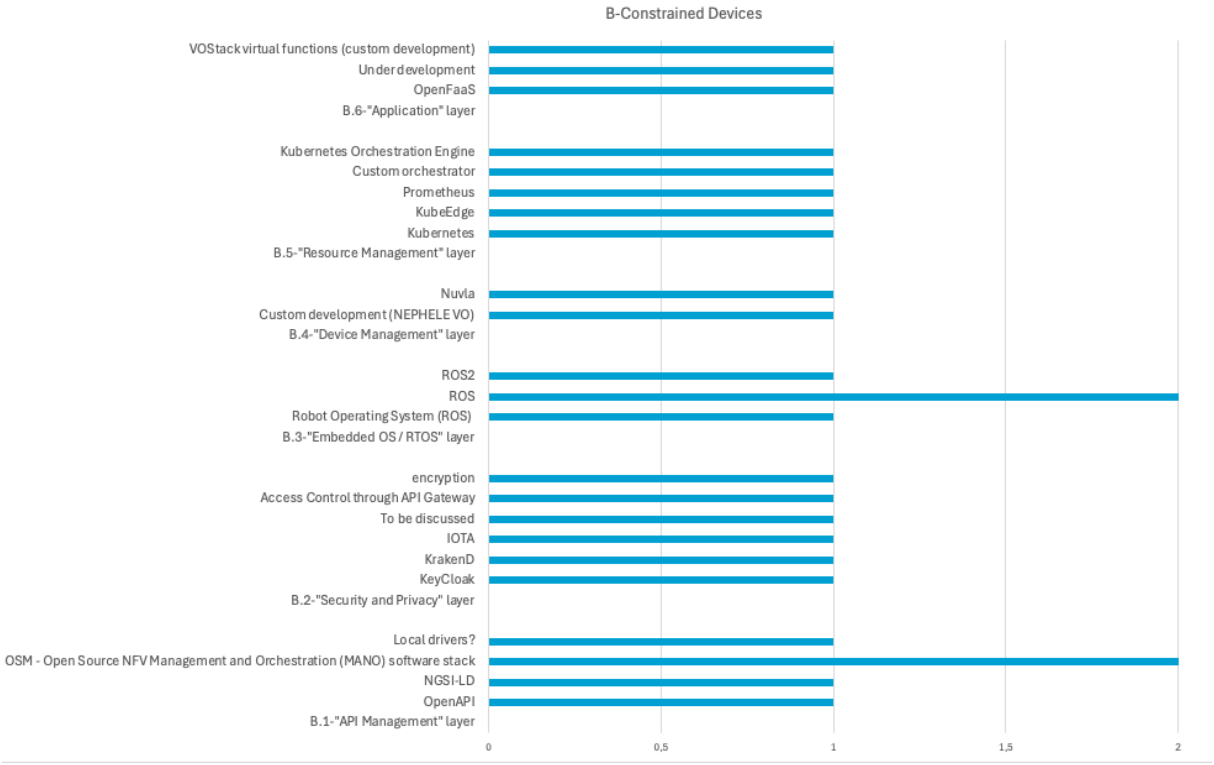

FIGURE 32 - METAOS B-CONSTRAINED DEVICES

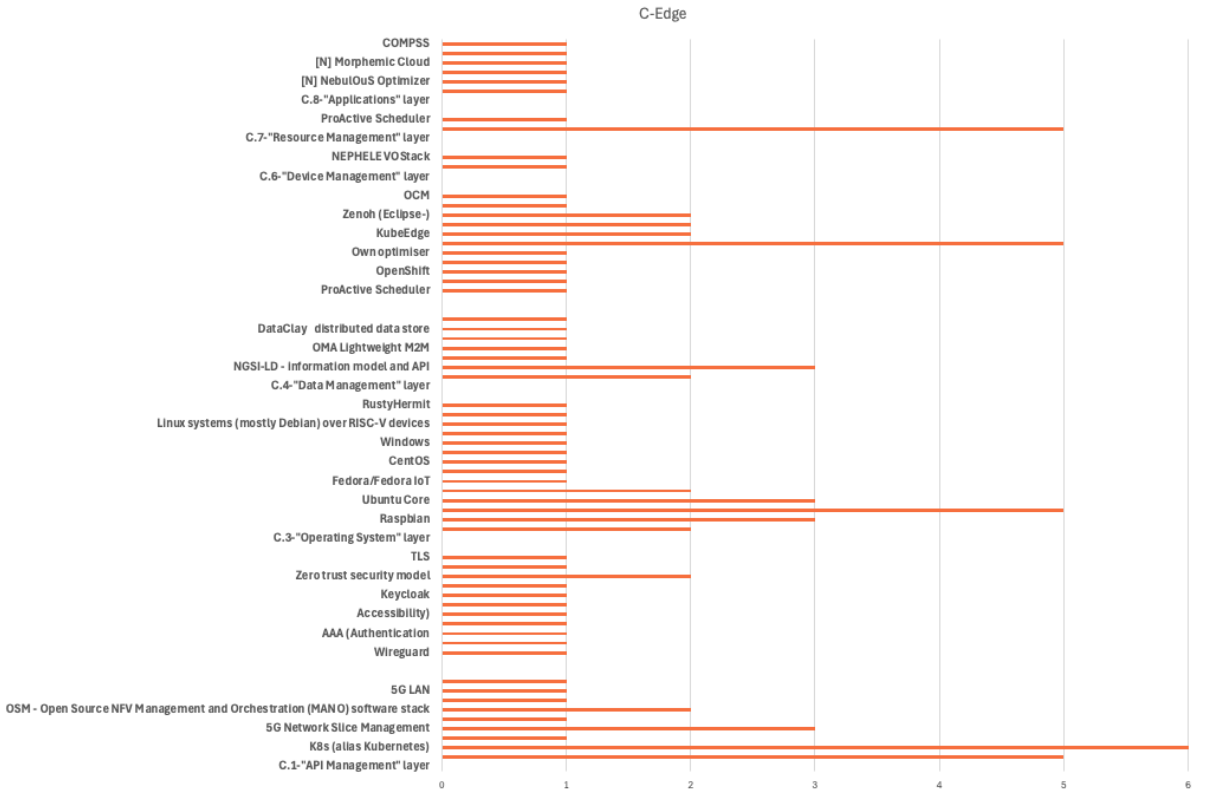

FIGURE 33 - METAOS C-EDGE

Funded by Horizon Europe Framework Programme of the European Union

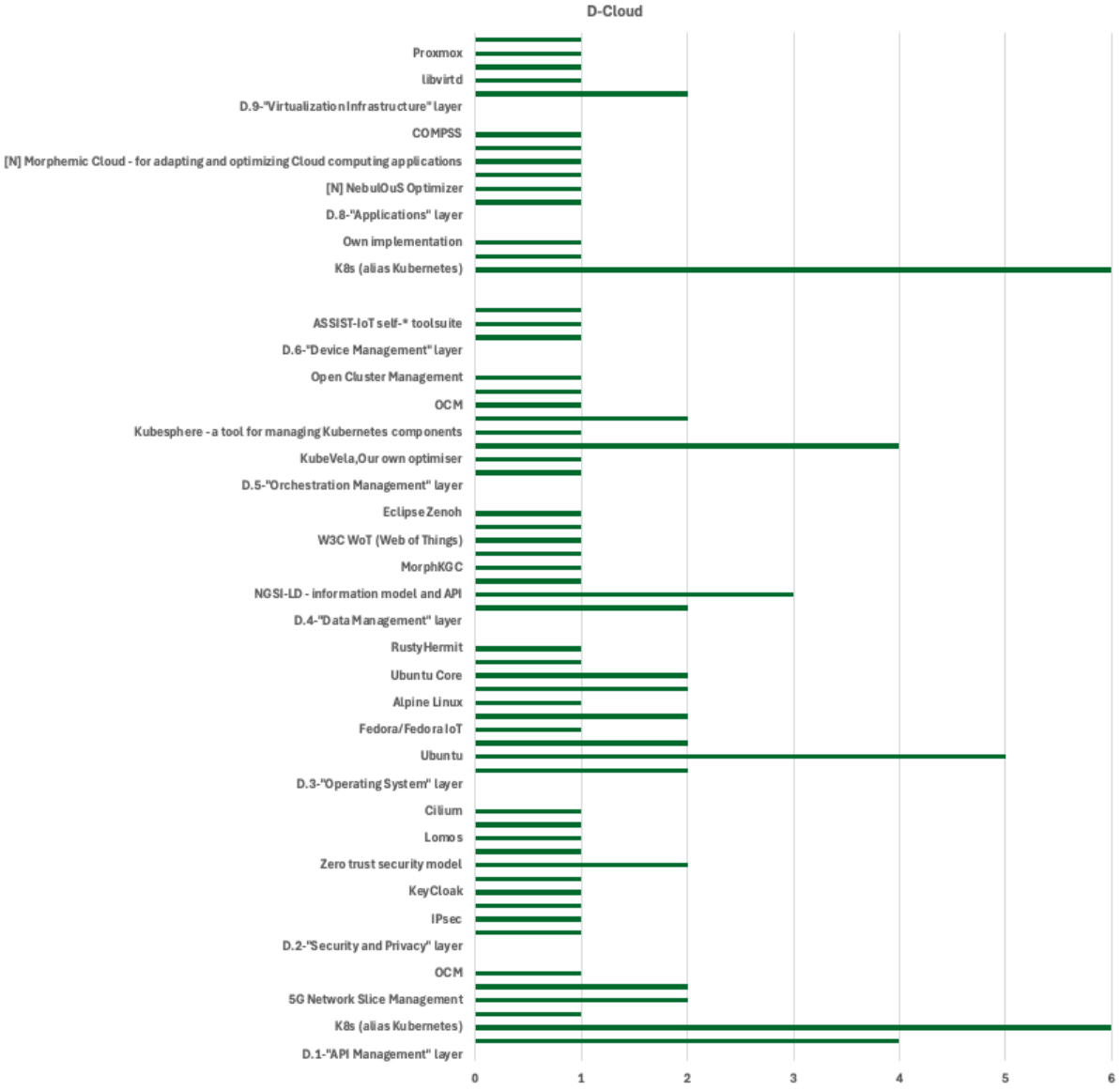

FIGURE 34 - METAOS D-CLOUD

7.1.5 Open Source for Cloud service

In this call 2 projects participated in the survey.

The projects have no components in the B-Constrained Devices.

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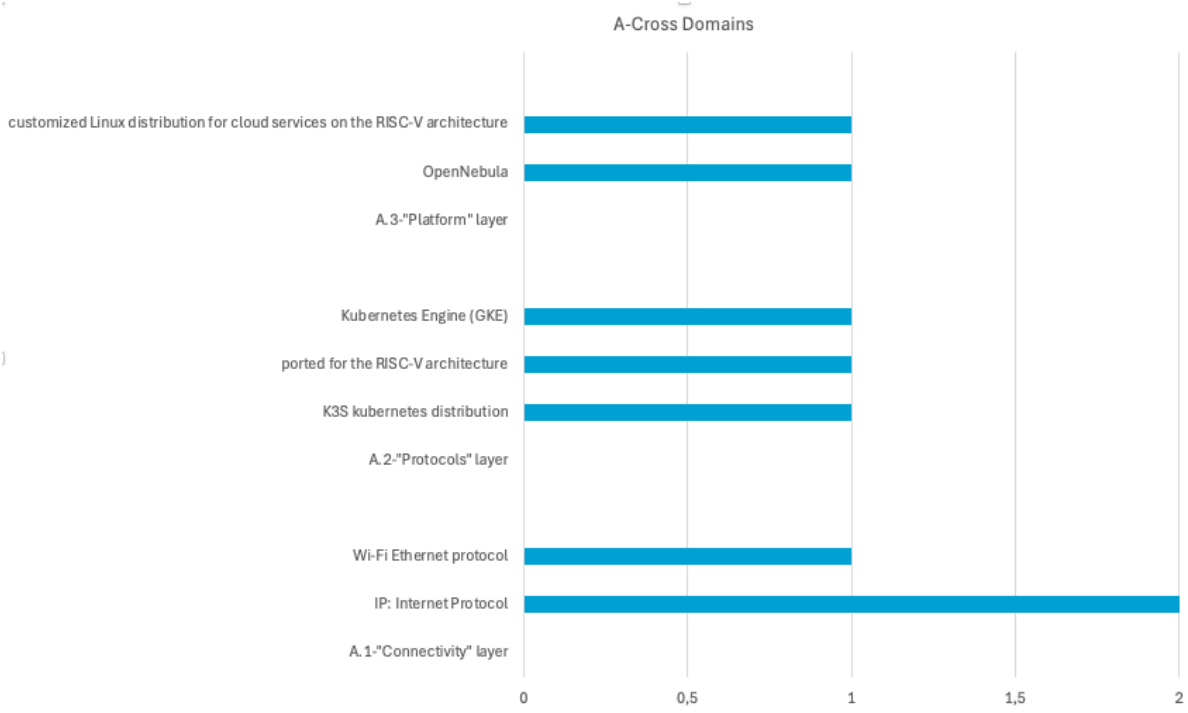

FIGURE 35 - OPEN SOURCE FOR CLOUD SERVICE A-CROSS DOMAINS

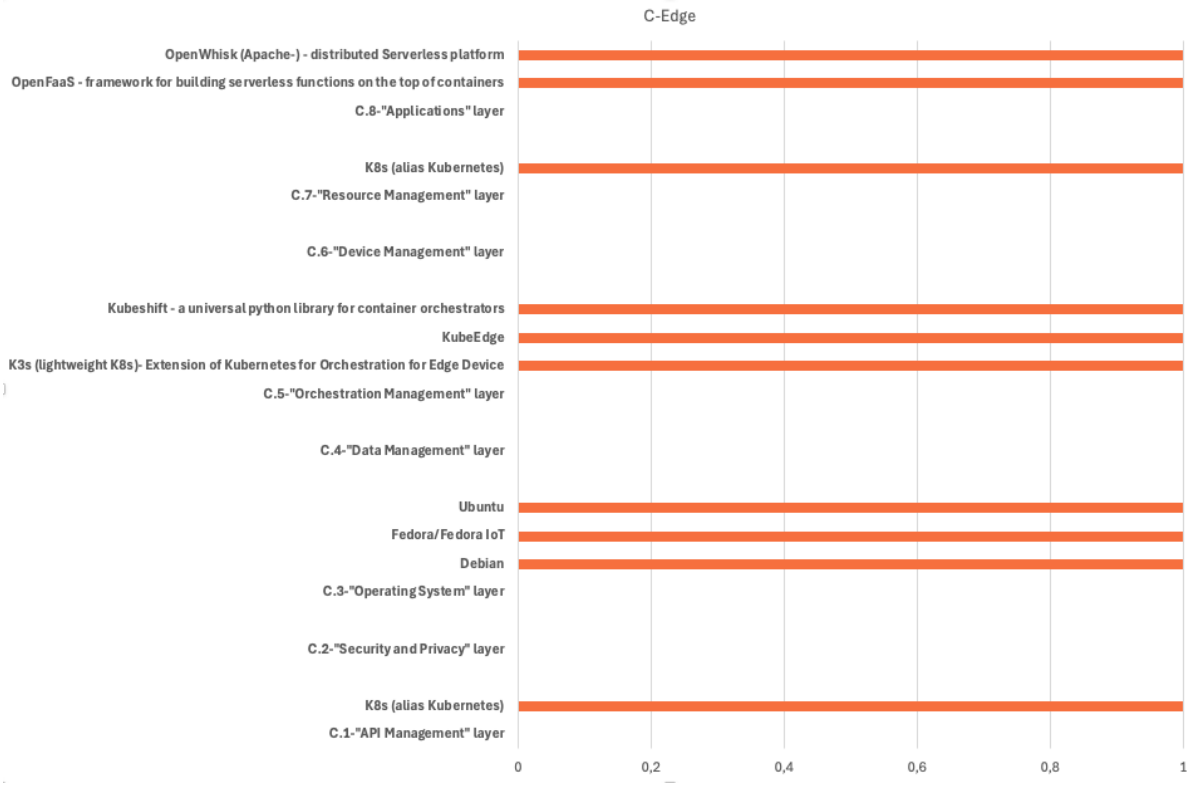

FIGURE 36 - OPEN SOURCE FOR CLOUD SERVICE C-EDGE

Funded by Horizon Europe Framework Programme of the European Union

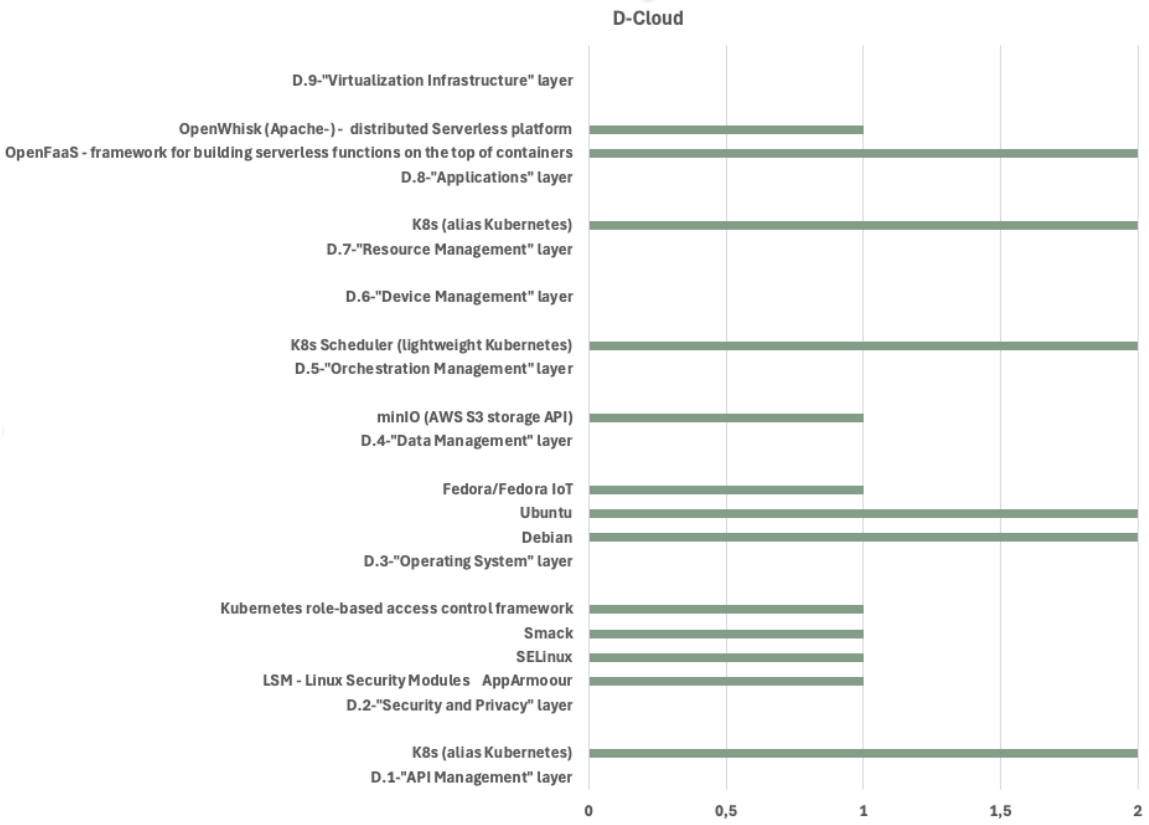

FIGURE 37 - OPEN SOURCE FOR CLOUD SERVICE D-CLOUD

7.1.6 Software Technologies

In this call 2 projects participated in the survey.

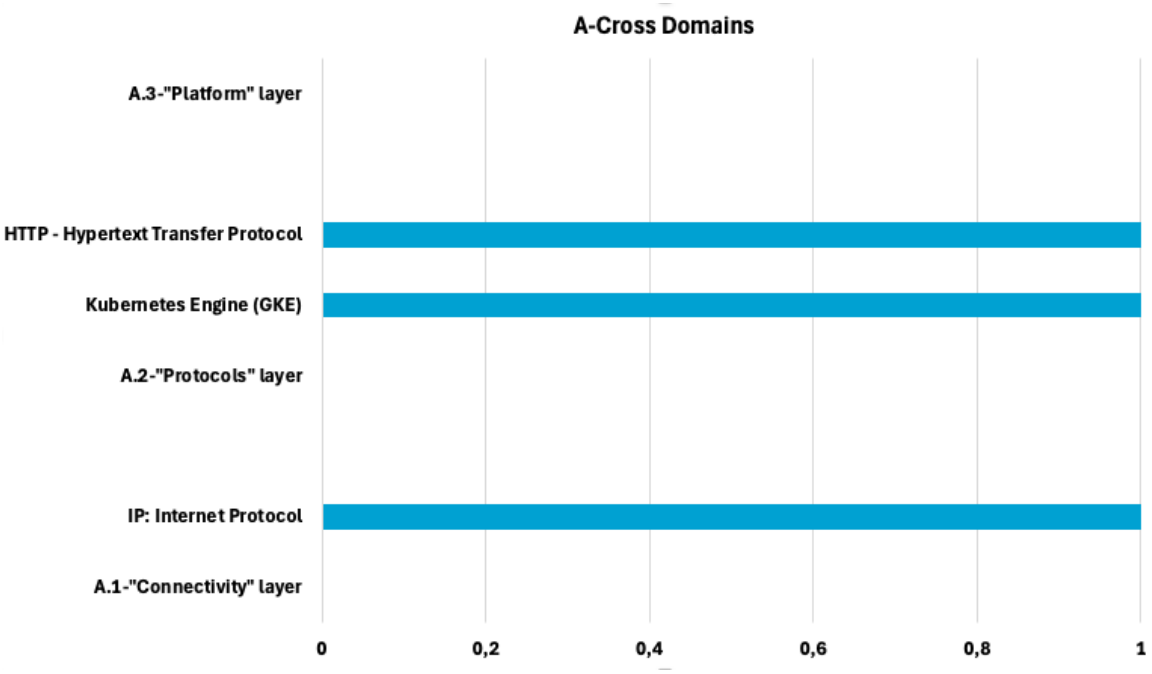

FIGURE 38 - SOFTWARE TECHNOLOGIES A-CROSS DOMAINS

Funded by Horizon Europe Framework Programme of the European Union

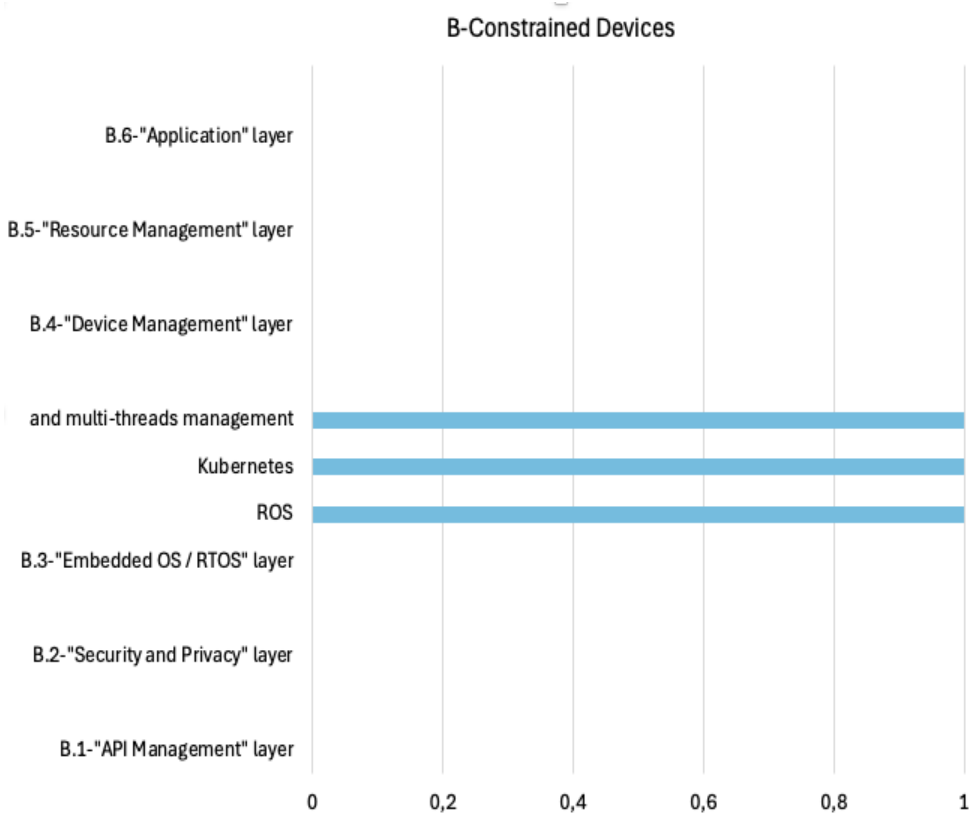

FIGURE 39 - SOFTWARE TECHNOLOGIES B-CONSTRAINED DEVICES

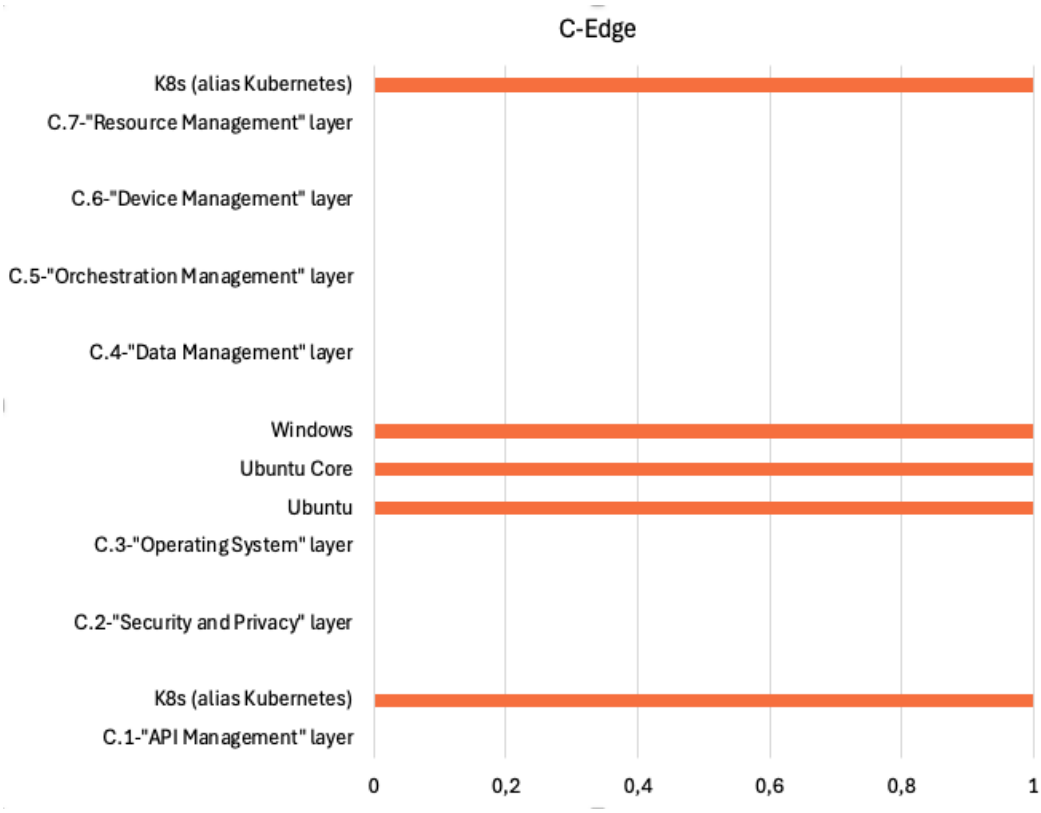

FIGURE 40 - FIGURE 36 - SOFTWARE TECHNOLOGIES C-EDGE

Funded by Horizon Europe Framework Programme of the European Union

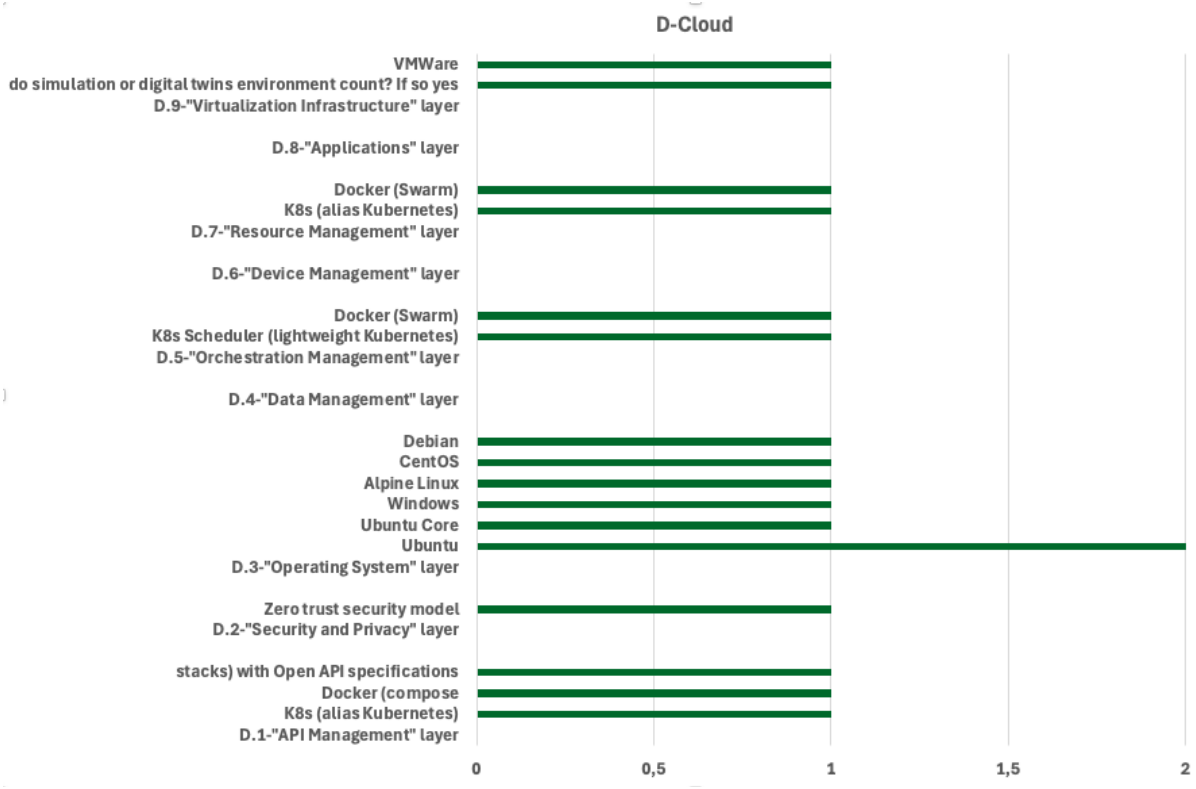

FIGURE 41 - SOFTWARE TECHNOLOGIES D-CLOUD

7.1.7 Swarm Intelligence

In this call 4 projects participated in the survey.

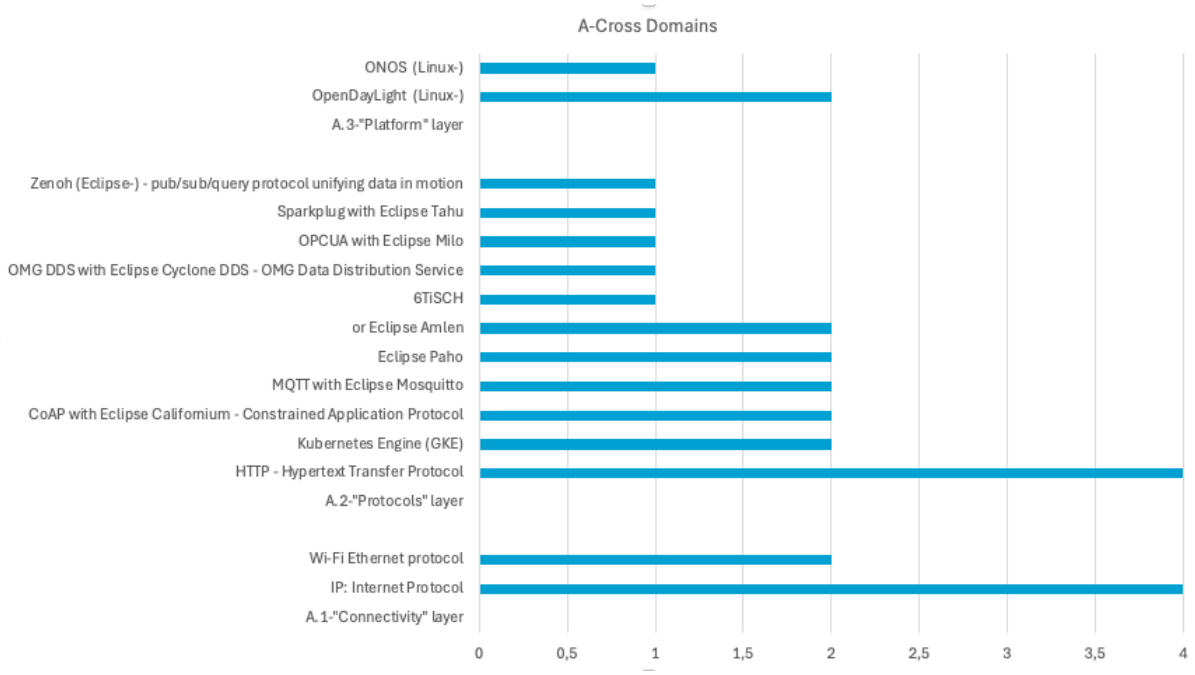

FIGURE 42 - SWARM INTELLIGENCE A-CROSS DOMAINS

Funded by Horizon Europe Framework Programme of the European Union

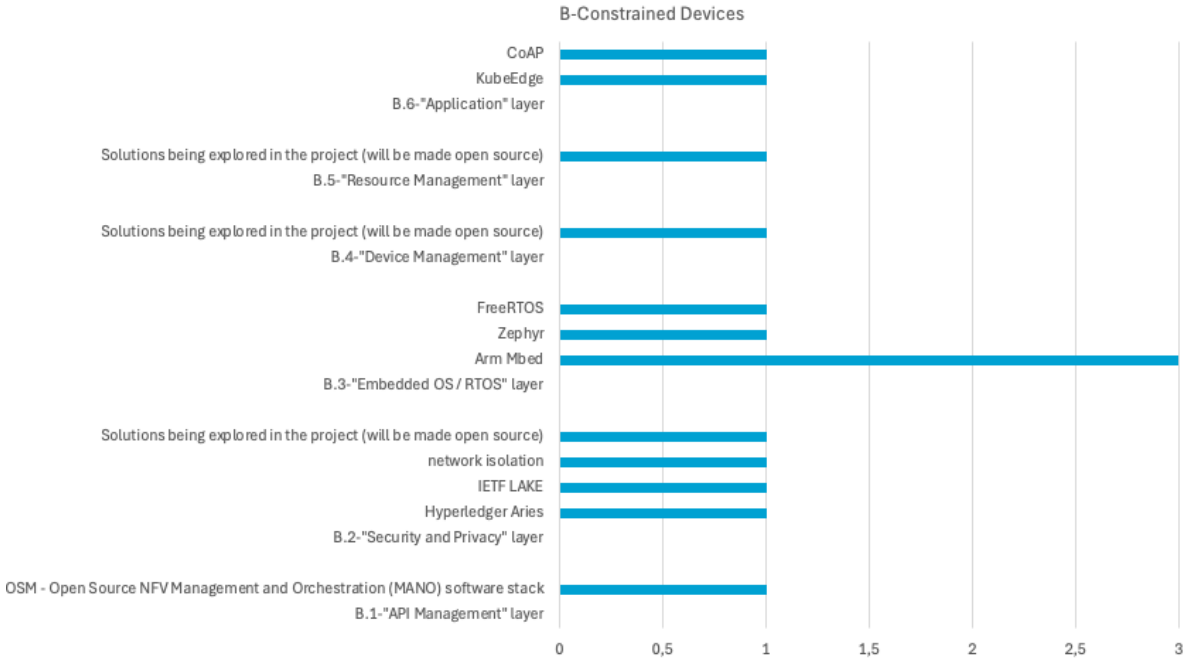

FIGURE 43 - SWARM INTELLIGENCE B-CONSTRAINED DEVICES

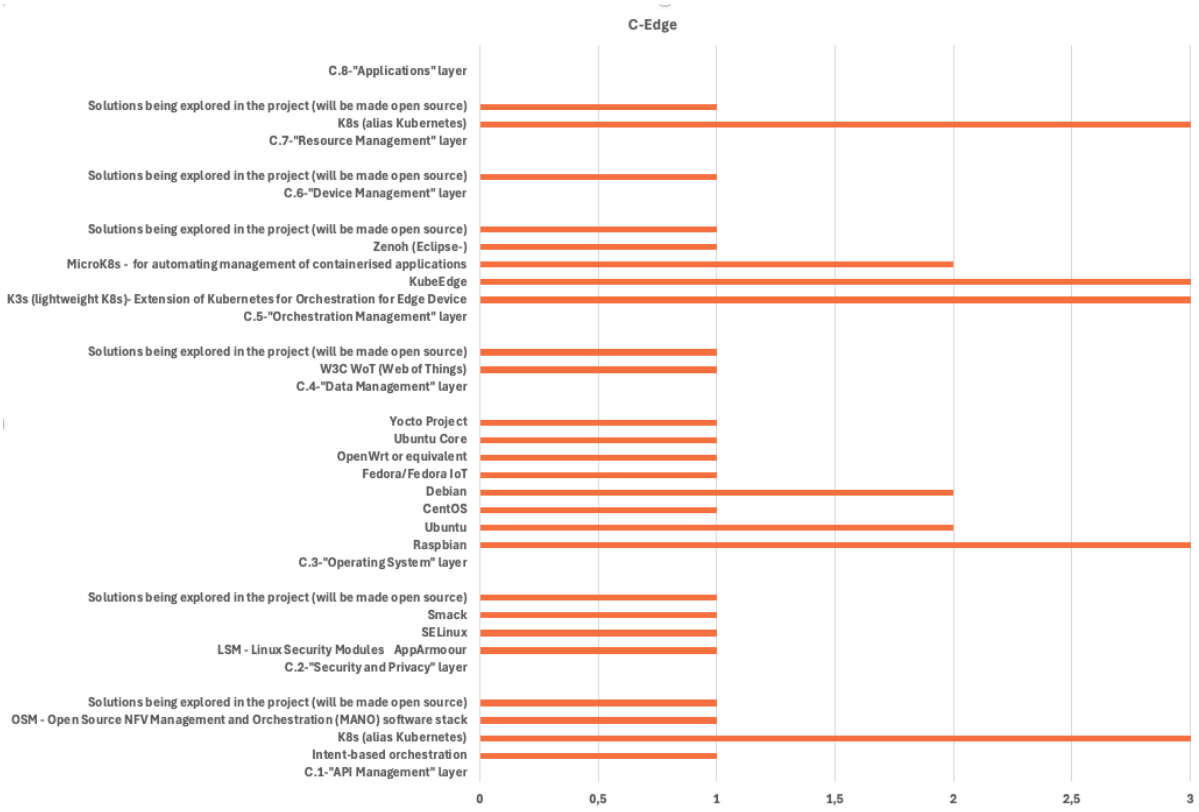

FIGURE 44 - SWARM INTELLIGENCE C-EDGE

Funded by Horizon Europe Framework Programme of the European Union

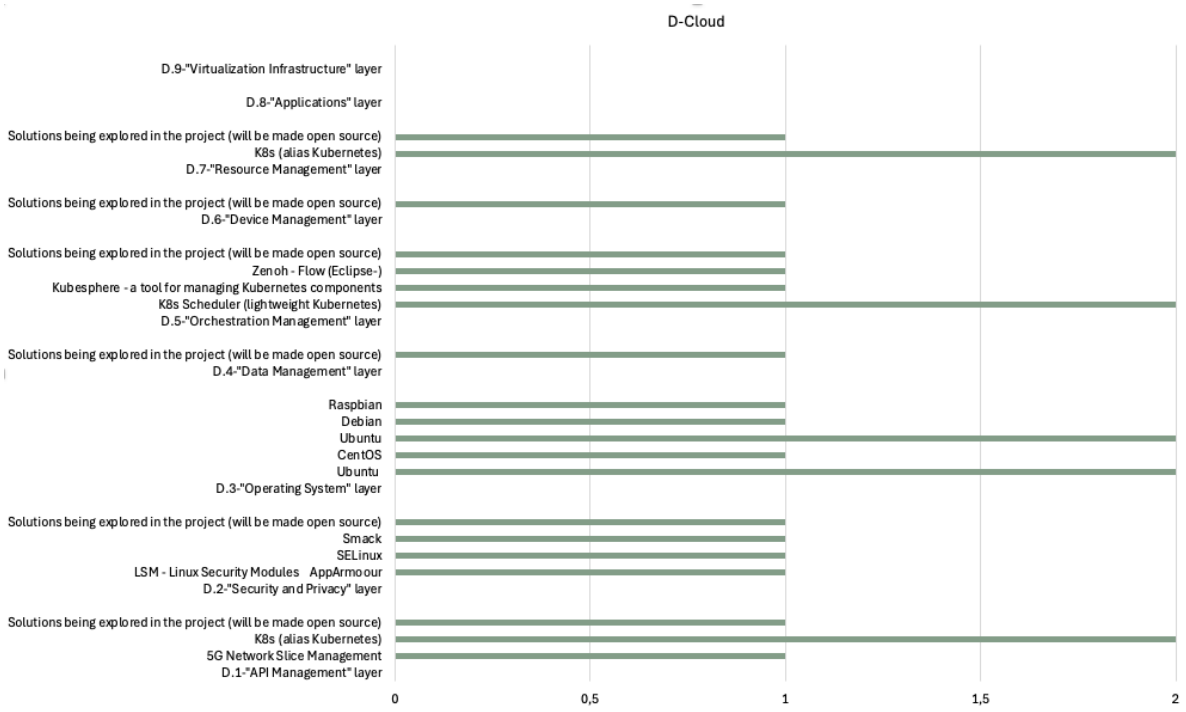

FIGURE 45 - SWARM INTELLIGENCE D-CLOUD

7.1.8 Next Generation IoT

In this call 3 projects participated in the survey.

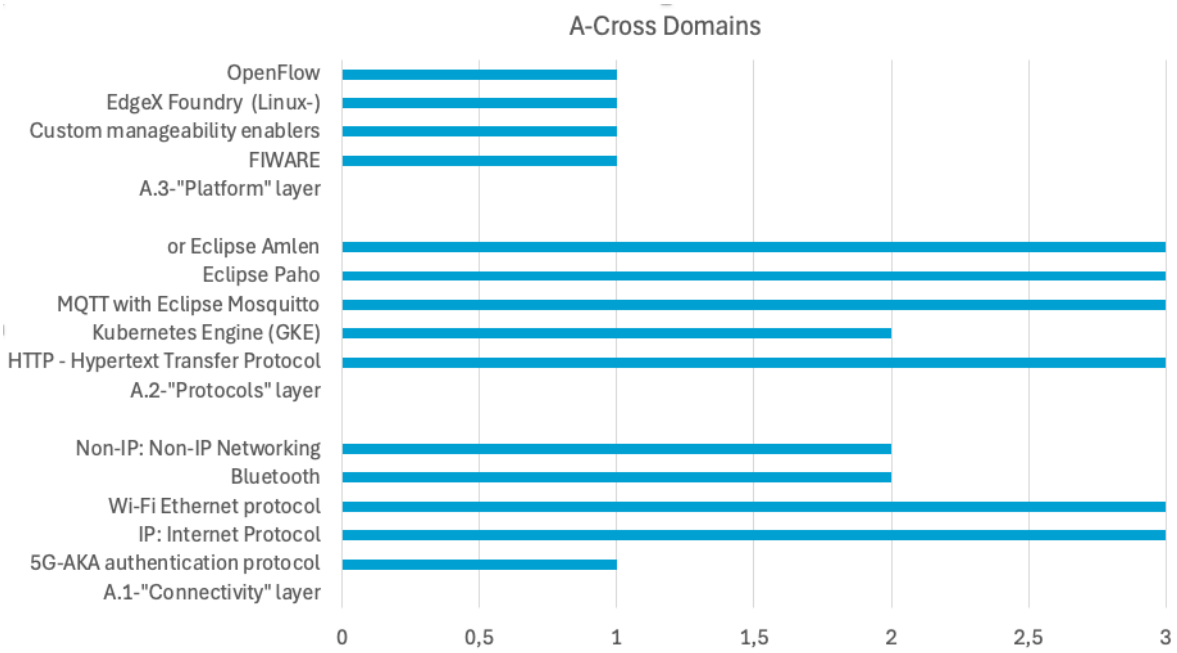

FIGURE 46 - NEXT GENERATION IOT A-CROSS DOMAINS

Funded by Horizon Europe Framework Programme of the European Union

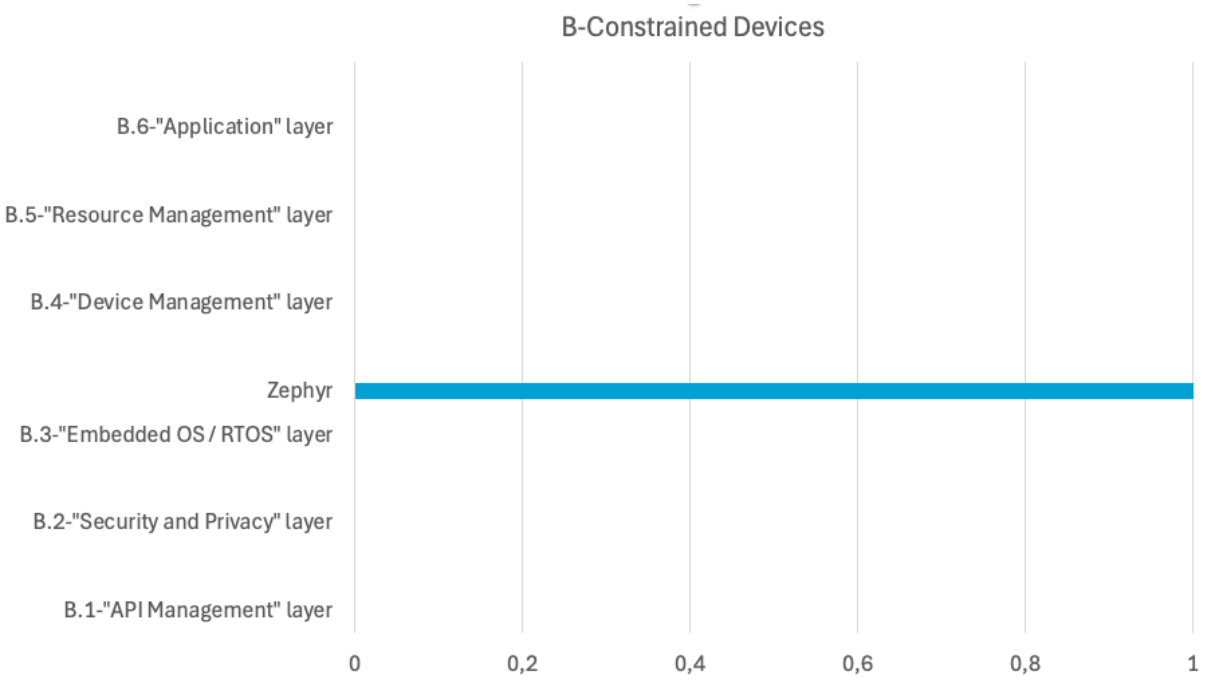

FIGURE 47 - NEXT GENERATION IOT B-CONSTRAINED DEVICES

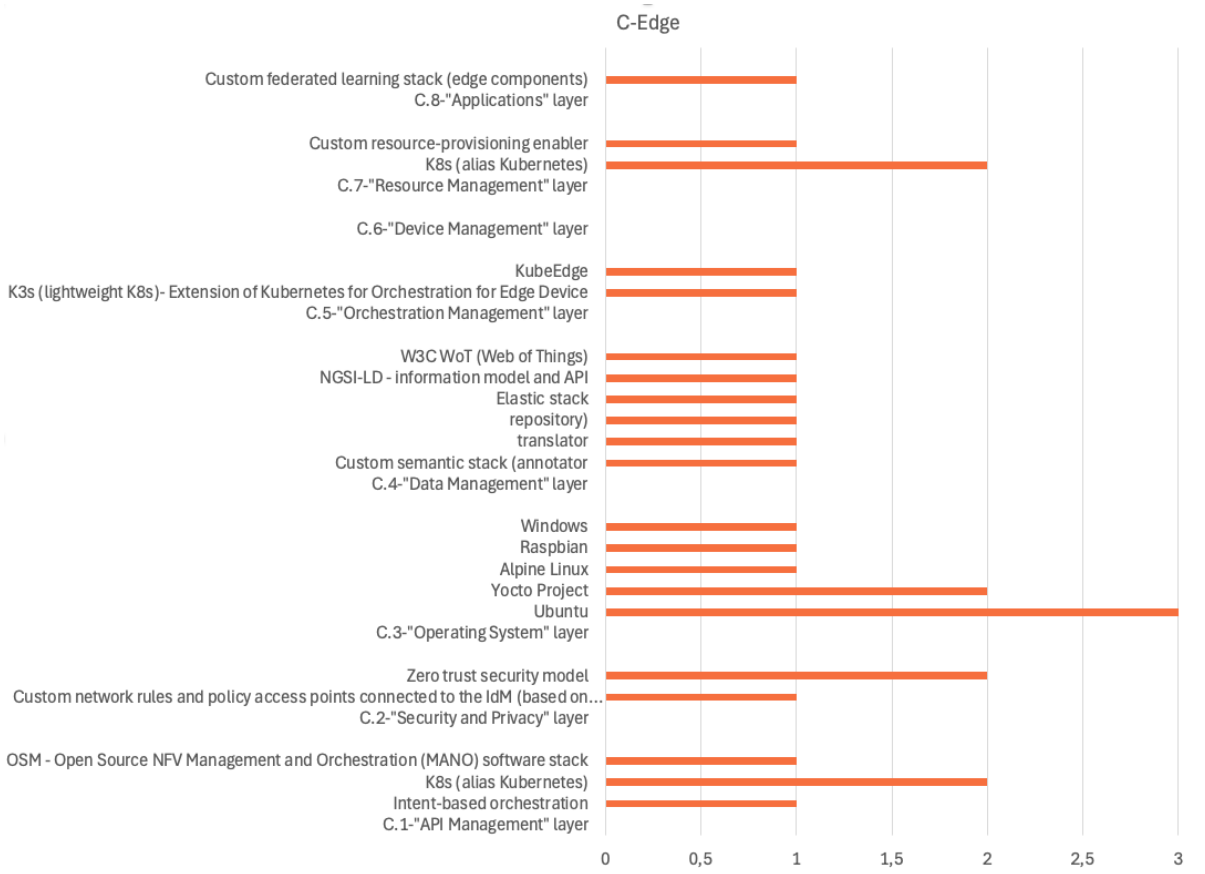

FIGURE 48 - NEXT GENERATION IOT C-EDGE

Funded by Horizon Europe Framework Programme of the European Union

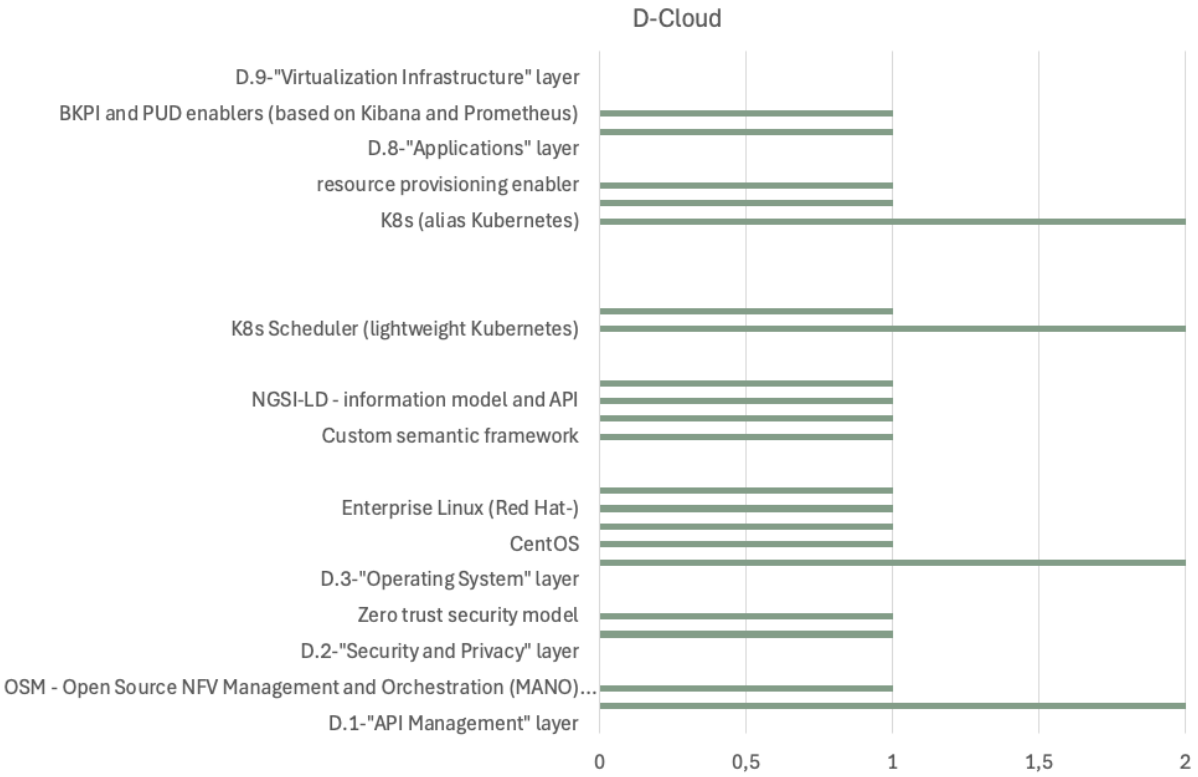

FIGURE 49 - NEXT GENERATION IOT D-CLOUD

7.1.9 HORIZON-CL4-2021-DATA-01-01

In this call 1 project participated in the survey.

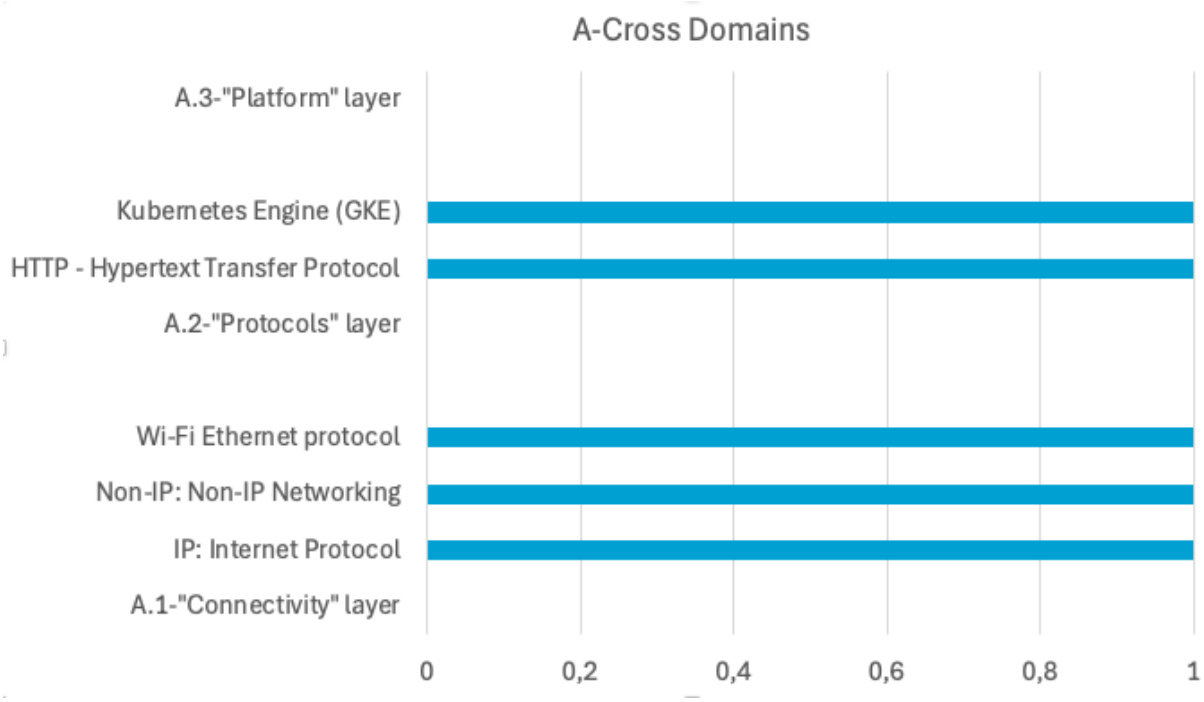

FIGURE 50 - HORIZON-CL4-2021-DATA-01-01 A-CROSS DOMAINS

Funded by Horizon Europe Framework Programme of the European Union

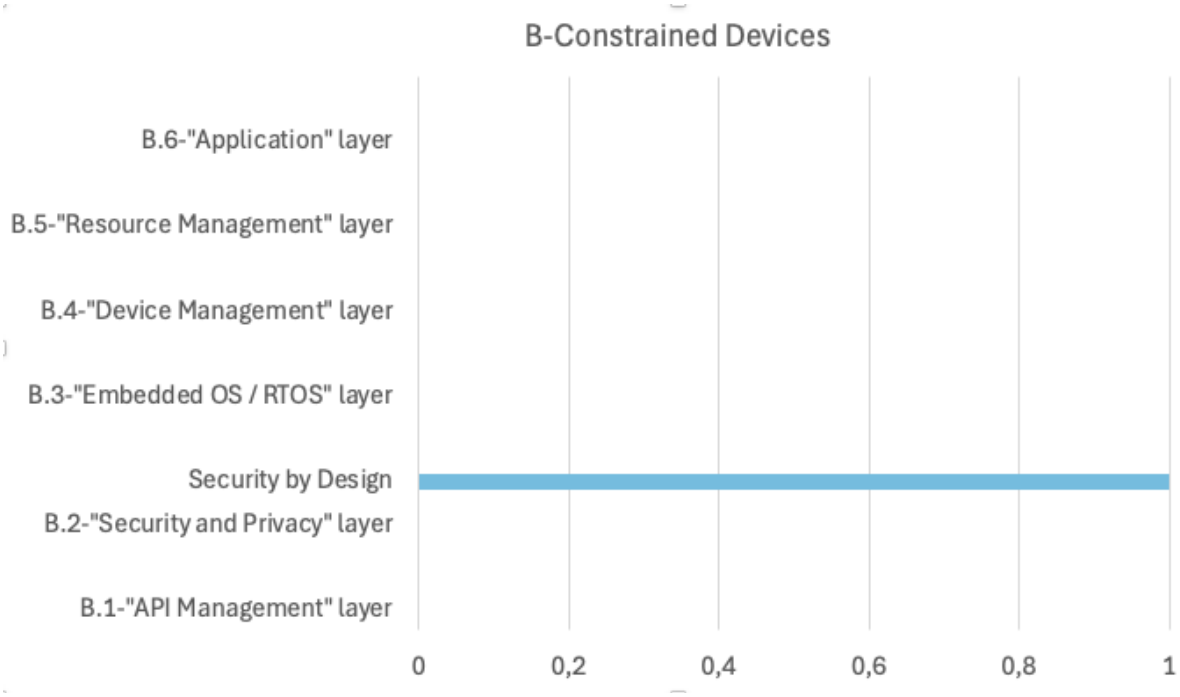

FIGURE 51 - HORIZON-CL4-2021-DATA-01-01 B-CONSTRAINED DEVICES

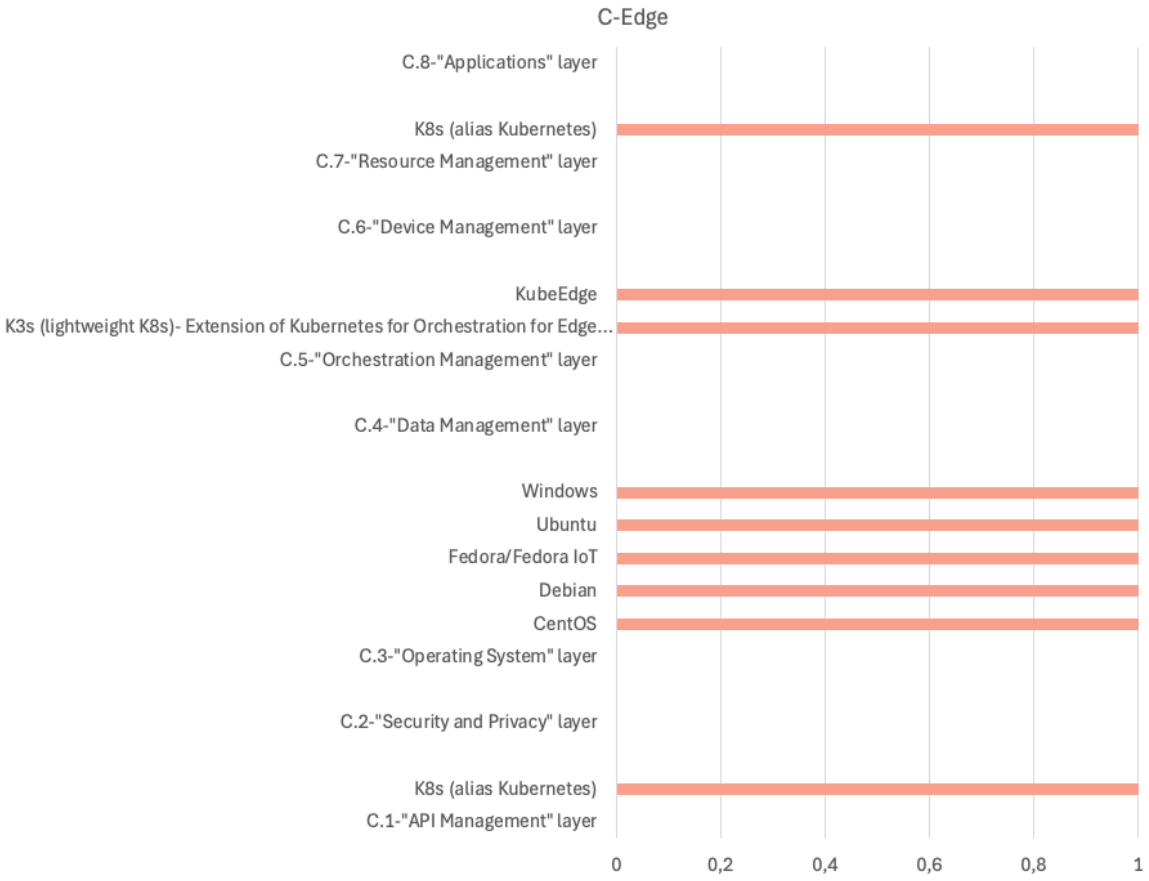

FIGURE 52 - HORIZON-CL4-2021-DATA-01-01 C-EDGE

Funded by Horizon Europe Framework Programme of the European Union

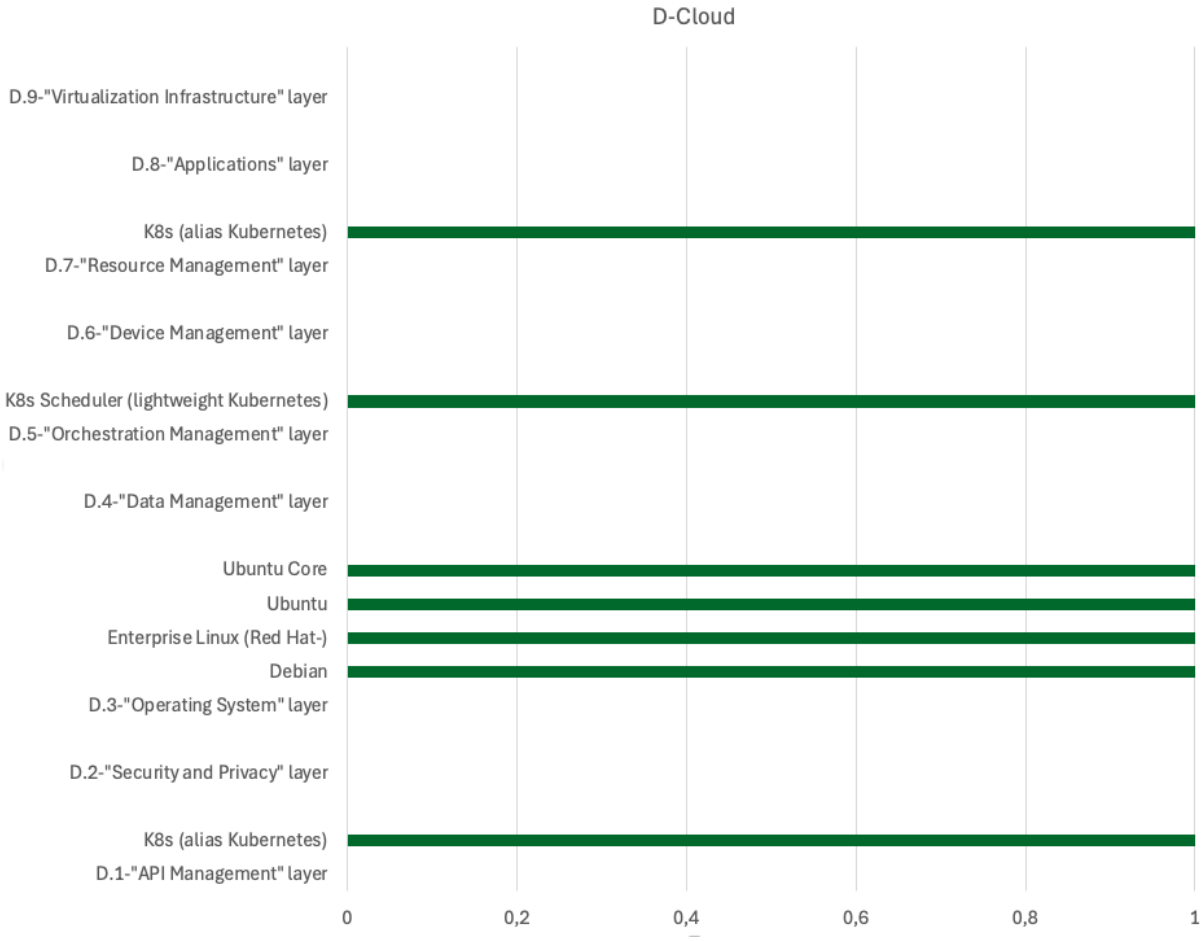

FIGURE 53 - HORIZON-CL4-2021-DATA-01-01 D-CLOUD

7.2 DATA OVERVIEW PER LAYER

In this second step the data are considered per layer and not per call.

Table 6 presents an overview of the data for each layer considered in the survey. As already mentioned, all the calls have at least one representative answering the survey. The total number of projects is thirty and the total number of components cleaned and with duplicates is 980 and the total without duplicates is 385.

TABLE 6 - OVERVIEW PER DOMAINS

Layers	Calls	Projects	Total Components	Single Components
A - Cross Domain	9	30	235	63
B - Constrained devices	9	30	115	74
C - Edge	9	30	309	113
D - Cloud	9	30	321	135

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Figure 54 shows a graphical visualisation of the table above.

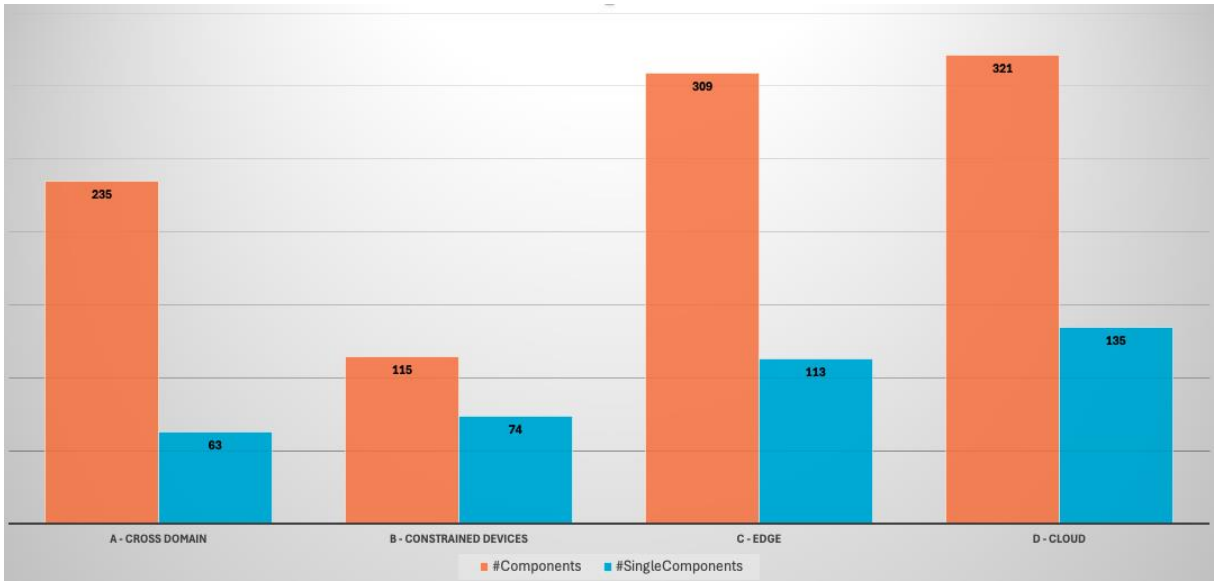

FIGURE 54 - DATA OVERVIEW PER DOMAINS

Here we can quickly notice that the orange bar, representing the total number of components in most of the case triple (or more) the numbers of unique components. This means that there are a lot of components shared by the project, this could also lead us to an underline structure that confirms our Open Source Stack with the consideration that if several projects use the same components in that sublevel into the layer, it means that sublevel can be confirmed.

Moving to the numbers of unique components per layer, they are aligned with not much gap between them and with a coherent pattern with the topics of the projects. In fact, as mentioned above, most projects are focusing on Cloud or/and Edge, which brings them to use cross-domain components to manage the edge and cloud continuum.

In the following subchapter we are presenting results and visualisation per layer.

7.2.1 A-Cross Domains

This layer interacts with the 3 domains: Devices, Edge and Cloud.

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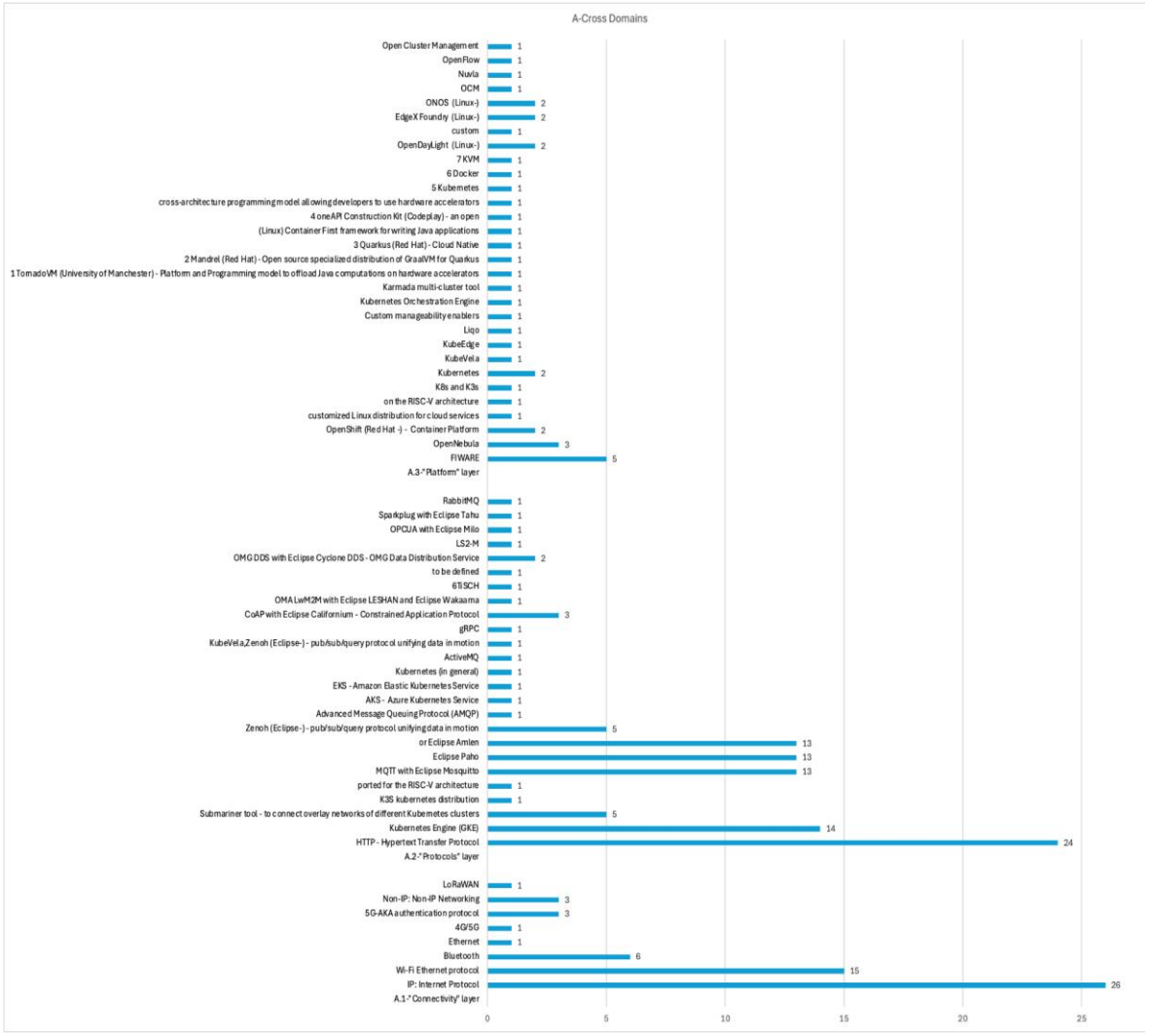

FIGURE 55 - A-CROSS DOMAINS

Considering the high number of answers, we are also reporting the single section alone in the following figures.

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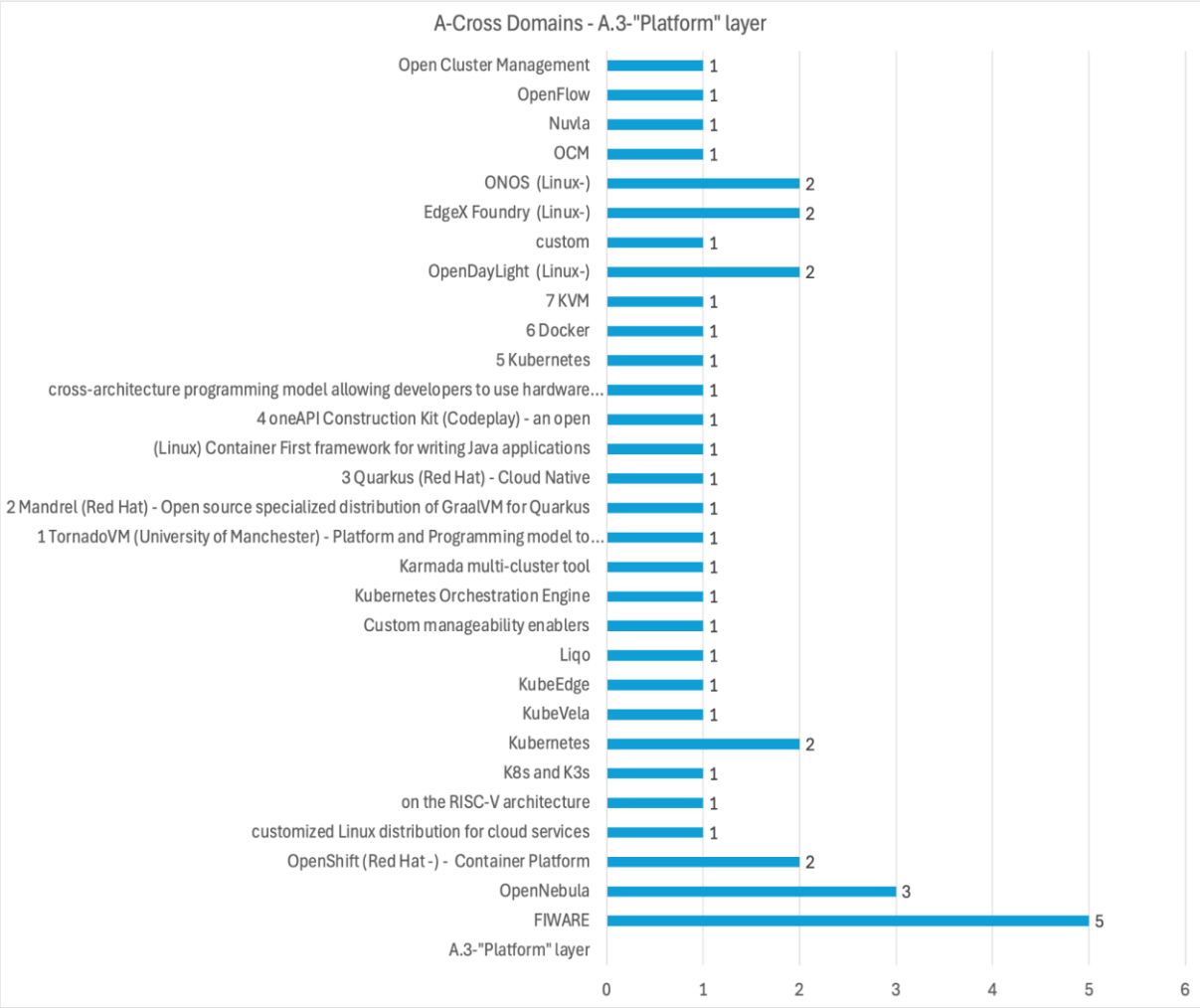

FIGURE 56 - A-CROSS DOMAINS - A.3 "PLATFORM" LAYER

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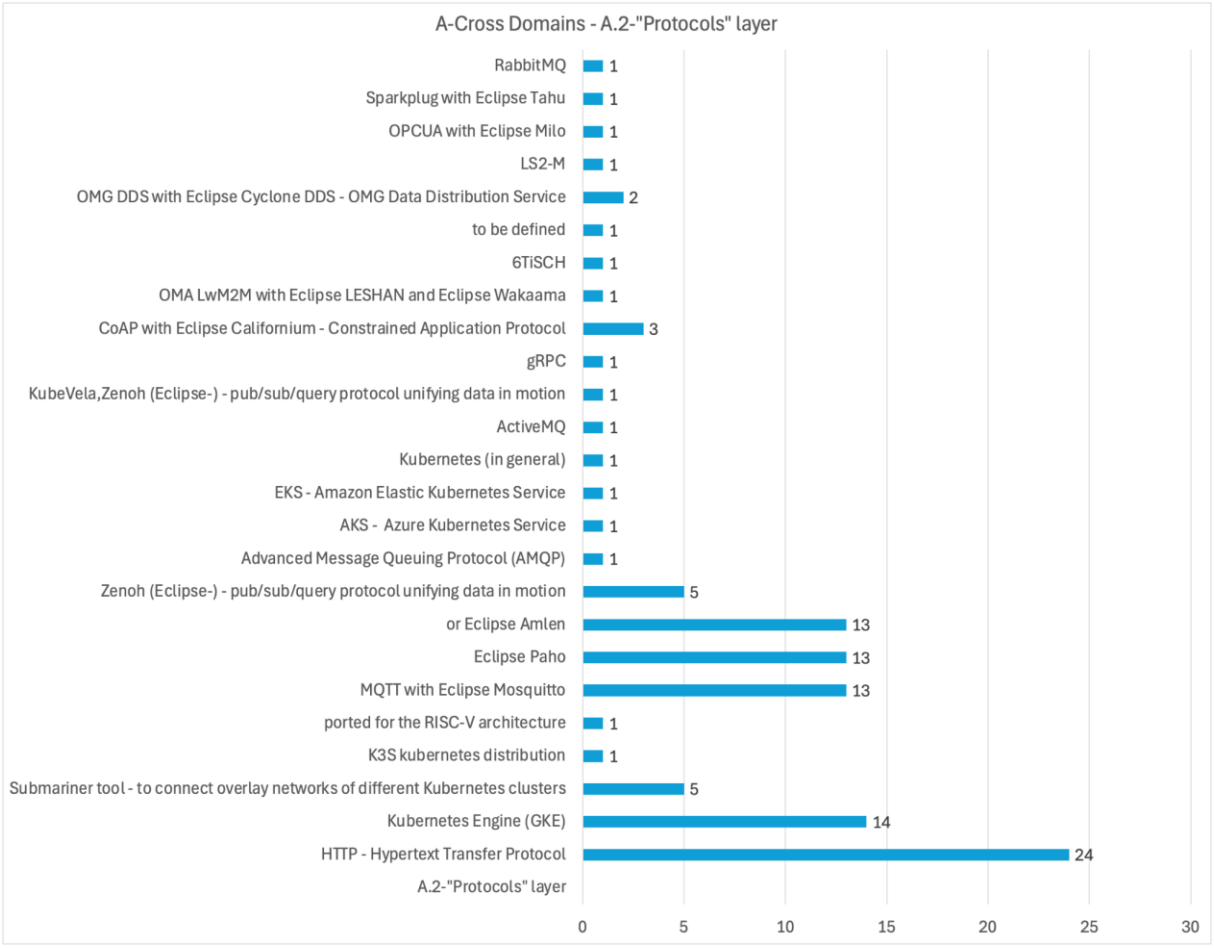

FIGURE 57 - A-CROSS DOMAINS - A.2 "PROTOCOL" LAYER

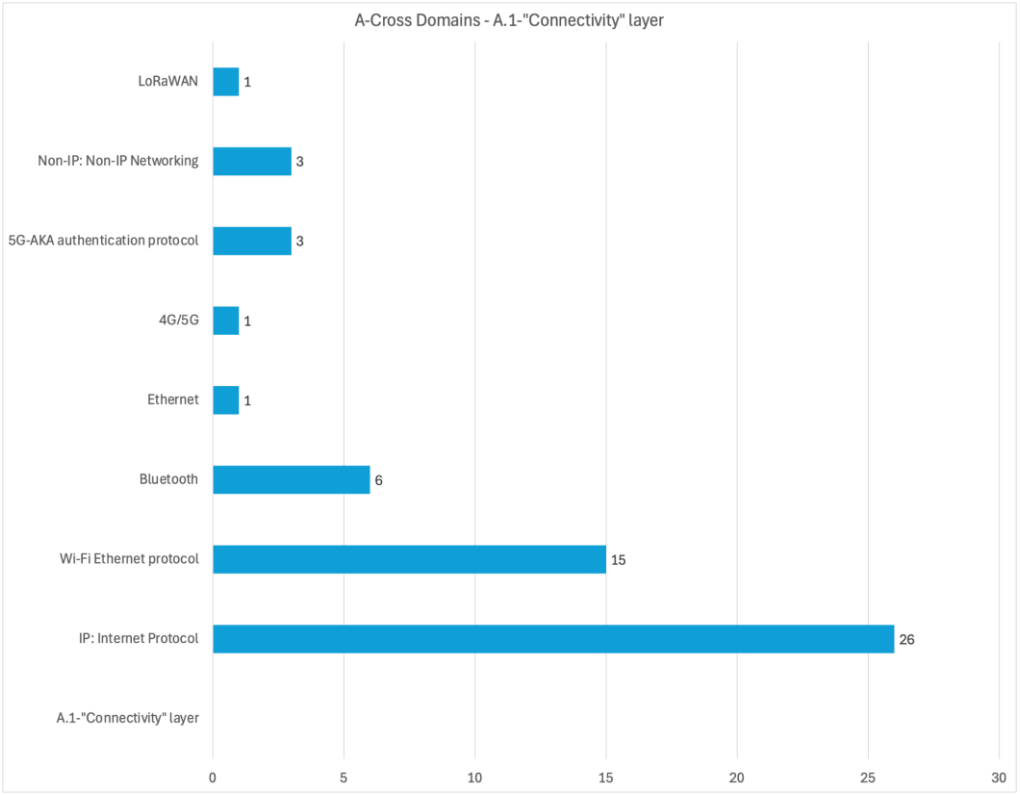

FIGURE 58 - A-CROSS DOMAINS - A.1 "CONNECTIVITY" LAYER

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7.2.2 B-Constrained Devices

Constrained devices are small devices with limited CPU, memory and power resources.

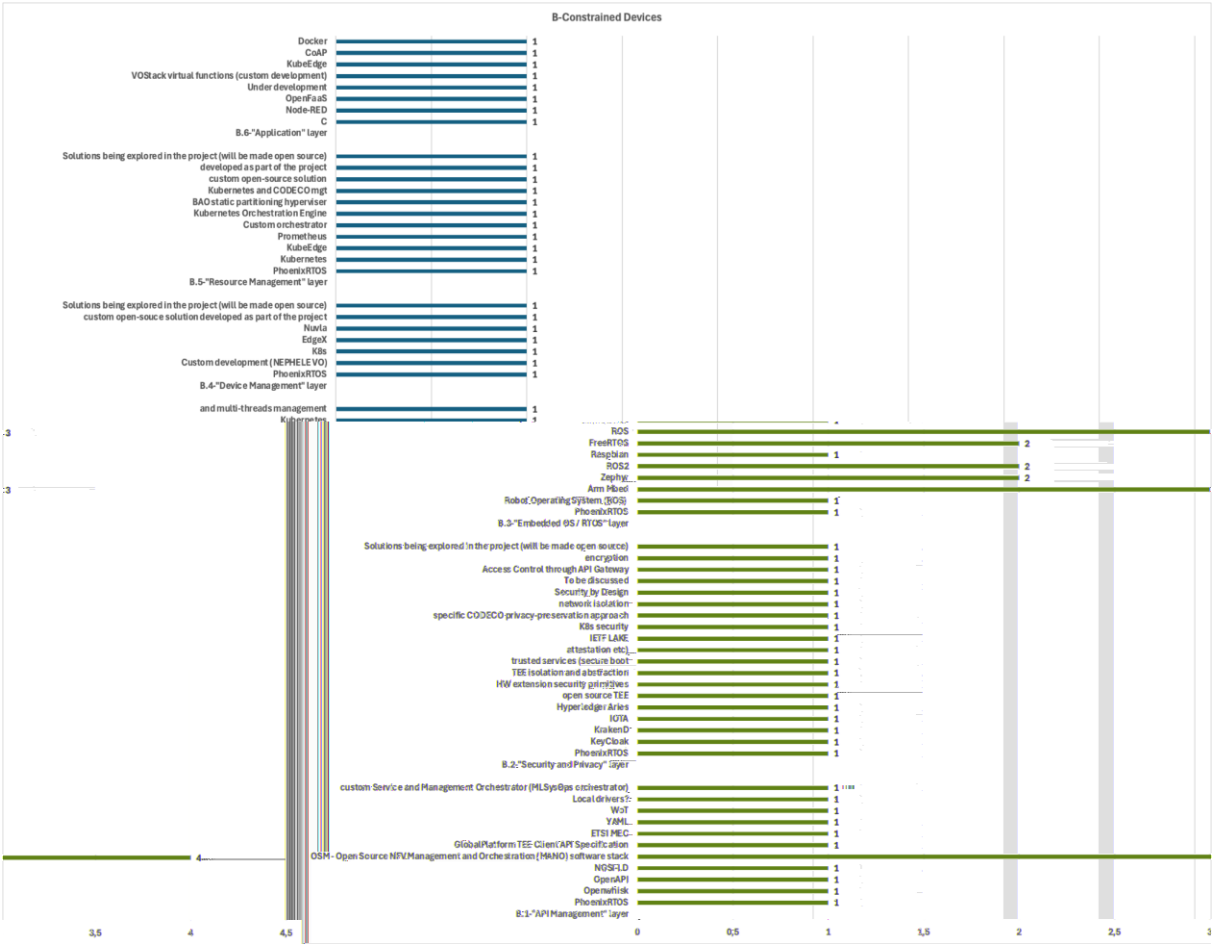

FIGURE 59 - B- CONSTRAINED DEVICES

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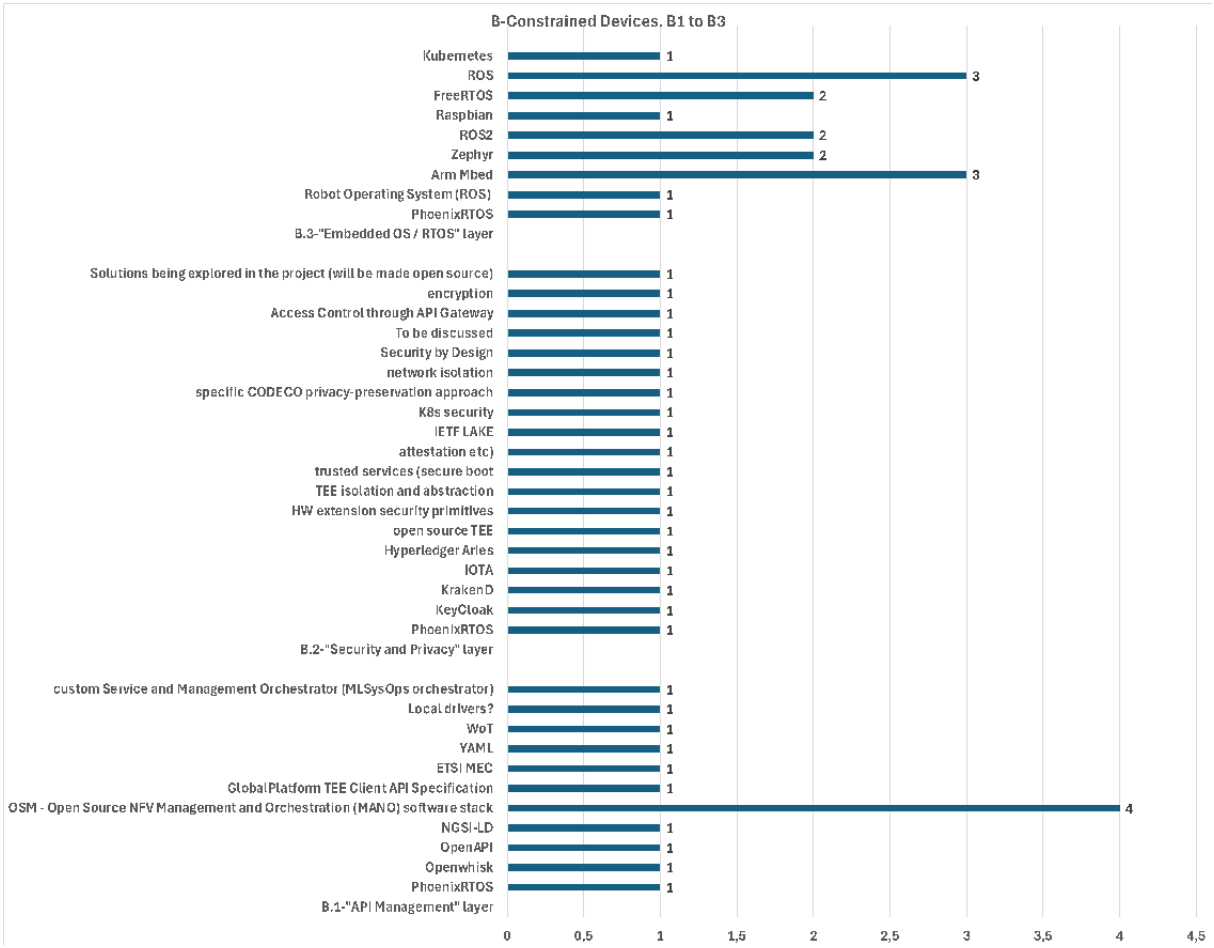

FIGURE 60 - B-CONSTRAINED DEVICES ANSWERS B1-B3

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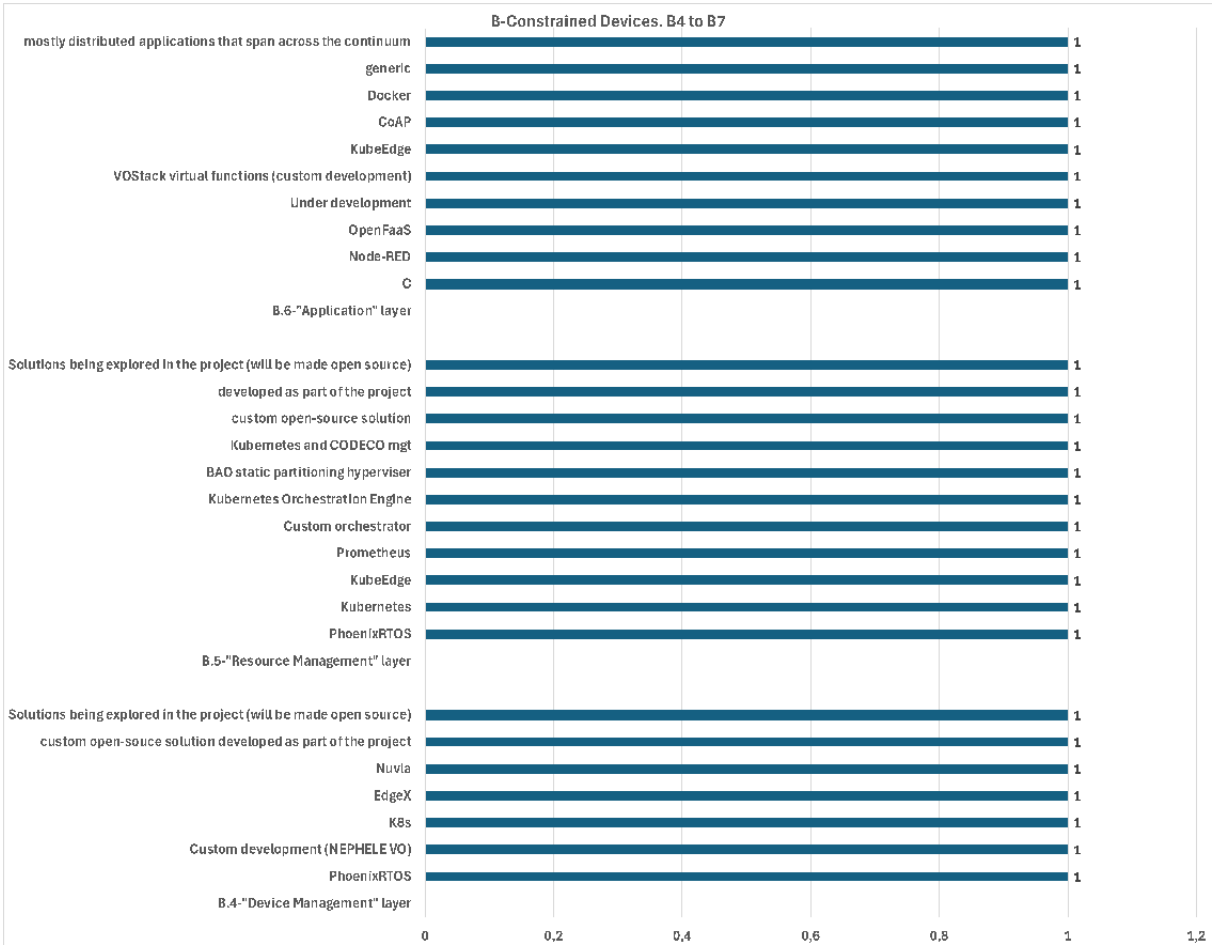

FIGURE 61 - B-CONSTRAINED DEVICES ANSWERS B4-B7

7.2.3 C-Edge

The Edge vertical domain is the boundary between pertinent digital and physical entities, delineated by networked sensors and actuators.

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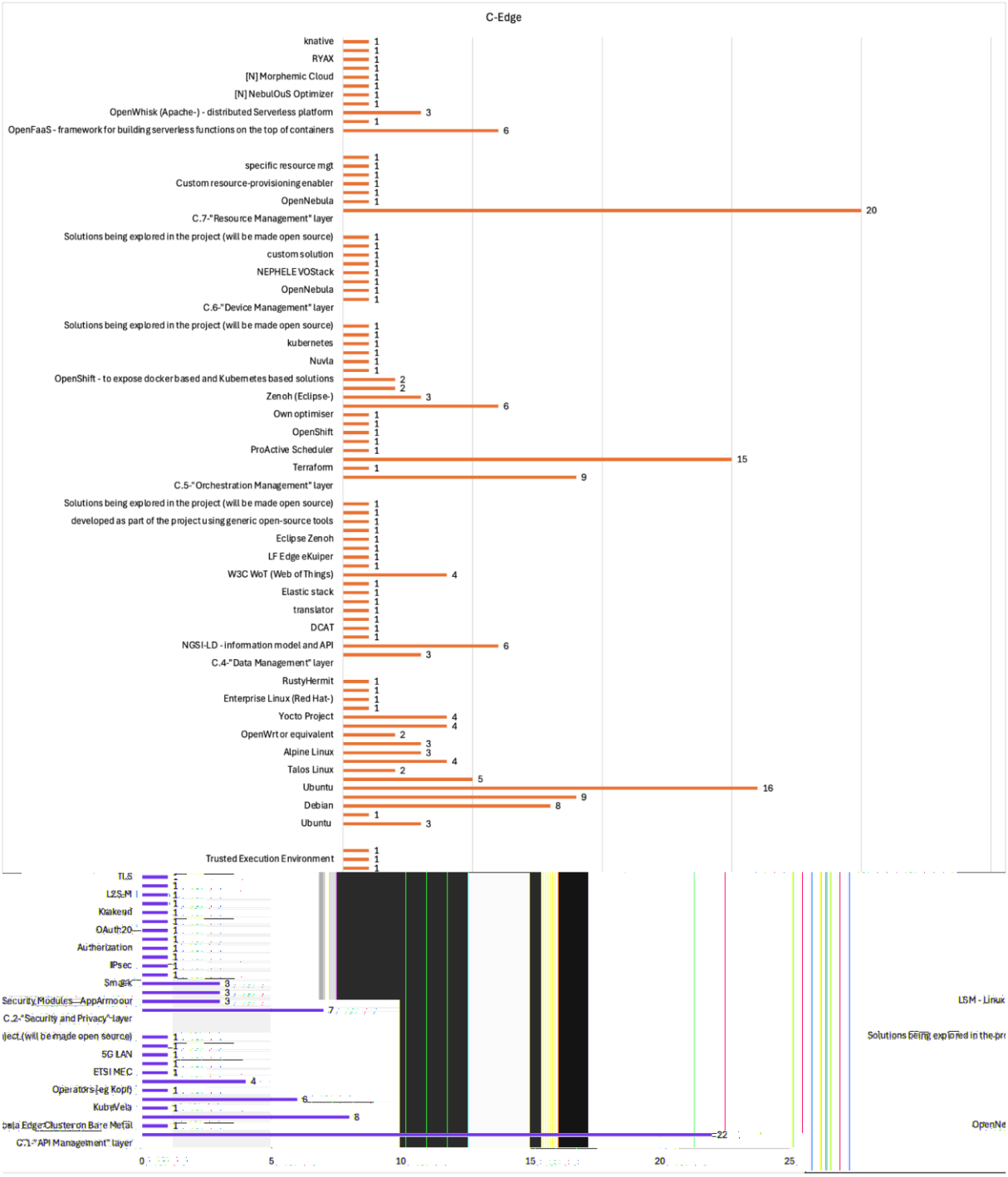

FIGURE 62 - C-EDGE

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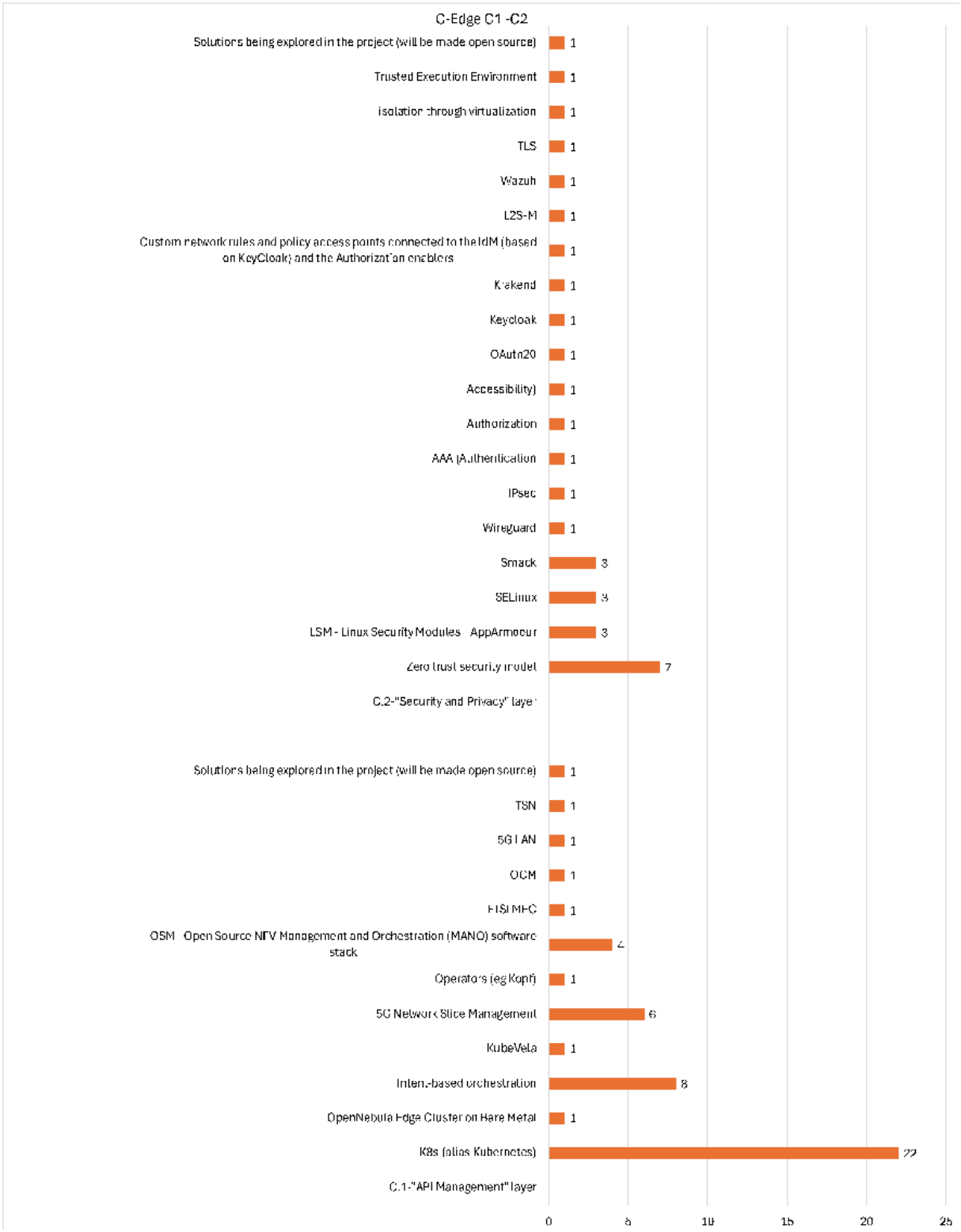

FIGURE 63 - C-EDGE ANSWERS C1-C2

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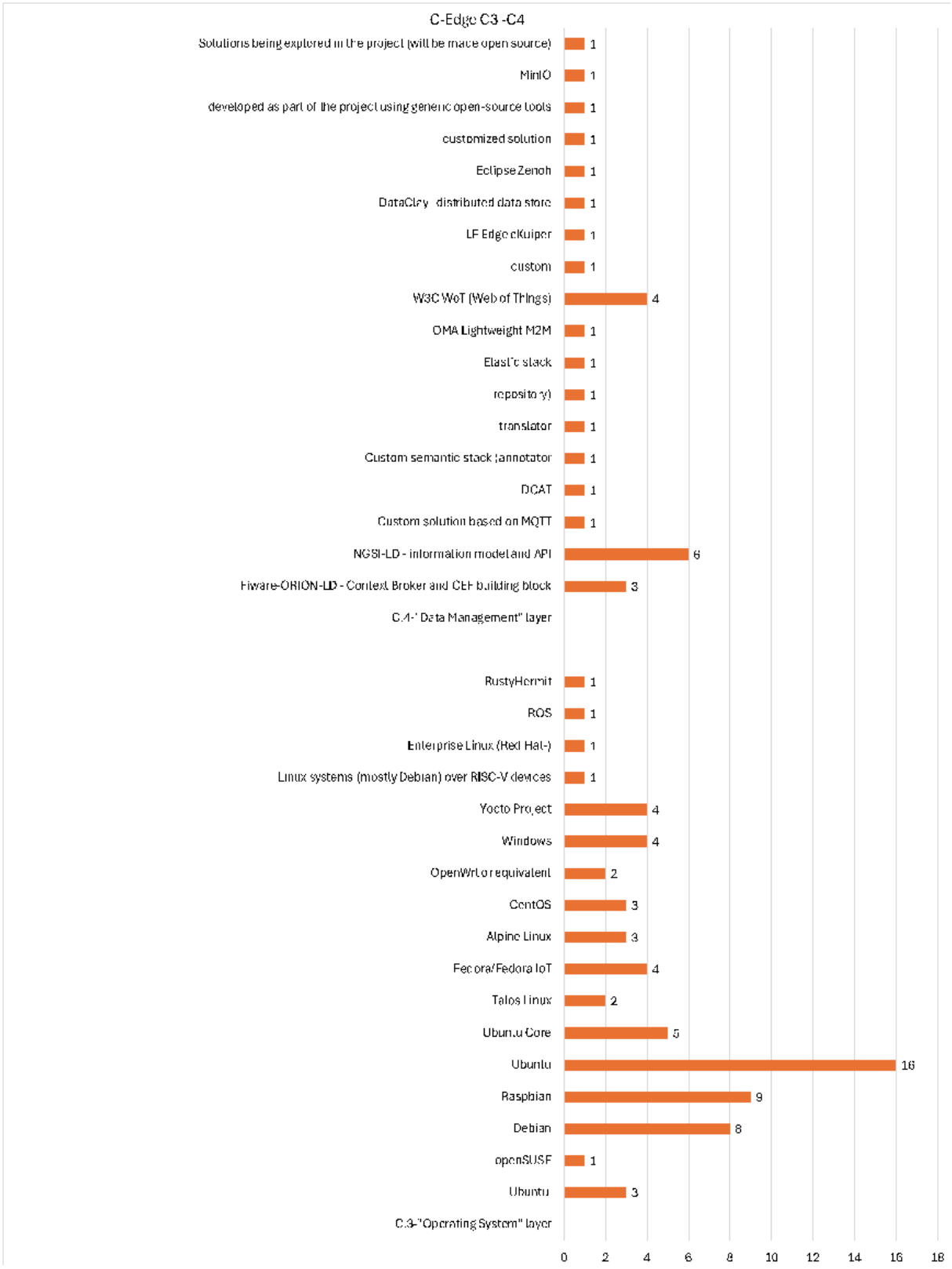

FIGURE 64 - C-EDGE ANSWERS C3-C4

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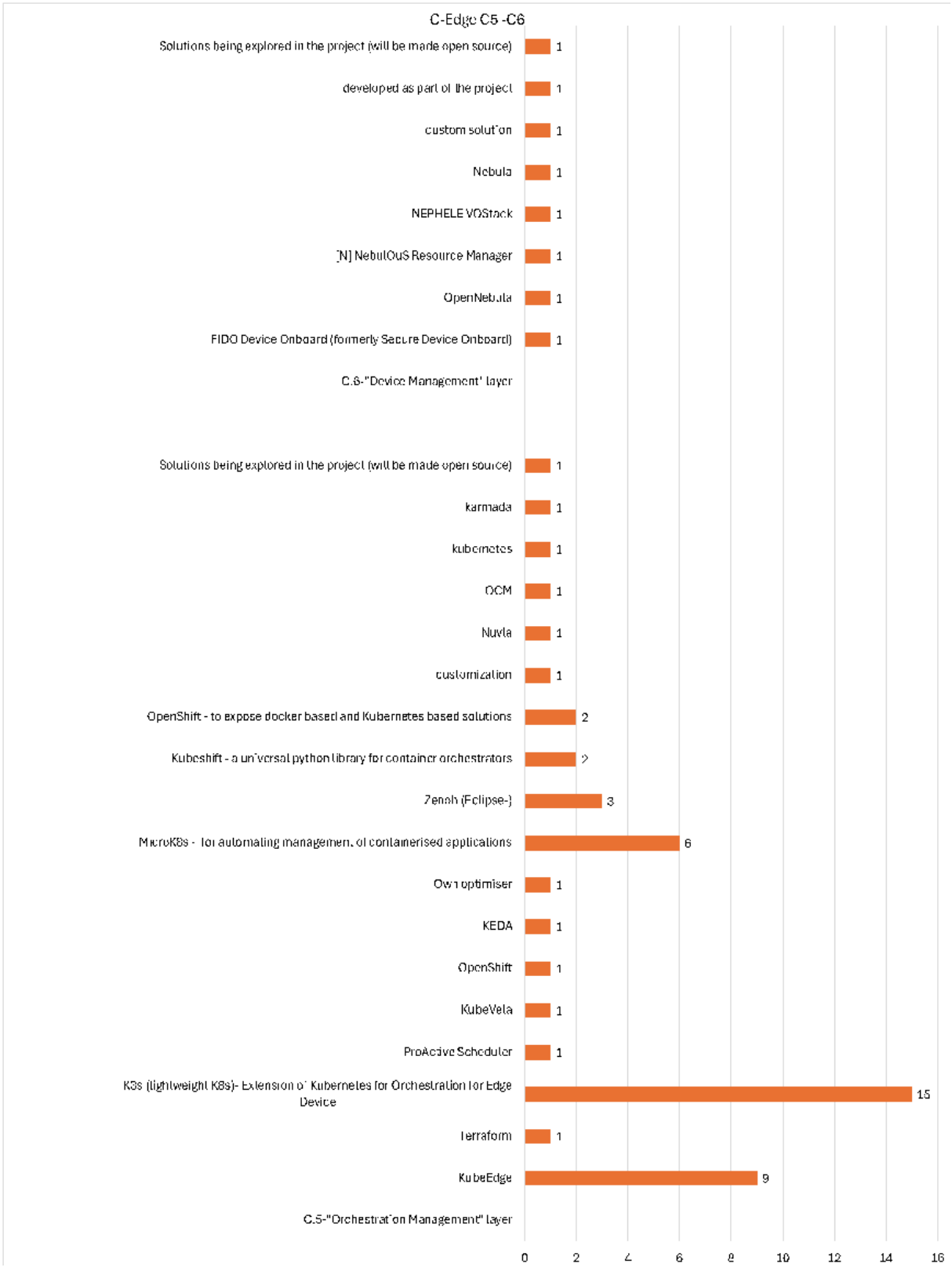

FIGURE 65 - C-EDGE ANSWERS C5-C6

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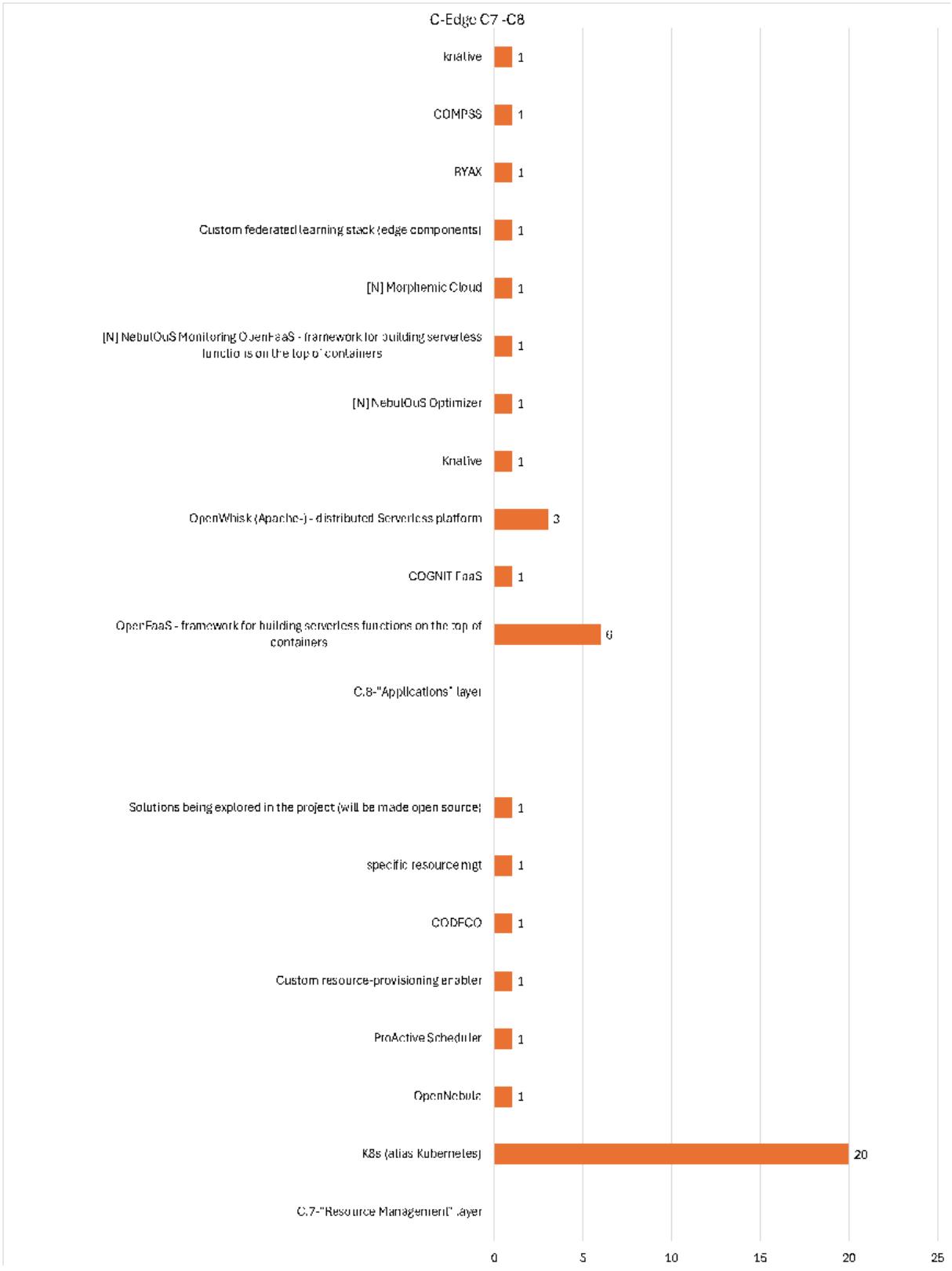

FIGURE 66 - C-EDGE ANSWERS C7-C8

7.2.4 D-Cloud

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Cloud is intended as Cloud Computing, a paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on-demand.

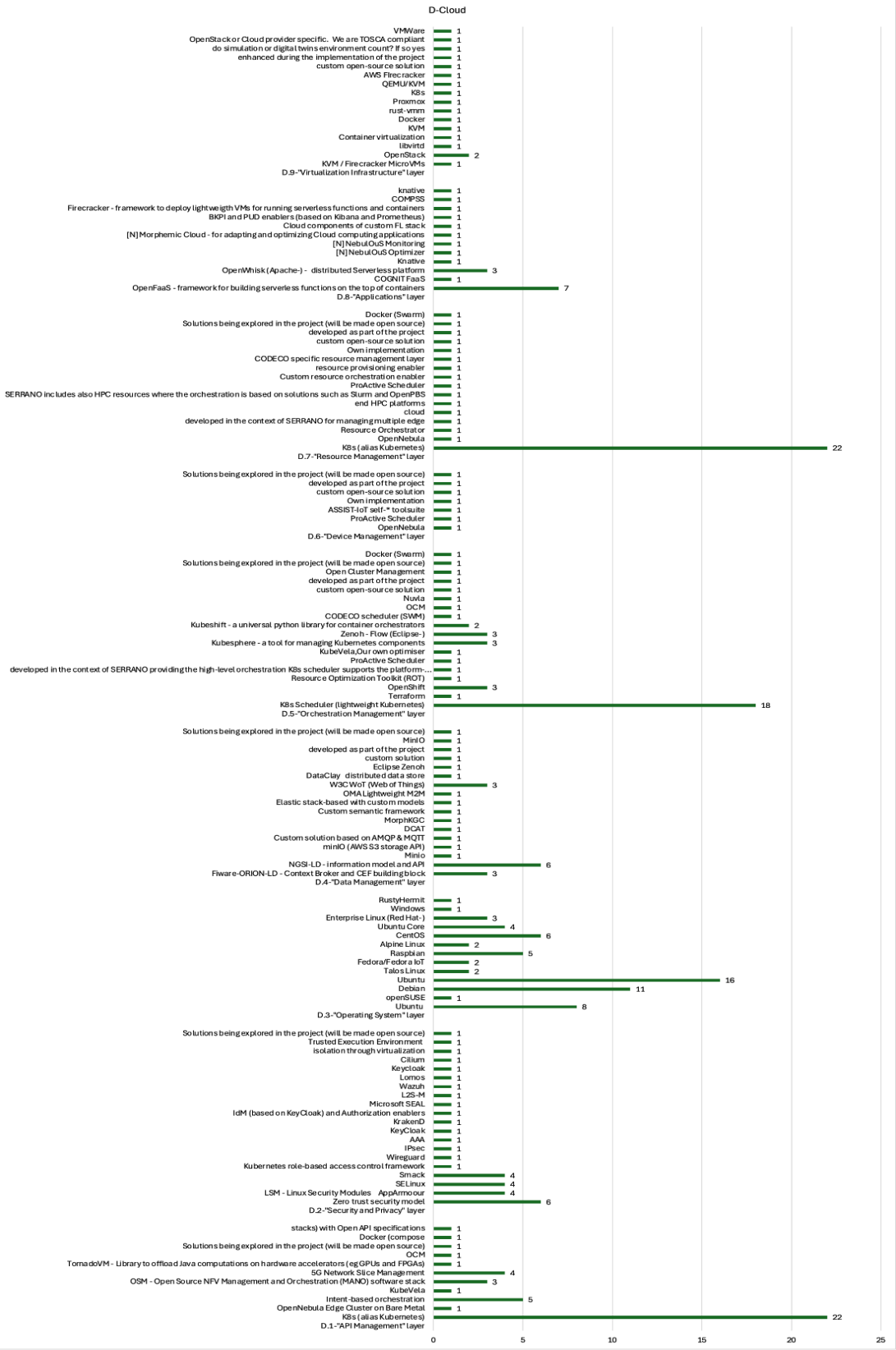

FIGURE 67 - D-CLOUD

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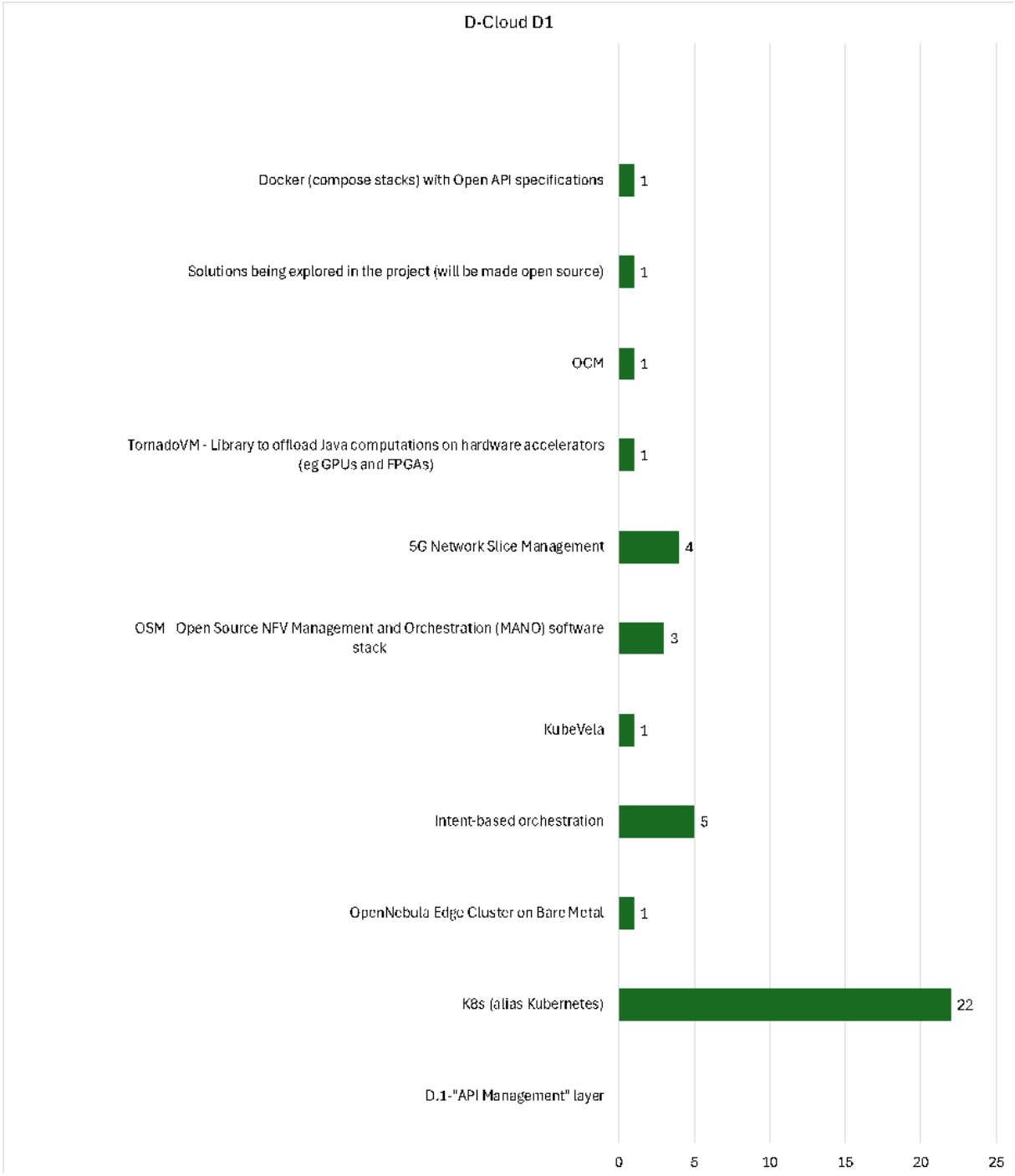

FIGURE 68 - D-CLOUD ANSWERS D1

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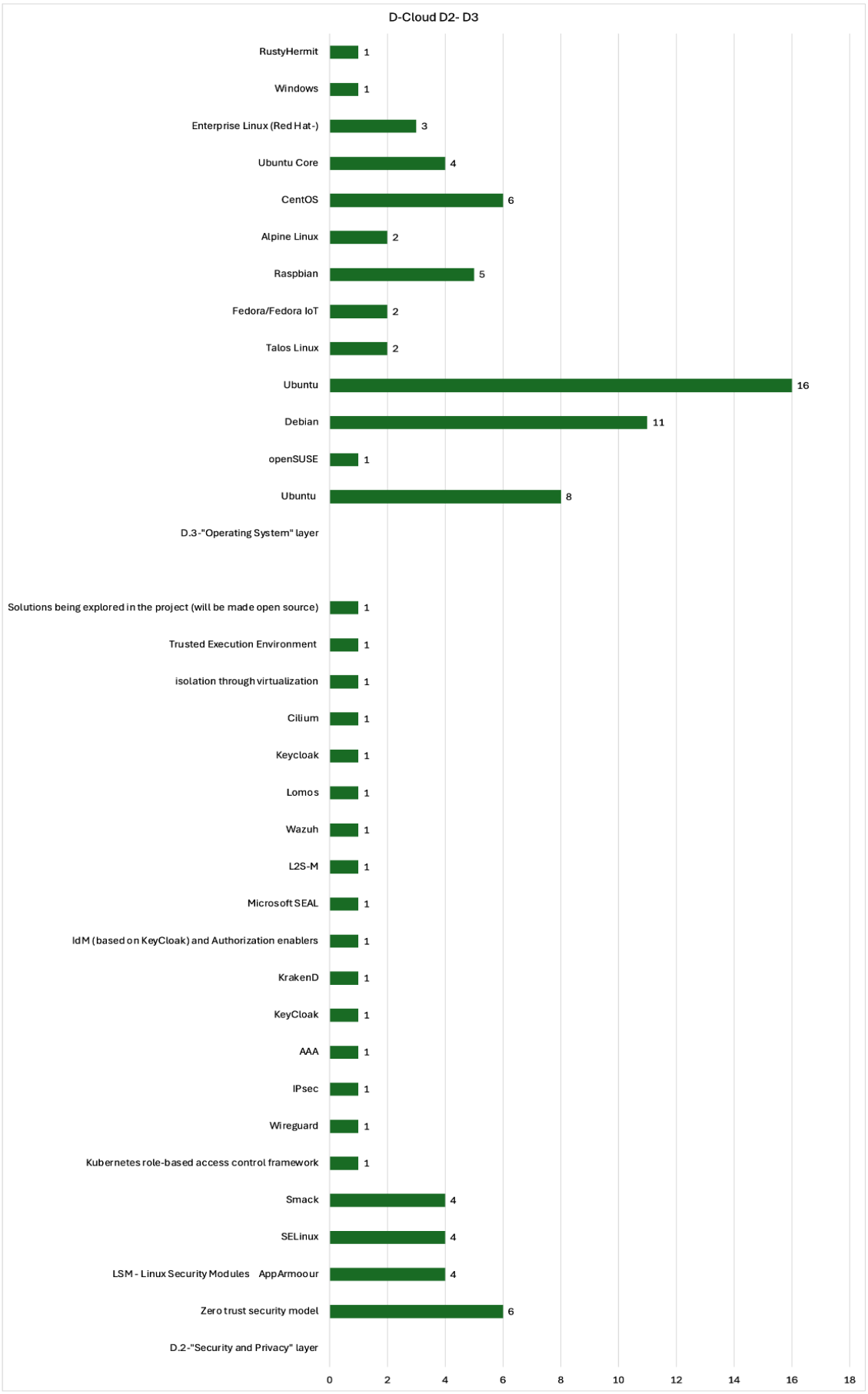

FIGURE 69 - D-CLOUD ANSWERS D2-D3

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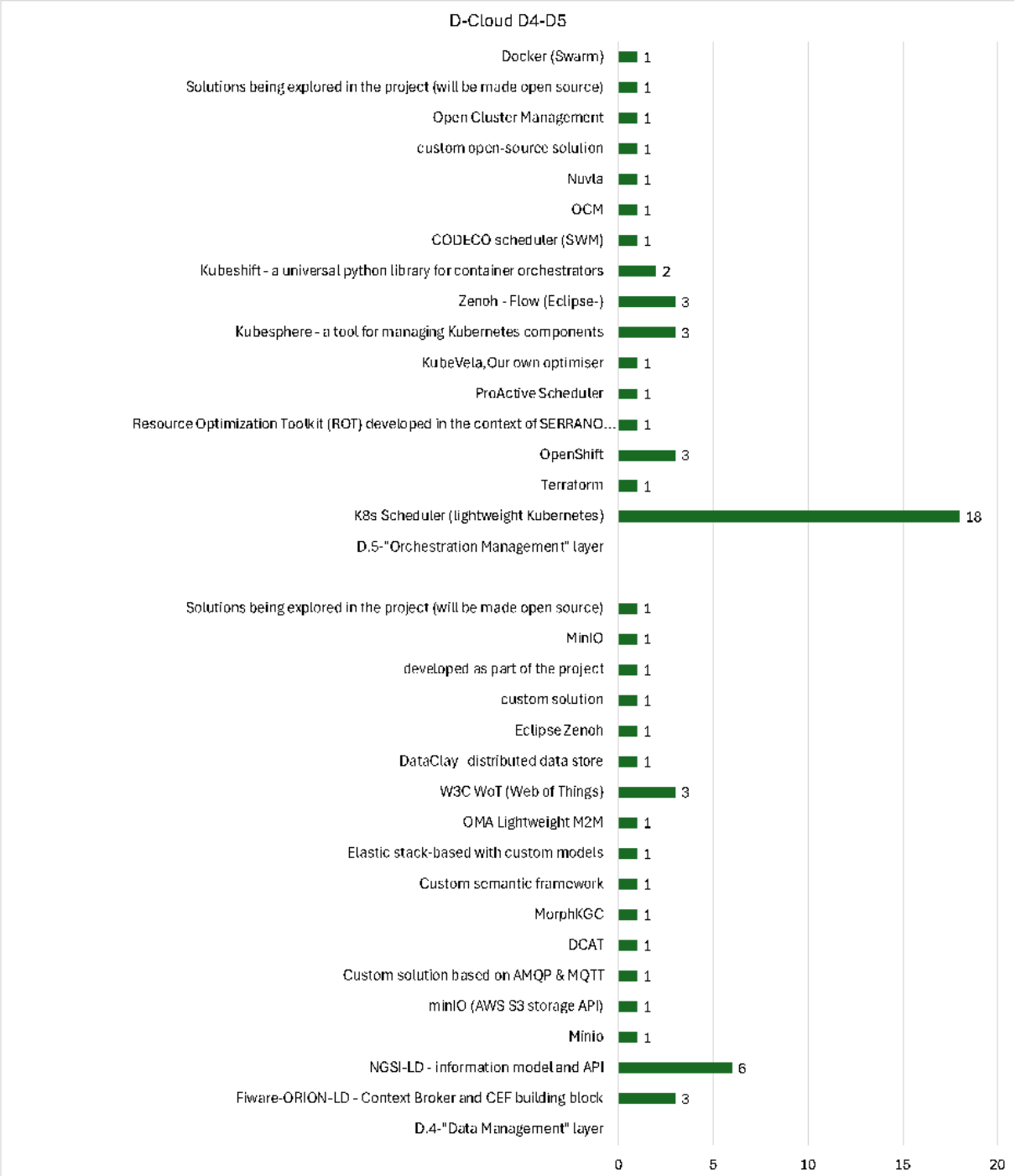

FIGURE 70 - D-CLOUD ANSWERS D4-D5

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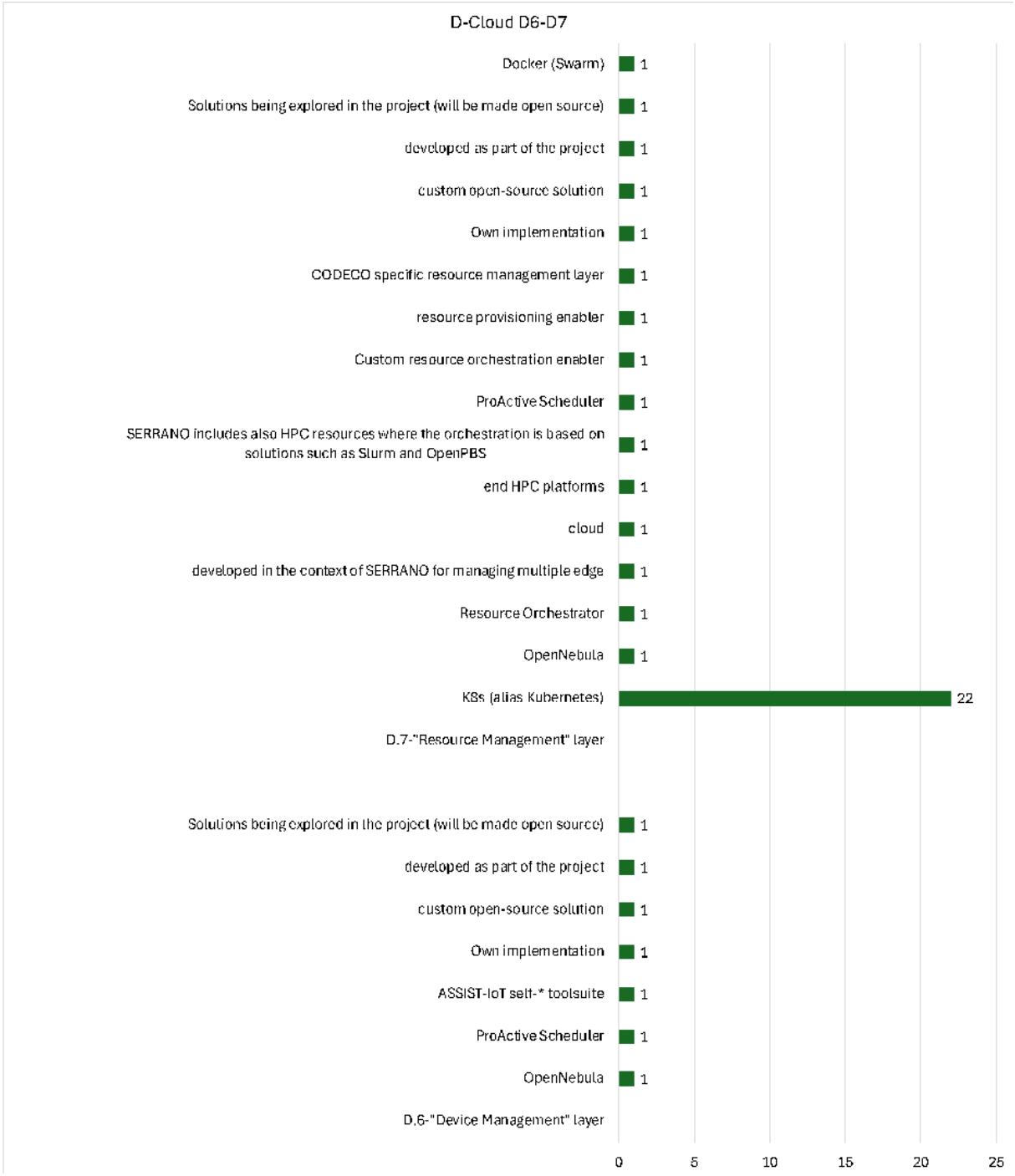

FIGURE 71 - D-CLOUD ANSWERS D6-D7

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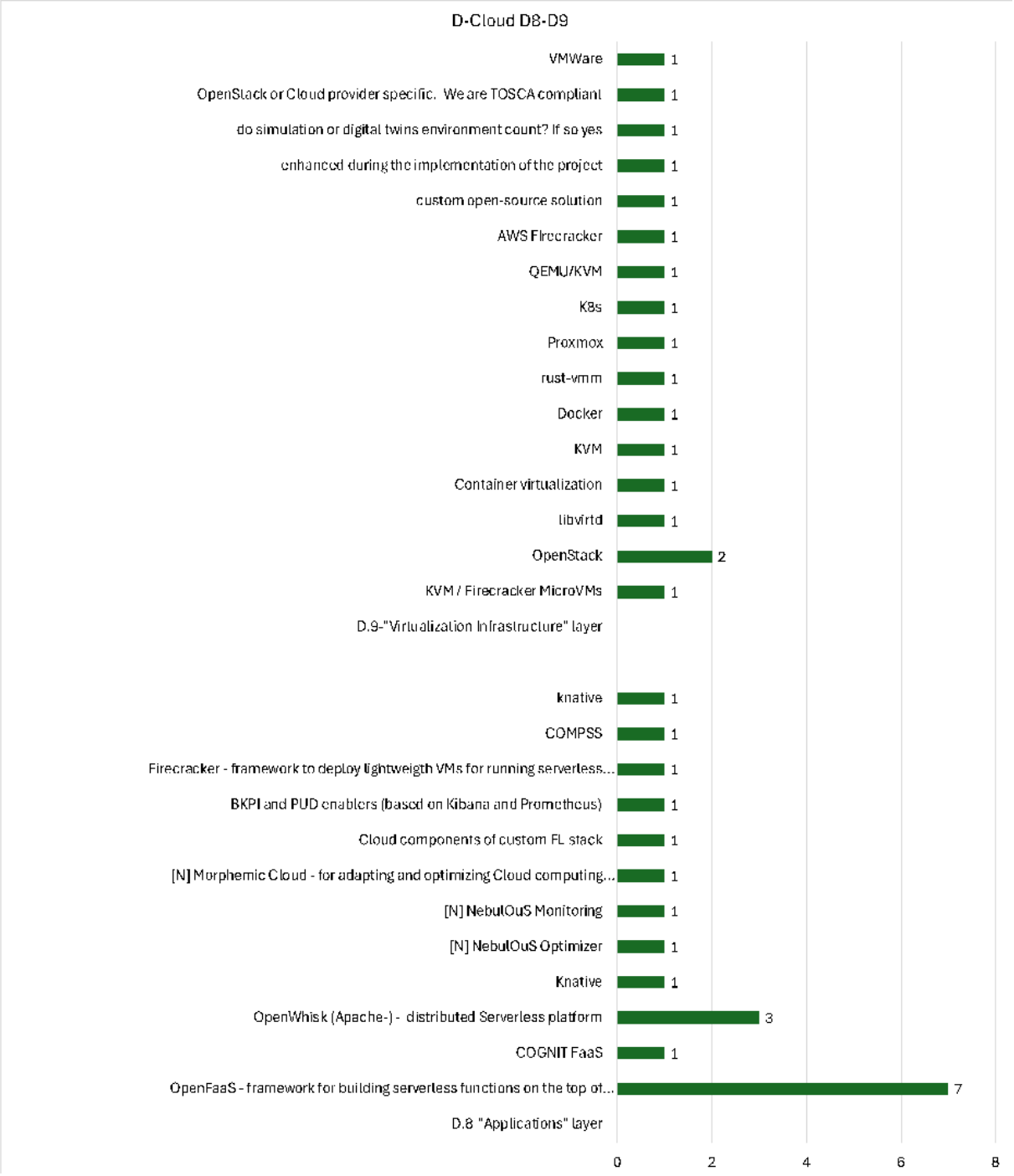

FIGURE 72 - D-CLOUD ANSWERS D8-D9

7.2.5 Free answers

As mentioned, in the survey each domain has a last free answer “Do you have different layers? If yes, please describe them and their components.” We are reporting here the answers for each domain.

Only 14 projects answered to these questions in different domains. From the answers does not emerge new layers but a fragmentation of some of them that could be seen as sublayers. Then, these answers are very specific to the projects, and they confirm the high level overview of the stack, since all answers can be included in some existing layer.

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- A-Cross Domains

none

- B-Constrained Devices

B.7-Do you have different layers? If yes, please describe them and their components.

  - Virtualization layer (Containers and associated resource management)
  - Network management (Cilium)
  - VPN-Wireguard
  - SDN/NFV (servicemesh) Federation
  - no
  - We decompose the application layer into additional application level distributed protocols that provide additional abstractions and whose specification and implementation can be reused in building different applications. The project also conducts research in that layer.

- C-Edge

C.9- Do you have different layers? If yes, please describe them and their components.

  - Application Choreography Layer/Orchestrator based on Node-RED
  - NO
  - Application layer is further decomposed to have multiple application-level distributed protocols that provide abstractions to (several) applications

- D-Cloud

D.10- Do you have different layers? If yes, please describe them and their components.

  - Application Orchestration/Choreography Layer based on Node-RED
  - No
  - do simulation or digital twins environments count? If so yes
  - Similarly to the previous sections
  - application layer is further decomposed to include application-level distributed protocols

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7.3 GUIDANCE FOR REFERENCE ARCHITECTURES (RA)

unchanged from D4.3

This section provides guidance for reference architecture deliverables that will subsequently be promoted at standardisation level. Figure 3 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.

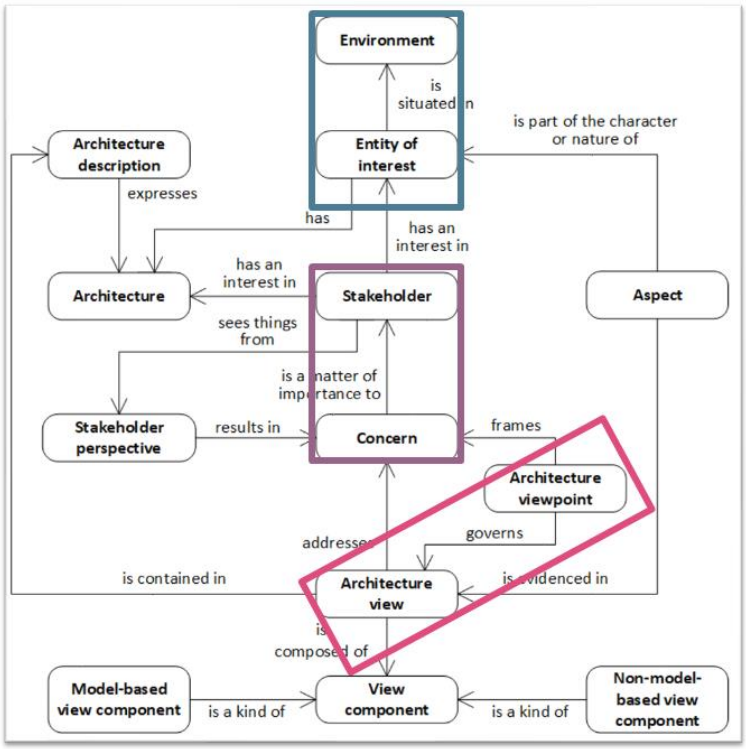

FIGURE 73 - CONCEPTUAL MODEL OF AN ARCHITECTURE (ISO/IEC/IEEE 42010)

Table 7 is the proposed structure for a reference architecture standard.

TABLE 7 - 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.

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			– 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)

Table 8 provides a template for viewpoint description.

TABLE 8 - 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

Table 9 is a template for model kinds.

TABLE 9 - MODEL KIND TEMPLATE

Model kind name [42010, 8.2]	Provide a name for this model kind.

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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.

7.3.1 Pattern template

Patterns can be understood as a solution to a particular system development problem. Table 10 provides a pattern template. For instance, an implementation architecture for industrial IoT can use the patterns library in [20].

TABLE 10 - 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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