Grant Agreement N°: 956671
Topic: ICT-56-2020

The European IoT Hub

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

D3.5: Mapping of Knowledge Areas to Standardisation

Version 1

Work package	WP 3
Task	Task 3.3
Due date	30/03/2022
Submission date	30/03/2022
Deliverable lead	Fortiss (FOR), Rute C. Sofia
Version	V1

Abstract

Deliverable D3.5 of EU-IoT relates with the work under development in WP3 – Catalyst, Task 3.3. The task is focused on strengthening the bridge between IoT research under development in ICT-56, and Standards Development Organisations. This deliverable specifically addresses the definition of knowledge areas and provides a mapping analysis of knowledge areas to the collected Standards Developments Organisations.

D3.5 corresponds to an intermediate version (version I) of the knowledge area mapping, which will be further developed during the project lifetime, and published in D3.6, month 30 of EU-IoT.

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

Document Revision History

Version	Date	Description of change	List of contributor(s)
V0.1	02.03.2022	Table of contents	Rute C. Sofia
V0.2	30.03.2022	Full deliverable and release to EU-IoT reviewers	Rute C. Sofia
V0.3	31.03.2022	Internal Review	Brendan Rowan
V1.0	01.04.2022	Integration of reviews, release	Rute C. Sofia

Project co-funded by the European Commission under H2020		
Nature of the deliverable:	R	
Dissemination Level		
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

D3.5 “Mapping of Knowledge Areas to Standardisation Version 1” is focused on i) defining a notion of knowledge area; ii) providing an identification of relevant knowledge areas; iii) providing a first mapping of knowledge areas to current Standards Development Organisation entities.

D3.5 comprises this report and the dataset of collected knowledge areas and respective sub-topics, provided as Annex I (D3_5_AnnexI.xls)

D3.5 corresponds to an intermediate version deliverable. The final and complementary report to D3.5 is D3.6, to be publicly released in month 30 (May 2023) of the project.

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ACRONYMS

Acronym	Description
AB	Advisory Board
AI	Artificial Intelligence
AR	Augmented Reality
BDVA	European Big Data Value
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
SDO	Standards and Development Organization
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 first mapping of knowledge areas to Standards Development Organisations. 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 knowledge areas that are relevant to the further development of the European IoT ecosystem, in a way that is open, human-centric and sustainable.

The deliverable therefore reflects a study of relevant related literature and efforts that address technological and societal innovation for the Internet, with specific focus on next generation IoT services. For this study, we have recurred to multiple related literature; experts interviews developed in WP2; ICT-56 RIA interviews. The initial mapping provided in this study intends to be a first exercise which shall serve as further development of the knowledge area mapping, until month 30 of EU-IoT. The final exercise and proposed mapping will be provided in Deliverable D3.6, month 30.

1.1 Document Structure

The remainder document is organized as follows:

- Still in section 1, the goals are provided.
- Section 2 provides the methodology that has been carried out to collect and to identify knowledge areas, also covering an overview on the collected data, available in Annex I, and how the different sources perceive and assess the impact of different knowledge areas.
- Section 3 provides our proposal for specific knowledge areas. The resulting knowledge areas dataset is provided in Annex I (worksheet “EU-IoT KA2022”).
- Section 4 provides the knowledge area mapping analysis, covering mapping to SDOs, and also addressing the status of contributions by RIAs to the knowledge areas.
- Section 5 concludes the deliverable, providing considerations and recommendations for the next phase of work.

1.2 Goals

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 1*.These projects have started during October and November 2020. Thus, the main aim of this first knowledge area mapping is to assist the RIAs in better understanding how different knowledge areas, and their sub-topics, are currently mapped to different *SDOs.* The aim is therefore to assist RIAs in better directing their standardisation efforts in the future.

Table 1 List of the NGIoT flagship projects.

Project	Link	Goals
assist-iot	https://assist-iot.eu/	Designing, implementing, and validating an open, decentralized reference architecture, associated enablers, services, and tools, to assist human-centric applications in multiple verticals
inGenious	https://ingenious-iot.eu/web/	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	https://iot-ngin.eu/	EEmpower 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 H2020 PROJECT	https://terminet-h2020.eu/	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 Very Efficient Deep Learning in IoT	https://vedliot.eu/	Develop 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 a large number of applications, including industrial robots, self-driving cars, and smart homes.
IntelIoT	https://intelliot.eu/	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.

By providing this intermediate perspective of knowledge mapping, this deliverable expects to assist ICT-56 RIAs with the following benefits:

- An overview on key knowledge areas in Europe, their current strategic impact, how is the evolution of knowledge areas foreseen.
- Strengthen the focus towards relevant knowledge areas in Europe, assisting in identifying a mapping to standardisation, to guide outcome in this context.
- Identify relevant SDOs, consortia, associations to further strengthen the standardization contributions.
- Further assist WP3 in supporting liaisons towards SDOs.

2 KNOWLEDGE AREAS DEFINITION AND COLLECTION

2.1 Methodology

The content of this deliverable has been developed based on different phases. The first phase comprised an analysis of existing literature that provides definitions for different knowledge areas, relevant to IoT. The second phase related with the systemic collecting and mapping of the content collected from different relevant related literature. A third phase addressed the outcome of interviews and discussion on standardisation involving different experts of EU-IoT in the context of WP2, and WP3 workshops with RIAs. A fourth phase relates with the identification of knowledge areas, and their mapping towards standardisation. The current results considered only statistical analysis and human evaluation. The next phase of the work (Period 2 of EU-IoT) shall consider an NLP approach to provide a more sophisticated mapping analysis.

In terms of related work, the data collection related with the analysis of multiple related work. The most relevant sources are discussed in section 2.3. The overall process is illustrated in Figure 1.

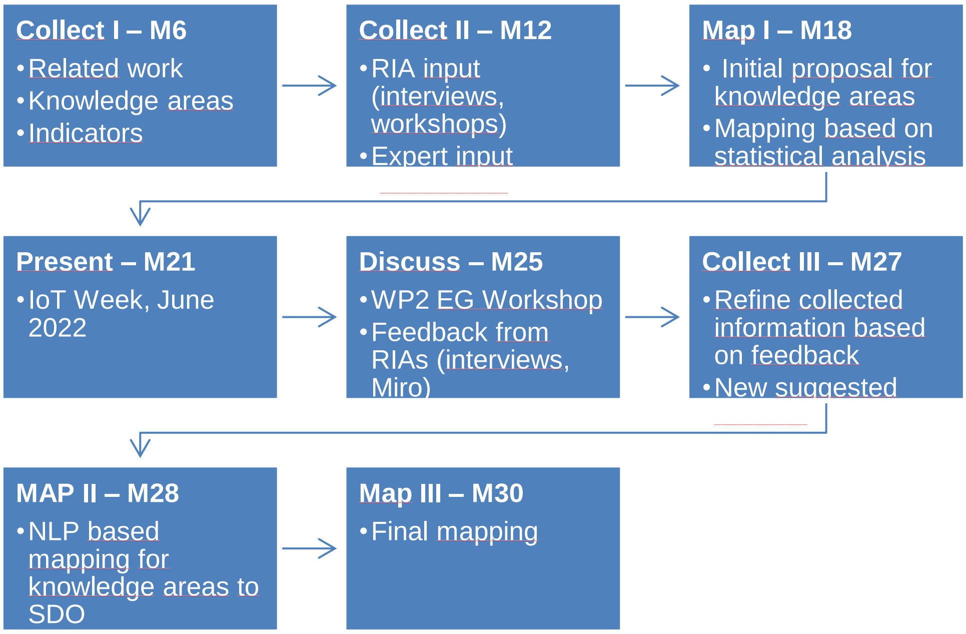

Figure 1: Knowledge area mapping to SDO process.

2.2 Knowledge Area Definition, the EU-IoT Vision

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*" [1].

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 therefore 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, and illustrated in Figure 2 are:

- **Human/IoT interfaces**, relating to novel 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.

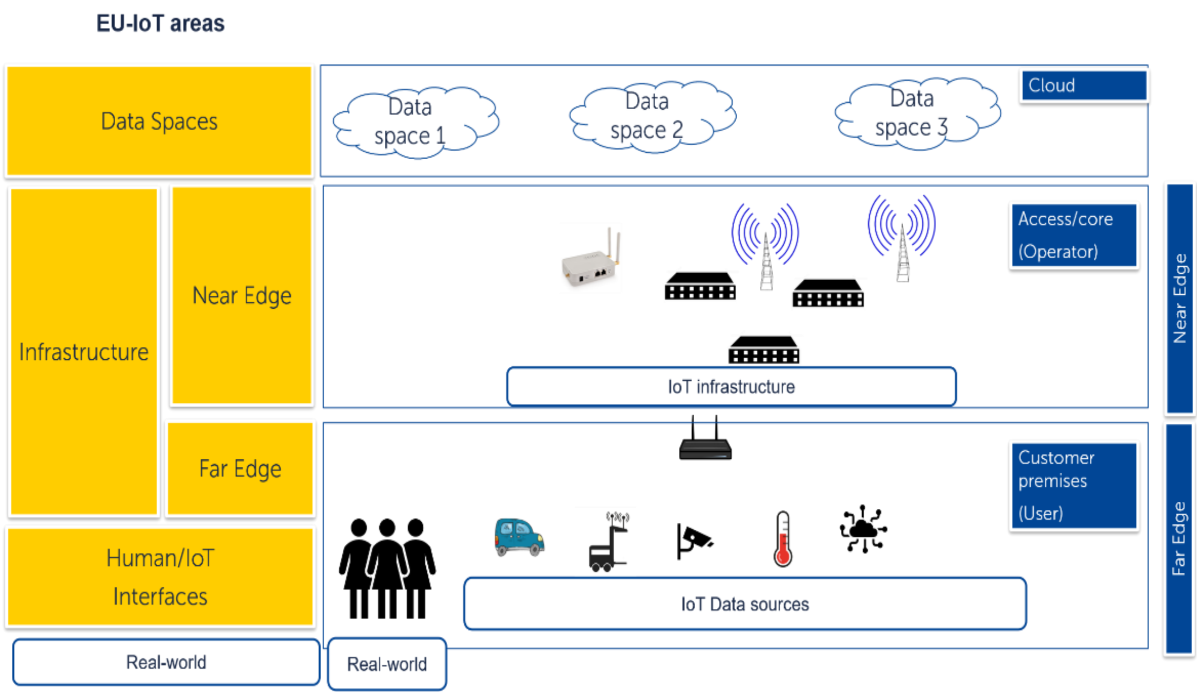

Figure 2: EU-IoT scope areas, end-to-end perspective.

Throughout the next sub-sections, we shall provide examples of knowledge areas based on different related sources. The collected content is available in Annex I.

2.3 Knowledge Areas in Related Work (Collect I)

2.3.1 JRC Digitranscope Perspective on Knowledge Areas

The European Commission *Joint Research Center (JRC)* Digitranscope[1] project has been developing work related with the digital transformation and the governance of human society. Among the different relevant reports, Digitranscope provides the study *"100 Radical Innovation Breakthroughs for the future" [2]*, an exhaustive study that provides a scan on innovative technologies that are on the genesis of the Horizon Europe programme. The study identifies 100 different technological areas providing an overview on different applications (*use-cases*) and an analysis of the use-cases in terms of the following aspects:

- **Likelihood to reach the market or significant use by 2038:** characterises the expectation of consulted experts concerning the future development of the specific knowledge area based on examples.
- **Maturity:** provided based on a Likert scale with 5 levels. Low maturity (1) indicates first proof of concept or even first speculations, and very high maturity (5) suggests that a technology is already applied in first products. This indicator has been assessed based on, for instance, patents or publications related with the area.
- **European Position:** This indicator captures the strength of Europe's current capability in research and innovation with regards to a knowledge area. The indicator has been captured via expert consultation and also implementation documents.

The study collected and positioned, based on the mentioned indicators, over 100 applications and has categorised them into 8 groups of knowledge:

- Group 1, Artificial intelligence and robots.
- Group 2, HCI and biomimetics.
- Group 3, Electronics and computing.
- Group 4, Biohybrids.
- Group 5, Biomedicine.
- Group 6, Printing and materials.
- Group 7, Breaking resource boundaries.
- Group 8, Energy.

The proposed areas cover diversified applications in different vertical domains. For instance, the "artificial intelligence and robots" group use-cases focus on the application of AI, automated indoor farming, chatbots, among others. Electronics and computing cover diversified technological area applications such as Quantum computing, neuromorphic computing, nanowires, etc.

Albeit varied, this study provides a relevant insight into existing technologies, and assists in defining knowledge areas in the context of EU-IoT. A possible representation of the grading of the groups as knowledge areas derived from the 3 types of categories of indicators (2038 market likelihood; maturity; European leadership position) is illustrated in Figure 2.

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[1] https://ec.europa.eu/jrc/communities/en/community/digitranscope

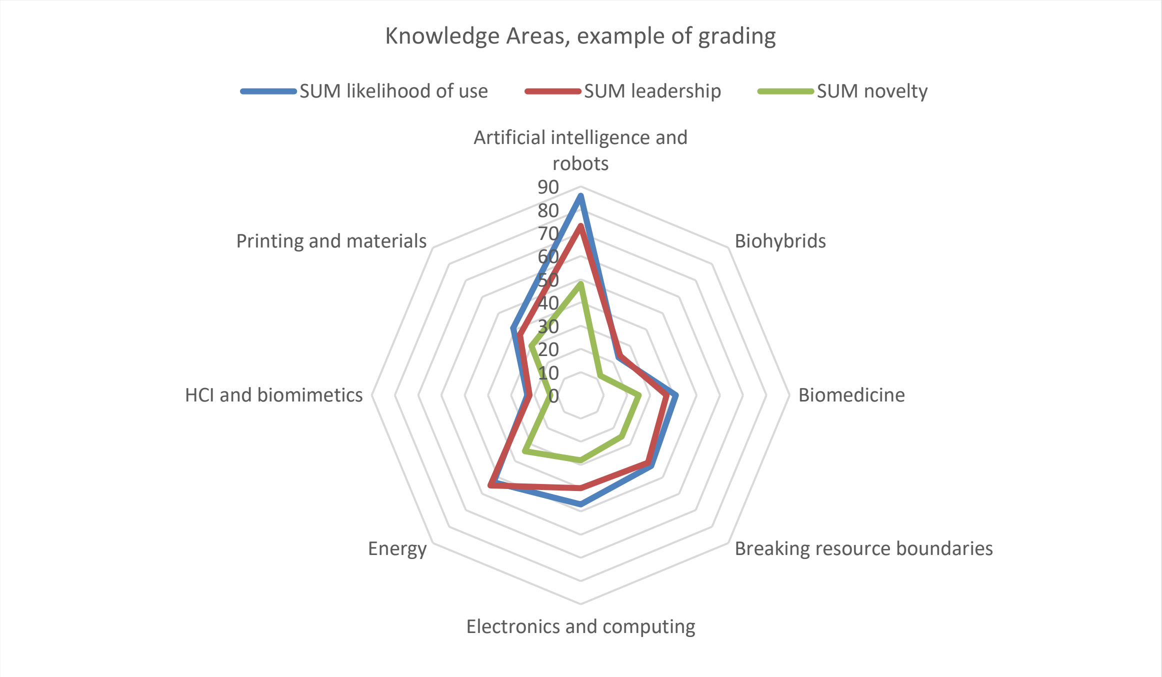

Figure 3: Knowledge areas from 100 radical innovations, example of a potential group grading, derived from the report's indicators (likelihood of use, leadership, novelty).

The European JRC Digitranscope therefore provides a relevant and useful example on knowledge area collecting and also on a methodology to assess potential relevancy of groups of topics to the European competitiveness.

2.3.2 NATO Science and Technology Trends 2020-2040

The NATO Science and Technology department has provided a study like Digitranscope, focused on *Emergent and Disruptive Technologies (EDTs)* [3] and based on its collaborative network of over 6000 active scientists, analysts, researchers, and engineers, and associated member research facilities. While the studied technologies are focused on the goals of NATO, the discussion and collection of different EDTs and their analysis based on different metrics is relevant to the work developed in EU-IoT. The specific NATO science and technology goals are [3]:

- **Intelligent**: Exploit integrated AI, knowledge-focused analytic capabilities, and symbiotic AI-human intelligence to provide disruptive applications across the technological spectrum;
- **Interconnected**: Exploit the network of virtual and physical domains, including networks of sensors, organisations, individuals and autonomous agents, linked via new encryption methods and distributed ledger technologies;
- **Distributed**: Employ decentralised and ubiquitous large-scale sensing, storage, and computation to achieve new disruptive military effects; and,
- **Digital**: Digitally blend human, physical and information domains to support novel disruptive effects.

An EDT is referenced to as a group of related technologies "*capable of technological disruption*". The grouping provided is not unique, as it is based on consultation and analysis. The different EDTs have, in this NATO study, been analysed in terms of their potential impact, described as moderate (10-50%); high (51-100%); revolutionary (over 100%). The scale related with performance aspects, such as speed, range, accuracy, lethality, survivability, affordability, availability, dependability or other defining capability characteristic.

To provide in this section an example on how such indicators may be applied to assess the impact capability of a knowledge area, we rely on the NATO proposed indicators providing each scale level with a numeric value:

- **Impact**, High (5-4); High (3-2); Moderate (1)
- **Attention**, which has been based on the Gartner Hype Cycle[2] approach, for which an example is provided in Figure 4. The following values are considered:
    - **Innovation Trigger (1):** A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist, and commercial viability is unproven.
    - **Peak of Inflated Expectations (2):** Early publicity produces a number of success stories — often accompanied by scores of failures. Some companies take action; many do not.
    - **Trough of Disillusionment (3):** Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters.
    - **Slope of Enlightenment (4):** More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious.
    - **Plateau of Productivity (5):** Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology's broad market applicability and relevance are clearly paying off.

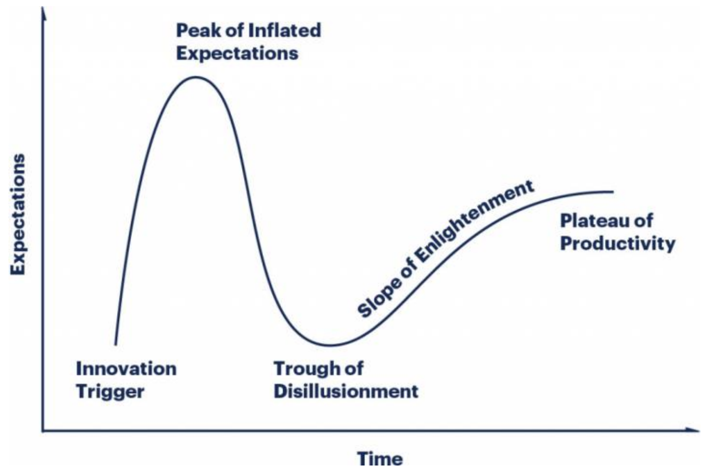

Figure 4: Representation of a Gartner Hype Cycle[3].

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[2] https://www.gartner.com/en/research/methodologies/gartner-hype-cycle

[3] https://www.bmc.com/blogs/gartner-hype-cycle/

EDTs can therefore be considered as knowledge areas:

- **Data**, covering applications such as advanced analytics, advanced data making, data communications, sensors/IoT data sources.
- **Artificial Intelligence**, covering applications such as advanced algorithms, applied AI, human machine symbiosis.
- **Autonomy**, covering applications such as autonomous systems, autonomous behaviour, human-machine interfacing.
- **Space**, covering aspects such as platforms, operations, sensors.
- **Hypersonics**, covering aspects such as platforms and propulsion, countermeasures.
- **Quantum**, covering applications such as communication, information science (e.g., encoding), precision navigation.
- **Biotechnologies**, addressing applications such as bioinformatics, human augmentation, synthetic biology.
- **Materials**, covering applications such as novel materials, additive manufacturing, energy storage

Based on the indicators provided by NATO, Figure 5 provides an example on how the different EDTs may be assessed in terms of impact, following an approach similar to the one from JRC Digitranscope, where technological topics are graded in regard to likelihood of use for a period; European leadership status; technology readiness level (TRL) or another form of technology maturity (e.g., software use, patents).

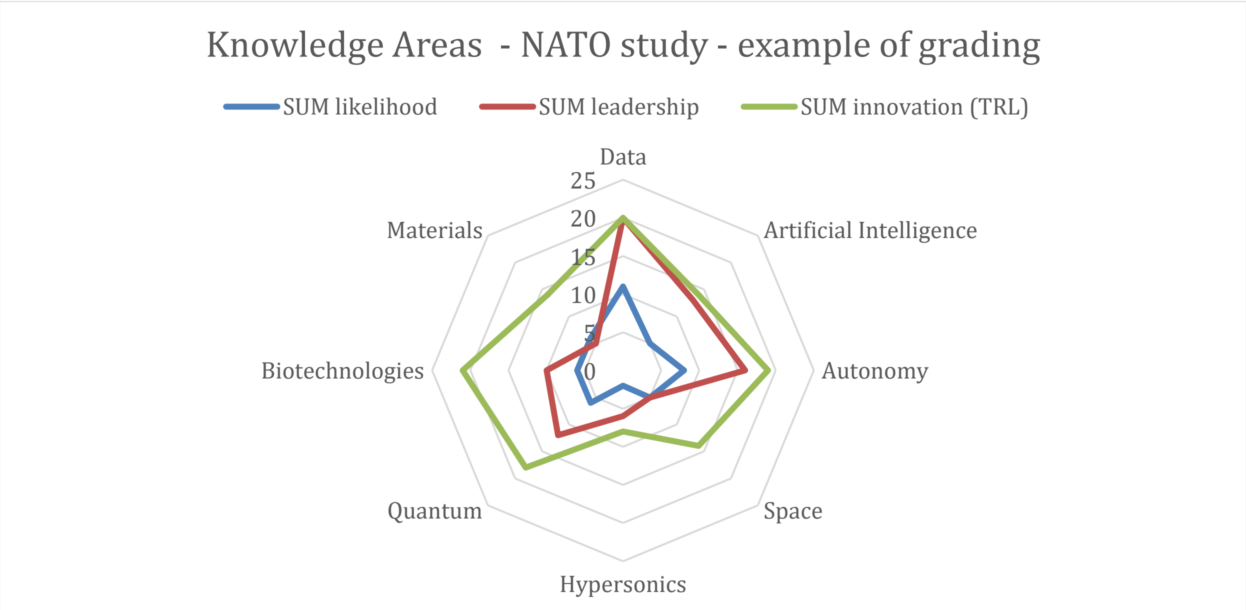

Figure 5: Example of grading for knowledge areas definition derived from the NATO perspective on EDTs.

2.3.3 AIOTI Research and Partnership Perspective on Key IoT Areas

The AIOTI[4] working group "Research and Partnerships"[5] 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. The following enabling technologies have been discussed:

- **Identification technologies**, e.g., standard profiling, tagging.
- **IoT architectures**, e.g., Cloud, federated architectures, Cloud-Edge, Edge-Edge.
- **Energy efficiency**, e.g., energy harvesting, green devices and communications, batteries.
- **Configuration and orchestration**, e.g., advanced network reorganization, dynamic function reassignment.
- **OS and software adaptation**, e.g., threading, scheduling and task prioritization, RTOS.
- **Next generation devices**, e.g., embedded devices, low-energy foot printing, TinyML
- **IoT infrastructures,** e.g., short-range and wide range networks; satellite, NTN.
- **IoT Platforms**, e.g., interoperability, trustworthiness
- **IoT distributed and federated technologies**, e.g., DLT, blockchain, decentralised Edge
- **Tactile IoT**, e.g., AR/VR, haptic interfaces, digital twinning
- **IoT privacy, safety, trust**, e.g., user privacy, trustworthiness, reliability.
- **Data aspects**, e.g., worthiness, validation, anonymization, privacy.

AIOTI[6] has extensively collected knowledge areas and topics, assisting in driving the vision of IoT and Edge computing in Europe with the latest edition to be presented at IoT Week 2022. However, currently there is not an intention to provide an assessment of the impact of the different topics and technological knowledge areas.

2.3.4 Inside Industry Association

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

[4] https://aioti.eu/

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

[6] https://aioti.eu/

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

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 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 proposed foundational technological areas are:

- Process technology, equipment, materials and manufacturing
- Components, modules, systems integration
- Embedded software and beyond
- System of systems

Cross-sectional areas are:

- Edge computing and Embedded AI
- Connectivity
- Quality, reliability, safety, security

Key application areas are defined as:

- Mobility
- Energy
- Digital Industry
- Health and Wellbeing
- Agri-food and natural resources
- Digital Society

IIA focuses on the debate on challenges for each area and also for different topics, giving insight for an evolution beyond 2030. The discussion and topics is also a relevant source to the definition of knowledge areas in EU-IoT. Similarly to AIOTI, the assessment of a potential grading for the knowledge areas has not been developed.

2.4 ICT-56 RIAs Technological Areas (Collect II)

Via workshop meetings (WP2, WP3) and via interviews, we have collected the key technology areas being tackled in the ICT-56 RIA projects and have also mapped them into the different EU-IoT scope areas, as presented in Table 2.

The technological areas collected relate with sub-topics in knowledge areas, while the EU-IoT scope areas can be defined as knowledge areas.

Table 2: 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, novel smart wearable	Device/user Self-awareness, novel Far Edge gateway	Intelligent IoT gateways, ASSIST-IoT Edge Node	5G core integration, SDN and NFV all along the	Edge data space based on semantic orchestration

Project	Human/IoT interfaces	Far Edge	Near Edge	Infrastructure	Data Spaces
		(ASSIST-IoT Far Edge node or Smart Device)		network, Multi-link connection	
VEDLIoT	-	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	-	-
IntellIoT	Tactile interface	Local AI decisions: distributed AI to assist learning from IoT data sources; offloading between Near and Far Edge	Intelligent offloading (e.g., due to energy consumption) between Near and Far Edge	5G core; TSN on the Edge	WoT interoperability integrated
IoT NGIN	Tactile internet and intelligent ambient monitoring	-	Device or edge side intelligence Supporting federated ML	5G, D2D / improvements to resource management, VFN based on MANO; integration of federated AI into networking nodes; TSN interconnection for real-time application support	SAREF ontologies for data modelling
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	R/VR, tactile IoT, smart	SDN interfaces to provide a	SDN-enabled vMEC	Private 5G RAN, SDN infrastructure	Semantic and abstraction mechanisms,

Project	Human/IoT interfaces	Far Edge	Near Edge	Infrastructure	Data Spaces
	wearable devices	better integration to the infrastructure; new Edge node based on open hardware acceleration and ML software integration			data visualization

3 KNOWLEDGE AREAS PROPOSAL (MAP I)

The collected data shows that there are different and relevant definitions of what a knowledge area may be, being the European Commission JRC Digitranscope approach for key technological areas the one that resembles the closest the European "Horizon Europe First Strategic Plan 2021-2024" [3], and its 6 clusters/ Figure 6 illustrates the clusters and the mapping of knowledge areas between clusters, JRS Digitranscope technological areas, and the NATO Science and Technology EDTs. 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.

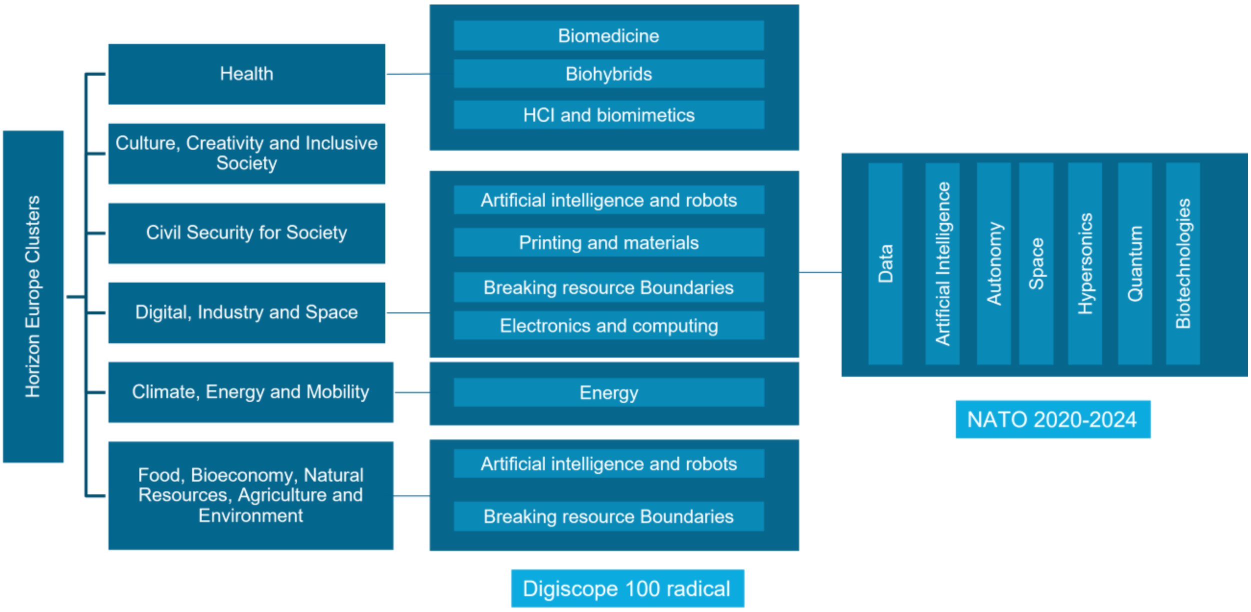

Figure 6: Horizon Europe strategic plan, 6 clusters.

Regarding IIA, Figure 7 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.

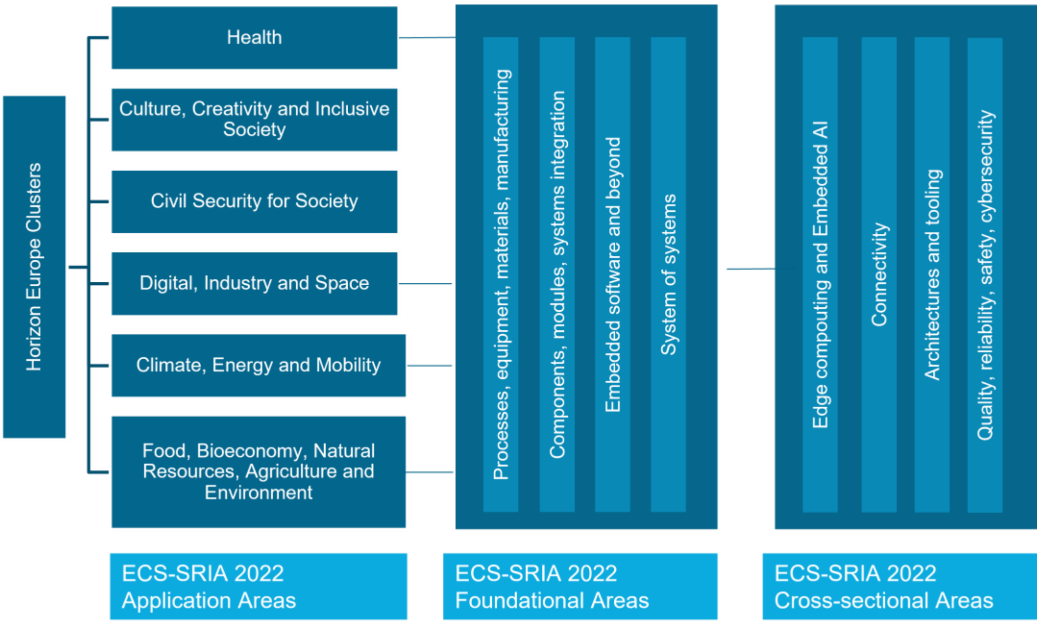

Figure 7: IIA ECS application areas, foundational areas, cross-sectional areas and their relation to the Horizon Europe Strategic clusters.

In terms of AIOTI and EU-IoT, the knowledge areas are also orthogonal to the HE clusters, as illustrated in Figure 8. There is also a direct correspondence between the EU-IoT scope areas and the AIOTI research knowledge areas. However, while 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).

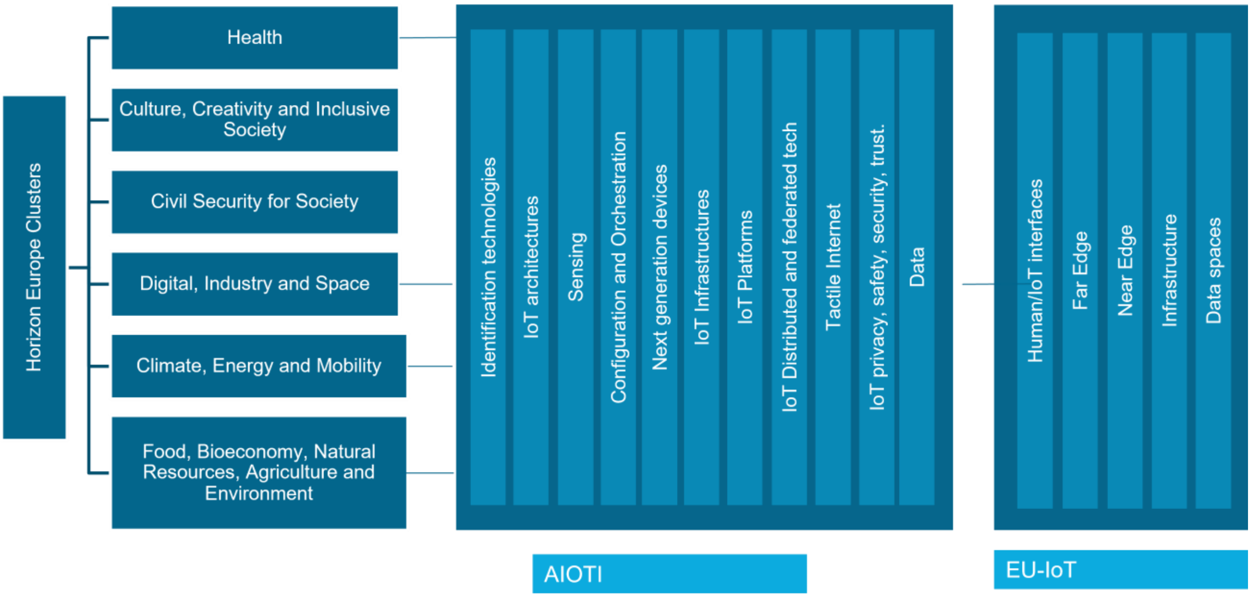

Figure 8: AIOTI and EU-IoT knowledge areas and their relation to the Horizon Europe strategic clusters.

The EU-IoT scope areas should not, however, be considered as knowledge areas, given that such an approach may limit the range of potential contributions. Therefore, we proposed to define knowledge areas based on technological topics and respective knowledge areas as defined in different sources, that have exhaustively collected data based on interviews to experts, to research entities. For the data aggregation and the derivation of a knowledge area map derived from the studied sources, the following steps have been considered:

1. Scoping of the areas based on the global list of sub-topics collected.
2. Concatenation of all topics and respective knowledge areas. We have obtained a list with over 300 topics.
3. Removal of sub-topics that referred to an application instead of to a technological sub-topic. 2 sub-topics were removed, namely, precision farming and asteroid mining.
4. Iteration of the resulting knowledge areas, removing duplicate sub-topics.
5. Simplification of the knowledge area naming based upon duplicate sub-topics. E.g., when the same topic appears under "Energy" and "energy efficiency", the smallest prefix match is considered.
6. Interaction based on human corrections to reduce the number of knowledge areas, e.g., change connectivity by infrastructure; all topics related with privacy, security aggregated under cybersecurity.
7. Topics related with the knowledge area "breaking resource boundaries" have been integrated into other, more specific knowledge areas.
8. Topics related with "artificial intelligence and robots" have been split into 2 knowledge areas, artificial intelligence and robotics.

After the data handling the total of sub-topics were 276, which resulted in the list of knowledge areas provided in Table 3 and illustrated in Figure 9.

Table 3: Proposed knowledge areas, number of collected sub-topics.

Knowledge Areas	Sub-topics
Next generation devices	36
Energy	30
Software	26
IoT interfaces	24
Infrastructure	24
IoT architectures	23
Data	18
Cybersecurity	15
Artificial Intelligence	15
Biomedicine	13
Autonomy	10
Configuration and orchestration	7
Robotics	7
Biotechnology	7
Printing	6
Materials	5

Knowledge Areas	Sub-topics
Quantum	4
Quality	4
IoT infrastructure	2
Total number of sub-topics	**276**

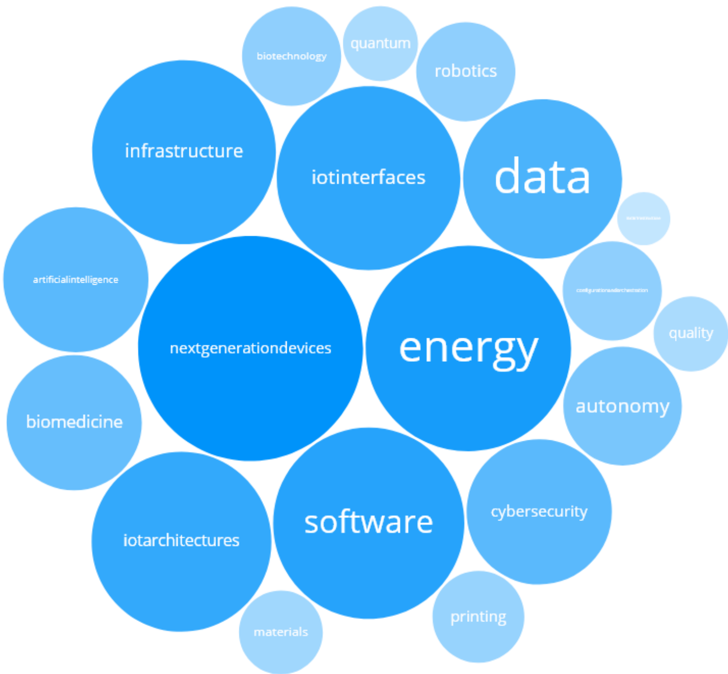

Figure 9: EU-IoT Knowledge Areas, illustrated per number of sub-topics.

4 KNOWLEDGE AREAS MAPPING ANALYSIS (MAP I)

This section provides a first analysis of the knowledge area mapping.

This analysis aims at answering the following questions:

- How are knowledge areas related to the EU-IoT scope areas, and where does the active focus of ICT-56 RIAs reside.
- Which are the top 10 topics overall, and where do they fit in terms of EU-IoT scope.
- What is the relative contribution of topics that RIAs are covering in regard to the knowledge areas.
- How are knowledge areas mapped to different standardisation, pre-standardisation, and standards-oriented consortia.

4.1 Knowledge Area to SDO Mapping

This first mapping counts with the collected SDOs that are currently part of the EU-IoT map of Standardisation entities, available online[8]. A full list of collected SDOs and their mapping to EU-IoT scope areas, as well as specific contributions of RIAs, has been provided in the WP3 deliverable D3.7 (M12), and is provided as Annex II in this document to facilitate the reading.

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 or not some sub-topics may be relevant still within the scope of ICT-56.

Table 4: Knowledge Area to SDO mapping.

Knowledge Area	Standardisation	Pre-standardisation	Consortia/Entities
Artificial Intelligence	IEEE	5G-ACIA, 5G-IA, IRTF	AIOTI
Autonomy	ODVA		
Biomedicine			
Biotechnology			
Configuration & orchestration	OGC, W3C/WoT		Linux Foundation, OMG
Cybersecurity	ISO		
Data	ETSI, OGC, BFF	5G-ACIA, 5G-IA	AIOTI, BDVA, Eclipse Foundation, FIWARE, GAIA-X, Linux Foundation, OMA

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

Knowledge Area	Standardisation	Pre-standardisation	Consortia/Entities
Energy	CENELEC, IEC, ISO		AIOTI
Infrastructure	3GPP, GSMA, IEEE, ITU-T, LoRA, OCF, oneM2M, ORAN, GS1, IETF, OASIS, OPC	5G-ACIA, 5G-IA, IRTF	VDMA, Weightless, Zigbee, Industry4.0, BBF, FIWARE, GSMA, IIC, LoRA, OCF, OneM2M, ORAN, OMA
IoT architectures	ETSI, GS1, OASIS, ODVA, OPC	IRTF	AIOTI, CNCF, Eclipse Foundation, Linux Foundation, EEC, FIWARE, GAIA-X, IIC, Industry4.0, OAA
IoT interfaces	CENELEC, W3C/WoT		Linux Foundation
Materials			
NG devices	RISC-V		
Printing			
Quality	CENELEC, ISO		
Quantum	IEEE	IRTF	
Robotics	OPC		VDMA, Industry 4.0
Software			

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

- **Some knowledge areas lack SDOs**. For instance, Artificial Intelligence sub-topics are only present in IEEE, 5G-ACIA, 5G-IA, AIOTI. Similarly, Quantum topics could only be found in IEEE and IRTF. NG devices related topics are only present in RISC-V.
    - More recent knowledge areas may be more present in pre-standardisation and consortia; or other sub-topics may have to be mapped to the proposed sub-areas, derived from further data collecting.
- **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).
- **The knowledge area Software and its sub-topics are currently not mapped to any of the collected SDOs**. This is an aspect to further investigate with the EU-IoT experts.
- **The knowledge areas of Printing, Materials, Biomedicine, Biotechnology are out of the scope of ICT-56** and therefore, sub-topics do not appear in the current SDO mapping. Nonetheless, some sub-topics are relevant for IoT and Edge and therefore, this aspect will be further researched.

4.2 Knowledge Areas and RIA Standardisation Contributions

Overall, RIAs have contributed so far with 38 out of the 276 topics collected, corresponding to 14% of the overall sub-topics. However, it is important to highlight that the RIA information has been collected on an early stage of development of RIAs, as shown in section 2.1, which may impact this value. A next step in the analysis of knowledge area contributions, it will be necessary to provide surveys that cover all the topics and knowledge areas mentioned in this document.

The sub-topics that appear the most in RIA contributions are:

- Explainable AI (knowledge area *Artificial Intelligence*).
- Virtualisation (knowledge areas *Data*, *Infrastructure*, *IoT interfaces*, *Software*).
- Federated learning (*IoT architectures*).
- Unikernels (*Software*).
- Digital twins (*Data*).
- AR/VR (*Artificial Intelligence*).
- Tactile Internet (*IoT interfaces*).

The contributions provided by RIA fall, as explained, into different knowledge areas, and different EU-IoT scope areas. The distribution of the contributions is illustrated in Figure 10, where the dark blue boxes correspond to active contributions in specific knowledge areas; the red boxes correspond to no contributions to knowledge areas that are within the scope of ICT-56; the grey boxes represent knowledge areas that are out of the scope of ICT-56. The mapping shows two aspects that shall be further work as next steps:

- **A few contributions are aggregated on a specific scope**, e.g., configuration and orchestration contributions are currently focusing on mechanisms for the near Edge, infrastructure, and data spaces. Similarly, contributions to the knowledge area "Autonomy" are currently concentrating into the Far Edge scope.
- **Some relevant knowledge areas, e.g., quality control, quantum, robotics, are still missing contributions** from RIAs. This aspect will have to be further analysed, via surveys and interviews to RIAs, to understand if it was out of the scope of the project, or if there are still contributions envisioned which, at an earlier stage, were not foreseen.

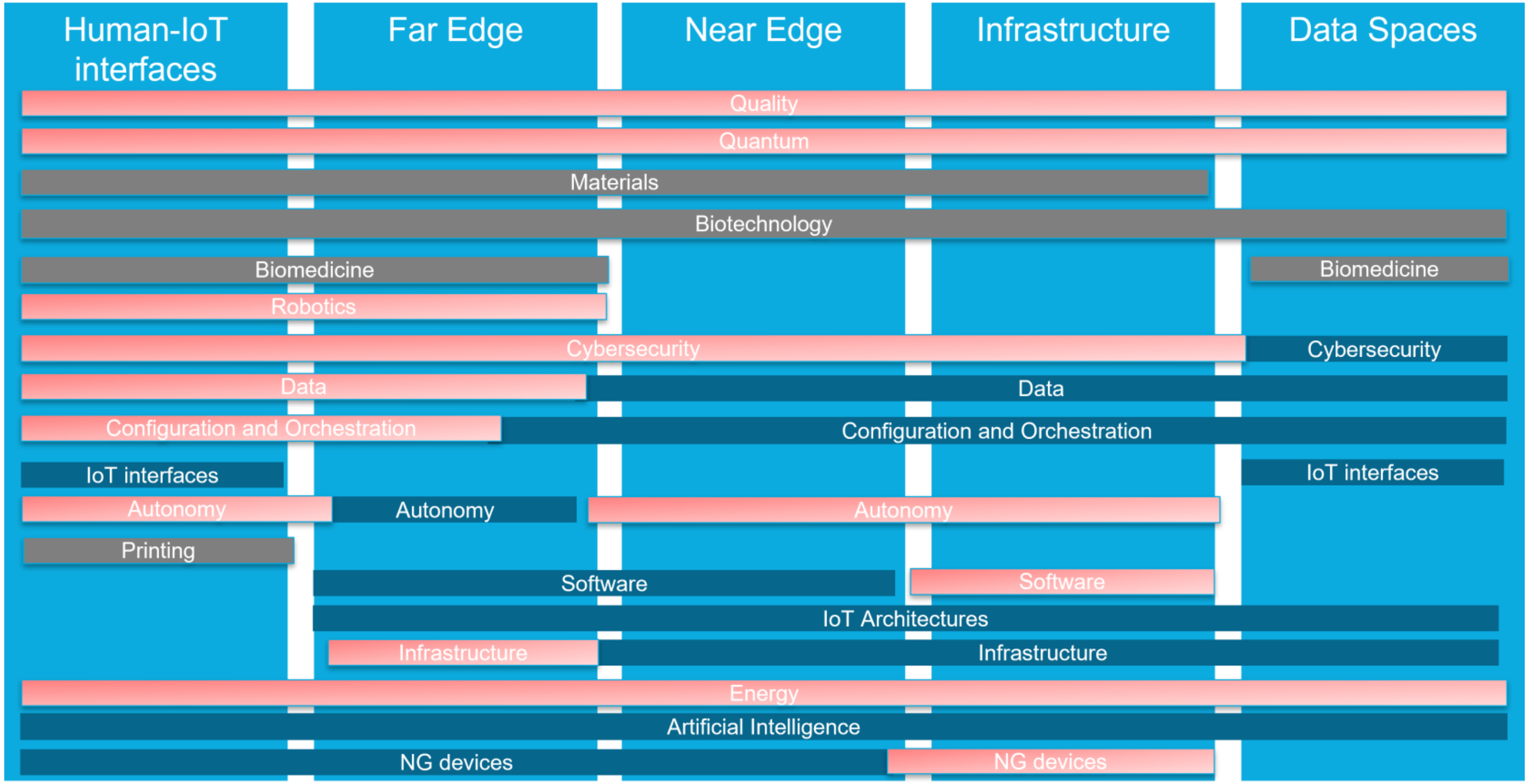

Figure 10: RIA contributions per knowledge area, positioning in the EU-IoT scope areas.

5 SUMMARY, RECOMMENDATIONS AND NEXT STEPS

The current knowledge area mapping derives from an exhaustive collection of data from related sources; 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, providing an analysis on how such knowledge areas meet the proposed EU-IoT scope areas.

The mapping presented in section 4 corroborates that the knowledge areas are aligned with the European strategic plan and respective clusters; and that they are also aligned in terms of sub-topics with the proposed EU-IoT scope areas.

Based on the developed analysis, a list of recommendations numbered as Rx to be addressed as part of the next steps of this specific activity in WP3, T3.3 is:

- R1: The knowledge areas and the collected set of sub-topics provides a good basis for further analysis. For that, it is important to develop an analysis on the sub-topic (and knowledge area) impact. A possibility is to consider the 3 indicators that have also been debated in section 2 in the context of related work by JRC and NATO, namely: maturity; likelihood of use until 2030 and beyond; European leadership position. This analysis will be developed in articulation with WP2 via surveys and interaction to the EU-IoT expert groups.
- R2: The current methodology for analysis is based on a statistical approach. We will continue the work, expecting to integrate an NLP-based approach (string and semantic similarity), which will assist in a broader and finer-grained mapping of knowledge areas to SDOs, scopes, and to vertical domains.
- R3: The current RIA contributions in terms of knowledge areas fall short in the following knowledge areas: cybersecurity; energy, robotics. Moreover, the current RIA contributions for different knowledge areas are often concentrated in specific EU-IoT scopes, e.g., cybersecurity topics relate with the Data Spaces scope only. This may be due to an initial dataset having been collected, or there is the need to alert to this aspect, and discuss with RIAs a better articulation, if possible, or propose measures to assist other projects in the future, in reaching a broader coverage.
- R4: The current knowledge area to SDO mapping shows that there are some knowledge areas that are not yet adequately mapped to SDOs. This may occur because the collected data so far is missing some sub-topics; or there is indeed a gap in terms of knowledge area on standardisation.

The proposed next steps attempt to address the collected recommendations, as detailed in Table 5

Table 5: Next Steps.

Ref	Recommendation	Steps to take - deadline
R1	Assess the likelihood, maturity, impact of each sub-topic.	Establish a questionnaire /interaction with EU-IoT experts in articulation with WP2, to assess the current sub-topics (and as consequence provide a measure of impact of the proposed knowledge areas) - **Sep 2022**
R2	Provide an NLP-based analysis of the knowledge area mapping to SDOs	Develop the tool to provide the NLP based mapping – **May 2023, D3.6**.
R3	Lack of contributions in knowledge areas	Follow-up surveys to RIAs, to assess the status of contributions; discussion about gaps and eventual

		interest in further contributions - **May 2022**.
R4	Mapping of knowledge areas to SDOs shows weaknesses	Collect additional data (keywords, topics and entities) for SDOs; analyse whether there are gaps or whether data is missing - **November 2022.**

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ANNEX I: COLLECTED KNOWLEDGE AREAS AND TECHNOLOGICAL SUB-TOPICS

Refer to the document "D3.5_AnnexI.xls".

ANNEX II: LIST OF SDOS, CONSORTIA AND ALLIANCES

Acronym	Title	URL
	SDOs	
3GPPP	3rd Generation Partnership Project (3GPP)	https://www.3gpp.org/
CENELEC	European Committee for Electrotechnical Standardization	https://www.cenelec.eu
ETSI	European Telecommunications Standards Institute	https://www.etsi.org/ https://www.etsi.org/technologies/internet-of-things
GS1		https://www.gs1.org
IEC	International Electrotecnical Commission	https://www.iec.ch
IEEE	Institute of Electrical and Electronics Engineering	https://www.ieee.org
IETF	Internet Engineering Task Force	https://www.ietf.org
ISO	International organisation for Standardization	https://www.iso.org

ITU-T	International Telecommunication Union	https://www.itu.int
OASIS	Organization for the Advancement of Structured Information Standards	https://www.oasis-open.org
ODVA	ODVA	https://www.odva.org
OGC	Open Geospatial consortium	https://www.ogc.org
OPC	Open Platforms Communication Foundation	https://opcfoundation.org/
W3C/WoT	World Wide Web Consortium/Web of Things	https://www.w3.org/
	Pre-normative entities	
5G-ACIA		https://www.5g-acia.org/
5GIA	5G Industry Association	https://5g-ia.eu/about/
IRTF	Internet Research Task Force	https://irtf.org/
	Alliances and Consortia	
AIOTI	Alliance for Internet of Things Innovation IVZW	https://aioti.eu/
BBF	Broadband Forum	https://www.broadband-forum.org/
BDVA	Bid Data Value Association	https://www.bdva.eu/
CNFC	Cloud Native Computing Foundation	https://www.cncf.io/
Eclipse	Eclipse foundation	https://www.eclipse.org
EdgeX	EdgeX Foundry	https://www.edgexfoundry.org/
EEC	European Edge Computing Consortium	https://ecconsortium.eu/
FIWARE	FIWARE: The Open Source Platform for Our Smart Digital Future	https://www.fiware.org/
Gaia-X	A federated data infrastructure for Europe	https://www.data-infrastructure.eu
GSMA	GSMA Alliance	https://www.gsma.com/aboutus/
IIC	Industrial Internet Consortium	https://www.iiconsortium.org/
Industry4.0	Platform Industrie 4.0	https://www.plattform-i40.de/PI40/Navigation/DE/Home/home.html
Linux	Linux Foundation	https://www.linuxfoundation.org/
LoRA	LoRa Alliance	https://lora-alliance.org

OAA	Open Automotive Alliance	https://www.openautoalliance.ne
OCF	OCF, Open Connectivity Foundation	https://openconnectivity.org
OMA	Open Mobile Alliance	https://www.openmobilealliance.org
OMG	Object Management Group	https://www.omg.org/
One M2M	One M2M Standards for M2M and the Internet of Things	https://www.onem2m.org/
ORAN	Operator Defined Open and Intelligent Radio Access Networks	https://www.o-ran.org/
RISC-V	RISC-V International	https://riscv.org/
QUIC	Quantum Industry Consortium	https://www.euroquic.org/
VDMA	Mechanical and Plant Engineering Association	https://www.vdma.org/
Weightless	Weigthless Alliance	https://www.weightless-alliance.org/
Zigbee	Zigbee Alliance	https://zigbeealliance.org