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The European IoT Hub

Growing a sustainable and comprehensive ecosystem for Next Generation Internet of Things

D3.6: Mapping of Knowledge Areas to Standardisation Version 2

Work package	WP 3
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Abstract

Deliverable D3.6 of EU-IoT relates with the work under development in WP3 – Catalyst, Task 3.3 and represents an update of D3.5 "Mapping of Knowledge Areas to Standardisation v1.0", released in 2022. Task 3.3 focuses on strengthening the bridge between IoT research under development in ICT-56, and Standards Development Organisations, via the development of a set of activities and a knowledge area analysis. This deliverable specifically addresses the definition of knowledge areas and provides a mapping analysis of knowledge areas to the collected Standards Development Organisations.

Keywords: Standardisation, IoT and Edge research, open-source ecosystem.

Document Revision History

Version	Date	Description of change	List of contributors(s)
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V0.2	22.03.2023	Review	Emilie M. Jakobsen (AU)
V0.3	23.03.2023	Revisions integrated and release to internal reviewers	Rute C. Sofia (FOR)
V0.4	30.03.2023	Revision by Martel	Eleni Pechlivanidou (MAR)
V1	30.03.2023	Final integration of suggestions and release to coordinator	Rute C. Sofia (FOR)
V2	31/03/2023	Final quality check and submission	Eleni Pechlivanidou (MAR)

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PU	Public, fully open, e.g., web	√
CI	Classified, information as referred to in Commission Decision 2001/844/EC	
CO	Confidential to EU-IoT project and Commission Services	

EXECUTIVE SUMMARY

D3.6 “Mapping of Knowledge Areas to Standardisation Version 2” represents an update of D3.5 and focuses on providing a final mapping of relevant IoT/Edge knowledge areas to Standards Development Organisation entities, based on the articulation of work that has been developed by EU-IoT with the ICT-56 RIAs.

In D3.5 “Mapping of Knowledge Areas to Standardisation version 1”, EU-IoT has developed an analysis of knowledge areas in relation to IoT/Edge based on multiple international landscape documents. Out of this analysis, EU-IoT has proposed an initial set of knowledge areas and has derived an analysis of technological topics mapping to SDOs, derived from input from RIAs, EU-IoT scope area analysis.

D3.6 provides a final vision of the proposed knowledge area mapping and provides an analysis of the research recommendations of RIAs, in alignment with the derived knowledge areas to SDOs.

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ACRONYMS

Acronym	Description
AB	Advisory Board
AI	Artificial Intelligence
AR	Augmented Reality
BDVA	European Big Data Value Strategic Research Innovation Agenda
D2D	Device to Device
EC	European Commission
EDT	Emergent and Disruptive Technology
ETSI	European Telecommunications Standards Institute
H2020	Horizon 2020
IIA	Inside Industry Association
IoT	Internet of Things
IP	Internet Protocol
JRC	Joint Research Center
MEC	Mobile Edge Computing
ML	Machine Learning
NGIOT	Next Generation IoT
NGIoT	Next Generation Internet of Things
NIST	National Institute of Standards and Technology
NLP	Natural Language Processing
RAN	Radio Access Networks
RAT	Radio Access Technology
RIA	Research and Innovation Action
RNC	Radio Network Controller
SDN	Software Defined Networking
SDO	Standards Development Organisation
SDR	Software Defined Radio
TRL	Technical Readiness Level
TSN	Time Sensitive Networking
VR	Virtual Reality
WoT	Web of Things

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1 INTRODUCTION

This deliverable has as main goal to provide a final mapping of knowledge areas to *Standards Development Organisations (SDOs)*. For that purpose, the deliverable describes the work that has been developed in the EU-IoT Work Package 3 (WP3) – Catalyst, Task 3.3, to collect active knowledge areas that are relevant to the further development of the European IoT ecosystem, in a way that is open, human-centric, and sustainable.

D3.6 is an update of deliverable D3.5 [1], which focused on the definition of knowledge areas based on collected information across the world and taking into consideration the EU-IoT end-to-end IoT scope area vision, i.e., an abstraction of an end-to-end IoT system integrating interfaces, near and far Edge technologies; infrastructure and data spaces; expert interviews held via EU-IoT WP2; specific and thematic workshops held in WP3.

The main differences between D3.5 and D3.6 are summarized in Table 1.

Table 1: Main differences between D3.5 and D3.6.

WP6 activity	Deliverable and Section
To define Knowledge areas in accordance with an IoT end-to-end abstraction that takes into consideration hardware and software; infrastructure and computational aspects; and the EU-IoT scope areas.	D3.5, section 2
To collect knowledge areas in accordance with the proposed definition, based on related work across different SDO-oriented activities in Europe and in the USA (COLLECT I, II)	D3.5 section 2
To provide an initial mapping of active contributions of RIAs to the defined knowledge areas to SDOs, deriving a set of recommendations.	D3.5 sections 3 and 4.
To provide a refined version of the knowledge areas, based on additional input collected	**D3.6, section 3**
To collect knowledge areas in accordance with the proposed definition, based on related work across different SDO-oriented activities in Europe and in the USA (COLLECT III)	**D3.6, section 4**
To provide a final mapping of RIA contributions to the defined knowledge areas (MAP III)	**D3.6, section 5**

1.1 Document Structure

The remainder document is organized as follows:

- Still in section 1, information on ICT-56 RIAs, and the EU-IoT scope areas is provided.
- **Section 2** provides a summary of the methodology that has been carried out to collect and to identify knowledge areas, also covering an overview of the collected data, available in Annex I, and how the different sources perceive and assess the impact of different knowledge areas.
- **Section 3** provides a refined version of the proposed knowledge areas. The resulting knowledge areas dataset is provided in Annex I (worksheet “EU-IoT KA2023”).
- **Section 4** provides the last collection of RIA research contributions towards SDOs, which has been developed between March 2022 and March 2023.
- **Section 5** provides the knowledge area mapping analysis, covering mapping to SDOs, and addressing the status of contributions by RIAs to the knowledge areas.
- **Section 6** concludes the deliverable, describing key takeaways.

1.2 The ICT-56 Flagship Projects

The main goal of the knowledge area mapping to SDOs, is to provide a better characterisation of the coverage of relevant knowledge topics by ICT-56 RIAs, and to provide an understanding on eventual gaps and challenges that should be addressed, as well as to assist in a better cross-addressing of key knowledge areas in Europe. During the period being reported, EU-IoT has collected information based on related work; expert consultation; RIA consultation. The ICT-56 RIAs consulted are presented in Table 2.

Table 2: List of the NGIoT flagship projects.

Project Logo	Project Name	Project Link
assist-iot	ASSIST-IoT	https://assist-iot.eu/
ingenious	iNGENIOUS	https://ingenious-iot.eu/web/
IoT-NGIN	IoT-NGIN	https://iot-ngin.eu/
TERMINET H2020 PROJECT	TERMINET	https://terminet-h2020.eu/
VEDLIoT Very Efficient Deep Learning in IoT	VEDLIoT	https://vedliot.eu/
IntelliIoT	IntelIIoT	https://intelliot.eu/

- **ASSIST-IoT**[1]: aims at designing, implementing, and validating an open, decentralized reference architecture, associated enablers, services, and tools, to assist human-centric applications in multiple verticals.
- **iNGENIOUS**[2]: aims to design and evaluate the Next-Generation IoT solution, with emphasis on 5G and the development of Edge and Cloud computing extensions for IoT, as well as providing smart networking and data management solutions with Artificial Intelligence and Machine Learning.
- **IoT-NGIN**[3]: aims to empower Edge Cloud with federated on-device intelligence, enforce interoperability and data sovereignty, ensure trust, cybersecurity, and privacy, and introduce novel human-centric interaction based on Augmented Reality.
- **TERMINET**[4]: aims to provide a novel next-generation reference architecture based on cutting-edge technologies such as SDN, multiple-access edge computing, and virtualization for next-generation IoT, while introducing new, intelligent IoT devices for low-latency, market-oriented use cases.
- **VEDLIoT**[5]: develops an IoT platform that uses deep learning algorithms distributed throughout the IoT continuum, thus proposing a new platform with innovative IoT architecture that is expected to bring significant benefits to many applications, including

[1] https://assist-iot.eu/
[2] https://ingenious-iot.eu/web/
[3] https://iot-ngin.eu/
[4] https://terminet-h2020.eu/
[5] https://vedliot.eu/

industrial robots, self-driving cars, and smart homes.

- **IntellIoT**[6]: focuses on the development of integrated, distributed, human-centered, and trustworthy IoT frameworks applicable to agriculture, healthcare, and manufacturing while enabling technologies such as 5G, cybersecurity, distributed technology, Augmented Reality, and tactile internet, focusing on end-user trust, adequate security, and privacy by design.

All RIAs started in October or November 2020 and are expected to finish in September-October 2023.

1.3 The EU-IoT Scope Areas

To provide a mapping of knowledge areas it is first necessary to define what is perceived as a knowledge area in IoT. Therefore, a first step is the definition of IoT, which is in EU-IoT perceived as "*an ecosystem in which applications and services are driven by data collected from devices that sense and interface with the physical world*".

This implies that IoT as an ecosystem relies on "including all devices and objects whose state can be altered via the Internet, with or without the active involvement of individuals. This includes laptops, routers, servers, tablets, and smartphones, often considered part of the "traditional Internet. However, these devices are integral to operating, reading, and analysing the state of IoT devices and frequently constitute the "heart and brains" of the system. As such, it would not be correct to exclude them" (OECD, 2015)."

Knowledge areas are here defined as technological knowledge areas that assist the development of different components of an EU-IoT end-to-end system.

In EU-IoT, the initially defined knowledge areas correspond to the EU-IoT scope areas, which are a common point for the development of a categorisation and mapping of knowledge areas to standardisation and to the overall work in EU-IoT. These areas, defined in the context of WP2 are therefore the conducting line for the work developed are:

- **Human/IoT interfaces**, relating to interfaces capable of integrating and adapting to human behaviour and human activities.
- **Far Edge**, relating to smart Edge functions reaching the end-user (also in end-user devices), and therefore supporting services beyond the reach of the operator. This implies the use of ML (e.g., federated learning) and the engineering of AI (TinyML) into embedded IoT devices, for instance.
- **Near Edge**, related to smart Edge functions, including context-awareness, within the access/core networking regions under the control of the operator.
- **Infrastructure**, related to the core networking region, and adaptation required to support end-to-end services in Industrial IoT environments (criticality, resilience) and consumer IoT environments (security, large-scale sensing).
- **Data spaces**, related to the data sharing and processing and to handling sovereignty across decentralized data spaces.

[6] https://intelliot.eu/

2 METHODOLOGY SUMMARY

The content in this section corresponds to a summary of the content provided in the EU-IoT Deliverable D3.5. The summary aims at assisting the reader in understanding the definition of knowledge areas in this context.

In D3.5 EU-IoT has proposed a methodology to collect and analyse the mapping of knowledge areas towards SDOs, which is illustrated in Figure 1. This deliverable provides a summary for the initial steps taken and addresses the results derived from COLLECT III, and MAP II and III.

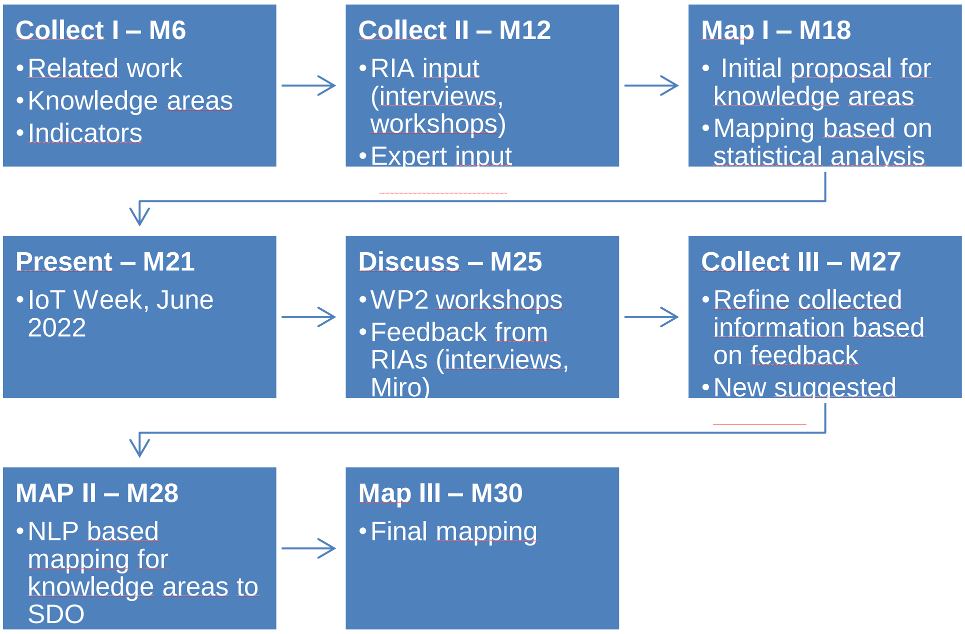

Figure 1: Knowledge area mapping to SDO process.

3 REFINED KNOWLEDGE AREAS (MAP II)

3.1 Summary, Collected Data

The collected data has been presented and a first analysis has been provided in D3.5. This deliverable contains therefore a detailed explanation of the data collection and selection.

In this section, a refined analysis of the collected data is provided, being the data analysed again provided in Annex 1 (D3.6-annex-1.xls).

The data collected represents the perspective of knowledge areas coming from different international sources as presented in D3.5:

- EC JRS Digitranscope.
- NATO.
- IIA.
- AIOTI.

The EC JRS Digitranscope approach for key technological areas [2] shares a significant resemblance to the European "Horizon Europe First Strategic Plan 2021-2024" [3], and its 6 clusters.

In total, the EC JRS Digitranscope considers 90 distinct applications (use-cases), grouped into 8 knowledge areas, as represented in Table 3. The knowledge area integrating more use-cases is **Artificial intelligence and robots**, closely followed by **Energy**.

Table 3: EC JRS Digitranscope knowledge areas.

Knowledge *Area*	Number of applications
Artificial intelligence and robots	19
Biohybrids	6
Biomedicine	10
Breaking resource boundaries	11
Electronics and computing	11
Energy	16
HCI and biomimetics	6
Printing and materials	11
Total	**90**

Regarding NATO, the knowledge areas are defined as *Emergent and Disruptive Technologies (EDTs)* (rf. To D3.5) [3]. While Digitranscope provides knowledge areas in the different clusters, NATO is focused on the digital, industry, and space cluster, as expected due to its goals. Therefore, based on the NATO data, 8 main knowledge areas can be considered, derived from 27 main applications, as presented in Table 4.

Table 4: NATO Emergent and Disruptive Technologies.

EDT	Number of Applications
Artificial Intelligence	3
Autonomy	4
Biotechnologies	4
Data	4
Hypersonics	2

Materials	3
Quantum	4
Space	3
Total	**27**

The fourth data set for knowledge areas derives from the *Inside Industry Association (IIA)*[7], formerly ARTEMIS-IA, has developed a strategic research agenda with AENEAS and EPOSS. This document, ECS SRIA 2022 [6] corresponds to a revision of the 2021 strategic agenda (ECS SRIA 2021). This revision focuses on a fine-grained delineation of Edge computing and AI, focusing on convergence towards embedded intelligence on the Edge for Electronic Components and Systems (ECS).

The ECS SRIA 2022 [6] defines *Foundational Technological (FT)* areas which are then mapped to ECS key application areas, which contribute with different applications to the European competitiveness domains: mobility, digital industry, energy, health and well-being, agri-food and natural resources, digital society.

The total number of topics per FT, per cross-sectional area and per key application area is respectively presented in Tables 6 and 7.

Table 5: ECS SRIA FDTs and topics.

Foundational technology area	Topics
Components, modules, systems integration	5
Embedded software and beyond	21
Process technology, equipment, materials, and manufacturing	17
System of systems	19
Total	**62**

Table 6: ECS SRIA Cross-sectional technological areas.

Cross-sectional areas	Topics
Connectivity	10
Edge computing and embedded AI	13
Quality, reliability, safety, cybersecurity	11
Total	**34**

Table 7: ECS SRIA Application technological areas.

Application areas	Topics
Agrifood and natural resources	9
Digital Industry	6
Digital Society	21
Energy	12
Health and Well-Being	7
Mobility	9
Total	**64**

[7] https://www.inside-association.eu/

The AIOTI[8] working group "Research and Partnerships"[9] has been driving the research analysis on challenges concerning the development of an Internet of Things, including the mapping of specific knowledge areas to standardisation, e.g., IoT communication protocols to SDOs; the categorization and analysis of IoT applications and IoT areas covered by European IoT-oriented projects. Among the different relevant deliverables, AIOTI has been identifying, since 2018 [4][5], IoT enabling technologies and assisting in identifying fragmentation, gaps, and directions to take to allow for a sustainable and innovative development of next generation IoT services. The AIOTI output is relevant to understand the evolution of IoT enabling technologies, and challenges that need to be met to assist such evolution.

AIOTI[10] has extensively collected knowledge areas and topics, assisting in driving the vision of IoT and Edge computing in Europe. However, currently there is no intention to provide an assessment of the impact of the different topics and technological knowledge areas.

Table 8: AIOTI enabling technological areas.

Enabling Technological area	Count of topics
Configuration and orchestration	3
Data	5
Energy efficiency	5
Identification technologies	1
IoT architectures	5
IoT distributed and federated technologies	4
IoT infrastructure	6
IoT platforms	6
IoT privacy, safety, security, trust	5
Next generation devices	6
OS and Software	3
Sensing	1
Tactile and Intactile IoT	2
Total	**52**

3.2 Proposed Knowledge Areas

During the first analysis (D3.5), the different topics derived from sources have been compiled into a list (rf. Annex 1, EU-IoT KA2022) holding a total of 276 topics, as presented in Table 9.

Table 9: Total topics collected, compiled per knowledge areas.

Knowledge Area	Nr. topics
Artificial Intelligence	15
Autonomy	10
Biomedicine	13
Biotechnology	7

[8] https://aioti.eu/
[9] https://aioti.eu/about-us/our-groups/research-and-partnerships/
[10] https://aioti.eu/

Knowledge Area	Nr. topics
Configuration and orchestration	7
Cybersecurity	15
Data	18
Energy	30
Infrastructure	24
IoT architectures	23
IoT infrastructure	2
IoT interfaces	24
Materials	5
Next generation devices	36
Printing	6
Quality	4
Quantum	4
Robotics	7
Software	26
Total	**276**

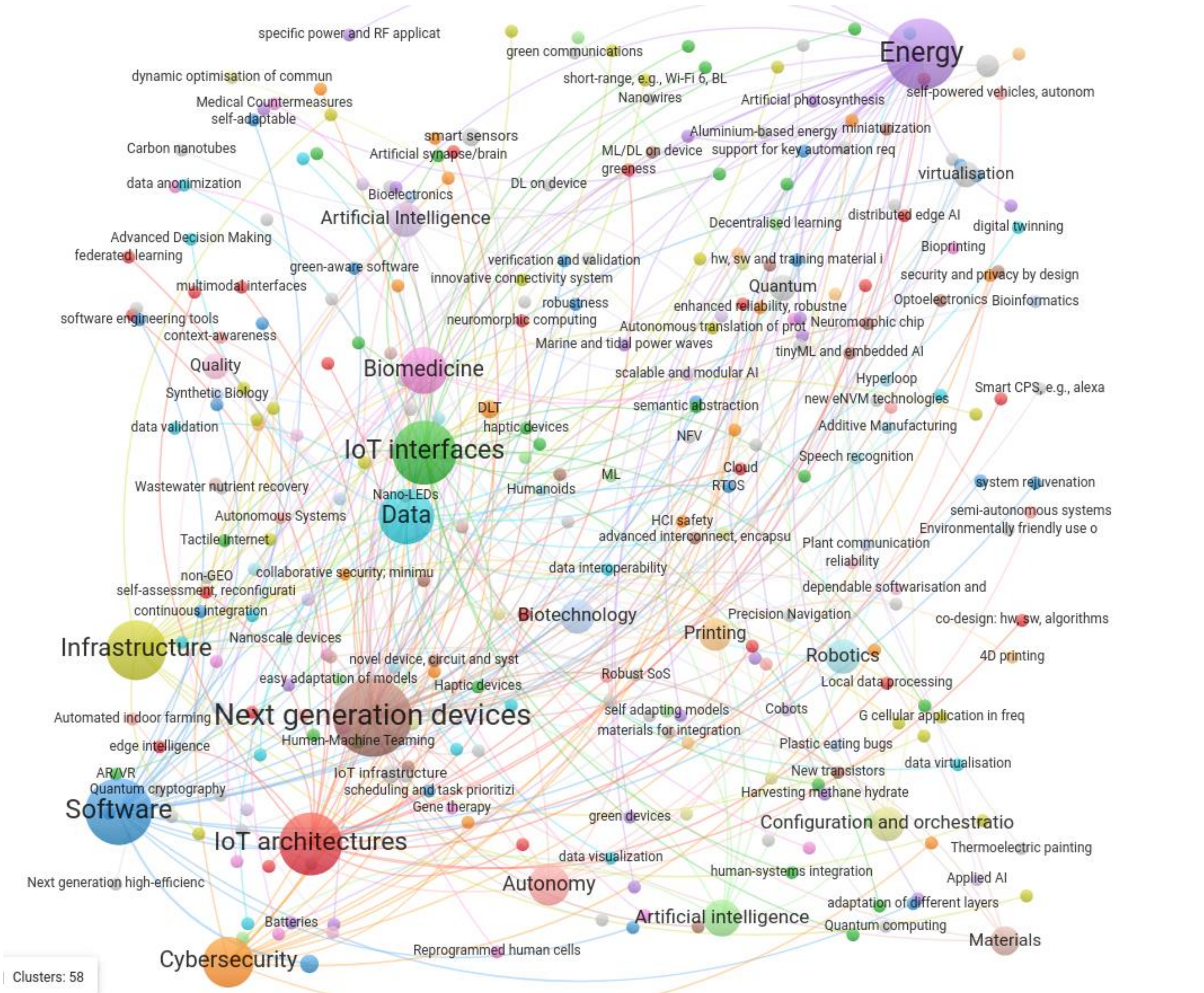

Figure 2: Derived knowledge areas graph representation. The node centrality relates with the number of topics.

3.3 Knowledge Areas Relation to the Horizon Europe Strategic Plan Clusters

Figure 3 illustrates the clusters and the mapping of knowledge areas between clusters, JRS Digitranscope technological areas, and the NATO Science and Technology EDTs.

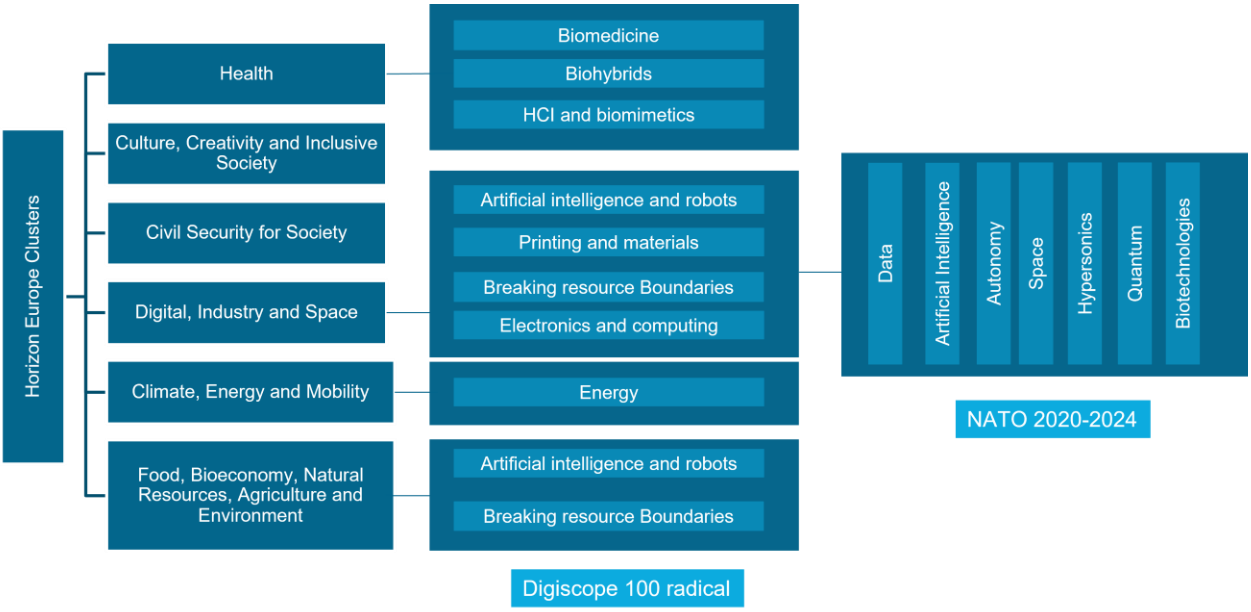

Figure 3: Horizon Europe strategic plan, 6 clusters.

Regarding IIA, Figure 4 provides a perspective on the ECS-SRIA 2022 application areas, foundational areas, and cross-sectional areas. The application areas are well aligned with the Horizon Europe clusters; while the foundational areas and cross-sectional areas represent knowledge areas that cover all HE clusters.

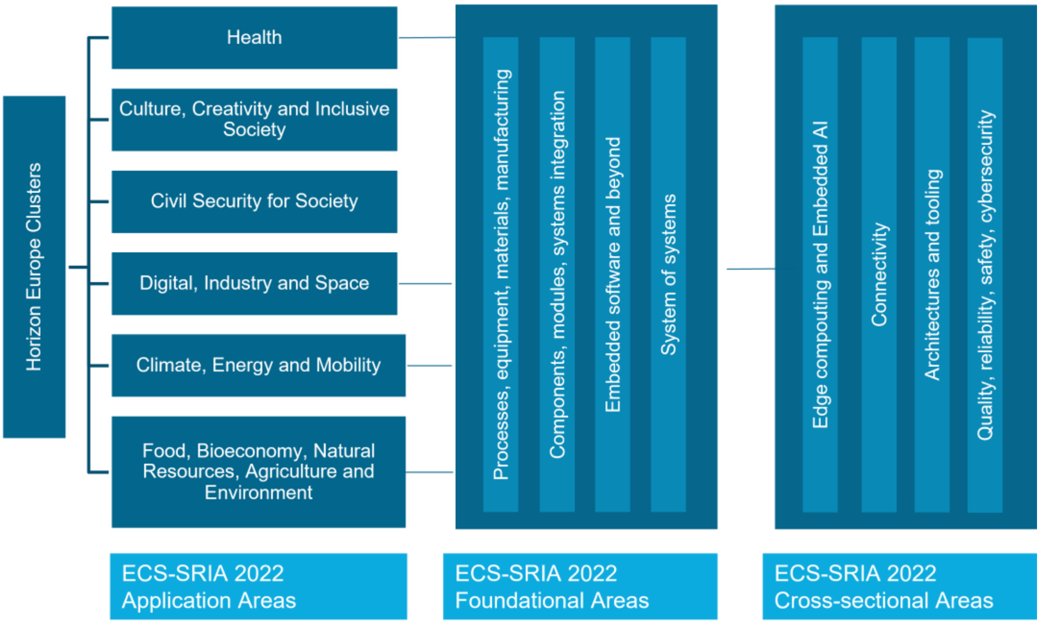

Figure 4: IIA ECS application areas, foundational areas, cross-sectional areas, and their relation to the Horizon Europe Strategic clusters.

Figure 5 provides the same mapping for the AIOTI detected knowledge areas, and for the EU-IoT scope areas. Here it is highlighted that the EU-IoT scope areas do not correspond to knowledge areas (as it would create a limited view in terms of knowledge). EU-IoT adopted an end-to-end perspective of an IoT system having adopted an interconnected system perspective with concrete borders, AIOTI adopted a strategy where some knowledge areas reflect a specific region of an end-to-end IoT system (e.g., tactile IoT, sensing), while other knowledge areas cover the full end-to-end perspective (e.g., IoT architecture, data).

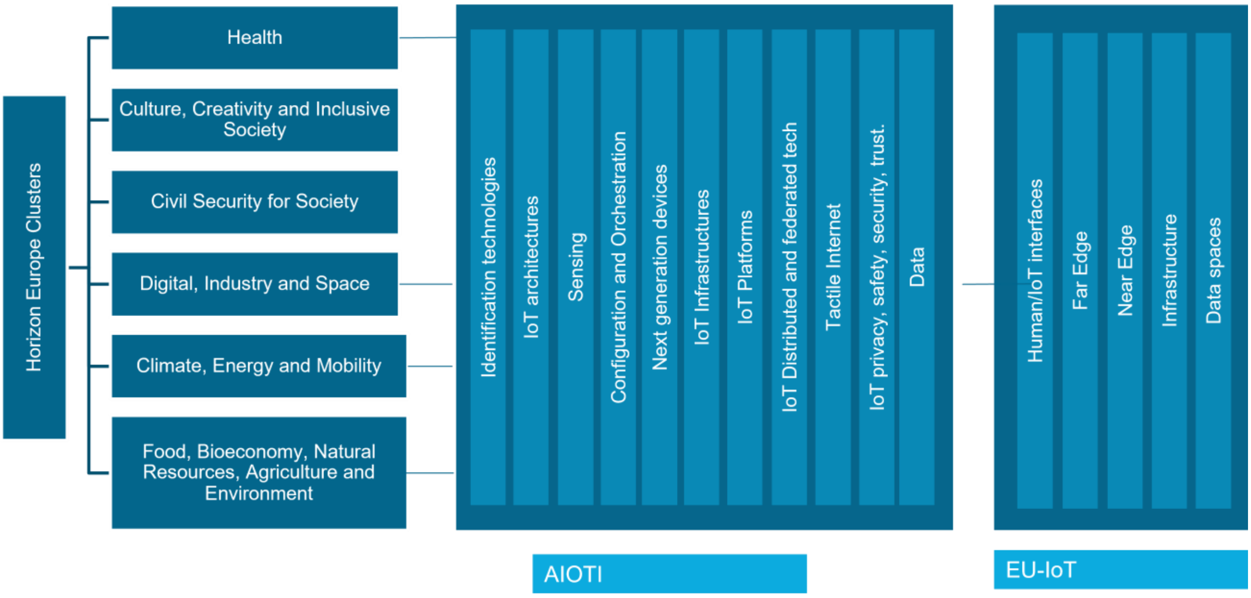

Figure 5: AIOTI and EU-IoT knowledge areas and their relation to the Horizon Europe strategic clusters.

4 ICT-56 RIAS TECHNOLOGICAL AREAS (COLLECT III)

During the COLLECT phases I, II, and III, input from RIAs has been collected, derived from interactions in WP2, WP3, and WP5. This included:

- Input from surveys developed in WP3.
- Input and interviews from documents in WP5 concerning impact assessment, namely, input concerning contributions to the SDG characterization; objectives of the project; key assets.
- Keywords derived from use-cases, for which information has been collected in WP2.

The data collected per RIA (rf. to Annex I, worksheet "Projects") has been extracted from the following fields, which have then been selected with the help of an NLP-based tool[11]. The tool has been fine-tuned to find fewer and larger topics, English language, where the minimum word length considers 3 characters.

- Summary.
- Expected contributions.
- Goals.
- Main research contributions.
- Descriptive assets.
- Descriptive technology.
- Success story.

The compiled topics have then been added to the key topics already collected during COLLECT-I-II. The results are presented in Table 10.

Table 10: Project key technological topics and key contributions to standards.

Project	Topics	Key Standards, contributions[12]
ASSIST-IoT	AR/VR, secure tactile support, smart wearable human-centric DLT Data Architecture	EN/TC248/WG 31 ETSI STF601, STF602 IEEE C/AISC/CEC, C/AISC/FML, COM/MobiNet-SC/TI ITU-T G13: Future networks, with focus on IMT-2020, cloud computing and trusted network infrastructures.
VEDLIoT	Compute, security, distributed. IoT platform IoT hardware architecture	PICMG COM-HPC RISC-V ISA
IntellIoT	Tactile interface Privacy and trust Agent IoT application Autonomy Collaborative IoT Human-in-the-loop	Contribution: W3C WoT Community Group on the topic of "Autonomous Agents on the Web" Contributions to W3C WoT TD v1.0
IoT NGIN	Tactile internet and intelligent ambient monitoring IoT, Cloud	ECSO WG6.2 Digital transformation in verticals

[11] https://nocodefunctions.com.
[12] For detailed information refer to the EU-IoT deliverable D3.8.

Project	Topics	Key Standards, contributions[12]
	Federated Learning Privacy Metadata architecture Condition monitoring Digital twin	
Ingenious	Tactile and immersive interfaces AI/ML Supply-chain Data management Smart networks Logistics pilots	-
TERMINET	Framework, chain, blockchain Communication, compute, health, wireless IoT, Edge, Data, Device AR/VR, tactile IoT, smart wearable SDN-enabled vMEC, Distributed AI SDN infrastructure Semantic technologies Data visualization	ETSI Teraflow SDN, MANO IEC UC6, new generation of RTU devices; IEC UC3, sustainable and efficient buildings IEC/IEEE 42010 systems and software engineering ISO UC1 (user-centric devices in Smart Farming); ISO UC4 (prediction and forecasting system for optimising the supply-chain. W3C CCG (Credentials community group); W3C DID (Decentralised identifier).

The topics collected have also been revised and mapped to the EU-IoT scope areas, as described in Table 11.

Table 11: ICT-56 RIAs technology areas and mapping to the EU-IoT scope areas.

Project	Human/IoT interfaces	Far Edge	Near Edge	Infrastructure	Data Spaces
ASSIST-IoT	AR/VR, secure tactile support, smart wearable Human-centric DLT	Device/user Self-awareness, novel Far Edge gateway (ASSIST-IoT Far Edge node or Smart Device) DLT	Intelligent IoT gateways, ASSIST-IoT Edge Node	5G core integration, SDN and NFV all along the network, multi-link connection	Edge data space based on semantic orchestration. DLT Data architecture
VEDLIoT	IoT hardware architecture, distributed, secure	ML integrated into open hardware to allow the support of more complex functions on the Edge.	ML integrated into open hardware to allow the support of more complex functions on the Edge	IoT hardware architecture, security, distributed.	-
IntelIIoT	Tactile interface Collaborative IoT Privacy and trust Agent IoT application	Local AI decisions: distributed AI to assist learning from IoT data sources; offloading	Intelligent offloading (e.g., due to energy consumption) between Near and Far Edge	5G core; TSN on the Edge	WoT interoperability integrated

Project	Human/IoT interfaces	Far Edge	Near Edge	Infrastructure	Data Spaces
	Autonomy	between near and Far edge			
IoT NGIN	Tactile internet and intelligent ambient monitoring	-	Device or edge side intelligence Supporting Federated learning	5G, D2D / improvements to resource management, VFN based on MANO; integration of federated AI into networking nodes; TSN interconnection for real-time application support.	Ontologies Metadata architecture
Ingenious	Tactile and immersive interfaces	Neuromorphic computing	Integration of the developed solutions with MEC	5G core and VFN orchestration based on MANO; 5G TSN	Data virtualisation Layer to support the data exchange on highly heterogeneous data spaces interconnected via 5G
TERMINET	AR/VR, tactile IoT, smart wearable devices, interaction	Distributed AI DLT	SDN-enabled vMEC, Distributed AI DLT	Private 5G RAN, SDN infrastructure. DLT	Semantic and abstraction mechanisms, data visualization

Figures 6-10 provide a representation for the key topics analysed with the help of the NLP Voyant toolset[13]. The topics in blue represent the ones with the highest centrality.

[13] https://voyant-tools.org

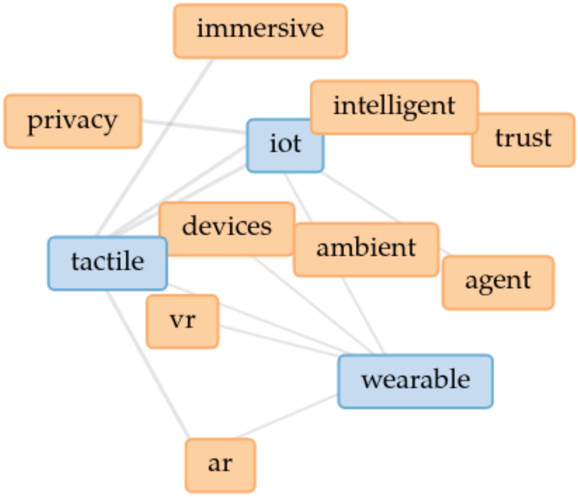

Figure 6: Key topics derived from the RIA collected data mapped to the EU-IoT scope of Human/IoT interfaces.

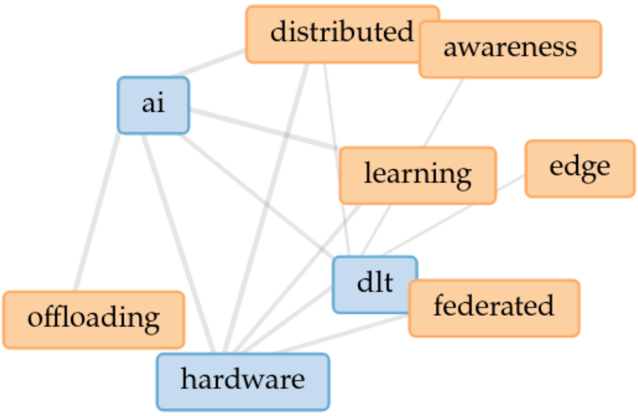

Figure 7: Key topics derived from the RIAs collected data mapped to the EU-IoT scope of far Edge.

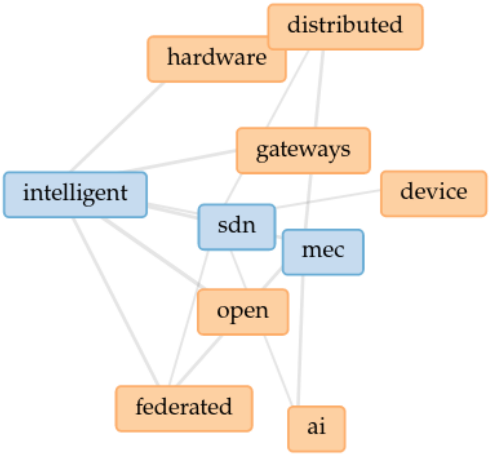

Figure 8: Key topics derived from the RIAs collected data mapped to the EU-IoT scope of near Edge.

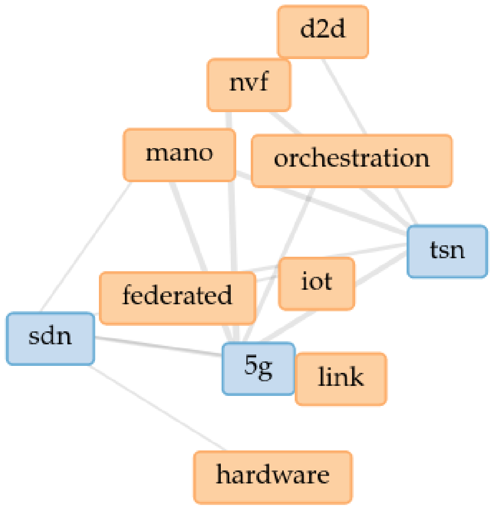

Figure 9: Key topics derived from the RIAs collected data mapped to the EU-IoT scope of infrastructure.

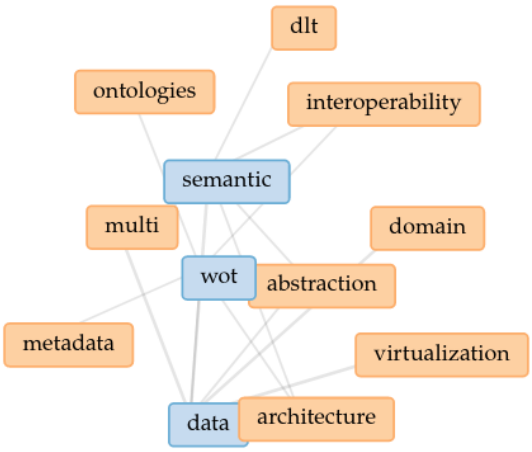

Figure 10: Key topics derived from the RIAs collected data mapped to the EU-IoT scope of Data spaces.

5 KNOWLEDGE AREAS MAPPING ANALYSIS (MAP III)

After the final data collection, MAP III relates to the final mapping of the derived knowledge areas and topics being worked in projects about the collected knowledge areas, across the EU-IoT scope areas, representing an interpretation of an end-to-end IoT abstracted system.

The key aspects analysed provide an update of the initial analysis described in D3.5 and relate to:

- How are knowledge areas mapped to different standardisation, pre-standardisation, and standards-oriented consortia?
- What is the current possibility provided by SDOs for RIAs to contribute, based in the defined knowledge areas?
- How are the research contributions being provided by RIAs to SDOs aligned across EU-IoT scope areas?

5.1 Knowledge Area to SDO Mapping

The SDO mapping relates to the final SDO collection that is described in EU-IoT D3.8 and which is part of the EU-IoT map of Standardisation entities, available online[14]. The respective xls is provided also as Annex 2 to this deliverable.

The mapping is based on string similarity, derived from the longest prefix match between SDO keywords and knowledge area sub-topic. Knowledge areas are provided per row; the greyed rows represent knowledge areas which are out of the scope of ICT-56; nonetheless, they are kept assessing, as a potential next step, whether some sub-topics may be relevant still within the scope of ICT-56.

Table 12: Knowledge Area to SDO final mapping.

Knowledge Area	Standardisation	Pre-standardisation	Consortia/Fora
Artificial Intelligence	IEEE	5G-ACIA, 5G-IA, IRTF, 6G-IA	AIOTI, BDVA, O-RAN, RISC-V
Autonomy	ODVA, IETF, GS1, ETSI	6G-IA, IRTF	OSA, AIOTI, GSMA, IIC, 5GAA, ONF, O-RAN
Biomedicine			
Biotechnology			
Configuration & orchestration	OGC, W3C/WoT, IEEE, IEC, IETF, GS1, ETSI	IRTF, 6G-IA, 5G-IA	AIOTI, Gaia-X, IIC, OAA, OCF, OMA, RISC-V. VDMA, 5GAA, O-RAN, OSA
Cybersecurity	ISO, ITU-T		ECSO
Data	ETSI, OGC, BFF, GS1, OASIS	5G-ACIA, 5G-IA	AIOTI, BBF, BDVA, Gaia-X, IDSA
Energy	CENELEC, IEC, ISO	IRTF	AIOTI, IDSA. EFFRA
Infrastructure	3GPP, GSMA, IEEE, ITU-T, LoRA, OCF, oneM2M, ORAN, GS1, IETF, OASIS, OPC, OGC	5G-ACIA, 5G-IA, IRTF, 6G-IA	VDMA, AIOTI, Gaia-X, IIC, LoRA, OAA, OCF, OMA, Weightless, 5GAA, ECSO, O-RAN, OSA
IoT architectures	ETSI, GS1, OASIS, ODVA, OPC, IETF	IRTF	AIOTI, IIC, OAA, EFFRA, O-RAN
IoT interfaces	CENELEC, W3C/WoT, IETF, GS1, OGM, OGC, ETSI	IRTF	AIOTI, IIC, EFFRA, O-RAN, OCF, OSA
Materials			

[14] https://www.ngiot.eu/archive-standardisation-bodies/

Knowledge Area	Standardisation	Pre-standardisation	Consortia/Fora
NG devices	RISC-V, GS1, 3GPP, IEC, OGC, CSA, oneM2M	6G-IA, IRTF	OAA, RISC-V, VDMA, 5GAA, ECSO
Printing			
Quality	CENELEC, ISO, IETF, 3GPP, ITU-T, CSA	5G ACIA, 6-IA	IIC, ECSO, EFFRA
Quantum	IEEE, ISO, ITU-T	IRTF, 6G-IA	-
Robotics	OPC, ETSI, IEC, ODVA	5G IA, 5G ACIA	VDMA, IIC
Software	ETSI, CSA, OMG, oneM2M, 5GAA	6G IA	ECSO, IIC, OAA, OCF, OMA, O-RAN

From this initial mapping, the following considerations can be drawn:

- **The derived knowledge areas are well covered in the analysed SDOs**. Exceptions to this are Quantum, where consortia/alliances/fora could not be found.
- **AI topics are addressed in SDOs, but there are no SDOs focused on AI**. There are currently several fora dedicating several study and research groups to AI application: and pre-standardisation. In terms of SDOs, AI topics are present in the most relevant SDOs.
- **Data, Infrastructure, Configuration, and orchestration as well as IoT architectures** are the knowledge areas that exhibit a better mapping towards the SDO spectrum (standardisation, pre-standardisation, consortia).

5.2 Knowledge Areas and RIA Standardisation Contributions

The key topics addressed by RIAs as described in section 4 (rf. To Table 10 and Figures 6-10) have been mapped onto the collected knowledge areas (rf. To Annex 1), to understand the coverage of contributions being proposed and derived in the context of RIAs. The mapping is presented in Table 13.

Table 13: Key topics covered by RIAs and mapping to the defined knowledge areas.

Knowledge Areas	Topics covered by RIAs
Artificial Intelligence	Explainable AI, Cobots, self-adapting models, orchestrated ML, federated learning, swarm learning
Autonomy	Immersion, wearable, device self-awareness, awareness
Biomedicine	-
Biotechnology	-
Configuration and orchestration	Offloading, SDN, dynamic, cognitive orchestration, semantic orchestration, MANO, D2D
Cybersecurity	Privacy, trust, DLT
Data	Semantic, digital twins, virtualization, visualization, governance, interoperability, ontologies
Energy	-
IoT infrastructure	MEC, micro-servers, network virtualization, efficient networks, NFV, SDN, TSN, resource allocation, 5G, self-contained networks
IoT architectures	Federated learning, GPU mapping, distributed learning
IoT interfaces	AR/VR, tactile internet, haptic devices, intelligent ambient monitoring, WoT
Materials	-
Next generation devices	Novel smart wearables, ML/DL on device, neuromorphic computing
Printing	-
Quality	-
Quantum	-

Knowledge Areas	Topics covered by RIAs
Robotics	-
Software	Awareness, SDN, virtualisation, unikernels, gateways, interoperability, open

Since March 2022 until March 2023, there has been an increase in terms of research contributions coverage towards knowledge areas in the scope of ICT-56. The contributions per knowledge area across the EU-IoT scope areas are illustrated in Figure 11, where light red provides knowledge areas for which we could not find coverage from RIA topics, and dark blue represents knowledge areas where RIAs have been contributing. The main changes were:

- **Cybersecurity**, contributions were focused on Data Spaces, and are now also present in the far Edge and interfaces.
- **Configuration and orchestration**, contributions are now also present in the far Edge.
- **Autonomy,** contributions in the EU-IoT scope of near Edge have increased.
- **Software (softwarisation)** contributions currently cover the overall spectrum (far Edge, near Edge, Infrastructure.
- **Areas such as robotics and energy** still fall short in terms of contributions to standardisation. However, this aspect also relates with the nature of ICT-56: research is focused on IoT/Edge and energy/robotics represent usage areas (use-cases), instead of scientific focus areas.

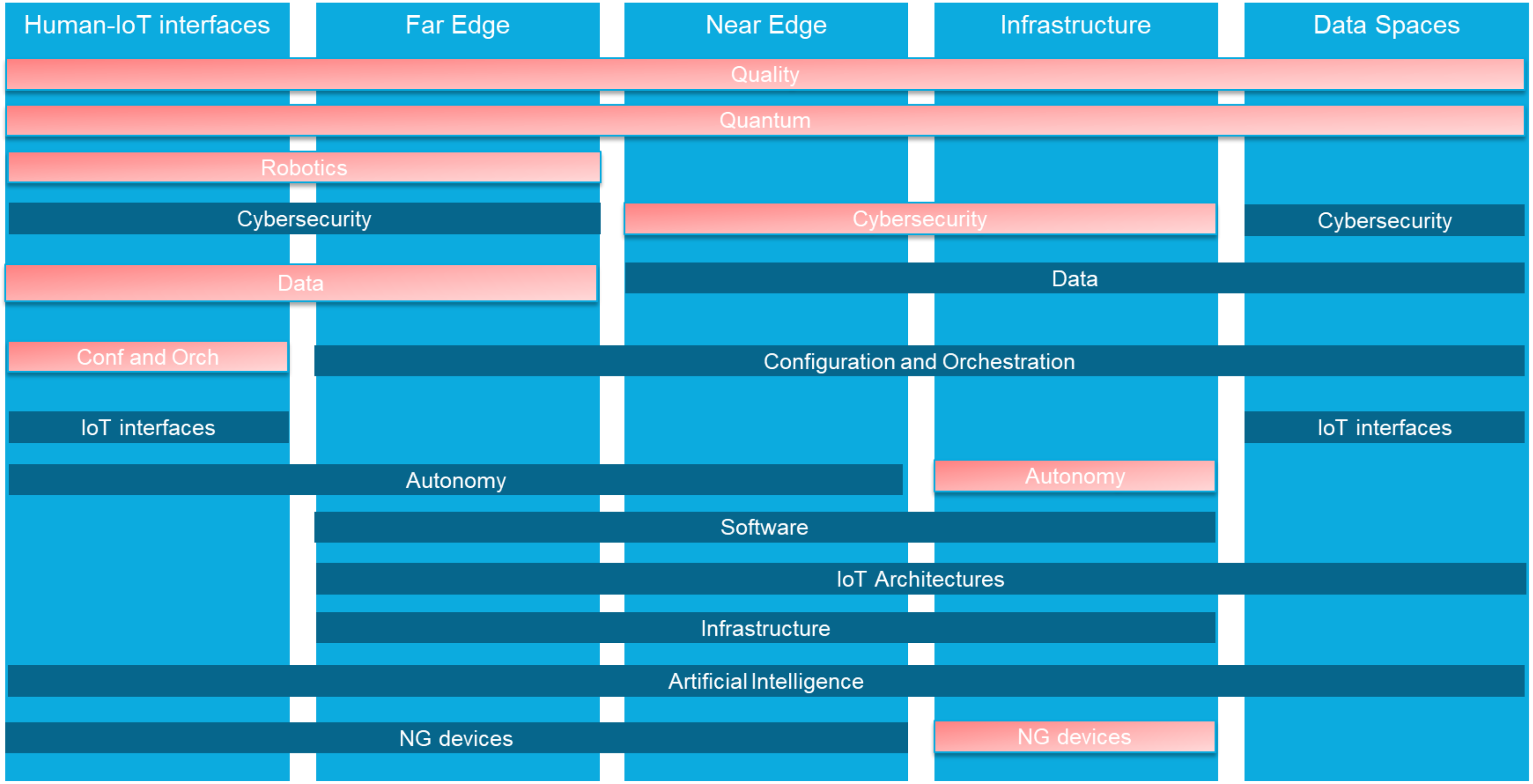

Figure 11: RIA contributions per knowledge area, positioning in the EU-IoT scope areas. Light red bars concern lack of contributions across one or more EU-IoT scope areas; dark blue represents existing contributions by ICT-56 RIAs across one or more EU-IoT scope areas.

6 CONCLUSIONS

The current knowledge area mapping derives from an exhaustive collection of data from related sources; ICT-56 RIA input; discussions with experts within the context of 3 WPs in EU-IoT: WP2, WP3, WP5. Derived from this data collection, this deliverable defines specific knowledge areas and provides an analysis of how such knowledge areas meet the proposed EU-IoT scope areas.

Over the last year, the ICT-56 RIAs have been increasing the research contributions towards standardisation both in terms of knowledge area coverage across the end-to-end IoT spectrum and in terms of standards.

Key takeaways from this analysis are:

- ICT-56 RIAs are providing relevant contributions towards relevant SDOs across the full IoT spectrum as explained in sections 4 and 5.
- There has been a significant increase in contributions between the period of March 2022 until March 2023. This aspect is related to the lifetime of the RIAs (second year). Knowledge areas that were before concentrated in one EU-IoT scope area (e.g., cybersecurity) are now also addressed across several EU-IoT scope areas.
- Contributions are being provided to SDOs and in the context of pre-standardisation and fora, aspect that is relevant to highlight, given that it increases the likelihood of subsequent exploration of technologies in the context of SDOs.

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ANNEX I: COLLECTED KNOWLEDGE AREAS AND TECHNOLOGICAL SUB-TOPICS

Refer to the document "D3.6_AnnexI.xls".

ANNEX II: SUMMARISED PROJECT DATA

Refer to the document "D3.6_AnnexII.xls".